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Volleyball is truly a universal sport; it can be played by people of all ages and nationalities in different locations anywhere in the world. The sport has experienced rapid development in recent years and is enjoying a golden era of success. We are seeing more nations compete at the FIVB’s flagship events and more people playing the sport at amateur level.

As the international federation responsible for volleyball, the FIVB has a duty to protect the health and well-being of volleyball athletes, and to educate and inform its 222 national federations on medical best practice. The FIVB’s Medical Commission is fundamental to this and carries out medical research in a number of areas, including prevention and treatment of common volleyball injuries, to ensure the volleyball environment is a safe one.

At a time when more and more people are participating in volleyball, it is important to raise awareness of the sport’s demands as well as promoting its health benefits. We therefore value this handbook as an important tool for volleyball medical professionals around the world and as a useful resource for players, coaches, and officials alike.

Dr. Ary S. Graça
FIVB President
Introduced to the world of sport in 1895, volleyball has become one of the most popular sports on the international sporting scene. Volleyball made its Olympic debut at the 1964 Games in Tokyo, and beach volleyball followed in 1996 at the Olympic Games in Atlanta. For both events, men and women compete. With great demands on biomechanics, coordination and physiology, the volleyball athlete must train for both the performance of skills and for physiological conditioning.

A first edition on volleyball for the IOC Medical Commission’s Handbooks of Sports Medicine and Science series appeared in 2003. This publication has enjoyed widespread use as a source of authoritative information on all aspects of volleyball competition. Both the first edition and the present edition were developed under the editorial leadership of Drs Jonathan Reeser (USA) and Roald Bahr (Norway). The co-editors benefitted from the expertise of a team of contributing authors representing outstanding clinicians and scientists. Authoritative information has been presented for various topics of volleyball sports science, topics of sports medicine, volleyball for special populations, and the special topics of ergogenic aids, doping, and sports psychology.

We are very grateful to the editorial team and all the contributing authors for the quality of their work in making this second edition of the IOC Handbook on Volleyball a highly valuable publication in both sports medicine and sports science literature.

Thomas Bach
IOC President
Preface and acknowledgments

Herewith, we proudly present the second edition of the IOC Handbook of Sports Medicine and Science: Volleyball. More than 10 years have elapsed since the first edition appeared, and over that time the sport has rapidly evolved. In addition, we have witnessed a veritable explosion of clinical and basic scientific literature pertaining to volleyball. This is reflected in the content of this handbook: the table of contents has been revised and most chapters have been essentially rewritten – typically with the inclusion of new contributors in order to bring a fresh perspective to the material.

While the content of the second edition has been updated, the process by which it was brought into being remained essentially unchanged. We remain ever appreciative of Dr Howard G. (Skip) Knutgen, coordinator of scientific publications for the IOC Medical Commission, for his patient oversight of this project. We extend our gratitude to the staff at Wiley-Blackwell for their myriad contributions to bringing this second edition to fruition.

We also acknowledge the support of the Fédération Internationale de Volleyball (FIVB) and its President, Dr Ary Da Silva Graça Filho, and that of the IOC Medical and Scientific Department (Richard Budgett, Director). Finally, we extend our sincere appreciation to our many contributors, without which this handbook would not have happened.

We sincerely hope that we have succeeded in providing you, the reader, with a work that captures most (if not all) of the advances that have become integral to our present understanding of volleyball sport science and to the practice of sports medicine as applied to our fabulous sport. As before, we invite you to share your comments and suggestions, so that future iterations of this Handbook may continually improve.

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PART 1
VOLLEYBALL SPORT SCIENCE
Chapter 1

Energy demands of volleyball

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Introduction

Volleyball, like all team sports, requires repetitive bouts of high-intensity exercise. For the volleyball player to achieve competitive success, he/she must possess the ability to rapidly generate power while executing precise sport-specific skills such as spiking and blocking. In addition, the ability to maintain sufficient power output for the full duration of matches is obviously of critical importance to sporting success. The extent and speed of recovery from exercise are influenced by the intensity and duration of the preceding bout of exercise, the nutritional status of the individual, and the time available for metabolic recovery. Volleyball athletes must perform numerous maximum effort jumps and quick, short sprints, interspersed by variable periods of exercise of lower intensity or brief periods of rest. The energy used during periods of high-intensity play is derived largely from anaerobic metabolism. Over the course of the match, however, the contribution of aerobic metabolism increases to cover the total energy cost. The cycles of activity and rest are imposed by the pattern of play which vary greatly from player to player and from one match to another, as the tactics and ability of the opposition also influence the demands on each player.

Compared with continuous exercise activities such as running and cycling, relatively little attention has been directed to the energy expenditure during games that involve complex movement patterns. This may be because of the lack of adequate experimental models to study these activities in the laboratory. However, some standardized models of intermittent exercise have been developed recently that simulate the activity patterns observed in team sport. This chapter describes how these protocols, as well as measurements made during competition itself, have shed some light on the metabolic processes that occur during match-play exercise and their importance for achieving peak performance.

Activity patterns and work rate in volleyball and other sports

Based upon unpublished data collected by the Fédération Internationale de Volleyball (FIVB) during the 2015 World League and Grand Prix competitions, it appears that the work periods for elite male indoor players range between 6–8 seconds in length, while for elite female indoor players the work periods typically measure 7–9 seconds. Furthermore, the ball is “in play” for approximately 15% of the duration of the match, resulting in a work:rest ratio of approximately 1:6. These data reflect the fact that volleyball athletes must generate explosive power, then recover quickly so as to be ready for the next point.
Chapter 1

It is predictable that players suffer from progressive fatigue as the competitive match wears on, as manifested by a drop in the work rate during the second half of the match (fewer number or reduced height of maximum jumps performed). A recent study of professional soccer players using Pro-Zone technology to analyze time spent in different activities during 28 English Premier League matches found that during the last 15 minutes of a match, athletes cover approximately 20% less distance than they had covered during the opening of the match. There was also a noticeable decline in high-intensity running immediately after the most intense 5-minute period of the game, with the greatest deficits (~40–50%) in attacking players and central defenders. Injuries are also more likely to occur late in the game when fatigue becomes more prevalent.

The development of fatigue during match-play seems to be related at least in part to depletion of muscle glycogen stores. It has been shown that football players who start a match with a low thigh muscle glycogen content cover 25% less distance than those who have normal prematch thigh muscle glycogen stores (see Table 1.1). Furthermore, players with a low initial muscle glycogen content covered 50% of the total distance walking and only 15% sprinting, compared with 27% walking and 24% sprinting for the players with normal to high muscle glycogen stores. Blood lactate concentration is consistently lower at the end of a match compared with values measured at half-time, and this ties in with the observation that the greatest rate of decline in muscle glycogen occurs in the first half of the match. Players who start matches with low glycogen stores in their leg muscles are likely to be close to complete glycogen depletion by half-time and these findings have important implications for training and the nutritional preparation of players. Until relatively recently, however, these issues have largely been ignored.

### Metabolic responses to intermittent high-intensity exercise

All cellular activities, including nerve transmission, biosynthesis, and muscle contractility, are fueled by the chemical energy released when the high-energy phosphate bond(s) in the adenosine triphosphate (ATP) molecule are broken (Figure 1.1). ATP is broken down under the influence of a specific enzyme (an ATPase) to adenosine diphosphate (ADP) and inorganic phosphate ($P_i$) to yield energy for muscle activity or to power other reactions. This high-energy phosphate bond is an immediate source of energy, the so-called energy currency of the cell. All other energy-producing reactions must channel their output through this mechanism.

There are three principal means by which cells maintain their supply of readily available ATP. The first and most rapid of the routes begins with the conversion of phosphocreatine (PCr) to creatine and phosphate. However, the phosphate group is not liberated as inorganic phosphate, but is rather transferred directly to an ADP molecule to re-form ATP. This reaction is catalyzed by the enzyme creatine kinase, which is present in skeletal muscle at very

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Rate (μmol/min/g muscle)</th>
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<tbody>
<tr>
<td>PCr hydrolysis</td>
<td>440</td>
</tr>
<tr>
<td>Lactate formation</td>
<td>180</td>
</tr>
<tr>
<td>CHO oxidation</td>
<td>40</td>
</tr>
<tr>
<td>Fat oxidation</td>
<td>20</td>
</tr>
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**Table 1.1** Maximum rates of ATP resynthesis that can be achieved by the metabolic pathways available to muscle cells.

**Figure 1.1** Energy is released to allow cells to do work when the ATP molecule is hydrolyzed to ADP and $P_i$. The ATP level in the cells must be maintained to allow work to continue, so other metabolic pathways must provide the energy for ATP resynthesis.
Energy demands of volleyball

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high activities, allowing the reaction to occur rapidly. In the second pathway, glucose-6-phosphate (derived from the breakdown of muscle glycogen or from glucose taken up from the bloodstream) is metabolized to lactate and produces ATP by substrate-level phosphorylation reactions. Neither of these reactions requires oxygen, and the pathways are therefore commonly considered to be “anaerobic.”

In the third pathway, the products of carbohydrate, lipid, protein, and alcohol metabolism can enter the tricarboxylic acid (TCA) cycle (also known as the citric acid or Krebs cycle, after Sir Hans Krebs, who first described it) in the mitochondria and can be oxidized to carbon dioxide and water. This process is known as oxidative phosphorylation, and in the presence of oxygen yields substantial energy used in the synthesis of ATP.

Adenosine triphosphate, then, is the immediate source of cellular energy and the purpose of the three mechanisms described is to regenerate ATP at sufficient rates to prevent a significant decline in the intramuscular ATP concentration. If the ATP concentration falls, the concentrations of ADP and adenosine monophosphate (AMP) will rise. The concentration ratio of ATP to ADP and AMP is a marker for the energy status of the cell. If the ratio is high, the cell is in effect “fully charged.” This energy charge is monitored in every cell; a fall in the ATP concentration or a rise in the concentration of ADP or AMP will activate the metabolic pathways necessary to increase ATP production. This is achieved by activation or inhibition of key regulatory enzymes by changes in the concentration of the adenine nucleotides.

It may also be helpful to think of the various pathways that can be used to resynthesize ATP in terms of the maximum rates of resynthesis that can be achieved. Some typical values are shown in Table 1.1. It is important to note that these rates are influenced by many factors, including muscle fiber type, fitness level, and the nutritional status of the athlete.

Since substantial storage of ATP in tissues is not possible (the amount of chemical energy stored in each molecule of ATP is rather small and it would be inefficient to store more because of the mass that would have to be carried), the challenge during exercise is for the cell to resynthesize ATP as fast as it is broken down, thereby maintaining an adequate intracellular supply of energy. A 70 kg runner moving at a speed of 15 km/h will require about 3.5 L of oxygen per minute, or about 1.17 kW. To meet this energy demand, the runner must break down about half a kilogram of ATP every minute to maintain pace. Given that the total ATP content of the body is about 50 g, this means that each molecule of ATP in the body turns over on average about once every 6 seconds. In active muscle cells, the rate of turnover will be much higher.

The data in Table 1.1 show the maximum rate of ATP resynthesis that can be generated by the various metabolic pathways in muscle and most other tissues. The power which each of these systems can generate is dependent upon the capacity of the system (Table 1.2). The capacity of the oxidative metabolic pathways is essentially unlimited because of the very large amounts of substrate stored and the fact that these substrates can be replenished during exercise by ingestion.

Every time a player initiates a burst of activity, the rates of PCr utilization and glycolysis increase. Muscle samples collected from soccer players during and after matches show progressive reduction in the [PCr] and severalfold increases in blood and muscle lactate concentrations as the intensity and duration of exercise increase. Thus, the anaerobic energy systems are heavily taxed during periods of intense exercise during match-play.

Glycolysis converts one 6-carbon glucose molecule to two 3-carbon molecules, while allowing some of the energy liberated to be conserved as ATP. The key reactions of anaerobic glycolysis are shown in Figure 1.2. It is important to note that there is an initial investment in the form of energy, but there is a net yield of ATP when glycogen

<table>
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<th>Table 1.2</th>
<th>Power that can be generated by the various metabolic pathways and the total capacity of those systems.</th>
</tr>
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<tbody>
<tr>
<td>Power (W/kg)</td>
<td>Capacity (J/kg)</td>
</tr>
<tr>
<td>ATP/PCr hydrolysis</td>
<td>800</td>
</tr>
<tr>
<td>Lactate formation</td>
<td>325</td>
</tr>
<tr>
<td>Oxidative metabolism</td>
<td>200</td>
</tr>
</tbody>
</table>

ATP, adenosine triphosphate; PCr, phosphocreatine.
(or glucose) is broken down to lactate. Degradation of glycogen to lactate allows formation of ATP at relatively high rates; the enzymes that catalyze the reactions of glycolysis are present at high activities and the substrate (glycogen) is normally present in relatively large amounts, though the concentration falls rapidly during high-intensity activity. For each glucose residue converted to lactate, three ATP molecules are formed if glycogen is the starting point, and two are formed if glucose is the substrate.

When muscle glycogen is rapidly broken down, pyruvate is produced at a rate faster than it can be oxidized via the TCA cycle. This leads to depletion of nicotinamide adenine dinucleotide (NAD), which acts as a co-factor in the glycolytic pathway by accepting a hydrogen atom, being converted in the process to NADH. NAD is present in the cell in very small amounts, and for glycolysis to continue, it must be regenerated. At rest and during low-intensity exercise, this is accomplished by the oxidation of the pyruvate produced by glycolysis to carbon dioxide and water. During high-intensity exercise, however, glycolysis proceeds faster than the capacity of the aerobic pathway to dispose of the pyruvate formed (Figure 1.3).

Conversion of pyruvate to lactate occurs faster than the metabolism of pyruvate to carbon dioxide and water, thereby allowing energy production by glycolysis to continue at high rates. Thus, although lactate formation is often seen as a negative process, it is actually a positive process in that it allows high-intensity work to be performed. Anaerobic glycolysis is clearly an important source of ATP resynthesis during high-intensity activity, and becomes especially important during repeated bouts of high-intensity exercise when the creatine phosphate content of the muscle may be depleted. Anaerobic glycolysis produces only three molecules of ATP for each molecule of glucose 6-phosphate derived from muscle glycogen, compared with 38 molecules of ATP when the glucose molecule is completely oxidized to carbon dioxide and water. However, the limited capacity of ATP regeneration made possible by shunting pyruvate to the anaerobic glycolytic pathway may be considered compensated for by the speed of the reaction and the high power that can as a result be generated.

The reactions of glycolysis result in a release of hydrogen ions that cause the muscle pH to fall as lactate accumulates. This has a variety of effects on the muscle as shown in Figure 1.4. Some of the hydrogen ions are immediately buffered within the muscle cell and some diffuse out of the cell into the extracellular space, limiting the intracellular in intracellular pH.

Despite the negative effects of a falling pH, the energy made available by anaerobic glycolysis allows a higher intensity of exercise than would otherwise be possible.
Energy demands of volleyball

Aerobic metabolism ultimately provides all the energy used by the body, and this is achieved by the oxidation of stored or ingested fuels in the form of carbohydrate, protein, fat, and alcohol (Figure 1.5).

The pyruvate that results from glycolysis (which occurs in the cell's cytoplasm) normally moves into the mitochondria where it is aerobically metabolized via the citric acid cycle. This cyclical series of biochemical reactions leads to the oxidation of pyruvate to carbon dioxide and water, and in the process generates ATP via oxidative phosphorylation (aerobic metabolism). The citric acid cycle is the final common pathway for the metabolism of carbohydrate, fats, and protein. Aerobic metabolism generates about 90% of all the ATP produced by the body, while anaerobic metabolism produces the remaining 10%.

---

Figure 1.4  The glycolytic pathway (note that several steps have been omitted to show only key reactions and consequences).

Figure 1.5  Integration of substrate metabolism across different tissues. ADP, adenosine diphosphate; AMP, adenosine monophosphate; ATP, adenosine triphosphate; CK, creatine kinase; CP, creatine phosphate; CS, citrate synthase; Cytox, cytochrome oxidase; FA, fatty acids; FFA, free fatty acids; IMP, inosine monophosphate; LDH, lactate dehydrogenase; NH3, ammonia; PDH, pyruvate dehydrogenase; PFK, phosphofructokinase; Phos., phosphorylase; SDH, succinate dehydrogenase; TG, triglycerides. Source: Bangsbo (1994). Reproduced with permission of John Wiley & Sons.
By definition, oxygen is required in the final series of aerobic metabolic reactions, combining with hydrogen ions to produce water. Oxygen is extracted from inspired air by the lungs, where it binds to hemoglobin and is transported to the tissues by red cells within the bloodstream. One measure of an athlete’s fitness is his/her ability to utilize oxygen to efficiently produce ATP. This capacity is commonly known as the maximal oxygen uptake, or VO₂max. Although respiration is the principal source of oxygen utilized during aerobic metabolism, it is important to note that skeletal muscle does store a small amount of oxygen bound to myoglobin, a heme-containing molecule that can provide an immediately available source of oxygen in the absence of adequate respiratory oxygen delivery.

Fatigue is an inevitable consequence of sufficiently intense or prolonged exercise. Many factors contribute to fatigue and in all but a few situations, it is probably futile to look for a single cause of fatigue. Possible causes of fatigue during high-intensity exercise include:

- phosphocreatine depletion
- decrease in pH
- glycogen depletion
- electrolyte imbalance
- central nervous system effects.

Each of these factors may be responsible for limiting exercise performance in specific situations, and some of these have practical implication for the athlete seeking to maximize performance (Mohr et al. 1996).

In the early 1990s it was shown that short periods of diet supplementation with creatine could increase muscle phosphocreatine stores and enhance performance in high-intensity sprints (Birch et al. 1994). Creatine enhances performance in activities lasting less than about 5 minutes, particularly when performing repeated sprints with short recovery periods (Casey et al. 1996). There is also some evidence that a few days of creatine supplementation can promote increases in muscle strength.

The acidosis that results from a high rate of anaerobic glycolysis can be countered by ingestion of buffering agents. Bicarbonate and citrate act as extracellular buffers, promoting the efflux of hydrogen ions from the cells where they are produced into the extracellular space and thus allowing more lactate (and hence ATP) to be produced before the pH becomes limiting. Ingestion of β-alanine can increase the intramuscular concentration of the dipeptide carnosine, and this in turn can increase intracellular buffering capacity and enhance sprint performance.

Glycogen availability per se is not usually considered to be responsible for fatigue during short-term high-intensity exercise, provided that the preexercise glycogen store is not less than 25 mmol/kgww. However, some scientists have suggested that the critical level of muscle glycogen concentration below which impairment of anaerobic ATP resynthesis occurs is somewhat higher than this, at about 45 mmol/kgww. It is possible that glycogen unavailability limits performance during repeated bouts of high-intensity exercise if performed for a prolonged period. Note, however, that this effect depends to a large degree on the extent of the decline in the rate of glycogenolysis and lactate production that occurs under these conditions. As described earlier, the initial muscle glycogen level of soccer players influences their performance (particularly in the second half of a game). A similar message comes from a study of ice hockey players who raised their preexercise muscle glycogen content by 12% after dietary carbohydrate loading before competition. The group of players who glycogen-loaded covered greater distances during the game, and at faster average speeds than the control group that did not carbohydrate load.

Furthermore, in recent years, several studies have documented beneficial effects of ingesting carbohydrate solutions on soccer and tennis performance. It has been observed that a majority of goals in soccer are scored towards the end of matches. This may occur due to a reduction in the work rate of the defenders or because of mental fatigue, leading to lapses in concentration and deterioration in skill. As blood glucose concentration does not decline during soccer-specific exercise
protocols, it can be concluded that carbohydrate ingestion does not improve endurance performance and execution of skills in soccer by preventing the development of hypoglycemia.

According to time-motion analyses and performance measures during match-play, fatigue or reduced performance seems to occur at three different stages in a soccer match: after short-term intense periods in both halves; in the initial phase of the second half; and towards the end of the match. Temporary fatigue after periods of intense exercise does not appear to be linked directly to muscle glycogen concentration, lactate accumulation, acidity or the breakdown of PCr (Krstrup et al. 2006). Instead, it may be related to disturbances in muscle ion homeostasis and an impaired excitation of the sarcolemma.

Soccer players’ inability to perform maximally in the initial phase of the second half may be due to lower muscle temperatures compared with the end of the first half. Thus, when players perform low-intensity activities in the interval between the two halves, both muscle temperature and performance are better preserved. Muscle glycogen is typically reduced by 40–90% during a game and is probably the most important substrate for energy production. Even when whole muscle glycogen may appear adequate, fatigue toward the end of a match might be related to depletion of glycogen in some individual muscle fibers that have been active during the game. In one study, it was found that whole muscle glycogen decreased by about 43% during a soccer match, but that almost half of the muscle fibers were completely or nearly devoid of glycogen after the contest.

A group of Swedish professional soccer players was studied after playing a midweek game and preparing for another match on the Saturday (Table 1.3). One part of the group was fed a high-carbohydrate (CHO) diet for the few days between the games and the other part of the group consumed their normal diet, which had a relatively low CHO content. Muscle biopsies were taken from the thigh muscles of the players before the Saturday game, at halftime, and at the end of the match. Video analysis of the match was used to measure the distance covered by each of the players during the contest. The fraction of the total distance covered at sprinting speed and walking speed was also determined, the remaining distance being covered at an intermediate speed. The high CHO group had higher muscle glycogen stores at the start of the game, and at the end of the game still had some muscle glycogen left, whereas the control group had none. The total distance covered by the two groups of players in the first half was not significantly different but in the second half, when muscle glycogen concentration was lower, the players on the lower CHO diet were not able to run as far. The high CHO group covered more distance at sprinting speed (24% of a total distance of 12.0 km) and spent less time walking compared with the other group (see Table 1.3) (Jacobs et al. 1982).

At rest, sodium concentration inside cells is low and potassium concentration is high, while the situation is reversed in the extracellular environment. When muscles and nerves are activated, sodium enters the cells and potassium exits. In high-intensity exercise, the transmembrane gradients for potassium and sodium in the active muscles fall, causing the membrane potential to fall. This can impair development and propagation of the action potential, but there is little evidence to show failure. The metabolic acidosis that results from high rates of glycolysis helps counter this effect by maintaining membrane excitability.

### Table 1.3  Muscle glycogen concentration and distance covered during the first and second half of a soccer match.

<table>
<thead>
<tr>
<th>Muscle glycogen concentration (g/kg muscle ww)</th>
<th>Distance covered (km)</th>
<th>% Distance covered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st half</td>
<td>2nd half</td>
</tr>
<tr>
<td>Before</td>
<td>Half-time</td>
<td>End</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
One of the consequences of rapid PCr hydrolysis during high-intensity exercise is the accumulation of Pi, which has been shown to inhibit muscle contraction directly. However, the simultaneous depletion of PCr and Pi accumulation makes it difficult to separate the effect of PCr depletion from Pi accumulation. Calcium release from the sarcoplasmic reticulum as a consequence of muscle depolarization is essential for the activation of muscle excitation-contraction coupling. It has been demonstrated that during fatiguing contractions, there is a slowing of calcium transport and progressively smaller calcium gradients that have been attributed to a reduction in calcium reuptake by the sarcoplasmic reticulum and/or increased calcium binding in the cytoplasm. Strong evidence that a disruption of calcium handling is responsible for fatigue comes from studies showing that stimulation of calcium release from the sarcoplasmic reticulum of isolated muscle by the administration of caffeine can improve muscle force production, even when muscle pH is low. Thus, there may be a long-term effect of prior high-intensity exercise on calcium ion handling by the sarcoplasmic reticulum.

Several studies have shown that reduced muscle pH can interfere with excitation-contraction coupling, and high muscle lactate concentrations have also been reported to inhibit calcium ion release from the sarcoplasmic reticulum. Therefore, the removal of lactate and H⁺ from skeletal muscle is likely to be important for the ability to maintain power output during repeated bouts of high-intensity exercise. Export of lactate across the sarcolemma membrane is mediated by a lactate/H⁺ co-transporter, and high-intensity exercise training enhances the lactate/H⁺ transport capacity of human skeletal muscle. Light-to-moderate exercise increases the rate at which lactate is eliminated from the muscle and the circulation following high-intensity exercise: an active warm-down is therefore more effective than rest at clearing lactate and promoting recovery. Lactate is taken up from the blood mainly by the liver, heart, and type I skeletal muscle fibers. Most of it is converted to pyruvate and oxidized by these tissues.

In a hot and humid environment, dehydration and hyperthermia may result in reduced cerebral function that may also contribute to fatigue and deterioration in performance. This may be related to changes in brain oxygenation resulting from reductions in blood flow or to a reduced synthesis and release of key neurotransmitters, but it may also be related to changes in the permeability of the blood-brain barrier. These changes may influence the recruitment of motor neurons causing a deterioration of muscle function. There is some evidence that muscle contractility remains intact, as shown by the continued ability of the muscle to contract in response to direct electrical stimulation of the motor nerve or to magnetic stimulation of the brain.

In conclusion, fatigue or impaired performance in sports involving multiple sprints occurs during various phases in a match, and different physiological mechanisms appear to be responsible for fatigue during different periods of a contest.

### Integrated physiological response

The metabolic response to exercise is dictated largely by the biochemical characteristics of the muscle fibers and their recruitment pattern. In low-intensity work, only a few motor units are activated and these will involve predominantly type I fibers. These fibers have a high oxidative capacity, a relatively low glycolytic capacity, and a good supply of oxygen (Box 1.1). Most of the energy required by these fibers is derived from the oxidation of fatty acids derived either from the plasma or from intracellular fat stores. Carbohydrates contribute only a small amount of energy to these type I muscle fibers. However, as motor unit recruitment continues, fibers with less capacity for fat oxidation and a progressively greater reliance on carbohydrate metabolism are activated (type II). When the muscle is breaking glycogen down to pyruvate faster than the pyruvate can be oxidized in the TCA cycle, the excess pyruvate is converted to lactate, regenerating the co-enzyme NAD within the cytoplasm of the cells and permitting glycolysis to continue. Some of this lactate diffuses out of the muscle and causes a progressive rise in the blood lactate concentration.

The pattern of substrate utilization during exercise is therefore dictated by intensity and duration of activity.
The pattern is not fixed, however, and will change over time. It is modulated by a number of factors, including prior diet and exercise, fitness level, and environmental conditions. Increasing the muscle glycogen content by feeding a high-carbohydrate diet for a few days will lead to an increased rate of glycolysis at rest and during exercise; blood lactate will be elevated and carbohydrate oxidation also increased. Likewise, feeding a high-fat, low-carbohydrate diet will shift metabolism in favor of fat oxidation. Increasing aerobic fitness by endurance training has a number of cardiovascular and metabolic effects, but one of the key adaptations is an increase in the oxidative capacity of muscle, and in particular an increase in the ability to oxidize fatty acids. This results in a marked shift in the pattern of substrate use in favor of fat oxidation.

An individual's maximum oxygen uptake (VO$_2$max) is a key element of performance in exercise lasting more than a few minutes. VO$_2$max represents the peak rate of energy production that can be achieved aerobically – the energy required for any power output exceeding this must come entirely from anaerobic metabolism. The importance of VO$_2$max for endurance athletes such as marathon runners lies in the fact that endurance capacity is largely a function of the fraction of VO$_2$max that is required: the higher the fraction of aerobic capacity that must be used, the shorter the time over which a given pace can be sustained. Improving performance requires an increase in VO$_2$max, an increase in the fraction of VO$_2$max that can be sustained for the duration of the race, or a decrease in the energy cost of running. In practice, all of these can be achieved with suitable training. Interestingly, there is some recent information that ingesting high doses of nitrate can reduce the oxygen cost of sub-maximal exercise, and more recent data suggest that this same effect can be achieved by feeding beetroot juice, which has a high nitrate content.

The factors that limit VO$_2$max have been the subject of much debate over the years, in part because the limitation may vary in different types of exercise, in different environments, and in different individuals. Thus, it would not be unusual to find a VO$_2$max of 70 mL/kg/min in a marathoner, but only 55 mL/kg/min in a volleyball athlete, reflecting the typical response to training in these different sports. The lungs are not usually thought to limit performance at sea level in the absence of lung disease, and attention has focused primarily on whether the limitation lies in the delivery of oxygen by the cardiovascular system or the ability of the working muscles to utilize oxygen. However, the oxygen content of the inspired air falls at altitude, leading to a decline in arterial oxygen saturation, decreased oxygen transport, and a fall in VO$_2$max. Performance in endurance events is generally reduced at altitudes above about 1500 m. Studies of the responses to training of the inspiratory muscles also provide some support for the idea that there may be a pulmonary limitation.

**Box 1.1 Muscle fiber types**

Human muscle fibers can be classified in a number of ways, depending on their maximum speed of contraction, their biochemical characteristics, and their resistance to fatigue. Contraction occurs by interaction of actin and myosin filaments within the fibers, and the speed of contraction is determined largely by the ATPase activity of the myosin: the faster ATP can be hydrolyzed to release energy, the faster contraction can occur. Three main fiber types are generally recognized in skeletal muscle.

- **Type I** slow oxidative (also called slow-twitch or fatigue-resistant fibers) are dark red because of their high myoglobin content and high density of blood capillaries, contain many mitochondria and so have a high oxidative capacity, have a slow peak contraction velocity, and are relatively fatigue resistant. They occur in higher numbers in postural muscle. Elite endurance athletes have higher than normal numbers of these fibers.

- **Type IIa** fast oxidative (also called fast-twitch A or fatigue-resistant fibers) also have a high myoglobin content and high density of blood capillaries, contain many mitochondria and so have a high oxidative capacity, but they can hydrolyze ATP at a high rate and so have a fast peak contraction velocity. They are resistant to fatigue, but less so than type I fibers.

- **Type IIb** fast glycolytic (also called fast-twitch B or fatiguable fibers) have a low myoglobin content, low capillary density, and few mitochondria. These fibers can hydrolyze ATP at a high rate and so have a fast peak contraction velocity. They have a high glycolytic enzyme activity and contain large amounts of glycogen. They are useful when high power outputs are needed, but fatigue rapidly. The muscles of elite sprinters have high proportions of these fibers.
Cardiovascular

The cardiovascular system fulfills a number of important functions, including delivery of oxygen and nutrients to all tissues and removal of waste products, control of heat flux within the body, and circulation of hormones from their production sites to their sites of action. The idea that limitations to oxygen delivery are imposed by the cardiovascular system has strong experimental support, and the limitation may lie at any one or more of several stages. The key element appears to be the maximum cardiac output that can be achieved, as this is closely related to both VO$_{2\text{max}}$ and endurance performance. Cardiac output is the product of heart rate (the number of times the heart beats each minute) and stroke volume (the volume of blood ejected by the left ventricle with each beat). The stroke volume is determined primarily by the dimensions of the heart – a large left ventricle is one of the defining characteristics of a successful endurance athlete. In contrast, the maximum heart rate does not differ greatly between trained and untrained individuals. The low resting heart rate of the highly trained endurance athlete (typically about 30–50 beats/min) compared to the sedentary person (typically about 70 beats/min) reflects the larger stroke volume of the trained individual. A high blood volume will also benefit the endurance athlete by helping to maintain the central venous pressure and thus maintaining stroke volume.

The oxygen-carrying capacity of the blood is also important, and this will be influenced by the hemoglobin (Hb) concentration and the total blood volume. Almost all the oxygen in the blood is transported bound to hemoglobin and each gram of hemoglobin can bind 1.34 mL of oxygen. This means that, for the average male with a Hb concentration of about 150 g/L, arterial blood contains about 200 mL of oxygen per liter of blood when it leaves the lungs. For the average female, with a somewhat lower Hb concentration of about 130 g/L, the oxygen content is about 175 mL. This difference accounts (in part) for the generally higher aerobic capacity of males. It also explains the various strategies used by athletes to increase the hemoglobin content of the blood; these strategies include altitude training, the use of agents such as erythropoietin (EPO) that stimulates the formation of new red blood cells, and the use of blood transfusions prior to competition. These latter strategies are prohibited by the World Anti-Doping Agency, but their use is more common in endurance athletes than in volleyball players.

Oxygen delivery to the muscles will depend in part on the density of the capillary network within the muscles. An increase in the number of capillaries, or a reduction in the size of the muscle fibers, means less distance for oxygen to diffuse from the capillary to the mitochondria within the muscle where it is used.

Thermoregulatory

Body core temperature must remain within narrow limits, but about 80% of the energy available from the catabolism of nutrients appears as heat. This is useful for the maintenance of body temperature in cold environments but presents a challenge in prolonged hard exercise in hot environments, where heat is generated at high rates but heat loss to the environment is more difficult. Heat stress during exercise poses a major challenge to the cardiovascular system; in addition to continuing to supply blood to the working muscles, the brain, and other tissues, there is a greatly increased demand for blood flow to the skin. This requires an increased cardiac output, but also means that a large part of the blood volume is distributed to the skin so the central blood volume is decreased. This in turn may reduce the return of blood to the heart and result in a fall in stroke volume; if the heart rate cannot increase to compensate, cardiac output will fall. If this happens, there must be either a reduced blood flow to the muscles, and hence a reduced supply of oxygen and substrate, or a reduced blood flow to the skin, which will reduce heat loss and accelerate the development of hyperthermia. It seems likely that the temperature of the brain is the most relevant parameter, but there seems to be no set temperature at which exercise must be terminated and fatigue may occur across a wide range of core temperatures.
Adaptations to training

The aim of training is to increase functional capacity, and a few basic principles apply to all types of training. Training affects every organ and tissue of the body, but the adaptation is specific to the training stimulus and to the muscles being trained. A well-designed strength training program will have little effect on endurance, and vice versa. One leg can be specifically trained for strength and the other for endurance, with relatively little crossover. Training is not entirely specific, as the effects on the cardiovascular system will be similar whether running or cycling – or indeed skipping or dancing – are performed. The improvement in performance is, or at least should be, proportional to the training load; the training load is described by the intensity, duration, and frequency of the training sessions. Within limits, the harder an athlete trains, the greater the improvements in performance that result. Few athletes reach the limit, but a small number of those who do can experience an overtraining syndrome that results in long-term fatigue and loss of performance.

Training provides the stimulus to turn on the genes responsible for the expression of functional proteins. Strength training leads to synthesis of more actin and myosin, making muscles bigger and stronger, while endurance training leads to synthesis of more oxidative enzymes and all the other components necessary for endurance performance. A selective stimulation of protein synthesis and degradation must be taking place. Strength and power athletes train to increase muscle strength, peak power, and anaerobic capacity. Such training typically involves high-load resistance training and repeated short sprints, resulting in:

- increased muscle size, and hence muscle strength, which is closely related to the muscle cross-sectional area
- increased activity of the glycolytic enzymes in the trained muscle, leading to an increased capacity for ATP generation by anaerobic glycolysis
- increased buffering capacity of the skeletal muscle.

These changes result in part from a specific hypertrophy of the type IIb muscle fibers – the fast-twitch, high-glycolytic fibers. These fibers are typically recruited only during high-intensity efforts or when the slow-twitch, high-oxidative fibers are fatigued and cannot be activated. Training at low intensity or lifting light weights will not activate these fibers; if they are not activated during training, there is no stimulus for them to adapt.

Aerobic training enhances the body’s oxygen-carrying capacity and utilization, and thereby improves the ability to perform prolonged submaximal exercise. Elite endurance-trained athletes can typically achieve VO₂max values in the range of 70–85 mL/kg/min. Elite volleyball athletes appear to generally fall within the range of 55–65 mL/kg/min, which is the value typically expected for good club-level endurance athletes. Thus, an athlete’s cardiorespiratory performance capacity is determined both by training and by genetic endowment, e.g. the proportion and distribution of different muscle fiber types. Physiological adaptations to aerobic conditioning include:

- increased heart size, resulting in increased maximal cardiac output
- reduction in resting heart rate, reflecting the increased cardiac stroke volume
- increased blood volume and oxygen-carrying capacity
- increased number and size of mitochondria.

Summary

All team games, including volleyball, involve repeated bouts of high-intensity exercise interspersed with short periods of relatively lighter exercise. The average exercise intensity during play may be as high as 75% VO₂max but the pattern of play is complex and energy demands fluctuate constantly. Maintaining performance for the full duration of matches is crucial to success and depends to a large degree on the ability of the muscles to generate high power while performing skilled movements and to recover quickly. The extent of recovery is affected by the intensity and duration of the last bout of exercise, the biochemical and physiological characteristics of the individual, and the time available for recovery before
another bout of exercise. At the onset of intense muscle contraction, a rapid hydrolysis of PCr and accumulation of lactate occur to provide energy without the need for oxygen delivery. When repeated bouts of maximal exercise are performed, the rates of muscle PCr hydrolysis and lactate accumulation decline.

Other factors that are likely to have an impact on performance during multiple sprint activities include the ability to reestablish skeletal muscle interstitial potassium concentration and the intracellular concentrations of glycolytic intermediates, inorganic phosphate (Pi) and hydrogen ions as these affect electrochemical-mechanical coupling. A gradual depletion of muscle glycogen stores is also likely to affect performance later in match situations.

**References**


**Recommended reading**


Chapter 2

Nutrition for optimum volleyball performance

Louise M. Burke
Sports Nutrition, Australian Institute of Sport, Canberra, ACT, Australia, and Mary McKillop Institute for Health Research, Australian Catholic University, Melbourne, Victoria, Australia

Introduction

Volleyball, like many other team sports, is a game of intermittent high-intensity activity patterns with variable characteristics between positions and from one match to the next. This creates some diversity in the physiological challenges and nutritional needs of volleyball players. Nevertheless, there are clear ways in which nutrition can support the training and competition goals of players, as well as common strategies which can help players overcome the practical challenges of achieving these goals in a demanding lifestyle. The goal of this chapter is to overview four key areas in which nutrition can optimize performance in volleyball: achievement of ideal body physique and energy needs, nutritional support for training, strategies for optimizing competition performance, and considered use of sports foods and supplements within a sports nutrition plan.

Supporting adequate energy availability and the ideal physique for volleyball

Success in volleyball is strongly related to physical characteristics – being tall, powerful, speedy and agile – that raise several nutritional challenges for the volleyball player. First, there are the energy and nutrient requirements to support growth and maintenance of a large body size and muscle mass. Second, the specific support of a training program that combines strength training with sessions focusing on the skill/movement demands of match-play must be taken into account. Finally, there is the recognition that energy needs can vary over the player's week, year, and career to accommodate issues such as growth spurts, injury, the off-season, periods of intensified training, or a busy competition schedule. Therefore, the volleyball player needs not only to recognize his or her energy needs, but be able to increase and decrease energy intake according to fluctuations in these needs.

Achieving appropriate energy intake is a key principle of the player's nutrition plan as well as a challenge in their lifestyle. Energy intake plays this important role since it not only allows body composition to be manipulated and supports the fuel cost of exercise, but also determines whether all other body systems are working at optimal efficiency. Adequate energy intake should also be supported by a good spread of protein over the day to ensure that there is optimal opportunity to build the new proteins associated with growth, muscle hypertrophy or adaptation to training.

The baseline energy demands of a tall and well-muscled volleyball player are higher than for most other athletes. The growth demands of the youth and adolescent player create even higher energy requirements, especially when combined with the...
fuel needs of a busy training program. Energy availability is a new concept in sports nutrition which focuses on the player’s ability to consume enough energy to cover all these needs. It specifically covers the amount of energy left over once the energy cost of training or match-play has been subtracted from energy intake. Since this energy must cover the cost of all other body processes for growth, health, and optimal function, when it becomes too low, the body adapts by cutting back on the energy it can devote to these processes. Consequently, there is an impairment of bone turnover, muscle protein synthesis, immune function, and many other processes needed to optimize the player’s health and performance. Low energy availability – or what has now been termed relative energy deficiency in sport (RED-S) (Mountjoy et al. 2014) – can occur in sport via a variety of causes, with the most common being disordered eating, following an overenthusiastic and/or badly planned weight loss diet, or failing to recognize or respond to a period of higher energy need. In other words, this problem can require different solutions, ranging from time management counseling to expert psychological support.

The starting point for most volleyball players is to organize a basic eating plan with a regular spread of energy over the day, making use of nutrient-rich snacks and high-energy drinks to supplement the energy provided by meals. Many players follow the nutritional strategies of strength training athletes, emphasizing protein intake in the diet and using supplements claimed to achieve muscle gain. However, work with younger players, in particular, shows the main obstacles to optimal growth and gain in muscle mass are inadequate energy intake and uneven spread of nutritional support over a busy day. When the daily timetable includes combinations of training, a busy match schedule (young players may compete in multiple teams or competitions), school and medical/recovery activities, opportunities for food intake may be limited unless the player is well prepared. Table 2.1 identifies some of the key strategies to assist a player to meet high energy needs to support growth, deliberate weight/muscle gain or a high exercise volume.

Protein is of importance to the achievement of physique goals, as well as to support adaptation to training. While surveys generally find that athletes in team sports rarely fail to reach adequate amounts of total dietary protein, many are unaware of the role of the timing, spread, and quality of protein intake for optimal outcomes. Many studies have found that maximal protein synthesis in the muscle is produced when an exercise session is followed soon after by the intake of a high-quality protein source. Although this concept is better known in relation to resistance training, the same outcome occurs with high-intensity exercise and endurance exercise, with the type of exercise determining the types of proteins that are preferentially synthesized. For example, resistance exercise promotes the synthesis of proteins associated with muscle mass and strength while endurance exercise promotes the synthesis of enzymes and other proteins involved in metabolism. The amount of high-quality protein needed to maximize the postexercise response is ~20 g, although researchers now recognize that body size affects protein needs and that even within a single sport like volleyball, a range of body sizes can be found across age groups, sex, and playing positions. Therefore, the protein intake target might be better set as 0.3 g/kg BM, to accommodate the range between a small female setter and a large male blocker.

A further new concept is that the response to each training session lasts for at least 24 hours, and that spacing protein intake every 3–5 hours over the day provides the best overall opportunity for continued adaptation. The repetition of this protein target of ~0.3 g/kg BM, 4–5 times a day, seems the most appropriate way to maximize protein goals around muscle gain, adaptation, growth, and recovery. However, most of us do not consume meals that achieve such a protein distribution; rather, protein intake is typically the focus of the evening meal and provides only a small presence in breakfast and snack choices. Therefore, new sports nutrition guidelines (Thomas et al. 2016) have moved away from guidelines for total daily protein intake (e.g. athletes should aim for a protein intake of 1.2–1.7 g/kg/d) with a replacement message of a more even distribution of protein over 4–5 meals and snacks per day. Table 2.2 provides a checklist of high-quality protein-rich foods that can help to meet these targets. Animal sources of protein are
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are useful when appetite is suppressed after training or when it is difficult to eat a large volume of food; in addition, they are a rapidly digested form of protein for the postexercise situation where a quick increase in blood amino acid concentrations promotes rapid recovery.

The manipulation of body mass and composition is a frequent goal in sports nutrition. Gain in muscle mass is a natural part of growth and maturation in young players, but can be enhanced or continued in adulthood by a program of resistance training supported by a high energy intake and well-distributed protein intake. In many cases, it may take a plan of 5–6 eating occasions, including a final protein-rich snack just before bed, to promote overnight protein synthesis (Snijders et al. 2015), to maximize the results (see Table 2.1).

However, volleyball players may also need to achieve loss of body weight/fat at other stages of their careers. There is pressure in many sports for athletes to reduce body fat to very lean levels for actual or perceived performance advantages, as well as esthetic considerations. Although it is tempting to think that the loss of body mass/fat will lead to an increased vertical jump or greater speed and agility on court, this benefit will only hold true if it is part of achieving a healthy body composition for an individual which can be sustained as part of good nutrition practices. Although some situations of fat loss are warranted and beneficial, athletes are not immune to the temptations of fad diets and “extreme makeovers” that cause concern in the general community. Indeed, as in most sports, there are concerns around disordered eating and poor body image in team sports, particularly among female athletes. Volleyball programs should ensure that they provide an environment which is supportive of all aspects of performance nutrition, including an objective approach to periodic monitoring of body composition, and access to professional advice regarding the individualized selection and achievement of body composition goals (Sundgot-Borgen et al. 2013).

The problems of low energy availability were discussed in the first section, and are often identified in female athletes in the form of the loss of regular menstrual function. This should not be considered normal or healthy and should be discussed with a sports physician.

Loss of excess body fat may be required after periods of imbalanced energy intake such as the return from the off-season or injury break, or scenarios such as travel or relocation to a college or athlete program with a new eating environment. Ideally, better management would take place to minimize the gain in body fat associated with periods of reduced energy expenditure and increased food intake. Thereafter, reduction in body fat can be best achieved by a slow but continued process involving a small reduction in daily energy intake and an appropriate training plan (Garthe et al. 2011). An increase in protein intake during this period

---

**Table 2.2  Checklist of protein-rich foods providing 10 g protein.**

<table>
<thead>
<tr>
<th>Type of protein source</th>
<th>Amount of product needed to provide 10 g protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal foods</td>
<td>• 2 small eggs</td>
</tr>
<tr>
<td></td>
<td>• 300 mL reduced or low-fat milk</td>
</tr>
<tr>
<td></td>
<td>• 200 mL protein fortified milk</td>
</tr>
<tr>
<td></td>
<td>• 30 g (1.5 slices) of reduced fat cheese</td>
</tr>
<tr>
<td></td>
<td>• 70 g cottage cheese</td>
</tr>
<tr>
<td></td>
<td>• 200 g carton low-fat fruit yogurt</td>
</tr>
<tr>
<td></td>
<td>• 100 g protein-enriched Greek-style yoghurt</td>
</tr>
<tr>
<td></td>
<td>• 250 mL low-fat custard</td>
</tr>
<tr>
<td></td>
<td>• 35 g lean beef, lamb or pork (cooked weight)</td>
</tr>
<tr>
<td></td>
<td>• 40 g lean chicken (cooked weight)</td>
</tr>
<tr>
<td></td>
<td>• 50 g grilled fish</td>
</tr>
<tr>
<td></td>
<td>• 50 g canned tuna or salmon</td>
</tr>
<tr>
<td>Vegetable foods</td>
<td>• ¾ cup (150 g) lentils or kidney beans</td>
</tr>
<tr>
<td></td>
<td>• 200 g (small tin) baked beans</td>
</tr>
<tr>
<td></td>
<td>• 120 g tofu or soy meat</td>
</tr>
<tr>
<td></td>
<td>• 400 mL soy milk</td>
</tr>
<tr>
<td></td>
<td>• 60 g nuts or seeds</td>
</tr>
<tr>
<td>Supplements and sports foods</td>
<td>15–20 g high protein powder or protein hydrolysate</td>
</tr>
<tr>
<td></td>
<td>• 120–150 mL liquid meal supplement</td>
</tr>
<tr>
<td></td>
<td>• 20–30 g high protein sports bar</td>
</tr>
<tr>
<td>Less expensive alternatives to</td>
<td>25 g skim milk powder</td>
</tr>
<tr>
<td>sports foods and supplements</td>
<td>250 mL home-made fruit smoothie (recipe for 600 mL = 250 mL low-fat milk, 200 g fruit yoghurt, 1 banana or cup berries)</td>
</tr>
<tr>
<td></td>
<td>• 150 mL fortified milk shake (recipe for 600 mL = 500 mL low-fat flavored milk + 4 tablespoons ice cream + ½ cup skim milk powder)</td>
</tr>
</tbody>
</table>
can help to minimize the collateral loss of muscle mass (Phillips 2014). Guidelines to reduce energy intake to prevent or reverse gain of body fat are summarized in Table 2.1. Expertise in achieving body composition goals, or other matters of sports nutrition, can be provided by a sports dietitian.

**Nutrition to support training goals**

The goals of the everyday training diet are to assist players to perform, recover, and adapt to their training program, as well as to remain healthy and injury free. The importance of protein in these goals has been covered in the previous section, leaving this section to cover needs for carbohydrate, fluid, and micronutrients. It should be noted that as well as supporting the needs of daily training, the everyday diet should provide opportunities for players to practice with intended competition strategies. Sessions involving scrimmages, match-play, and other patterns similar to competition provide an opportunity to trial or fine tune strategies such as prematch eating, fluid and fuel intake during a match, and postmatch recovery eating.

Carbohydrate has become a misunderstood dietary energy source in recent times. In fact, carbohydrate provides an important fuel source for the muscle and brain, with the major sources being muscle glycogen and blood glucose. Unlike body fat stores, these carbohydrate stores need to be replenished on a daily basis according to the demands of practice and match-play. Although previous guidelines for sports nutrition promoted the more universal recommendation that athletes should eat diets “high in carbohydrate,” recent guidelines take an individualized and periodized approach to carbohydrate intake, recommending that athletes should consume carbohydrate-rich foods according to the likely fuel cost of the present or upcoming workouts/matches (Thomas et al. 2016). A range of carbohydrate intakes, scaled to the players’ body size, is suggested as a starting point to cover needs on match days or training days where high-quality/high-intensity training is required or in anticipation of demanding match-play (Table 2.3). Even then, players are encouraged to experiment with carbohydrate intake to find the amount that is right for their fuel needs, their overall energy needs, and food preferences/availability. It is recognized that carbohydrate targets are less important on days of light training. However, when fueling up for matches or practice or refueling between demanding sessions is important, well-scheduled intake of carbohydrate before, during, and soon after sessions can promote high carbohydrate availability for optimal performance. Table 2.4 summarizes some carbohydrate-rich menu choices (with other nutrient companions) that suit the practical needs of different situations.

<table>
<thead>
<tr>
<th>Table 2.3 Fuel requirements for training and match-play adapted for team players (adapted from Burke et al. 2011; Thomas et al. 2016).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Situation</strong></td>
</tr>
<tr>
<td>Daily training</td>
</tr>
<tr>
<td>Light/skill-based training or no training</td>
</tr>
<tr>
<td>Moderate training day</td>
</tr>
<tr>
<td>High training day or heavy match-play</td>
</tr>
<tr>
<td>Special situations of fueling</td>
</tr>
<tr>
<td>Match day fueling (before or between games in a tournament)</td>
</tr>
<tr>
<td>Speedy refueling (e.g. &lt;8 h between demanding workouts/games)</td>
</tr>
<tr>
<td>Repeat each hour until the normal meal schedule is resumed</td>
</tr>
<tr>
<td>Pregame fueling</td>
</tr>
<tr>
<td>During game:</td>
</tr>
<tr>
<td>Short match time or smaller fuel demands</td>
</tr>
<tr>
<td>Larger game demands</td>
</tr>
</tbody>
</table>

Fat is the other major nutrient in a player’s diet, and its role in health and performance is also misunderstood. Popular diets promoting a high-fat, low-carbohydrate intake have not been proven to be of benefit for sports performance, particularly in sports that are reliant on high-intensity activities. While reducing unnecessary intake of fats and oils can be a useful way to reduce energy intake, it is also unnecessary to obsessively avoid fat-containing foods. Indeed, restrained eating of this type reduces
dietary enjoyment as well as the opportunity to eat many otherwise nutrient-rich foods. Furthermore, we need to eat some fat-rich sources to obtain our requirements for essential fatty acids and fat-soluble vitamins. Table 2.5 provides some examples of nutrient-rich sources of good fats.

Typically, athletes who consume moderate to high energy intakes from a varied diet based on nutrient-rich foods report intakes of vitamins and minerals well in excess of Recommended Daily Allowances/Intakes and any increases in micronutrient demand caused by training, as well as phytochemicals associated with good health (see Table 2.5). Thus routine supplementation with vitamins is not justified, and research has failed to show evidence of an increase in performance following vitamin supplementation except in the case where a preexisting deficiency was corrected. Energy restriction, fad diets, and disordered eating are the typical causes of inadequate micronutrient intake of some athletes. Food variety may also be restricted by poor practical nutrition skills, inadequate finances, and an overcommitted lifestyle that limits access to food and causes erratic meal schedules. Players in this situation should receive education about the quality and quantity of food intake, but a low-dose, broad-range multivitamin/mineral supplement may be useful when they are unwilling or unable to make dietary changes, or when traveling to places with uncertain food supplies or eating schedules.

The micronutrients most likely to be consumed in inadequate amounts by volleyball players are iron and calcium. Inadequate iron status can reduce exercise performance via suboptimal levels of hemoglobin and perhaps iron-related muscle enzymes. However, it may be difficult to distinguish true iron deficiency from alterations in measures of iron status that are caused by exercise itself (e.g. changes in hemoglobin due to changes

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### Table 2.4 Practical carbohydrate-rich food choices to meet special situations in sport.

<table>
<thead>
<tr>
<th>Carbohydrate-rich choices for prematch meals</th>
<th>Carbohydrate-rich snacks for traveling or busy lifestyle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics: familiar and easily digested foods eaten 1–3h before match according to logistics and personal experience</td>
<td>Characteristics: portable and easy to prepare or eat. Ideally should provide a source of protein*</td>
</tr>
<tr>
<td>Suitable for morning matches:</td>
<td>Breakfast cereal (+ skim milk powder*)</td>
</tr>
<tr>
<td>Breakfast cereal + milk + fresh/canned fruit</td>
<td>Crackers and tins of tuna*</td>
</tr>
<tr>
<td>English muffins/bagels + toppings</td>
<td>Crackers and cheese* snack packs</td>
</tr>
<tr>
<td>Pancakes + syrup</td>
<td>Trail mix with nuts* and dried fruit</td>
</tr>
<tr>
<td>Toast + baked beans or eggs</td>
<td>UHT treated flavored milk*</td>
</tr>
<tr>
<td>Suitable for afternoon or evening matches:</td>
<td>Liquid meal supplements* – powder and ready-to-drink Tetrapacks</td>
</tr>
<tr>
<td>Rolls or sandwiches with fillings</td>
<td>Sandwiches or wraps with meats/cheese fillings (check ability to keep cool)</td>
</tr>
<tr>
<td>Pasta with simple sauce</td>
<td>Flavored Greek-style yogurt + fruit salad (check ability to keep cool)</td>
</tr>
<tr>
<td>Stir fry with rice</td>
<td></td>
</tr>
<tr>
<td>Risotto – hold heavy cream sauces</td>
<td></td>
</tr>
<tr>
<td>Baked potatoes with low-fat filling</td>
<td></td>
</tr>
<tr>
<td>Easily digested liquid meals:</td>
<td></td>
</tr>
<tr>
<td>Fruit smoothie (low-fat milk + fruit + yogurt/ice cream)</td>
<td></td>
</tr>
<tr>
<td>Liquid meal supplement</td>
<td></td>
</tr>
</tbody>
</table>

### Postmatch recovery eating

Characteristics: provides carbohydrate for refueling and protein for adaptation. Fluid and electrolyte replacement is also useful

<table>
<thead>
<tr>
<th>Snacks for competition venue or lighter-style meals (including easily eaten choices):</th>
<th>Meals:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandwiches or wraps with meats/cheese/egg fillings</td>
<td>Pasta with meat sauce</td>
</tr>
<tr>
<td>Pizza with healthy toppings</td>
<td>Main meal salads with noodles or bread</td>
</tr>
<tr>
<td>Liquid meal supplement or fruit smoothies</td>
<td>Make your own fajitas with tortillas and rice</td>
</tr>
<tr>
<td>Sushi rolls with salmon/chicken fillings</td>
<td>Baked or grilled meats with baked potatoes</td>
</tr>
<tr>
<td>Flavored milk</td>
<td>Healthy burgers with salad and wholegrain buns</td>
</tr>
<tr>
<td>Creamed rice</td>
<td>Stir fry or curries with rice</td>
</tr>
<tr>
<td>Soup made with milk or added meats + rolls</td>
<td>Risotto or rice dishes</td>
</tr>
<tr>
<td></td>
<td>Fruit-based dessert with yogurt or custard</td>
</tr>
</tbody>
</table>

---
in plasma volume or increases in ferritin due to the inflammatory response to exercise). Therefore, measurements of iron status should be taken under standard conditions and interpreted by experienced practitioners.

Conditions that can lead to a true risk of becoming iron deficient include situations of increased iron requirements (e.g. growth spurts) or increased iron losses (heavy menstrual periods, gastrointestinal bleeding, or destruction of red blood cells through traumatic damage such as bruising or foot strike hemolysis). A thorough patient history and investigation may reveal these factors to be present in some volleyball players. However, the most common risk factor among players, as in all young people, is a low-energy diet or low intake of available iron. Females, athletes who restrict dietary energy intake or variety, vegetarians, and athletes eating low quantities of meat or iron-fortified cereals are most at risk. Evaluation and management of iron status may need assessment by a sports medicine expert. Low iron status (serum ferritin levels lower than ~30ng/mL) should be considered for further assessment and treatment.

Although the effect of low iron status without anemia on performance is unclear, many athletes with low iron stores, or a sudden drop in iron status, complain of fatigue and inability to recover after heavy training or a failure to respond to altitude training. Many of these respond to strategies that improve iron status or prevent a further decrease in iron stores. Although one study has reported a preservation of iron status and better performance over the competition season in a group of volleyball players (Mielgo-Ayuso et al. 2015), individual screening of iron status with appropriate attention to the results is generally preferred to a philosophy of routine iron supplementation for all players.

Prevention and treatment of iron deficiency may, of course, include iron supplementation. However, long-term management should be based on dietary counseling to increase intake of bioavailable iron by increasing intake of heme iron sources and complementary intake of vitamin C or meat foods with non-heme iron foods (see Table 2.5). There is evolving knowledge about the role of exercise in increasing levels of hepcidin, a hormone that reduces iron absorption, and the recycling of iron released from the destruction of red blood cells. Future research may see this translated into more definite recommendations around the timing of iron intake after exercise sessions to avoid the coincidence of iron-rich meals with the periods of reduced capacity for iron absorption.

### Table 2.5 Checklist of common food sources of key nutrients.

<table>
<thead>
<tr>
<th>Iron-rich foods</th>
<th>Calcium-rich foods</th>
<th>Vitamins and phytochemicals</th>
<th>“Good” fats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef, lamb</td>
<td>Milk</td>
<td>Wholegrain cereals</td>
<td>Oily fish – salmon, tuna, sardines, etc.</td>
</tr>
<tr>
<td>Dark cuts of poultry</td>
<td>Cheese</td>
<td>Nuts</td>
<td>Nuts</td>
</tr>
<tr>
<td>Shellfish</td>
<td>Yogurt</td>
<td>Legumes</td>
<td>Seeds</td>
</tr>
<tr>
<td>Liver and offal</td>
<td>Calcium-fortified soy products</td>
<td>Dairy foods</td>
<td>Avocados</td>
</tr>
<tr>
<td>Legumes</td>
<td>Calcium-enriched juice</td>
<td>Soy products</td>
<td>Olives and olive oil</td>
</tr>
<tr>
<td>Tofu</td>
<td>Fish with soft bones, e.g. salmon, sardines</td>
<td>The “rainbow” of fruit and vegetables:</td>
<td></td>
</tr>
<tr>
<td>Iron-fortified breakfast cereals</td>
<td>Leafy green vegetables</td>
<td>• Pink-red (e.g. tomatoes, watermelon, ruby and pink grapefruit, cherries and red berries, rhubarb)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Yellow-orange (e.g. carrots, pumpkin, sweet potatoes, peaches, apricots, papaya, cantaloupe, mango)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Green (e.g. broccoli, beans, dark lettuce, silverbeet, spinach, peas, avocados, green capsicums, green apples)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Blue-purple (e.g. purple grapes, raisins, blueberries, blackberries, raspberries, plums, eggplant)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• White (e.g. mushrooms, bananas, onions, cauliflowers, potatoes)</td>
<td></td>
</tr>
</tbody>
</table>
Some players are at risk of problems with calcium status and bone health. Although bone-loading exercise, such as the jumping patterns found in volleyball, is an important protector of bone health, a serious consequence of the low energy availability discussed earlier in this chapter is the high risk of either direct loss of bone density or failure to optimize the gaining of peak bone mass that should occur during the 10–15 years after the onset of puberty. Calcium requirements may be increased to 1200 mg/day in female athletes with impaired menstrual function. Where adequate calcium intake cannot be met through dietary means, usually through use of low-fat dairy foods or calcium-enriched soy alternatives (see Table 2.5), a calcium supplement may be considered.

Vitamin D deficiency or insufficiency is now recognized as a potential problem in the general population, at least for individuals who have poor exposure to UV from sunlight. Volleyball players often share some of the “high-risk” characteristics for inadequate sunlight exposure: training indoors, residing at latitudes greater than 35°, or overzealous use of protective clothing or sunscreen when outdoors. Athletes with these characteristics should seek professional advice and have their vitamin D status monitored. Although there is dispute over optimal vitamin D status, prevention or treatment of vitamin D insufficiency may require supplementation.

Fuel and fluid for match-play

The goal of match nutrition is to anticipate the nutrition-related factors that cause a decrease in performance over the course of a match or tournament, and to align eating strategies to reduce or delay the onset of these causes of fatigue or loss of skill/concentration. Table 2.6 summarizes a number of these factors, with most focus on inadequate fuel and fluid status, factors that can be addressed by well-chosen nutrition strategies before, during or between matches.

Although there are no studies on the actual glycogen costs of a volleyball match (and in any case, these will vary from match to match and between players within the same match), it is generally accepted that players will be able to fuel up adequately for a match by consuming carbohydrate-rich meals/snacks on the day before and day of competition (see Table 2.3), with the prematch meal (see Table 2.4) providing the final chance to top up muscle fuel stores. Poor performance and fatigue associated with depletion of muscle glycogen stores in a match are most likely to occur when a match is commenced with inadequate refueling from a previous demanding match or training session. This can occur during a crammed tournament or multicompétition match schedule, or when matches are played during a period of intensified training. Conversely, players who are restricting total energy intake (e.g. weight loss diets) or carbohydrate intake may not refuel efficiently before a match. Attention to overall training/match load and matching these demands with appropriate intake of carbohydrate can help to avoid this cause of impaired performance.

Attention to hydration issues for optimal performance mirrors the principles of carbohydrate needs whereby fluids and electrolytes should be replaced on a daily basis to track sweat losses, and that a well-chosen fluid plan during training and match-play can generally reduce dehydration to levels which will have little impact on performance. However, challenges to this occur in situations where players carry dehydration from one match or practice to the next, due to inadequate rehydration between sessions. Sweat losses occur during exercise to allow the cooling effects of sweat evaporation to assist with the dissipation of heat produced by the working muscle. Large sweat losses occur when exercise is of high intensity, prolonged, and conducted in a warm environment with poor air circulation. Athletes with high muscle mass will also generate more heat and require greater sweat loss for temperature regulation. Since all these conditions can coincide in a volleyball practice or match, it makes sense for players to become familiar with their typical sweat loss characteristics and to develop hydration plans matched to these. Weighing before and after a session provides an estimate of the fluid deficit that has occurred as a result of a mismatch between sweat losses and fluid intake (1 kg = 1 L of fluid), and players are generally
advised to keep this to less than 2% of body mass (e.g. 1.5 kg and 2 kg in a 75 kg and 100 kg player, respectively). Periodic assessments in demanding training sessions and matches will allow the player to assess how successful they are in meeting these targets.

A volleyball match provides opportunities for fluid intake at the sideline during substitutions or between sets, and players should use opportunities in training sessions to develop and practice an individualized plan of intake of appropriate drinks. This will allow the player to develop appropriate behaviors/routines, as well as to learn to tolerate the feeling of fluid in the gut during high-intensity match-play. Of course, in the training scenario, breaks in play are under the control of coaching staff, so it is important that they encourage good behavior and provide ample access to fluid intake. Fluids should be kept cool to promote palatability and to assist with temperature regulation, while the addition of flavor, carbohydrate, and electrolytes can be justified, in many situations, on the basis of improved palatability and/or physiological need. As we will see below, the use of sports drinks can offer some performance advantages in many match situations. Although there are no specific studies on the effect of carbohydrate and fluid replacement on volleyball performance, research on basketball has shown that a proactive fluid/fuel plan is associated with better performance, if not a reduced perception of effort by players (Baker et al. 2007; Dougherty et al. 2006).

After the session is finished, players should recover from residual dehydration by addressing both the fluid deficit and the electrolytes lost in sweat. When rehydration is a priority – for example, to prepare for the next match or demanding workout within the next hours – it makes sense to have a rehydration plan for this recovery period: this should involve the intake of a volume of fluid equivalent to ~125–150% of the remaining fluid deficit (to account for ongoing sweat and urine losses) as well as the replacement of sodium (via the use of electrolyte-containing sports drinks or oral rehydration fluids or by the intake of sodium containing fluids) (Maughan and Shirreffs 2010; Shirreffs and Sawka 2011). Hydration goals should be integrated into the larger recovery plan which is likely to also involve the replacement of protein and carbohydrate (see Table 2.4).

Carbohydrate is another nutrient that might be consumed during exercise, and there is a large body of research which shows that this strategy can improve performance by providing an alternative fuel source as muscle glycogen stores become depleted (Burke et al. 2011). Therefore, this metabolic role for carbohydrate might be justified for players with the heaviest match-play demands, especially in tournament or other situations in which full recovery of glycogen stores between

---

**Table 2.6** Common factors related to nutrition that could produce fatigue or suboptimal performance in a volleyball match.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
<th>Examples of high-risk/common occurrence in volleyball</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehydration</td>
<td>Failure to drink enough fluid to replace sweat losses during a game. May be exacerbated if player begins match in fluid deficit</td>
<td>Matches played in hot conditions, particularly for players with high activity patterns. Repeated matches (e.g. tournaments) may increase risk of compounding dehydration from one match to the next</td>
</tr>
<tr>
<td>Muscle glycogen depletion</td>
<td>Depletion of important muscle fuel due to high utilization in a single match and/or poor recovery of stores from previous activity/match</td>
<td>Unlikely to occur in a single match, but repeated matches or training sessions with inadequate recovery time between may lead to gradual glycogen depletion, especially in players eating a low-carbohydrate diet</td>
</tr>
<tr>
<td>Depletion of phosphocreatine stores</td>
<td>Inadequate recovery of phosphocreatine system of power production</td>
<td>Prolonged or repeated intervals of high-intensity activities</td>
</tr>
<tr>
<td>Gastrointestinal disturbances</td>
<td>GI disturbances, including vomiting and diarrhea, may directly reduce performance as well as interfering with nutritional strategies aimed at managing fluid and fuel status</td>
<td>Poorly chosen intake of food and fluid before and/or during match</td>
</tr>
</tbody>
</table>
sessions is difficult. In these scenarios, a carbohydrate intake of 30–60 g/h is recommended, and can be achieved via sports foods (sports drinks, gels, etc.) or by everyday foods (juice, fruit, confectionery) according to the budget and gut tolerance of the player or their team (see Table 2.3). Again, practice in training may help to develop tolerance for this match plan.

A recent area of interest in sports nutrition involves the recognition that carbohydrate intake during sport plays a secondary role in performance via its effect on the brain. A number of studies have shown that even in brief high-intensity sports, in which there is little need for muscle fuel support, the intake of small amounts of carbohydrate promotes faster speeds or greater power outputs (Burke and Maughan 2015). The mechanism for this benefit appears to be the stimulation of reward centers in the brain and central nervous system that make the athlete feel “better” and motivated to push harder. Although this has not been specifically studied in scenarios mimicking the activity patterns and skills of real-life team sports, it provides another reason to consider the intake of carbohydrate during a match. In this instance, only small amounts are needed— including simply rinsing the mouth with a carbohydrate drink— and the best pattern of use seems to be small but frequent mouth contact where the drink or food item is exposed to receptors in the mouth and throat for ~10 seconds (see Table 2.3). Opportunities to practice this type of intake are particularly suited to team games where there is access to fluids/supplies during substitutions or sets.

Some final issues of competition eating around prematch and postmatch food choices merit comment, particularly in the context of team sport and tournament play. In the case of the team issue, the opportunity to organize catering for all players is valuable since it can be used to educate and feed players appropriately while also promoting team culture and match preparation/debriefing activities. The tournament style of competition adds extra and unique challenges to performance nutrition by increasing nutritional demands due to more frequent match-play and shortened recovery periods. In addition, the tournament may require that match nutrition be achieved in spite of an unusual and changing timetable. For example, the competition fixture might involve both early morning and late night matches within a brief period, requiring players to adjust both their pre- and postmatch timetables and food choices appropriately. When travel is involved, the team and each player must consider whether access to food in the location needs to be supplemented by supplies brought from home (see Table 2.4).

In the case of the prematch meal, the major goals relate to fueling up with carbohydrate-rich choices and choosing a menu that is familiar and comfortable for the player. Table 2.4 presents different choices that might suit different times of day, but all menus should allow individual preferences and individualized needs to be met. When players are nervous, or the timetable does not allow time for larger meals to be comfortably consumed, liquid meals and smoothies are a useful option. In the postmatch setting, early intake of carbohydrate and protein can be provided by snacks or immediate access to a meal (see Table 2.4), although, again, individual preferences, appetite suppression, and the logistics around access to food supplies might dictate what is suitable.

One postmatch dietary practice that has been documented in sources ranging from formal studies to lay reports and newspaper headlines is the apparently high rates of excessive alcohol intake among team sport athletes. Alcohol has a strong relationship to sport through the sponsorship of events and teams by companies that produce or serve alcoholic drinks. Some dietary surveys have shown that reported alcohol intakes are higher among team sports than other athletic groups, with the pattern of consumption involving binge drinking sessions after a match or during the off-season. Problems that may arise from these patterns include some level of direct impairment of the physiological processes underpinning recovery as well as the larger problem of indirect interference secondary to the failure to follow optimal nutritional and lifestyle practices while intoxicated. There is public documentation of the unfortunate outcomes of the poor judgment and high-risk behavior undertaken by athletes who are intoxicated, including loss of sponsorship value and public regard, criminal offences and, in
Nutrition for optimum volleyball performance

extreme cases, serious injury and death (Burke 2007). Chronic episodes can lead to health problems and failure to achieve performance nutrition goals such as weight control. For these reasons, many team sports and individual clubs now run education programs related to alcohol and illicit drug use, which include information about the damaging effects on a sporting career via loss of performance and reputation.

Supplements and sports foods for volleyball

The sports world is filled with supplements and sports foods that claim to make the athlete faster, higher, stronger, or whatever other factors are important to performance. Many authorities are concerned about the lack of regulation of much of this industry and warn athletes that supplements are unnecessary and dangerous. However, such a blanket ban is generally unpopular and unrealistic in addressing the interests of athletes/coaches and fails to recognize the different types of products that can fall under the banner of sports supplement/food. The ever-growing range of products can be divided into three separate categories: sports foods, medical supplements, and performance supplements. Sports foods address the special nutritional needs of athletes, offering the ability to deliver convenient amounts of key nutrients at times when it might not be practical to consume everyday foods. This is particularly relevant for intake immediately before, during or after exercise and these products can be shown to improve performance when they allow the athlete to achieve their sports nutrition goals. However, they are more expensive than normal food, a consideration that must be balanced against the convenience they provide. Products which may be of use to volleyball players are summarized in Table 2.7, along with examples of medical supplements which may be used under supervision to correct or prevent nutrient deficiencies.

Finally, performance supplements – products that promise a direct and “supraphysiological” benefit to sports performance – are the supplements that seem most appealing to athletes. These products, which continually change in popularity, include a large number of ingredients or different formulations for which there is no evidence of performance benefits. However, there are a small number of performance supplements for which there is evidence of competition benefits (see Table 2.7), when they are used according to a well-researched protocol to address a specific aspect of physiological fatigue or limitation. In the case of volleyball, there is evidence that caffeine (Del Coso et al. 2014; Pérez-López et al. 2015) can be used in modest doses to improve some of the movement patterns and skills of match play. Furthermore, a 4-week program of creatine loading has been shown to provide a likely benefit to volleyball specific jumping ability in highly trained volleyball players (Lamontagne-Lacasse et al. 2011). This study adds to the body of evidence that this supplement can enhance training outcomes or competition performance in sports involving repeated high-intensity work bouts. Of course, such performance supplements should not be used by junior players due to general health issues, but also to acknowledge that young athletes should prioritize the other many opportunities to improve their performance via good nutrition, sleep, and training habits as well as general maturation in age and in their sports experience (Desbrow et al. 2014).

Volleyball players should seek expert advice about such supplements to see if their sport/training warrants experimentation with sports foods or supplements, and to ensure that a correct protocol is tried. The Sports Supplement Framework of the Australian Institute of Sport provides information about many products, and rates supplements and sports foods into four categories based on the amount of scientific support for the claims made about the use of the product, and whether there is a risk of an antidoping rule violation (see www.ausport.gov.au/ais/nutrition).

One risk that should be considered when contemplating the use of supplements is the potential for a product to contain impurities and contaminants. Since the mid-1990s it has become apparent that some supplements contain prohormones and stimulants that are banned under antidoping codes. While these products should be declared as
Table 2.7  Sports foods and supplements that may be used by volleyball players to achieve nutritional goals.

<table>
<thead>
<tr>
<th>Product</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sports foods</strong></td>
<td>These products are more expensive than everyday foods, but there may be times when this expense is justified</td>
</tr>
<tr>
<td>Sport drinks</td>
<td>Convenient source of fluid, carbohydrate, and electrolytes to refuel and rehydrate during prolonged training sessions and matches and to rehydrate after the session</td>
</tr>
<tr>
<td>Sport gels</td>
<td>Convenient and compact carbohydrate source that can be used for additional refueling during prolonged matches and prolonged training sessions</td>
</tr>
<tr>
<td>Liquid meal supplements (and meal replacement bars)</td>
<td>Convenient, portable, and easy-to-consume source of carbohydrate, protein, and micronutrients for postexercise recovery, including “recovery” intake before resistance exercise</td>
</tr>
<tr>
<td></td>
<td>Low-bulk and practical form of energy and nutrients that can contribute to high energy needs, especially to support resistance training program or growth</td>
</tr>
<tr>
<td></td>
<td>Well-tolerated prematch meal that can provide a source of carbohydrate quite close to the start of a match or workout; seems to be better tolerated than solid food by some athletes with high risk of gastrointestinal problems</td>
</tr>
<tr>
<td></td>
<td>Convenient and compact source of energy and nutrients for the traveling athlete</td>
</tr>
<tr>
<td>Protein supplements (especially whey powders)</td>
<td>Convenient, portable, and easy-to-consume source of high-quality protein for postexercise recovery, particularly for immediate intake after key sessions and matches, to provide a presleep protein boost, and to add protein to meals/snacks where the available food choices cannot meet protein goals (20–30 g)</td>
</tr>
<tr>
<td></td>
<td>Source of protein to be used under medical supervision to treat or prevent protein deficiency</td>
</tr>
<tr>
<td></td>
<td>Convenient way to consume fluid and electrolytes post exercise to promote rapid rehydration and restoration of sweat losses</td>
</tr>
<tr>
<td><strong>Medical supplements</strong></td>
<td>These should be taken only on the advice of a sports physician or dietitian, and as part of an overall plan to prevent or treat a nutrient deficiency</td>
</tr>
<tr>
<td>MultiVitamin and mineral supplement</td>
<td>Supplemental source of micronutrients for traveling when food supply is not reliable</td>
</tr>
<tr>
<td></td>
<td>Supplemental source of micronutrients during prolonged periods of energy restriction (female athletes)</td>
</tr>
<tr>
<td>Iron supplements</td>
<td>Source of iron to be used under medical supervision to treat or prevent iron deficiency</td>
</tr>
<tr>
<td>Calcium supplements</td>
<td>Source of calcium to be used when optimal intake cannot be met via dietary sources. If used in relation to poor bone status (especially female players), should be part of an interdisciplinary approach</td>
</tr>
<tr>
<td>Vitamin D supplements</td>
<td>Source of vitamin D used under medical supervision in the treatment or prevention of vitamin D deficiency due to inadequate exposure to sunlight</td>
</tr>
<tr>
<td><strong>Performance supplements</strong></td>
<td>These should be used only when the player reaches maturity in their age and sporting talent, and only with the advice of a sports physician or dietitian who can develop an evidence-based plan for their use. Care should be taken in purchasing reputable products that are low risk in terms of contamination with banned products</td>
</tr>
<tr>
<td>Caffeine/energy drinks</td>
<td>Several studies have shown that small doses of caffeine (3 mg/kg BM) can enhance the performance of movement patterns and skill in volleyball matches</td>
</tr>
<tr>
<td></td>
<td>This is not appropriate for young players or those playing in competitions where caffeine use is restricted</td>
</tr>
<tr>
<td></td>
<td>The effect on sleep patterns should be considered if caffeine is used in matches played in the evening</td>
</tr>
<tr>
<td>Creatine</td>
<td>Creatine loading may improve the outcomes of resistance training and “interval”-based conditioning training, leading to greater strength and fatigue resistance on court</td>
</tr>
<tr>
<td></td>
<td>This is not appropriate for young players or those playing in competitions where creatine use is restricted</td>
</tr>
</tbody>
</table>
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Ingredients on supplement labels, this does not always occur. In fact, a study by an IOC-accredited laboratory found that 15% of supplements contained detectable levels of undeclared banned prohormones. Situations of “contamination” can include products containing therapeutic doses of banned stimulants or steroids, not identified on the ingredients list, presumably to ensure that the supplement “works.” More frequently, however, the contamination occurs in trace amounts. These impurities may be sufficient to cause an inadvertent doping outcome in drug testing. Athletes face a code of strict liability under antidoping laws and will be held responsible for any failed drug test even when it can be proved that they ingested a supplement containing banned ingredients unwittingly.

Conclusion

The goals of sports nutrition vary even within the same sport, so an individualized approach to nutrition for each volleyball player is warranted. Nevertheless, there are common themes involved with the support of the training program, the achievement of an ideal physique, and optimizing match day performance. On occasion, the use of well-chosen sports foods and supplements may contribute to a sports nutrition plan. The player can be assisted by the advice of a sports dietitian to adopt eating practices that achieve all their goals for health and performance, with clever menus, meal spacing, and food choices allowing a number of goals to be integrated into the same nutrition plan.

References


**Recommended reading**


Introduction

Biomechanics has been defined as the study of the mechanical laws relating to the movement or structure of living organisms. As such, it enables sport scientists to understand the forces that result from or which influence movement. An analysis of the biomechanics of the specific skills that are performed by volleyball athletes permits optimal sport performance while minimizing the risk of injury.

Jumping and landing

Jumping ability is a key component of competitive success in indoor and beach volleyball. Jumping ability influences each of the fundamental skills of volleyball in important ways:

- jumping higher allows the server to play the ball with a flatter initial projection angle;
- it allows the setter to decrease the time between the set and the attack;
- it allows the attacker to spike over the block and the blocker to penetrate far over the net with his/her arms, thereby increasing the effectiveness of the block.

Individual muscle properties, movement conditions, and jumping technique all help to determine the height of a jump. It is important to remember that following a jump, landing is inevitable. The way athletes land influences the load transmitted to their joints. Therefore, landing techniques are a crucial component of volleyball injury prevention.

Neuromechanics of jumping

There is a deterministic relationship between the velocity of the center of mass (CoM) at take-off ($v_{TO}$) and the height attained during a jump (Eq. (i)). Thus, to jump higher, athletes should maximally accelerate their center of mass prior to take-off. According to Newton's law of motion (Eq. (ii)), the acceleration ($a$) of an object is proportional to the sum of the forces ($F$) applied to that object. During a jump, the forces acting on the body include the weight due to the mass of the athlete and forces transferred from the activated muscles to the ground (ground reactive forces). While the body weight acting on the athlete is constantly directed downward, the athlete extends his/her hips, knees, and ankles to produce force that accelerates the CoM upwards. The greater the force the athlete is able to apply to the ground prior to take-off (i.e. the greater the applied impulse), the more the athlete accelerates his/her center of mass, resulting in a higher take-off velocity and a greater jumping height.
Besides the intrinsic development of force by the muscles due to recruitment of motor units and an increased rate of firing of those motor units, the amount of force acting on the center of mass depends on movement conditions, i.e. the contraction dynamics or the transfer of force to the ground. According to the force–velocity relationship, the force a muscle is able to develop is related to the inverse of its contraction velocity. Higher forces may be developed by slower concentric contraction velocities, while even greater muscle contractile forces are generated by isometric contractions (contraction velocity=zero) or by eccentric contractions (in which the contractile velocity is negative, reflecting the fact that the muscle fiber lengthens in this type of contraction). In addition, the force–length relationship describes the force which a muscle can develop depending on its length.

The force generated by the muscle is transferred via the tendons to the bones and subsequently to the ground. This is influenced by composition of the tendons and the jumping surface (including both shoes and floor type).

Intrinsic muscle properties such as the neural activation capacity, the force–velocity relationship, and the force–length relationship can be altered (within individual limits) by training. Simulation studies (Thaller et al. 2010) have shown that in order to increase jump height, individuals should target the specific physiological aspects of their neuromuscular system in which they might be deficient. This underlines the importance of individualized training. While some athletes might have to increase their maximal force development, others might have to improve upon a deficit in maximum muscle contraction velocity or maximum power capacity. Regression analyses on experimental data have shown that in general, the capacity to develop high mechanical power during the push-off phase is closely related to jumping height (Aragon-Vargas and Gross 1997). The general importance of muscular power is also underlined by the results of a review by Ziv and Lidor (2010) who demonstrated the ability of explosive plyometric training to increase jump height in volleyball players. Since jump movements are limited in time, an improvement in neural activation capacity will increase the capacity for force generation and therefore improve jump height.

Different aspects of jump technique such as a countermovement or the arm swing may have substantial effects on jump height performance. A counter movement, i.e. a lowering of the CoM just before the beginning of the push-off phase, can potentially increase jump height by approximately 7% (Wagner et al. 2009). The reasons for this increase are increased myoelectrical activity in the stretch-shortening cycle (SSC), the storage and recoil of elastic energy, and a higher active state, i.e. increased motoneuron activity before the start of the muscle shortening (Bobbert et al. 1996). Researchers have also reported a 19–23% increase in jumping height due to the use of an arm swing. The reasons for this improvement are an elevated center of mass (due to arm elevation at take-off) and a decrease of contraction velocity of the leg muscle which leads to an increase in muscle force generation via the force–velocity relationship.

Another important movement condition is the surface on which the jump is performed. It has been shown experimentally that jumps on sand are on average 14% lower than jumps from a rigid surface. The reason for this decrease is the energy absorbed by the soft surface (i.e. the sand). Similar but less substantial effects can be expected from different shoe sole or indoor surface materials. Although stiff materials have advantages during the take-off, they will also absorb less energy during the landing phase which might lead to higher stress in the athlete’s lower limb joints.

Jumping is a skill demanded of elite volleyball players. Jumping ability correlates with performance, as a recent study (Sattler et al. 2015) revealed that volleyball players from the Slovenian first division jump higher than their colleagues from the second division. Furthermore, when combined with a countermovement, volleyball players were found to jump higher compared to soccer, handball, basketball, or rowing athletes.
Jumping as a component of spiking and serving

In order to smash an unreturnable volleyball into the opposing team's court, volleyball athletes try to reach the greatest possible jumping height during their spike jump. The volleyball spike jump technique is a three-step approach with a two-legged jump, a countermovement, and the use of an arm swing (Wagner et al. 2009). Due to these favorable movement conditions, spike jump (SPJ) heights are generally greater than the heights reached during a squat jump (SJ) or a countermovement jump (CMJ) from a standing position. While SPJ are reported to be approximately 25% higher than CMJ, CMJ are about 7% higher than SJ (Bobbert et al. 1996; Wagner et al. 2009). The kinematics of the volleyball SPJ was first analyzed by Coleman et al. (1993). More recently, Wagner et al. (2009) analyzed SPJ technique and identified the most important kinematic parameters related to the volleyball SPJ height in high-level athletes. SPJ height correlated significantly with the maximal horizontal velocity of the CoM, and with a minimum vertical displacement of the CoM during the three-step approach. Thus, within the measured ranges, a faster approach and a lower squat during jump preparation (Figure 3.1) were related to greater jumping heights.

Although the SPJ is a two-legged jump, only the range of motion (RoM) of the right knee (flexion–extension) and the maximal angular velocity of the left (nondominant) shoulder hyperextension were significantly related to jumping height. The reason for this is probably that the SPJ is rather asymmetrical, as can be seen in Figure 3.1. Wagner et al. (2009) found that during the upward phase, the right foot is closer to the CoM than the left foot and therefore would contribute predominantly to the vertical acceleration of the CoM. Another asymmetry that can be observed to occur is trunk rotation in the upper body. Figure 3.1 shows the trunk rotation around the vertical axis, enabling acceleration of the hitting arm.

Jumping as a component of blocking

Similar to a soccer goalkeeper reacting to an approaching attacker, blockers try to minimize the opponent's attacking angle by reaching over the net with their arms. Mechanically, this produces angular momentum around the transverse axis. Since the blocker is in the air during the jump, the laws of physics implicate a preservation of (angular) momentum. Hence, the momentum generated by the arms has to be counterbalanced by an equal and
opposite (angular) momentum of a different body part. If this compensatory movement is not actively executed by the legs (Figure 3.2), the compensation might occur by a backward movement of the trunk. This would not be preferred since it would decrease the ability of the blocker to reach over the next with his/her arms and might open a gap between the arms and the net. Compensation of the angular momentum of the arms by the lower limbs can also be observed to occur around the anterior-posterior axis (see Figure 3.2). In order to avoid a technical mistake by penetrating the centerline, or an uncontrolled landing, these angular moments have to be compensated during the landing.

**Landing from the jump**

As the adage goes, “What goes up, must come down.” Thus, landing is inevitable following a jump. During the downward phase of a jump, the athlete increases his/her downward momentum due to gravity. This momentum must be dissipated during the touch-down phase by the ground reaction forces acting on the body. Depending on the firmness of the surface (hard/soft) or the muscle activation status and hence the stiffness of the legs, the peak ground reaction forces can vary substantially during landing. The peak forces and loading rate during landing generally exceed those generated during take-off. Such high forces are related to high stress in the joints of lower limb and may contribute to both acute and overuse injuries such as anterior cruciate ligament ruptures or patellar tendinopathy (Bahr and Reeser 2003).

In volleyball, several factors influence the ground reaction force produced during landing. The landing surface affects the forces acting on the athletes. Firmer playing surfaces are well known to contribute to the risk of overuse pathology in the lower limb, as does the stiffness of the footwear worn by the athlete. Conversely, it is equally well appreciated that playing beach volleyball on soft sand reduces the risk of patellar tendinopathy compared to indoor players. Besides the environmental

**Figure 3.2** Upper body movement (*dashed arrow*) compensated by lower body movements (*full arrow*) around the transverse (*open circle, left picture*) and anterior-posterior axis (*open circle, right picture*) during block movements. Source: FIVB Photo Gallery. Used with permission of FIVB.
factors, the lower limb muscle activation pattern and landing technique of the athlete will affect the forces generated during landings. Researchers analyzed landing patterns (single leg landings (left or right) or both feet together) in high-level volleyball players and detected differences between males and females in block, set, and spike but not for the jump serve. Furthermore, one-footed landings carried a higher risk of injuries related to court position and setting trajectory. Athletes who spiked faster sets were more likely to land on one foot (e.g. the slide).

**Differences between indoor and beach volleyball**

Although in concept indoor and beach volleyball are quite similar, certain demands vary significantly between disciplines, including substantial variation in the number of ball contacts made by each player during an average match. Beach volleyball athletes were found to adapt their techniques to playing on the softer sand surface. For example, beach players slowed their movements, particularly during the eccentric-concentric phase of maximum knee flexion and during the acceleration phase. One explanation is that higher accelerations might only lead to greater penetration into the sand but not greater jumping height. On sand, players tended to lower their CoM even lower than indoors (Figure 3.3) in an effort to reach maximum jump height. Furthermore, beach volleyball players placed their feet more parallel and flatter on the ground compared to indoor players. The authors hypothesized that the flatter foot orientation on sand increases the contact area where force can be distributed and therefore may reduce any tendency to sink into the sand.

While sand volleyball has acknowledged disadvantages regarding jump height, it has definite advantages regarding landing. Lower jump heights result in a reduced downward momentum prior to landing. In addition, the yielding property of sand decreases ground reactive forces generated during landing compared to harder, indoor surfaces. At touch-down, the downward momentum must be decreased by the ground reaction force acting on the body. On a softer surface, the sum of the ground reaction forces is distributed over a greater distance (due to the greater penetration in the sand compared to a hard surface in the gym) and over greater time. Thus, the maximum force generated by a sand surface is smaller compared to that generated by a hard surface. Furthermore, with only two players per team, beach volleyball is somewhat more predictable strategically than is the six-person-a-side indoor game. This results in more controlled two-footed landings during a contest, particularly for males (Tilp and Rindler 2013). This might be one reason for the fewer acute injuries in beach compared to indoor volleyball, despite the fact that

![Figure 3.3](image-url) **Figure 3.3** Vertical position (solid lines) and linear velocity (dashed lines) of the center of mass during a beach volleyball (black) and an indoor volleyball (gray) spike jump. Source: Tilp et al. (2008). Reproduced with permission of Taylor & Francis.
beach volleyball players tend to land more often on one foot compared to their indoor colleagues following setting actions. It has been speculated that the reason for this is that beach volleyball players have less time to assume the setting position because at the time of the serve, it is not yet clear which of the two players will be setting the volleyball.

Spiking

Volleyball is referred to as an overhead sport, since many of the skills require overhead contact with the ball. Although other sports, such as team handball, tennis, and baseball, are also considered overhead sports, the kinetics and kinematics of each sport-specific skill differ from each other. In volleyball, an overhead technique is used to accelerate the volleyball with a downward trajectory over the net and towards the opponents’ side of the court. While handball or baseball players throw the ball and tennis players hit the ball with a racket, indoor or beach volleyball players spike the ball with their hand to score a point. A biomechanical comparison of the upper limb movement patterns (Reeser et al. 2013) has revealed greater shoulder abduction and horizontal adduction during spike and float serve movements in volleyball compared to baseball pitching and tennis serving. The authors suggested that this extreme shoulder movement may be related to unique scapular mechanics, which in turn may be responsible for the increased risk of developing infraspinatus syndrome among volleyball athletes compared to other overhead sports athletes.

At the instant contact is made with the volleyball, momentum (= mass \cdot velocity) is transferred from the hand to the ball. Besides mass and velocity, the elastic properties of the ball and the hand affect the speed the driven ball can obtain. The mass and elastic properties of the ball are regulated by the FIVB and the manufacturer. The elastic properties of the hand and the mass acting on the ball can be regulated by muscle activation of the athlete. Briefly, the stiffer the hand and the more mass that is included along the kinetic chain (i.e. the sequential interaction of legs, trunk, shoulder, arm, and hand), the greater the momentum transferred to the ball. This is, however, an optimization process since a fusion of the acting body parts into one mass by muscle activation would also decrease the overall movement velocity. The body solves this by a coordinated proximal-to-distal sequencing of the maximum velocities of the interacting body parts (Wagner et al. 2014). Coleman et al. (1993) determined that maximal humeral velocity was associated with high postimpact (spiking) ball speed. Furthermore, an increase in ball speed can be achieved by an increase in pelvis, trunk, and shoulder rotation in the cocking and acceleration phases (Figure 3.4) of the spike which increases the range of motion of the joints of the upper limbs. A large range of motion of the elbow joint is a key factor of the spiking technique and differentiates

![Figure 3.4](image)

Figure 3.4 Aerial phase of the spike jump including the smash: 1–3 cocking phase, 3–5 acceleration phase, 6 follow-through phase. Source: adapted from Wagner et al. (2014). Reproduced with permission of John Wiley & Sons.
beginners from high-level athletes. During the aerial phase and at the instant of the spike, the volleyball athlete is in the air and therefore (similar to the block movement), the laws of physics demand preservation of angular momentum. Hence, the angular momentum generated by the upper body has to be counterbalanced by an opposite (angular) momentum of the lower body, i.e. hip extension and knee flexion during the cocking phase and hip flexion and knee extension in the acceleration phase (see Figure 3.4).

Physics of ball trajectory

Depending on technique, ball trajectories are slightly different. During a set, the trajectory will be approximately parabolic because the ball has low velocity and no rotation. Hence, besides gravity, the parabolic trajectory is determined by the initial position, take-off angle, and velocity at the instant of the set (Figure 3.5).

On the other hand, when the ball flies with a higher velocity, air resistance affects the trajectory significantly. Air resistance, described in Equation (iii), is related to the drag coefficient ($C_D$), the air density ($\rho$, 1.2 kg/m$^3$), the projected area of the volleyball ($A$), and the velocity ($V$). An important factor influencing air resistance (through the drag coefficient $C_D$) is the boundary layer, defined as a thin layer of air near the surface, which the ball carries with it. During flight, this boundary layer will peel away from the surface at the back of the ball and has two distinct states: “laminar” and “turbulent.” While in the laminar state, tiers are laid one on top of each other, in the turbulent state the air is moving chaotically. A turbulent state is related to a smaller wake behind the ball and therefore a smaller drag coefficient and thus lower air resistance. The transition from laminar to turbulent state is influenced by the Reynolds number, which depends on ball velocity, air viscosity, and ball surface (Metha 2008). When a critical Reynolds number is reached, $C_D$ drops abruptly. Interestingly, critical Reynolds numbers of $Re=220.000–270.000$ for volleyballs occur at typical volleyball spike or service velocities and therefore lead to laminar-turbulent transitions and deviations of the trajectory. During a float serve, this process leads to irregular nonsymmetrical lateral forces acting on a ball and thus to unpredictable trajectories. Due to structural differences on the surface of volleyballs manufactured by different companies (some surfaces are smooth, while others are honeycombed or dimpled),

![Figure 3.5](image-url)  

**Figure 3.5** Different parabolic setting trajectories related to take-off velocity ($V_0$) and take-off angle ($\alpha$). Note the maximal height ($H$), length ($L$), and especially the time ($T$) of the sets.
volleyballs have also changed their floating properties and therefore trajectories (Asai et al. 2010).

\[ F_d = \frac{1}{2} C_d \cdot \rho \cdot A \cdot V^2 \]  \hspace{1cm} (iii)

\[ F_l = \frac{1}{2} C_l \cdot \rho \cdot A \cdot V^2 \]  \hspace{1cm} (iv)

In a rotating ball, the so-called Magnus effect alters the ball trajectory by introducing a lift force \( F_L \); see Equation (iv) including a lift coefficient \( C_L \) in the direction of the ball rotation. Initially, the German physicist Heinrich Gustav Magnus explained this by different streaming velocities which result in different pressures (Bernoulli effect) on the different sides of the ball. Later, the American physicist Lyman J. Briggs explained this effect by a turbulent wake behind the spinning ball. Metha (2008) explained that the rotation of a ball leads to an asymmetrical separation of the boundary layer and therefore to a wake deflected in the opposite direction to the rotation. Following Newton’s Third Law of Motion, the deflected wake implies a (Magnus) force on the ball and thus a curved trajectory. Thus, services or spikes with a topspin rotation are deflected downwards (Figure 3.6). Consequently, a ball that was spiked over the opponent’s block with topspin rotation might still hit the ground within the court while a ball without spin or even backward spin would be out. Similarly, a topspin serve will come down closer to the net or can be played with higher velocity due to its downward deflection.

Based on knowledge of the influence of ball rotation on trajectory and further experimental data, Kao et al. (1993) carried out simulations to determine the optimal spike position on the court against a two-person block. They defined the optimal spike position as the coordinates from where an attacker has the greatest possible attacking angle against a central double block of 1.2 m width. They used a ball velocity of 20 m/s and an angular velocity of 7 revolutions/s. Using this information, they calculated an optimal spike position with an attacking angle of 30° at 1.6–2.5 m behind the middle line and 0–1.5 m from the side line from position II or IV on the volleyball field. This underlines the excellent spiking conditions for back row spikers.

**Summary**

An understanding of biomechanics in volleyball is important for maximal performance and injury prevention. Maximal jumping height is achieved by maximizing take-off velocity. This is supported by a countermovement and the use of an arm swing and will be decreased by a yielding surface like sand.

During the aerial phase of serve, spike or block movements, the (angular) momentum is preserved. Therefore, angular moments produced by the arms are compensated by other body parts. This coordinated process should be trained in order to use...
adequate techniques. During the overhead spike technique, the momentum (mass-velocity) of the hand is transferred to the ball. Coordinated muscle activity increases the momentum and the elastic properties of the hand.

Ground reaction forces during the landing phase are influenced by the landing surface and by technique. A yielding surface and landing on two feet will reduce force peaks and therefore injury risk.

The volleyball trajectory is greatly affected by velocity and rotation. While setting trajectories are approximately parabolic, following spikes and serves at critical velocities the boundary layer around the ball peels away in a turbulent state behind the ball, which makes the trajectory less predictable. A rotation on the ball leads to an asymmetrical separation of the boundary layer and therefore to deflection in the opposite direction to the rotation.

References


Recommended reading

Chapter 4
Developing a resistance training program for volleyball

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Introduction

Volleyball is among the most popular sports in the world, as reflected by membership of the Fédération Internationale de Volleyball (FIVB), the international governing body for the sport, which now totals in excess of 225 national federations. This burgeoning popularity has resulting in a growing need for training prescriptions for the competitive volleyball athlete. The exercise prescription must address the physical requirements of the sport but must also be individualized to match the training experience and developmental needs of the athlete. This chapter describes a paradigm for designing a resistance training program for volleyball that can be adapted to meet the specific demands of athletes, optimizing those characteristics which are essential to effective programming at every level.

The primary goals of a strength and conditioning program are to prevent injury and to improve performance by enhancing physical development. Creating a training program to achieve these fundamental goals is an individualized process which must take into consideration unmodifiable factors such as genetic inheritance (which influences qualities such as height, limb length, number of muscle fibers, and distribution of muscle fiber type), while concurrently optimizing those modifiable factors that can be influenced by training (e.g. muscle fiber size, strength, agility, recovery capability). Designing a volleyball-specific strength and conditioning program science requires not only knowledge of and expertise in exercise science, but also an appreciation of the art of working with athletes to set goals and motivate them to attain optimal individual development. It is therefore essential that qualified strength and conditioning coaches are involved in teaching and prescribing exercise, as well as evaluating the athlete’s progress based upon his/her age, competitive level, and experience.

The basis of strength and power development is the “Size Principle” which dictates that motor units are recruited in an orderly manner from the lower threshold motor units made up of smaller type I muscle fibers on up to larger motor units made up of type II muscle fibers. Recruitment always goes from low to high based on the need for force or power. Higher force and power demands require the nervous system to go higher in the recruitment ladder to recruit type II motor units. Thus, whether on the court performing a maximal jump for a block or in the gym lifting a heavy weight, the body must recruit the needed high threshold motor units to meet the demands. Conversely, lifting light weights or performing endurance-type training can be accomplished with lower threshold motor units as the force and power demands are so much lower. Thus, training or competition runs...
on a motor unit recruitment continuum to meet the demands of an activity.

The percentage composition of type I or type II muscle fibers that make up the various motor units is genetically determined, and gives athletes their inherent physical capacity for a sport or activity. Muscle fiber type composition cannot be modified to any significant extent (or to a level that might impact performance). As many coaches say, “It is important to pick your parents correctly.” While fiber type is not the only factor that influences performance, it contributes to one’s physical capabilities. It is not uncommon to describe an athlete’s performance in terms of his/her predominant phenotype, e.g. a fast-twitch athlete (e.g. sprinter or volleyball outside hitter) or a slow-twitch athlete (e.g. marathon runner). Many athletes and most individuals typically range from 60% type I to 40% type II or 40% type I to 60% type II for the major locomotor muscle of the body.

The strength and conditioning coach should have a solid understanding of workout design and training progression approaches that can be used over the year or a career. One starts this process with thorough needs analysis of the physiological demands of the sport in order to select the appropriate exercises to stimulate athlete development.

**Bioenergetics of volleyball**

The primary energy system employed in volleyball is the high ATP-PC system, due to the short-duration, high-intensity burst movements and explosive jumps needed to conduct volleyball skills. A moderate contribution of energy from glycolysis during intense continuous play can also be observed. While aerobic fitness is necessary, caution is needed so such training does not negatively impact power capabilities. Any training that negates the development of power, quickness, and speed is counterproductive.

**Applied biomechanics of volleyball**

The fundamentals of volleyball involve the mastery of a few key neuromuscular skills: the serve, spike, pass, set, block, and dig. Resistance training programs should focus on developing the movement patterns specific to those skills. For example, jumping is essential to many of volleyball’s skills. The major muscle groups involved in the jump are the glutei, hamstrings, quadriceps, and calves. During the jump, an athlete flexes the ankles, knees, and hips and propels the body upward with an extension at each joint. Equally important for the volleyball skill set is development of the upper body. Shoulder extension as well as internal and external shoulder rotation are necessary for the serve and spike. Shoulder flexion, shoulder abduction, and elbow stabilization are important movements in the pass and dig, while overhead shoulder abduction and elbow extension are necessary to the set and block. Another important mechanical consideration for volleyball is an athlete’s ability to quickly change direction. The fast-paced nature of the game requires an athlete to quickly react to the ball while maintaining control and balance. Often this requires the ability to stabilize body movements over a single limb.

**Volleyball injury profile**

Epidemiological research has demonstrated that volleyball players are at risk for various types of acute and overuse injuries. The most common overuse injuries include rotator cuff tendinopathy and
patellar tendinopathy, while common acute injuries include ankle sprains, muscle strains, and contusions. Overuse injuries are often associated with the repetitive motions required by the sport, such as overhead swings and jump landings. Thus, it is important to include exercises that promote joint stability, strength, and flexibility. Due to the stress on the lower back, many players experience compressive stressors, hyperextension stress, and lower back pain as well and thus a focus on lower back strength and stability for this body segment is important.

Considerations for exercise selection

Based on the needs analysis for volleyball, it is necessary to select exercises that develop lower body power, upper body power, unilateral limb strength, core stability, and flexibility (Figure 4.1).

Strength development

Development of strength is the basis of any resistance training program. Strength can be developed using a variety of different exercises, including unilateral exercises to address limb dominance and bilateral exercises to maintain functional symmetry. Upper limb strength and stability is vital to an athlete’s ability to extend for a dig, spike, or serve. Additionally, stabilization and passing skills may be enhanced by training core stability. As alluded to above, when selecting exercises it is important to consider symmetry across joints and between upper and lower body. However, in women, it might be advisable to emphasize upper body development. Women have been shown to have less upper body musculature (number of muscle fibers) than men due to normal maturation.

Figure 4.1 The sport of volleyball requires the ability to produce vertical power for a host of different skills. The development of whole-body power is an important goal for any resistance training program designed to enhance a player’s physical potential for the sport. Source: The Ohio State University Athletics Communications. Used with permission of The Ohio State University.

Box 4.1 Basic power exercises and modalities.

Free weights
- Power cleans
- Hang cleans
- Snatch lift
- Hang snatch lifts
- Jump squats
- Bench throws
- Medicine ball throws

Machine modalities with no deceleration when performed at maximal speed
- Pneumatic machines as they have both a concentric and eccentric component to the repetition (fixed form, no balance benefits)
- Hydraulic machines have only a concentric component with no eccentric component to the repetition (fixed form, no balance benefits)

Plyometric exercises
- Box jumps
- Depth jumps
- Tuck jumps
- Broad jumps
- Squat jumps
During puberty and the role of testosterone. While many great women athletes have had inherently more muscle in the upper body than the normative woman, significant benefits can still be realized with attention to upper body training in women to insure no muscle has been left undeveloped due to not recruiting muscle with heavier resistances or not using an exercise that gets at a recruitment angle of the muscle. This can be accomplished by adding a few more exercises that stimulate upper body musculature at different angles, e.g. one might use the bench press but also include an incline dumbbell press. Fundamental strength training exercises for volleyball are listed in Box 4.1.

**Power development**

The formula for power (Eq. (i)) suggests how to best train for explosive strength:

\[
\text{Power (W)} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} \quad (i)
\]

Heavy resistance training develops the force component of the equation. The velocity with which the force-producing exercises are performed is the other critical component to training power (Box 4.2). Power exercises should be performed with moderate to heavy loads. Power exercises include Olympic weightlifting movements and plyometrics. It is important for each exercise to be carefully instructed by qualified coaches and to not eliminate these elements due to the fear of acquiring the skill or sustaining injury while performing the various lifts (Table 4.1).

When training for power, it is important to avoid voluntary deceleration while completing the lift. For example, in the bench throw, the weight is released at the end of the movement. Compare this to a bench press, in which the weight is not released but rather is eccentrically lowered to the starting position, completing the repetition. When the weight is held for the entire repetition for bench press “speed reps,” only deceleration is trained, not power. Pneumatic machines have both a concentric and eccentric force and allow for speed training and power development by not inhibiting acceleration through the range of motion (Figure 4.2). However, training effects are realized in a fixed movement path with no balance requirements.

A cautionary tale is that a coach needs to understand that an excess of aerobic training using long duration endurance exercise, especially running, can negatively affect power development and therefore vertical jump (Figure 4.1). Thus, cardiovascular exercise training should be carefully prescribed and power carefully monitored to avoid negative effects. The use of sprint intervals can achieve basic aerobic fitness adaptations without compromising power. Many nonfunctional over-reaching or even overtraining syndromes can be due to this incompatibility of training modes.

**Training the core**

The core muscles of the body (generally agreed to include the musculature of the abdominal wall, the diaphragm, the thoracolumbar back muscles,
and the pelvic floor) perform a vital role by providing support for the extremities to properly perform the various volleyball-specific skills. This function is especially important to proper and efficient performance of overhead skills, such as spiking and serving. Greater core stability helps prevent shoulder and knee overuse injuries. Power cleans, squats, and deadlifts are examples of effective common core exercises. Additional core exercises include those that employ movement limitations and isometric muscle activation, such as planks, back extensions, and hip extensions.

**Local muscular endurance**

Local muscular endurance can be developed within the context of the program with the use of shorter rest periods or higher repetitions. Typically, the athlete progresses from low- to high-intensity workouts, and this is dictated by the goals of the program. Higher repetitions of greater than 20 reps for one or two sets or reductions in rest periods with moderate-intensity 10RM loads have been used to enhance local muscular endurance. Circuit programs can also be effective when increased local muscular endurance is desired. Short rest circuits can also induce high stress levels and should be followed by recovery days as again, nonfunctional overreaching can occur if stress levels continue and catabolic (break down) hormonal increases of cortisol continue to rise and not return to resting levels within 24 hours of the workout.

**Flexibility**

Flexibility is vital for volleyball players. Functional movement screens should be used to help identify the need for and guide the development of specific flexibility exercises. It is important to understand that successful completion of functional movement screens does not obviate the need for ongoing strength and conditioning training. “Corrective” exercises can be part of warm-ups and cool-downs. It is important to avoid static flexibility exercises directly before power, speed or agility training due to their negative effects (e.g. lower power production) on workout performance.
Developing a resistance training program for volleyball

Both volleyball-specific publications (e.g. Performance Conditioning Volleyball) and the fitness industry have touted sport-specific strength and conditioning programs. These programs should be carefully reviewed to ensure that the information presented is accurate and avoids overuse injury, nonfunctional overreaching or overtraining. Incorporating adequate time for rest and recovery as part of the training cycle will minimize the risk of burnout and injury.

Designing a strength and conditioning program

Acute program variables

Workouts should be created within a periodized model, taking care to individualize workouts and develop a program to meet the sport-specific needs of the individual athlete, using the basic principles and concepts discussed in this chapter. When designing a program, choices of program variables must reflect the desired training adaptations for the athlete. Each workout consists of components designed and chosen with a specific purpose in mind. Over time, exposure to workouts (e.g. heavy loading) will result in specific adaptations (e.g. increases in maximal strength). Specificity relates to the relationship of the workout stimuli to the desired training endpoint adaptation.

The program variables are as follows.

<table>
<thead>
<tr>
<th>Lower body power</th>
<th>Lower body strength</th>
<th>Upper body power</th>
<th>Upper body strength</th>
<th>Core strength</th>
<th>Unilateral limb strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power cleans</td>
<td>Squats</td>
<td>Power cleans</td>
<td>Bench press</td>
<td>Planks</td>
<td>Single limb strength</td>
</tr>
<tr>
<td>Hang cleans</td>
<td>Split squats</td>
<td>Hang cleans</td>
<td>Military press</td>
<td>Rotational pull variations</td>
<td></td>
</tr>
<tr>
<td>Snatch lift</td>
<td>Lunge</td>
<td>Snatch lift</td>
<td>DB rows</td>
<td>Crunch variations</td>
<td></td>
</tr>
<tr>
<td>Hang snatch lifts</td>
<td>Side squats</td>
<td>Hang snatch lifts</td>
<td>Incline DB press</td>
<td>Multiple-joint power and strength exercises</td>
<td></td>
</tr>
<tr>
<td>Jump squats</td>
<td>Trap bar deadlifts</td>
<td>Bench throws</td>
<td>Upright rows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plyometrics</td>
<td>Romanian deadlifts</td>
<td>MB throws</td>
<td>Seated rows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stiff leg deadlifts</td>
<td></td>
<td>Rotator cuff series</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DB, dumbbell; MB, medicine ball.
(e.g. power clean) that require additional coaching of exercise technique beyond simple movement patterns. Structural or multiple-joint exercises are especially important to include in a program when whole-body strength movements are required for a particular target activity.

Free versus fixed form exercises
Exercises done with free weights are classified as “free form,” since balance and neuromuscular control are required to move the weight along the path of repetition. Exercises performed on machines where no balance is needed and the path is preset are called “fixed form.” When balance is important to the sport, as in volleyball, the use of free weights is generally preferable to machines since “free form” exercises help train this capacity.

Order of exercise
The order in which exercises are performed is important as fatigue influences the quality of exercise. Exercising the larger muscle groups first provides a superior training stimulus to all the muscles involved, since no prior fatigue exists. This is thought to be true because exercising larger muscle groups stimulates greater neural, metabolic, endocrine, and circulatory responses, which potentially augment the training of subsequent muscles later in the workout. Thus, more complex multiple-joint exercises should be performed initially, followed by the less complex single-joint exercises. Another rationale for sequencing the multiple-joint exercises before the single-joint exercises is that exercises performed at the beginning of the workout will be able to access the greatest amount of stored energy to permit optimal performance. Thus, these sequencing strategies focus on attaining a greater training effect for the exercises involving large muscle groups.

Resistance training experience
When deciding on the order of exercises, it is important to take into consideration the fitness level of the athlete and his/her experience in resistance training (Box 4.3). The order of exercises in a workout can be very stressful, so workouts must be designed so that, although challenging, they can be tolerated by the athlete. This is especially true for younger athletes just being introduced to volleyball or resistance training.

Resistance used
Selecting the appropriate loading stimulus for each exercise is an important component of weight training program design (Table 4.3). The amount of resistance used for a specific exercise is a critical component in any resistance training program (recall the formula for power.) Mass or weight is the major stimulus related to adaptations in strength and local muscular endurance. It is well established that lifting heavier weights promotes strength gains and that lighter weights that can be repeated many times promote muscular endurance. The target for a lift should not be muscle failure, as this stresses the joints involved if done repeatedly over time, and has been associated with overtraining.

A key tool used in program design is the use of RM (repetition maximum) zones. A general guideline for number of repetitions at each zone is described below (see Table 4.3). Note that differences exist between machines and free weights and between large and small muscle groups. For example, in a free form squat at 80% of 1 RM, an athlete may be able to complete just 10 repetitions, while on a leg press machine at the same RM, the same athlete can complete 20–25 repetitions. The reason for this is that more muscles and their associated motor units are recruited when performing a free weight exercise as there is a greater need for stabilization.
Developing a resistance training program for volleyball

of the resistance and assistance in each phase of the movement path. This means that more energy is required, more muscle is needed, and the exercise is biomechanically and bioenergetically different in its demands.

**Number of sets**

Total exercise volume (e.g. 5 sets of 5 repetitions at 90% of 1 RM) is a vital concept of training progression. Using a program with a constant volume (or intensity) may lead to plateaus in a particular strength variable, or staleness. The number of sets completed, or total exercise volume, can be used as an indicator of strength over time, ranging from low-volume exercise with a single set to higher work volumes with multiple sets. Varying the training volume is key to both periodization and recovery from workouts. Every exercise does not have to be performed for the same number of sets each time. Workout volumes should change over time or between workouts, depending on whether the periodization model used is linear or nonlinear (see later in this chapter). Most beginner programs are designed to include multiple low-intensity sets, while recovery workouts are constructed using lower repetition volumes or single sets.

**Rest between sets and exercises**

Rest periods between sets and exercises help to determine the ability of the ATP-PC energy source to keep up with the energy expended, and therefore the concentration of lactic acid (lactate) in the blood. The length of the rest period can significantly alter the metabolic, hormonal, and cardiovascular responses to an acute bout of resistance exercise, as well as the performance of subsequent sets. Short rest periods can promote tolerance to decreases in blood pH, a common factor associated with fatigue. However, rest after the workout is needed in order to limit any overreaching effects that may create a catabolic state in the body. In concert with the resistance used and the order in which the exercises are performed, rest period lengths can dramatically affect the force-generating capability of the muscle, with shorter rest periods being more detrimental to force production (Table 4.4). Thus an athlete should use longer rest periods when lifting heavy weights and shorter rest periods when training with moderate to light resistance.

**Approaches to the periodization of training**

The main goal of periodization, or periodized training, is to optimize the athlete’s ability to adapt to his/her training protocol by scheduling periodic rest and recovery from training stress. Phases of a training cycle generally include (in increasing length) microcycles, mesocycles, and macrocycles. Depending on the type of periodization, (linear and nonlinear, discussed later), microcycles can last from 1 day to 2–4 weeks, while a mesocycle ranges from 2 to 6 months, and the macrocycle may be as long as a year.

Periodization plans are frequently designed to allow the athlete to achieve peak physical performance at a particular point in time (e.g. in concert with major competitions, such as the Olympic Games). Another goal of periodized training is to avoid training plateaus. During bouts of long-term training, training plateaus are common, in part because athletes begin to approach their genetically determined maximal capacity for a specific characteristic, such as strength. By planning periodic rest periods from training, and by varying the intensity of training, athletes maintain

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**Table 4.3** General guidelines for selecting appropriate loading zones.

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Zone</th>
<th>% 1 RM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very heavy</td>
<td>1–3 RM</td>
<td>90–100</td>
</tr>
<tr>
<td>Heavy</td>
<td>4–6 RM</td>
<td>85–90</td>
</tr>
<tr>
<td>Moderate</td>
<td>7–10 RM</td>
<td>75–85</td>
</tr>
<tr>
<td>Light</td>
<td>11–15 RM</td>
<td>65–75</td>
</tr>
<tr>
<td>Very light</td>
<td>15–20 RM</td>
<td>55–65</td>
</tr>
</tbody>
</table>

RM, repetition maximum.

**Table 4.4** General guidelines for selecting appropriate rest durations.

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Rest</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Short</td>
<td>1–2 minutes</td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate</td>
<td>2–3 minutes</td>
</tr>
<tr>
<td>Heavy</td>
<td>Long</td>
<td>3–5 minutes</td>
</tr>
</tbody>
</table>

---
their capacity for training and avoid staleness, burnout, and overtraining.

Periodized training programs use different combinations of acute training program variables to emphasize different training outcomes (e.g. hypertrophy, maximum strength, local muscular endurance, and maximum power). This does not imply that a training session emphasizing one training outcome over time will not result in increases in other training outcomes. Rather, it means that a given training session is designed to develop one training outcome to a greater extent than others. As an example, a training session emphasizing maximal strength will result in muscle hypertrophy over time, even though the session is meant to preferentially develop maximum strength.

Manipulation and sequencing of the eight variables integral to a resistance training program results in thousands of combinations of those variables. Thus, a practically limitless number of both short- and long-term training strategies can be programmed.

To date, the sport science community has described and investigated two major types of periodized resistance training: linear periodization and nonlinear periodization.

Linear periodization
Linear periodization is the older or more classic form of periodization, developed in many forms over the past 50 years. Linear periodization follows a general trend of decreasing training volume and increasing training intensity as training progresses through the cycle. For weight training, this means that a relatively high total number of repetitions is performed at low intensity when training is initiated, and as training progresses, the total number of repetitions performed decreases and training intensity increases (Box 4.4). This type of periodization tends to work best when scheduling demands are more predictable.

Planned nonlinear periodization
Nonlinear periodization may be more useful when the athlete’s schedule is variable or unpredictable.

Nonlinear models are gaining popularity in sports and activities with long seasons for several reasons. With planned nonlinear periodization, training intensity and volume are varied by using different percentage loads or RM training zones on different days. The concept of nonlinear periodized training programs was developed to maintain variation in the training stimulus over the training interval. The nonlinear program allows for variation in the intensity and volume within each week over the course of the cyclical training program (e.g. a 12-week planned mesocycle) (Table 4.5).

Distinct from linear programs, nonlinear programs train the different components of muscle size, power, local muscular endurance, and strength within the same week. Nonlinear programs also attempt to train both the hypertrophy and neural aspects of strength within the same week. Thus, one is working towards two different physiological adaptations simultaneously within the same 7–10-day period of the 12-week mesocycle. The order of the training sessions is established for each 12-week mesocycle, depending upon the goal of each cycle (which may range from general preparation emphasizing light-to-moderate loads, to in-season programs which maintain strength and further develop power).

In this program, an athlete rotates through the different protocols. This concept means that one can set a specific rotation for each workout style – for example, a heavy day, a light day, a power day, and a moderate intensity set of workouts for different days. So the rotation can be preset based on the periodization approach you want to use. Nonlinear workouts typically try to vary the type of workout dramatically. However, one can change the sequence to be very different and

<table>
<thead>
<tr>
<th>Box 4.4</th>
<th>A general linear periodization model used for the primary exercises in a program. Each microcycle can last from 2 to 4 weeks, with most programs using a 2-week microcycle and 12-week mesocycle.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcycle 1</td>
<td>Microcycle 2</td>
</tr>
<tr>
<td>3–5 sets of 12–15 RM zone</td>
<td>4–5 sets of 8–10 RM zone</td>
</tr>
<tr>
<td>Microcycle 3</td>
<td>Microcycle 4</td>
</tr>
<tr>
<td>3–4 sets of 6–8 RM zone</td>
<td>3–5 sets of 1–3 RM zone</td>
</tr>
<tr>
<td>RM, repetition maximum.</td>
<td></td>
</tr>
</tbody>
</table>
put, say, two heavy workouts back to back on consecutive days. Or have a plan but alter it based on the demands that day in a practice. So rotation is how one goes from day to day with different workouts or different workout sequences used. Thus, workout sessions rotate between very heavy, heavy, moderate and light training day, and/or training volumes. Thus, one is not only setting up the training resistance intensity but the training volume of work, rest periods, order, etc. as reflecting the acute program variable structure for workout design.

Missing a scheduled workout means the rotation order is pushed forward on the rotated workout schedule. For example, if the athlete misses a light 12–15 repetition workout scheduled for Monday, he/she can perform the workout missed or, if capable, can perform the scheduled workout planned for Wednesday. Either way, the athlete continues to complete the the whole workout sequence designed in a planned nonlinear approach to periodization.

Again, the strength and conditioning professional along with the coach can design any approach they want to with each mesocycle sequence based on level of athlete, time of year, competitive demands, and/or level of player development and experience. The training goals for the individual must always be kept in mind and assessed to determine progress and effectiveness of the training program or for that training cycle.

Again, the primary exercises are typically periodized but one can also use a two-cycle program to vary the small muscle group exercises. For example, in the triceps pushdown, one could rotate between the moderate (8–10 RM zone) and the heavy (4–6 RM zone) cycle intensities. This would provide the hypertrophy needed for such isolated muscles but also provide the strength needed to support heavier workouts of the large muscle groups.

Flexible nonlinear periodization

The concept of “flexible” nonlinear periodization gained popularity in the early 2000s, in response to limitations on athlete availability. Long seasons, sport practices, relegating training times to after practices, academic schedules, illness and injuries, and scheduled competitions all combine to make it difficult to train optimally. As a result of these factors, athletes were found to have non-uniform development of strength and power. The solution was “flexible nonlinear” periodization training, which is a method of optimizing strength training under less than ideal circumstances. This approach allowed for planning a workout sequence but then being able to modify the sequence in response to the changing environment of the athlete and their external demands. Flexible nonlinear periodization takes an athlete’s readiness to train into account when selecting the intensity and type of training to be performed on a given day. Athletes may use flexible nonlinear periodization in order to accommodate their ever-changing schedules and also factor in their readiness to train. This allows the creation of a general plan for the mesocycle, which can be modified if the athlete shows signs of not being ready to train a specific area of muscular fitness in the face of conflicting schedules, injury, illness, or extreme fatigue. An alternate workout is prescribed, or the athlete takes a day off to rest and recover.

The workout log is a critical component of this workout strategy, as it facilitates fitness tracking and the monitoring of performance. Quick inspection of the log will enable the athlete or coach to assess current performance. For example, say the athlete is scheduled to squat on Friday. The previous Friday, using the same rotation for a heavy day, the athlete lifted 200 kg for 3–5 reps for each of the four sets. Today the athlete can only do 1 rep on the first set using 200 kg. On the next set, they can

Table 4.5  Example of planned nonlinear periodized program loading examples.

<table>
<thead>
<tr>
<th>Monday</th>
<th>Wednesday</th>
<th>Friday</th>
<th>Monday</th>
<th>Wednesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 set of</td>
<td>6 sets of</td>
<td>3 sets of</td>
<td>6 sets of</td>
<td>4 sets of</td>
</tr>
<tr>
<td>12–15 RM</td>
<td>1–3 RM</td>
<td>4–6 RM</td>
<td>2–3 reps at</td>
<td>8–10 RM</td>
</tr>
</tbody>
</table>
| RM, repetition maximum.

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only complete 2 reps, telling both the coach and the athlete that something is wrong and that the quality of the work has been compromised. The first step is the athlete realizing something is preventing him/her from performing a quality workout, so some strength diagnosis is needed. Choices for the athlete include resting, seeing the athletic trainer or team physician, or defaulting to a lighter workout for the day. Each case must be addressed individually when the planned sequence cannot be accomplished for that workout for that mesocycle. Again, the sequence of workouts for any nonlinear periodized mesocycle can be ordered with loads and intensities as desired if related to the training goals identified by the athlete.

With limited training time, every training session must represent progress towards targeted training goals for that particular microcycle workout or mesocycle sequence. Workouts in the weight room that do not optimize the time are counterproductive to optimal gains in performance. For example, power workouts should not be performed after practice as the actual power output (W) in the power clean or in jump training at that time will be significantly lower than the athlete’s maximal capacity. Training at submaximal power output will not provide the stimulus necessary to improve maximal power. Furthermore, there is diurnal variation to power production, as not every athlete can produce his/her peak power in a plyometric drill at 6am. Thus, “individualization,” a word at odds with whole-team training, is an important consideration for program implementation and monitoring. Failure to recognize individual differences does not diminish their existence or their potentially deleterious training effects.

A programming approach predicated on a flexible nonlinear periodization model designed to be responsive to a fast-changing environment should result in more frequent use of the weight room. When coupled with technologically advanced devices that record and display past and present strength training data, these tools provide the athlete with the motivation and the means to achieve their strength and conditioning goals, and thereby improve their sport-specific performance.

**Summary**

Creating a resistance training program for a volleyball player is dependent upon many different factors including age, sex, maturity, training experience, injury history, and physical development needs. The array of choices in the design of programs can be daunting but a systematic view of the program via a needs analysis and then overlaid to the individual player allows for more precision in its approach. Thus, understanding of evidence-based practice (Amonette et al. 2016) is needed to make key decisions in the program design and progression process. Implementation requires qualified strength and conditioning professionals capable of teaching and training athletes using both the art and science of the field.

**Reference**


**Recommended reading**


Chapter 5

Environmental concerns in volleyball

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Introduction

The sporting environment in which the volleyball athlete trains and competes clearly influences performance and risk of injury. Although in a broad sense, the “environment” can be considered to include the court or playing surface and the other equipment of the game, in addition to the presence (or absence) of spectators, the principal focus of this chapter will be on weather and temperature-related concerns. In this regard, the most important environmental concern pertaining to the sport of volleyball is exertional heat illness. Obviously, heat illness is likely to occur more frequently during outdoor competitions, such as beach volleyball and park volley. However, symptoms of heat illness can also occur during indoor events contested in conditions of high heat and ambient humidity.

Heat illness

Humans can tolerate a wide range of environmental temperatures, but ultimately cellular viability is affected by temperature extremes. At –1 °C (30.2 °F), ice crystals form in the tissues. At temperatures above 43 °C (109 °F), cellular proteins begin to denature. The human body can withstand temperatures above 41.5 °C (107 °F) for only brief periods of time without sustaining potentially fatal tissue damage.

The heat load on an athlete may be defined as the sum of the heat produced by the athlete’s basal metabolism combined with the heat generated by exercise and that absorbed through environmental exposure. Because the body is only about 20–25% efficient, only one-fifth to one-quarter of the energy expended during exercise results in useful work or movement. The other 75–80% is released as heat that must be dissipated if the athlete is to continue functioning. Active muscles are capable of generating heat at a rate 100 times greater than inactive muscles. During intense exercise, the rate of heat production may exceed 60 kJ/min.

There are four avenues via which heat exchange with the environment may occur. Dry or nonevaporative heat exchange is achieved by radiation, conduction, and convection whereas wet or evaporative heat loss is achieved by evaporation. Radiation refers to heat exchange between the body and surrounding environmental objects via electromagnetic waves. Radiative heat transfer is most effective when the air in contact with the skin is significantly cooler than that of the body. Conduction is the transfer of heat through direct contact with solid objects. Usually this represents minimal heat loss as it relies on the thermal conductivity of the object and the amount of surface area in contact with the object. Convective heat exchange occurs via the movement of air or water.
over the surface of the skin. On a windy day, heat will be lost more effectively through convection (e.g. the wind chill index). Evaporation results in heat loss through the conversion of liquid (i.e. sweat or water) to water vapor on the surface of the skin. Evaporation is the body’s most effective pathway for heat loss, but is affected by ambient humidity and wind velocity. When treating an athlete with acute exertional heat illness, it may be necessary to employ techniques based on each of the avenues of heat energy transfer.

Thermoregulation is an integrative process by which the resting body core temperature is maintained around 37°C (98.6°F) through behavioral and physiological temperature regulation. Behavioral thermoregulation is achieved through conscious adjustments in behavior, which include standing in the shade and wearing light-colored clothing, as well as altering work rate during exercise. Physiological temperature regulation operates through thermogenic (i.e. heat gain) and thermolytic (i.e. heat loss) responses that are independent of conscious voluntary behavior. This process is controlled by the central nervous system’s temperature regulatory center, located in the preoptic area of the anterior hypothalamus. Afferent receptors from temperature sensors in the skin and body core provide input to the thermoregulatory center. Efferent nerve fibers then transmit the autonomic nervous system response that results in thermoregulation. The sympathetic nervous system regulates vascular constriction and dilation, while both the sympathetic and parasympathetic systems innervate the sweat glands. The onset thresholds for increases in sweating and cutaneous vasodilation during exercise correspond to an absolute change in mean body temperature, usually occurring within a few minutes after the start of exercise. Sweating and cutaneous vasodilation usually increase for the next few minutes and then level off when exercise intensity remains constant. These heat dissipation mechanisms form the body’s acute response to exercise in heat.

The average athlete will sweat 1 or more liters per hour; however, when acclimatized to exercising in hot climates, he/she may generate up to 2 or even 3 liters of sweat per hour in extreme cases (Figure 5.1). The evaporation of 1 mL of sweat dissipates approximately 2.45 kJ of heat energy. Thus, a well-trained athlete who is acclimatized to

Figure 5.1 Time course of induction in human adaptations to heat stress. Within this first week of exercise, heat acclimatization increases, plasma volume expands and heart rate decreases during exercise at a given work rate. Perceptually, the rating of thermal comfort improves. From a thermoregulatory perspective, core and skin temperature are reduced during exercise at a given work rate, whereas sweat rate increases. Consequently, aerobic exercise capacity is increased. Of note, the magnitude of these adaptations is dependent on the initial level of acclimatization, the environmental conditions (i.e. dry or humid), exercise intensity, and acclimatization regimen. Source: Périard et al. (2015). Reproduced with permission of John Wiley & Sons.
exercising in the heat is capable of transferring a much larger amount of heat energy to the environment, depending on ambient conditions. Note that sweat contains small amounts of electrolytes, including sodium, chloride, and, to a lesser extent, potassium and magnesium. As an athlete becomes better acclimatized and sweat volume increases, the concentration of electrolytes in the sweat is reduced. For example, an athlete not acclimatized to heat may secrete sweat with a sodium concentration of 60 mEq/L or higher, and therefore if sweating profusely can lose large amounts of sodium. With heat acclimatization, eccrine sweat glands increase sodium reabsorption along the duct, which can reduce sweat sodium concentrations to as low as 10 mEq/L.

**When is it safe to play?**

The Wet Bulb Globe Temperature (WBGT) index is generally considered the best measure of environmental heat stress and is often used to assess the risk of exertional heat illness; however, it must be emphasized that it does not provide a representation of human heat strain. The WBGT is a composite value used to estimate the combined effect of temperature, humidity, wind speed (wind chill), and solar radiation on humans. It is derived from a simple formula that incorporates the effects of wet bulb temperature (an indicator of humidity), black globe temperature (a measure of solar radiation), and normal air temperature. Instruments that measure the WBGT also factor in any evaporative wind cooling effect. Several systems utilizing the WBGT have been developed in order to estimate the risk of developing heat illness under varying environmental conditions, such as the American College of Sports Medicine (ACSM) and the United States Navy systems, which have adopted the “warning flag” concept to indicate the level of risk from exposure to high heat and humidity.

To assess the risk of heat illness in professional beach volleyball, the FIVB established a surveillance program to monitor the WBGT and record any cases of heat-related medical forfeits on the FIVB World Tour in 2009. As shown in Figure 5.2,
the initial 3 years of surveillance (2009–2011) documented that the risk of significant heat illness in professional beach volleyball on the World Tour is very low, even though hot and humid conditions were encountered frequently (Bahr and Reeser 2012). Since 2009, the peak WBGT has met the US Navy black flag condition of >32.3 °C in more than 30 tournaments (totalling more than 2500 matches). Despite this, only three cases of a medical forfeiture related to heat stress have been recorded, none of them severe. Two occurred in athletes whose fluid balance was compromised from bouts of acute gastroenteritis, and who played several matches during the tournaments, where the average WBGT was 25.9 °C (one case) and 33.0 °C (two of the cases).

Regardless of the low incidence of heat-related forfeiture, all outdoor volleyball players should be closely monitored for signs of heat illness. It is particularly important to identify and watch those athletes who have suffered from heat illness in the past, as they are more likely to be affected again. In FIVB events, decisions regarding suitability of competition should be made by the tournament supervisor, assisted by the medical team and based on the WBGT. Careful consideration should be given regarding continuing play if the WBGT exceeds 31 °C. It should also be noted that the WBGT probably underestimates heat stress under high humidity. The FIVB policy is that whenever the prevailing weather conditions indicate that the WBGT index will exceed 31 °C, the following measures should be considered.

1. Schedule matches in the morning and evening to avoid the heat of the day.
2. Permit side changes (with rest and water breaks) every 5 points in sets 1 and 2 and every 3 or 4 points in set 3.
3. Increase the time between rallies.
4. Provide each team with an extra time-out per set to use at their discretion.
5. Require electrolyte rehydration fluids to be available (not just water).

It should also be emphasized that tournament medical personnel must be competent and equipped in the optimal treatment of heat illness, including intravenous treatment. However, if emergency intravenous treatment is instituted, the player should be transferred to hospital for further assessment and treatment as soon as feasible. Also, because of antidoping rules, players requiring intravenous treatment must refrain from further play in the same event, unless a Therapeutic Use Exemption can be obtained.

Who is at risk for heat illness?

Athletes who exercise at high intensity but who are not acclimatized to the conditions in which they are competing are more likely to suffer from exertional heat illness. Those who are less conditioned or less fit may also be more likely to suffer symptoms of heat illness. Athletes who are acclimatized to exercising in high temperature extremes but not high humidity are also at increased risk. As mentioned, evaporation of sweat is the primary pathway by which heat loss occurs. High ambient humidity reduces the rate of sweat evaporation and therefore impairs the athlete’s heat loss capacity. This situation may occur in beach volleyball when athletes who train year round in warm but dry coastal areas travel to compete in summer tournaments in areas where the humidity may exceed 90%. Without the benefit of effective evaporation, the athlete’s body core temperature can rise quickly, resulting in heat illness.

Although uncommon in the elite athlete, certain types of medication may also put individuals at risk for heat illness. Diuretics (i.e. water pills) may result in relative dehydration. Athletes on these medications should be cautioned about the increased risk of dehydration and heat-related illness. Both caffeine and alcohol also have diuretic properties. Decongestant medications result in vasoconstriction, which impairs heat loss at the skin surface. Anticholinergic medications, such as some antidepressants, block parasympathetic tone, thereby inhibiting sweat production. Beta-blockers, a popular class of high blood pressure medication, may also decrease skin blood flow. Phenothiazides and other antipsychotic medicines such as haloperidol may result in decreased thirst, even in the face of significant dehydration.
Consequences of excessive heat stress

Heat stress may precipitate three different types of heat illness in athletes: heat cramps, heat exhaustion, and heat stroke (Table 5.1). While there are unique identifying characteristics for each of these conditions, more typically there is some overlap between them clinically. Certainly athletes can experience two of these conditions at the same time, such as concurrent heat cramps and heat exhaustion. Often, serious problems can be avoided if the affected athlete is identified early on, prior to the onset of severe symptoms. Players who feel dizzy or restless or who exhibit even minimal mental status changes (i.e. confusion) should, in the appropriate setting, be suspected of having heat stress. Vital signs will demonstrate an elevated core temperature, increased heart rate, and reduced blood pressure. Cooling the athlete in a well-ventilated and shaded area, and giving cool fluids orally may prevent the onset of more serious, life-threatening symptoms.

Heat cramps

Heat cramps are involuntary tetanic contractions or spasms of the exercising muscles. The athlete’s core body temperature may be elevated or normal. Heat cramps may even occur hours after exercise. The mechanism by which heat cramps occur has not been fully elucidated and remains somewhat contentious, with two different mechanisms proposed to explain their onset. The first etiological explanation suggests that heat cramps stem from the influence of extensive sweat inducing dehydration and an imbalance in fluid distribution and a deficit in total-body exchangeable sodium. There have also been anecdotal reports of magnesium deficiency contributing to symptoms in some individuals. The second and most recently proposed causal mechanism relates to altered neuromuscular control stemming from muscle overload and premature skeletal muscle fatigue.

In volleyball players, the muscles most frequently involved in cramping are those of the lower limb such as the gastrocnemius and hamstrings. Forearm and hand muscles may cramp in hand setters. However, severely affected individuals may experience tetanic contractions of several different muscle groups simultaneously, including the rectus abdominis and the shoulder girdle musculature. Acute treatment includes stretching the involved muscle as quickly and completely as possible. Stretching is often more easily performed passively, by an athletic trainer or physical therapist that may be attending to the athlete. Oral rehydration should be attempted, preferably with a beverage containing replacement electrolytes such as a sports drink with sodium. Some individuals may respond better to an infusion of intravenous saline (0.9 normal saline or lactated Ringer’s are the fluids of choice).

Prevention of heat cramps involves optimizing the athlete’s hydration and fitness level, as well as acclimatization to exercise in conditions of high

Table 5.1 Exertional heat illness symptoms and management.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Symptoms</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat cramps</td>
<td>Brief, painful spasmodic skeletal muscle contractions</td>
<td>Resting and stretching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Replacement of electrolyte losses</td>
</tr>
<tr>
<td>Heat exhaustion</td>
<td>Mild-to-moderate illness with inability to maintain cardiac output</td>
<td>Move supine individual to cool, shaded, and well-ventilated area</td>
</tr>
<tr>
<td></td>
<td>Moderate (38.5 °C, 101.3 °F) to high (40.5 °C, 105 °F) body core temperature</td>
<td>Elevate legs and loosen or remove clothing</td>
</tr>
<tr>
<td></td>
<td>Often accompanied by dehydration</td>
<td>Actively cool the skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Administer oral fluids</td>
</tr>
<tr>
<td>Heat stroke</td>
<td>Significant central nervous system dysfunction (agitation, delirium, stupor, coma)</td>
<td>Insure an open airway</td>
</tr>
<tr>
<td></td>
<td>Severe hyperthermia (&gt;40.5 °C, 105 °F)</td>
<td>Move supine individual to cool, shaded, and well-ventilated area</td>
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<tr>
<td></td>
<td></td>
<td>Cool immediately to &lt;39 °C using water bath, wetting with water and continuous fanning, or ice packs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Administer intravenous fluids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reestablish normal central nervous system function</td>
</tr>
</tbody>
</table>
heat and humidity. It may take 10–14 days of training in such conditions for the athlete to fully adapt physiologically (see Figure 5.1). For some, a training regimen of longer duration and greater intensity may help to prevent symptoms in the future. All outdoor volleyball athletes should be counselled regarding prehydration. It is recommended that athletes competing outdoors consume 6 mL of fluid per kg of body mass every 2–3 hours before training or competition in the heat. Prehydration is essential to maintaining fluid balance during exercise. Athletes should not rely on thirst as a trigger for fluid replacement, as significant fluid losses can occur before they become thirsty. Athletes who have suffered from heat cramps in the past should probably be advised to liberally salt their food. Predisposed individuals may benefit from regular dietary salt supplementation, although little well-designed research on this topic exists in the literature.

**Heat exhaustion**
Heat exhaustion is characterized by symptoms such as fatigue or weakness, light-headedness, headache, nausea with or without vomiting, and malaise. Findings on examination may include tachycardia, hypotension, “goose bumps,” profuse sweating, and reduced urinary output. The core temperature is elevated, but is typically 40.5 °C (105 °F) or less. Heat exhaustion is felt to occur because of dehydration and hypovolemia (reduced intravascular fluid volume). Electrolyte loss, particularly sodium, is also a contributing factor.

The acute treatment for heat exhaustion is to rapidly cool the affected athlete, reducing their core temperature to 39 °C (102 °F) or less. The athlete should be placed in a cool environment and sprayed with cool water to facilitate evaporation. Placing the athlete in front of a fan helps to maximize convective heat loss. Oral rehydration is the preferred method of fluid replacement. Athletes who are suffering from severe nausea or experiencing emesis may need intravenous rehydration. In this situation, 0.9 normal saline or lactated Ringer’s solution are again the intravenous fluids of choice.

**Heat stroke**
The definition of exertional heat stroke varies depending on the source, but the clinical hallmark is an elevated core temperature of 40.5 °C (105 °F) or greater. However, reliance on a specific core temperature in clinically diagnosing heat stroke is not advised as large interindividual differences occur in documented cases. Heat stroke results from a global dec compensation of the body’s mechanisms for heat loss. Volume depletion and peripheral vasoconstriction impair the ability to transfer heat to the environment. Signs and symptoms of exertional heat stroke include hypotension, cardiac arrhythmias, reduced urine output, vomiting, and diarrhea. The athlete may go into hypovolemic shock, possibly resulting in kidney failure. Mental status changes, including central nervous system dysfunction such as disorientation and delirium, are common. There may even be bleeding into the brain, and seizure activity and coma have been reported. Liver damage may occur, resulting in elevation of the liver enzymes that can be monitored by serial blood tests. Other organ systems can fail as well, including the hematological system, resulting in disseminated intravascular coagulation, and the muscles themselves may break down, resulting in rhabdomyolysis. Finally, cardiorespiratory overload can result in lung failure and/or myocardial infarction. Heat stroke must be regarded as a medical emergency and as a potentially fatal condition.

The most important goal in the treatment of exertional heat stroke is to cool the body to below 39 °C (102 °F) as quickly as possible. The most effective cooling method is to immerse the body in ice water (4–8 °C), since heat is lost from the skin much more quickly by conduction to cold water than it is to the air. Athletes with exertional heat stroke are quite sick, so total body immersion should probably be done only if there are emergency medical personnel present capable of intubating the patient to protect the airway and maintain respiration, if necessary. Most medical areas at volleyball competitions or tournaments may not be equipped with this level of acute care personnel or facilities. Therefore, it is vitally important that athletes with heat stroke are transported to an emergency medical center as quickly as possible. However, cooling should not be delayed. Packing the entire body in
Cold towels that have been immersed in ice water is often effective in rapidly lowering the core temperature. Remember that the skin is the organ responsible for heat loss. The more skin in contact with cold water, the more effectively heat will be lost. It was once felt that placing ice packs over the large vessels in the groin and axilla was an effective way to cool heat stroke patients. However, this intervention may actually result in a reflex peripheral vasoconstriction, so the practice should probably be avoided. Spraying cool water on the skin to maximize heat loss via evaporation and fanning air over the athlete to maximize convection are also beneficial.

**Prevention of heat illness**

Heat illness is preventable. Prevention strategies should emphasize athlete education and physiological adaptation (Figure 5.3). It is important to discuss heat illness with all athletes, particularly those who have been affected by it in the past.

It is well established that cooling the skin reduces cardiovascular strain during exercise in the heat, while whole-body cooling decreases organ and skeletal muscle temperatures. As such, external (e.g. application of iced garments, towels, water immersion or fanning) and internal (e.g. ingestion of cold fluids or ice-slurry) cooling methods have been devised to help athletes perform in the heat and reduce the risk of heat illness. Although several reports have concluded that cooling interventions can increase endurance exercise capacity in the heat, it has to be acknowledged that most laboratory-based precooling studies likely overestimate the effect of precooling relative to competing in an outdoor setting where there is greater air flow, or do not account for the need to warm up before competing. Notwithstanding, for beach volleyball, athletes may be advised to employ a mixture of cooling interventions during side changes and other breaks from play. Application of cold towels, fanning, and ingestion of cold fluids help to reduce the rate of rise in whole-body temperature during play.

Acclimatization to exercise in the environment in which the athlete will be competing is probably the most important consideration (see Figure 5.1). As discussed, the process of acclimatization should begin at least 10–14 days prior to the first day of competition. Although short-term (5–7 days) heat acclimatization has been shown to induce some early adaptation, complete physiological and

**Figure 5.3** Beach volleyball athletes are at risk of heat illness when competing in hot, humid conditions. Appropriate precautions include adequate hydration and acclimatization. Protection from the harmful effects of exposure to the sun’s ultraviolet radiation is also recommended.
behavioral adaptations take longer. Once aclimated, the benefits persist for 2–3 weeks when regular training is maintained, and for longer when exercise in the heat (2–3 times per week) is included in the training regimen. Advise athletes that they will probably begin sweating earlier and at a greater rate as they adapt. Athletes should keep in mind that muscle is about 80% water and that they can lose up to 1.5L of water before they demonstrate significant thirst. Body mass losses of more than 2% due to dehydration can noticeably impair endurance athletic performance. Outdoor volleyball athletes should therefore be urged to prehydrate in order to help prevent dehydration and optimize high-level performance. Reasonable fluid intake guidelines include the following.

1. Before training and competition in the heat, athletes should drink 6mL of fluid per kg of body mass every 2–3 hours, in order to start exercise euhydrated.
2. During intense prolonged exercise in the heat, body mass losses should be minimized (without increasing body weight) to reduce physiological strain and to help preserve optimal performance.
3. Athletes training in the heat have higher daily sodium requirements than the general population. Sodium supplementation may be required during exercise.
4. For competitions lasting several days (e.g. a beach volleyball tournament), simple monitoring techniques such as daily monitoring of body mass and urine specific gravity can provide useful insights into the hydration state of the athlete.
5. It is essential to adequately rehydrate after exercising in the heat. Provide plenty of fluids with meals. If aggressive and rapid replenishment is needed, then consuming fluids and electrolytes to offset 100–150% of body mass losses will allow for adequate rehydration.
6. Recovery hydration regimens should include sodium, carbohydrate, and protein.

**Heat illness and the medical team**

The medical team covering tournament play should be prepared to measure core body temperature accurately should the need arise. The only reliable means of measuring core temperature is rectally, and thus the tournament medical bag should include a rectal thermometer measuring up to 45°C (113°F). Aural, oral, and axillary thermometers all have significant shortcomings in the evaluation of heat illness. Normal saline or lactated Ringer’s solution should be available in quantities sufficient for an entire tournament. A shaded area or tent with adequate air circulation should be available with cots or tables on which athletes may lie down. A mechanism (e.g. water bath) for rapid cooling of athletes with heat exhaustion and heat stroke should be immediately available. A plan for rapidly transporting an athlete with heat stroke to a nearby emergency medical or intensive care facility should also be agreed upon in advance.

**Sun exposure**

One of the attractions of beach volleyball is that it is played outdoors during the summer months. As a result, participants typically wear swimming attire or other clothing that exposes their skin to the sun. Unfortunately, excessive exposure to ultraviolet radiation damages the skin. A single episode of prolonged UV-B exposure can cause sunburn, a thermal injury which may vary in severity based on the duration of exposure, the intensity of the light source, and the amount of pigment in the individual’s skin. UV-B radiation is not filtered by cloud cover and is reflected off both sand and water, further increasing the athlete’s UV exposure. Sunburn can be quite painful, and if severe can cause blistering, fluid loss, and temperature dysregulation. Prevention of sunburn is considered the best treatment, as no intervention is uniformly effective for sunburn once it occurs.

The cumulative effects of long-term exposure to ultraviolet light include weathered, wrinkled skin that appears prematurely aged. Significant sunburn acquired as a youth increases one’s risk of developing malignant melanoma, a particularly dangerous form of skin cancer, in later life. Furthermore, UV-A exposure increases an individual’s risk of developing squamous cell carcinoma of the skin. Outdoor volleyball athletes should therefore take appropriate
Injuries unique to competition on the sand

Beach volleyball is one of very few sports contested on the sand, and it is the only Olympic sport played on sand (Figure 5.4). This puts beach volleyball athletes at risk for some unique injuries. “Sand toe,” for example, is the name given to forced plantarflexion injury of the great toe. Sand toe occurs when a player lands from a jump or other movement of the lower limb with their great toe plantarflexed in the sand. The subsequent forced plantarflexion of the great toe underneath the foot results in a sprain of the dorsal aspect of the first metatarsophalangeal (MTP) joint (Figure 5.5). Severe cases of sand toe may result in open dislocation of the first MTP joint. Obviously, such an injury would require significant irrigation and antibiotic treatment. Fortunately, most cases of sand toe are not severe and can be managed with taping to support the first MTP joint. The injury typically results in significant pain and may impair jumping ability. With rest, these capsular sprains can be expected to heal over a period of approximately 8 weeks. The extent to which the incidence of sand

Figure 5.4 Beach volleyball is the only Olympic sport to be contested on sand. When the local geography does not provide a suitable beach, man-made sand volleyball courts may allow for world-class competition venues in exotic places, such as the Horse Guard Parades in London during the 2012 Games.
toe is related to sand quality and the degree of compactness is unknown. There is anecdotal evidence, however, that suggests that knee injuries occur more frequently when beach volleyball is played on hard, compact sand. The FIVB has established guidelines to insure a minimum standard of sand quality on the courts used in all its events.

Since beach volleyball is contested in bare feet on an uneven surface that may occasionally conceal unknown foreign objects, the tournament medical director must also be prepared for other foot and lower limb injuries, including nail avulsions, puncture wounds, lacerations, and other toe sprains/dislocations. At large tournaments, facilities and personnel for suturing lacerations should be available, if possible. Tetanus booster shots should also be available and administered when the athlete's immunization history is unknown or out of date. Athletes may continue competing even after a foot laceration has been sutured, if an occlusive dressing is worn. However, even the most adhesive of tapes or bandages often are not equal to the stresses placed on them by beach volleyball players, and as a result the dressings may come off during competition, leaving the wound exposed and vulnerable to infection. In such circumstances, a synthetic, fine-woven, nylon sock worn over the dressing will allow the athlete to continue to compete. Other types of materials such as cotton do not usually last even one game on the sand.

**Summary**

Much of our current understanding on exertional heat illness is derived mainly from military and occupational research fields, while the input from sport sciences is more recent. Based on this literature, athletes competing in the heat should train for at least 1 week and ideally 2 weeks to acclimatize using a comparable degree of heat stress as the target competition. They should also be careful to undertake exercise in a euhydrated state and minimize body water deficits (as monitored by body mass losses) through proper hydration before, during, and following exercise. They can also implement specific countermeasures (e.g. cooling methods) to reduce heat storage and physiological strain during competition and training, especially in conditions of high ambient...
heat and humidity. Athletes should pay particular attention to ultraviolet radiation when competing outdoors to protect against sunburn, thermal injury, and the long-term effects of exposure to the sun. Medical personnel should be prepared to rapidly cool athletes experiencing exertional heat illness and treat injuries specific to competing on sand.

References


Recommended reading

Every sport places unique biomechanical and physiological demands on the athletes who participate in that sport, resulting in a sport-specific pattern of injuries that reflects the interaction between the athlete and the sporting environment. In order to provide optimal care for the volleyball athlete, it is first necessary to understand the injury pattern.

**Injury patterns in volleyball**

As is the case for all sports, the injury pattern seen in volleyball is unique, and medical personnel who care for volleyball players should be familiar with the spectrum of injuries with which the athlete may present. A number of observational studies that establish the epidemiology of volleyball-related injuries have been published. These studies provide us with insight into the incidence and prevalence of various injuries, as well as an understanding of both the risk factors that predispose volleyball players to injury and the mechanisms that incite injury in susceptible athletes.

The risk of acute injury in volleyball is lower than that documented for other Olympic team sports such as basketball, soccer, or ice hockey (Bahr et al. 2002; Bere et al. 2015; Verhagen et al. 2004). This difference can arguably be attributed to the noncontact nature of the sport. However, recent studies using novel methods to register overuse injuries appear to demonstrate that the risk of overuse injuries is higher in volleyball than in other team sports (Clarsen et al. 2015). The injury spectrum characteristic of indoor volleyball also differs from that observed in beach volleyball. Fewer acute injuries (such as ankle sprains) are seen in outdoor volleyball, while a higher prevalence of overuse injuries of the lower back, knee, and shoulder are encountered in the beach game (Bahr 2009; Bahr and Reeser 2003).

Ankle sprains account for approximately half of all acute time-loss injuries in volleyball (Bahr and Bahr 1997; Bere et al. 2015; Verhagen et al. 2004). With an estimated rate of about one sprain per 1000 player-hours of exposure, ankle sprains make up between 25% and 50% of all volleyball injuries (Bere et al. 2015; Fong 2007). Although most ankle sprains seen in volleyball are mild to moderate, the overall injury rate is close to that observed in soccer and basketball – sports where the athletes are not separated by a net and where there is frequent player–opponent contact. This makes ankle sprains a significant source of disability in volleyball.

The most important overuse injury in volleyball is jumper’s knee (patellar tendinopathy). Jumper’s knee is more common in volleyball than in other team sports. Cross-sectional studies among volleyball players have shown that the prevalence of patellar tendinopathy lies between 40% and 50%
A more recent study shows that, at any given time, 36% of adolescent elite players are affected by anterior knee pain (Clarsen et al. 2015).

Risk factors for sport-related injuries may be generally classified as either “intrinsic” or “extrinsic.” Intrinsic risk factors are those qualities or features that are inherent to the athlete and which may predispose them to certain types of injury. Intrinsic risk factors might include the athlete’s sex, age, morphotype, history of prior injury, degree of strength and conditioning, and psychological make-up. Extrinsic factors are inherent to the sport and the athlete’s participation therein, and include the volume of training, playing surface, equipment used, position(s) played, environmental conditions, and the rules of the game.

From these few examples, it should also be evident that certain risk factors are “modifiable” (e.g. position played) while others are “unmodifiable” (e.g. age). Clearly, only interventions targeting modifiable risk factors are likely to be successful in reducing the incidence of injuries. For example, athletes who are well conditioned and physically fit are generally more resistant to overuse injuries than those who may be less well conditioned (possibly as the result of attempting to return to competition too soon after an injury).

Armed with a knowledge of the extent of the injury problem and an appreciation of risk factors that contribute to the mechanism(s) of injury, it is possible to design an experimental intervention in an effort to reduce the frequency and/or severity of a given injury in a particular sport. This iterative process, described by van Mechelen, has been employed by researchers in an effort to reduce the effect of injuries on the sport of volleyball.

Preventing ankle sprains

Injury mechanisms

Ankle sprains typically occur at the net when the athlete lands on the foot of an opponent or of a teammate after blocking or attacking (Figure 6.1) (Bahr et al. 1994; Verhagen et al. 2004). About half of all ankle sprains occur when a blocker lands on the opposing attacker's foot, while about one-quarter result from a player landing on their teammate's foot following a two- or three-person block (Bahr et al. 1994; Verhagen et al. 2004).

One common high-risk situation occurs when the volleyball is set too “tight,” i.e. too low, too quick, and too close to the net. In trying to reach the ball in this situation, many attackers try to outjump the ball, thereby risking a landing on or across the centerline (Figure 6.2). This in turn puts the opposing blocker at risk for landing on the attacker’s foot. Of the injuries caused by landing on an opponent, about one-half take place in the legal “conflict zone” under the net without violating the centerline penetration rule. The remaining 50% result from a centerline violation (the attacker is almost always at fault). It is important to understand that the present centerline rule allows a player...
to step across the centerline, as long as a part of their foot remains on or above the centerline.

A “new” injury mechanism, not uncommon at the elite level, is when a back row attacker lands on a front row player attempting to cover under the block. Top teams commonly use the so-called “pipe” attack, a tactic with a very quick set to the middle back player who jumps and lands well into the net zone. In this area, there is a risk that he/she may land on the foot of one of the front row players landing in the same zone, usually the middle attacker.

Figure 6.2  This figure illustrates the main injury mechanism for an ankle sprain in volleyball. Injuries result from the attacker trying to “outjump” a set that is faster, lower or closer to the net than anticipated, causing him to land on or across the centerline (b) and thereby putting the opposing blocker at risk for landing on his foot. This situation could be avoided if the attacker attempts to reach the ball with a final long approach step (a), instead of trying to reach the ball by jumping.
In summary, the most common mechanism for acute ankle injury occurs when a blocker lands on the opposing attacker’s foot, which may or may not have penetrated the centerline in violation of the rule. In addition, most of the ankle sprains in volleyball result from what could be termed technical errors, including an inadequate approach or flawed take-off or landing technique when blocking or attacking.

**Risk factors**

The most important risk factor that has been identified for ankle sprains is a previous ankle sprain injury. In fact, research has shown that among senior players, four out of five ankle sprains occur in previously injured ankles (an observation made in other sports as well) (Ekstrand and Tropp 1990; Fong et al. 2007; Verhagen et al. 2004). Compared to an ankle with no prior injury, the risk of injury is fourfold greater for an ankle that has been sprained one or more times (Bahr and Bahr 1997). Furthermore, the more recent the injury, the higher the risk of reinjury. The injury rate during the first 6–12 months after an ankle sprain is nearly 10-fold higher than for an ankle without a history of prior injury. An ankle sprain not only compromises the anatomical stability of the ankle, but it adversely affects the proprioceptive system as well. The athlete’s sense of movement at the ankle joint and the awareness of the joint’s position in space are hampered, elevating the risk of subsequent injury (Huurnink et al. 2014; Konradsen et al. 1998).

**Possible preventive strategies**

Several intervention strategies have been proposed based on the typical injury mechanisms and risk factors for ankle sprains (Bahr and Bahr 1997; Bahr et al. 1994):

1. change the centerline rule to reduce the “conflict zone” under the net
2. provide athletes with specific training on take-off and landing techniques during the attack and multi-person blocks
3. use tape or ankle braces as external ankle protection
4. adequately rehabilitate sprained ankles.

**Rule change**

A more restrictive (and therefore punitive) centerline rule has been suggested as a simple preventive measure, since it would further deter players from landing on the opponent’s side of the court and thereby reduce the incidence of conflicts between attackers and blockers when landing. It is possible, and perhaps even likely, that changing the centerline rule would significantly reduce the incidence of ankle sprains. However, a previous attempt at reducing injury risk by making any penetration of the centerline a fault resulted in an unacceptable number of game interruptions, and the proposed rule change was therefore abandoned (Bahr 1996). However, it is also important to note that the majority of the centerline violations occurred in “low injury risk” situations, e.g. setters approaching the net to set the ball, or blockers and attackers turning away from the net after landing. It may be, therefore, that a rule which discriminates between centerline contact/penetration based on the injury risk inherent in the situation (e.g. centerline contact within the conflict zone=fault versus penetration occurring away from the area in which the volleyball is being played=no fault) would be able to reduce the risk of ankle sprain injury while minimizing the stoppage of play, which players and spectators alike find disruptive to the game.

**Technical training**

A second prevention strategy is to teach proper movement, take-off, and landing techniques. A training program for volleyball should include drills specifically designed to teach players how to reach tight sets without stepping on the centerline (see Figure 6.2), as well as blocking drills (Figure 6.3) (Bahr et al. 1997). The ability to block effectively, including the ability to mount a two- or three-person block to gain a tactical advantage over the opposing attacker, requires the ability to move quickly sideways along the net and time both the movement pattern and the take-off between the players involved. Every practice session should include block movement drills performed in pairs as part of the warm-up routine to improve footwork, balance, and timing. An approach as outlined above has previously been linked to a
reduction in the number of ankle sprains due to technical errors (Bahr et al. 1997).

**Tape/brace**
Although there is no direct evidence from volleyball-specific studies, there is strong evidence from studies from other sports that the use of taping or bracing should be recommended for a period of up to 12 months after an ankle sprain, when the risk of injury is increased severalfold (Verhagen and Bay 2010). The mechanism by which such ankle orthoses are thought to work is not known with certainty, but may involve simply enhancing the athlete’s proprioceptive awareness of the ankle joint. This view is corroborated by the fact that the preventive effect of braces is limited to players with a history of previous injury (and thus impaired proprioceptive function) (Karlsson et al. 1992; Konradsen and Ravn 1991; Tropp et al. 1985). In addition, orthoses do not seem to restrict ankle inversion enough to explain their prophylactic effect on ankle sprain incidence. If the protective effect were purely mechanical, one would expect an effect in healthy, previously uninjured ankles as well.

Many different ankle supports are commercially available. Ankle taping has also been shown to be beneficial in restricting inversion motion, although it appears that ankle supports are superior to ankle taping since supports do not lose their ability to restrict inversion, while tape does “loosen up” after several repeated cycles of vertical jumping. Unlike semi-rigid orthoses, the effectiveness of ankle taping has not been tested in randomized controlled trials, but if the effect is mainly through enhancement of proprioception, there is no reason to expect taping to be less effective than orthoses. Other factors, such as cost and skin care, obviously should also be considered in the choice between tape and orthoses. Finally, there is no evidence that wearing an ankle orthosis increases the incidence of knee injuries, and most studies suggest that semi-rigid orthoses do not significantly impair athletic performance.

**Adequate rehabilitation, including “ proprioceptive” training**
Tropp et al. (1985) and others (Karlsson et al. 1992; Konradsen and Ravn 1991) have shown that proprioceptive function is reduced in athletes who complain of a feeling of persistent instability following an ankle sprain. Proprioceptive control of the affected ankle joint is impaired in the immediate recovery period following an acute sprain (Huurnink et al. 2014; Konradsen et al. 1998), but studies have shown that this function can be restored through a balance board training program (Gauffin et al. 1988; Holme et al. 1999). In these studies, proprioceptive function was quantified by measuring the reaction time to a sudden inversion strain, or the degree of postural sway during a one-legged balance test. It should be noted that the use
of the term “proprioceptive function,” which is defined as the function of the afferent components only, may be inappropriate in this context. The ability to react to a sudden inversion stimulus or balance on one leg clearly depends on both sensory and motor function, and should perhaps therefore be termed “sensorimotor control.”

A balance board training program has been shown to reduce the risk of reinjury in functionally unstable ankles in soccer players (Tropp et al. 1985). The program is performed as balance exercises on one leg on a disk (Figure 6.4). Based on the available literature, it appears reasonable to recommend a program of 10 minutes of balance board training five times a week over 6–10 weeks for all players with a history of ankle sprain. Volleyball-specific data suggest that balance board training alone is effective in previously injured players. In a one-season randomized trial, balance exercises were introduced as part of the regular warm-up for high-level recreational volleyball players (Verhagen et al. 2004b). Ankle sprain incidence was reduced by 60% among players who reported a history of previous injury.

Effect of preventive programs

While multiple (potentially) effective preventive approaches are available, a multifaceted program may be the most efficient intervention. An intervention program consisting of injury awareness information, specific technical training, and a program of proprioceptive training for players with a history of ankle sprains reduced the incidence of ankle sprains by 47% in the course of a single season (the rate of ankle sprain injury fell from 0.9 to 0.5 per 1000 player-hours) (Bahr et al. 1997). However, it should be noted that direct contact with each team participating in the study was (for practical reasons) limited to one visit. No information regarding how the coaches and players complied with the advice and information offered to them was collected. Although the athletes appeared well motivated, it is likely that the effectiveness of the prevention program could have been even better if it was reinforced on a regular basis. The results of this study should encourage medical personnel working with volleyball teams to institute a program of ankle injury prevention, as positive results can be expected if coaches and medical staff cooperate in establishing and encouraging participation in such a program.

Preventing patellar tendinopathy

Injury mechanisms

Patellar tendinopathy or “jumper’s knee” is the most common overuse injury in volleyball. Athletes with jumper’s knee, like most athletes with overuse
conditions, are usually unable to recall one specific traumatic event that precipitated their symptoms. Rather, it is the sum of all the events and exposures that results in the tissue injury complex.

**Risk factors**

The cumulative load put on the tendon, i.e. volleyball training and match exposure, represents a major risk factor for jumper’s knee (Table 6.1). A large cohort study among young elite volleyball players documented that the risk of developing jumper’s knee doubled for every extra hour of volleyball training per week. They also found that match exposure, i.e. the number of sets played per week, was the strongest sports-related predictor: the injury risk increased by 3.88 per set played (Visnes and Bahr 2013).

However, it is not known why some players have problems whereas others do well despite an equally high training volume. Men have a 2–4 times higher risk for developing patellar tendinopathy than do women (Lian *et al.* 2005; van der Worp *et al.* 2012; Visnes and Bahr 2013; Zwerver *et al.* 2011). This gender difference may be caused by the difference in the force-generating capacity of the quadriceps between men and women. However, a cross-sectional study among young elite athletes found that males jumped three times more than females per hour of training exposure (Bahr and Bahr 2014), so perhaps some of the gender difference is still caused by the exposure, not in the number of hours of training, but the number of jumps per hour of training.

Landing surface may be an important risk factor, and in fact beach volleyball players have a lower prevalence of jumper’s knee compared to indoor volleyball players (Bahr and Reeser 2003; Ferretti *et al.* 1984), presumably because jumping in sand is easier on the knees than is jumping (and landing) on hard flooring (Tilp *et al.* 2008).

“The jumper’s knee paradox,” the observation that symptomatic athletes appear to jump better in a standardized jump test emphasizing eccentric force generation compared to asymptomatic controls, is poorly understood. However, a recent prospective cohort study shows that jumping ability represents a risk factor for patellar tendinopathy (Visnes *et al.* 2013). Talent for jumping high, which results in higher tendon strain, amplifies the risk of tendon problems. In fact, this study showed that the risk of developing jumper’s knee increased by a factor of 2 for every cm difference in a standard countermovement jump.

Biomechanical evidence is limited, but there is no convincing evidence in support of suggestions that injury may be associated with malalignment of the extensor mechanism of the knee. Malliaras

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**Table 6.1** Volleyball-specific risk factors for jumper’s knee; the level of evidence is estimated as strong, medium, weak or unknown (Visnes 2014).

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Description</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Males &gt; females</td>
<td>Strong (OR: 3–4)</td>
</tr>
<tr>
<td>Tendon load</td>
<td>Per extra set played per week</td>
<td>Strong (OR: 3–4)</td>
</tr>
<tr>
<td>Match exposure</td>
<td>Per hour extra training per week</td>
<td>Strong (OR: 2)</td>
</tr>
<tr>
<td>Volleyball training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(previous and present)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jumping ability</td>
<td>Per cm difference in CMJ at the time of inclusion</td>
<td>Strong (OR: 2)</td>
</tr>
<tr>
<td>Ultrasound findings</td>
<td>If hypoechoic area is present</td>
<td>Medium (OR: 3)</td>
</tr>
<tr>
<td>Hypoechoic areas</td>
<td>If neovascularization is present</td>
<td>Medium (OR: 3)</td>
</tr>
<tr>
<td>Neovascularization</td>
<td>Concrete &gt; parquet &gt; sand</td>
<td>Strong</td>
</tr>
<tr>
<td>Court surface</td>
<td>Body mass/BMI among adults – not adolescents</td>
<td>Weak</td>
</tr>
<tr>
<td>Body composition</td>
<td>Different candidate genes</td>
<td>Unknown</td>
</tr>
<tr>
<td>Genetics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomechanics</td>
<td>Low range of ankle dorsiflexion</td>
<td>Weak</td>
</tr>
<tr>
<td>ROM</td>
<td>Knee position when landing</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

BMI, Body Mass Index; CMJ, countermovement jump; OR, odds ratio; ROM, range of motion.
Chapter 6

et al. (2006) found that having less than 45° of ankle dorsiflexion range doubled the risk of patellar tendinopathy. Players who develop the deepest knee flexion angle during landing from a spike jump have been shown to be more likely to suffer from jumper’s knee (Richards et al. 1996).

Several investigators have identified body mass as a risk factor for developing jumper’s knee and a mechanical explanation might be that higher body mass could cause higher load on the patellar tendon, but there is no evidence for a link between body composition and the risk of jumper’s knee among young, well-trained athletes. (Crossley et al. 2007; Gaida et al. 2009; Lian et al. 1996, 2003; Malliaras et al. 2007; Visnes and Bahr 2013).

Structural abnormalities are common in asymptomatic tendons; ultrasound examination revealed such changes (thickening and hypoechoic areas) in 10–30% of pain-free patellar tendons. Although the presence of the changes seen on ultrasound may represent a prepathological stage, as only one-third develop symptoms over an observation period of 1–2 seasons. However, such abnormalities increase the risk of developing jumper’s knee three-fold (Comin et al. 2013; Fredberg et al. 2008; Giombini et al. 2013; Visnes et al. 2015).

The relationship between a genetic component and tendinopathy has mainly been investigated in the Achilles tendon and although some candidate genes have been identified, their association with patellar tendinopathy needs to be further investigated.

Preventive measures

Perhaps the most important element in preventing jumper’s knee is to load the tendon appropriately. The balance between training hard to achieve results but not so much as to cause an overuse injury is difficult. A typical scenario may be the following: a young, promising player is recruited to play on a higher level (e.g. secondary school to university), and among the primary selection criteria are jumping ability and agility. This transfer from a “safe” training environment (2–3 days of training per week, no weight lifting) to a higher level with a concomitant increase in strength, muscle mass, and jumping ability may result in progressive overload of the extensor apparatus. The most talented boys stand out with a particular risk. An obvious explanation may be that the players affected are the best players, and the player and their school, club and national team coach had the same interest in their playing as much as possible, without much thought of the consequences for injury. Match exposure, i.e. the number of sets played per week, is the strongest sports-related predictor for developing jumper’s knee in this age group. Therefore, there needs to be a focus on how many different teams youth players should represent during the season and how many matches they should play. This issue is unlikely to be raised by the player; this is the responsibility of the coaching staff. Reducing the number of jumps may be a controversial strategy, but future guidelines might include “jump counts” among adolescent athletes. In baseball, safety recommendations have been developed for pitchers, limiting the number of pitches per game and number of months played per year from age 14 through 20 years. In volleyball, there is currently not enough evidence to introduce jump counts, nor do we know what the optimal number of jumps would be. Further research is clearly indicated.

Another approach would be to add “tendon strength training” to make tendons sufficiently strong to tolerate the sport-specific activity. Normal tendon adaptation to load is slow compared to muscles, especially when athletes rapidly increase the volume of training (Kjaer et al. 2009). Imbalances between muscle strength and tendon loading capacity in adolescent athletes might increase the risk of tendon injury. Structured warm-up programs, e.g. “the 11+,” have reduced the risk of lower limb injury in football (Soligard et al. 2008), including the risk of overuse injuries. Such programs typically combine strength training, stretching, balance training, core stability, and correct landing strategy after jumps. So far, the effect of and the potential mechanism behind structured warm-up programs in the prevention of overuse injuries like jumper’s knee are unclear. Currently, there are no guidelines on how to make tendons stronger and how to improve tendon properties in a safe manner.

To summarize, a potential prevention strategy among adolescents would be to gradually “develop”
athletes rather than to start with too much volleyball-specific training too soon. Even though a prevention program should not interfere with the development of the sports-specific skills, restrictions on the number of jumps and matches among adolescent athletes would probably reduce the risk of jumper’s knee. The problem is that we do not know where these limits should be set, and there are insufficient data to adapt programs to the risk profile of each athlete.

**Preventing finger injuries**

**Injury mechanisms**

Finger injuries occur frequently in volleyball and represent about 10% of all time-loss injuries (Bere et al. 2015). These injuries mainly occur when blocking, when a player tries to stop or deflect a spike from the opponent by reaching across the net with one or both hands and with fingers extended. However, rule changes on defensive ball handling have led to the development of new effective defensive techniques, such as the overhand dig, a common defensive action used to stop hard-driven spikes in the back court (Figure 6.5). This has been described as an additional mechanism for finger injuries in beach volleyball (Bahr and Reeser, 2003) and volleyball (Bere et al. 2015).

The thumb and little finger are the most vulnerable phalanges. That these two digits are injured more frequently than others is easy to understand, considering their vulnerable position when blocking and playing defense (Figure 6.6). The metacarpophalangeal joint of the thumb is the most frequent location of ligamentous injury, but unlike some other sports (such as skiing), it is the radial, not the ulnar, collateral ligament that is typically injured.

**Risk factors**

Finger injuries are mainly caused by contact with the ball, which is in accordance with the literature reporting that a typical situation occurs during a block where the ball hits the fingertips and transmits a high impact to the extended and spread fingers (Eerkes 2012; Reeser et al. 2006). As with ankle injuries, a history of previous injury is the most significant risk factor for finger injuries. The skill level of the player may also be expected to play a role, both when blocking and playing defense.

![Figure 6.5 Overhand defensive techniques are frequently used in the back court, leading to a risk of finger injuries, particularly among libero players. Source: FIVB Photo Gallery. Used with permission of FIVB.](image)
Proper finger position and timing are essential to be able to withstand the considerable forces involved when the spiked ball impacts on the extended digits. While the forces are higher at the elite level, unexperienced players often injure their fingers because of inadequate hand/finger positioning and timing when blocking or playing defense.

**Preventive measures**

The most important preventive measure is to teach players proper hand and finger positioning when blocking. Timing is also important, since being too early or too late on the block means that the player may not be prepared for ball contact at the proper time. Players with previous injury and instability problems should tape their fingers. “Buddy taping” the affected digit to an adjacent digit is an effective way to protect the injured finger from further injury. Finally, players should not wear jewelry while playing volleyball, since rings may get entangled in the net and result in a traumatic amputation or avulsion injury.

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**Preventing acute knee injuries**

**Injury mechanisms**

The rate of volleyball-related acute knee injuries, including anterior cruciate ligament (ACL) injuries, is considerably lower than in other team sports (Prodromos et al. 2007). ACL injuries in other team sports are for the most part noncontact injuries, and result from one-leg landing or plant-and-cut maneuvers with the knee in a vulnerable position, usually in valgus. This seems to be the case in volleyball too, and most of the injuries occur during landing after attacking or blocking (Ferretti et al. 1992). Since jumping and cutting are the dominant lower limb movement patterns in volleyball, it might be expected that ligamentous knee injuries would be as common in volleyball as in basketball or soccer. One possible explanation for the lower incidence of ACL injuries in volleyball may be that landing and cutting skills can be performed in a more predictable manner than in basketball and soccer. In both of these other sports, it is not uncommon for an opponent to suddenly block the way, forcing the player to perform the skill in a different way than anticipated. Unlike ACL injuries, meniscus injuries occur predominantly during the defensive phase of play, when players perform rapid twisting movements with the knee in the typical defensive position of near 90° of flexion. In this position, the meniscus is subjected to considerable compression and torsion stress, and the athlete is therefore at increased risk of meniscal injury.

**Risk factors**

Knee injuries, and ACL injuries in particular, occur more frequently among female than among male volleyball players. This gender disparity has been
observed in most other sports as well. Several explanations for this phenomenon have been proposed. A disproportionate number of knee injuries also seem to occur during games compared with training, probably reflecting the maximum effort expended and the greater risks taken in a competitive situation.

Preventive measures

A structural warm-up program has previously shown to reduce the number of new ACL injuries by 50% in both football (soccer) and handball, but so far no volleyball-specific study has been conducted (Myklebust et al. 2003; Olsen et al. 2005; Soligard et al. 2008). These programs, for example the 11+, typically combine strength training, stretching, balance training, core stability, and correct landing strategy after jumps. Particular attention must be paid to knee positioning during training (have the athlete keep the knee above the toe and flexion in the hip and knee). This program is performed periodically, instead of the regular warm-up. It takes approximately 15 minutes to complete, after which the athletes are ready to begin sports-specific activities.

Preventing low back pain

Injury mechanisms

Low back pain is a common complaint among volleyball players. Data from the FIVB volleyball injury study in 2008 found that 47% of professional beach volleyball players reported low back pain during the preceding 2 months (Bahr 2009), and data from the FIVB ISS from 2010–2014 indicated that back pain is the fourth leading cause of time lost due to injury (Bere et al. 2015). Among adolescent elite players, 16% are affected by low back problems at any given time (Clarsen et al. 2015). Low back pain is a non-specific diagnosis and is often used to describe a regional pain syndrome that worsens with activity.

There are a number of potential pain generators in the back which, if injured, can result in low back pain. These include the intervertebral disks, bony elements such as the pars interarticularis (a common site of stress reaction) and facets (a common cause of pseudoradicular pain), and muscles that may be overloaded or strained. Volleyball athletes are at considerable risk for low back disorders, in view of the movement patterns involving trunk rotation and lumbar flexion and extension that are common to volleyball skills such as spiking and jump serving.

Risk factors

Risk factors for low back pain and injury that have been identified include repetitive lumbar extension and trunk rotation, and cigarette smoking. Athletes who are particularly tall may be at increased risk by virtue of the longer lever arm of the spine when compared with shorter individuals. Athletes with spondylolysis are frequently found to have a flattening of the normal lumbar lordosis and relative inflexibility of the hamstrings. However, it is not clear whether these findings represent an intrinsic risk factor for the condition or a compensatory adaptation by the body in an effort to minimize the degree of lumbar extension to which the spine is subjected in these athletes.

Preventive measures

To minimize the risk of low back pain, volleyball athletes should follow a program of generalized strength and conditioning, in addition to maintaining flexibility through the low back, hips, and lower limbs through regular stretching. Exercises designed to specifically improve the athlete’s “core” stability and the endurance of the muscles that dynamically stabilize the lumbar spine should (theoretically) enhance the athlete’s ability to withstand repetitive overload of the spine, which is inherent to the skill set of the sport, particularly at the elite level.

Preventing shoulder pain

Injury mechanisms

Shoulder injuries account for 5–20% of all volleyball injuries, and at any given time, 14% of adolescent elite players are affected by shoulder problems (Clarsen et al. 2015). Shoulder injuries occur largely as the result of chronic overuse, and only rarely
result from acute trauma. Although the incidence of time loss injuries is low, the prevalence of shoulder pain and dysfunction may be much higher. The mechanism of injury is often complex, but most likely involves repeated spiking and serving. The kinematics of these skills are similar to those from other overhead throwing or racquet sports, such as baseball and tennis. The high angular velocities generated at the often extreme range of motion observed at the end of the cocking phase of the arm swing place the shoulder under great stress (Figure 6.7). Considering the multiple repetitions involved – an elite attacker spikes about 40,000 times a year – this can lead to overload of the structures at risk.

When these stresses are applied at a rate exceeding that of tissue repair, progressive damage to both the static and dynamic stabilizing structures of the shoulder can occur. In keeping with the complex mechanism of injury, volleyball players with shoulder problems often present with vague complaints. In addition to or instead of pain, they may report fatigue, discomfort, apprehension, paresthesia or numbness as their principal symptoms, and only rarely do they describe any feeling of instability. Apprehension is a term specifically used by shoulder instability patients in describing the fear that the shoulder will sublux or dislocate. In these cases, the athlete experiences a sharp pain on extreme external rotation. This may lead to transient loss of muscular control over the extremity (the “dead arm” syndrome). The severe pain usually subsides quickly, but soreness and weakness may persist for a period of time.

**Risk factors**

Obviously, the main risk factor for shoulder pain is the volume of training performed. Elite volleyball athletes are at particular risk for overuse syndromes of the shoulder girdle. Older athletes are also at increased risk of developing shoulder pain, although problems may occur in younger athletes after a sudden increase in training intensity. Talented spikers – who are able to generate superior ball speed – may also be at higher risk. In their case, the ability to develop extreme velocities and torques in the spiking arm puts the passive and active stabilizers of the glenohumeral joint at greater risk of fatigue and dysfunction.

It is felt that a combination of lax tissues on the anterior side of the glenohumeral joint and contracted tissues on the posterior side of the joint may contribute to instability by “pushing” the humeral head forward. Consequently, players with restricted range of motion and muscle weakness/imbalance are at risk for compromised glenohumeral joint function. Volleyball players typically develop reduced shoulder internal rotation and increased shoulder external rotation of the dominant (hitting) limb, which can be interpreted as indirect evidence of anterior capsular laxity. At the same time, there is often reduced rotator cuff function and reduced scapular control. This can be seen as lateralization or even as winging of the scapula.
Preventive measures

The prevention of shoulder pain and injury begins with a preseason conditioning program and continues throughout the season. The program should focus on stretching and strengthening exercises.

Stretching exercises should focus on the posterior structures (Figure 6.8). Exercises should be performed as repeated slow, sustained stretches, holding the position for at least 45 seconds at the point of slight discomfort. However, it is important to note that too much flexibility can become a liability. In someone who already possesses a lax gleno-humeral joint capsule, further stretching may predispose to increased laxity and even joint instability. Thus, a stretching program must be individually designed for each athlete, stressing development of flexibility where it is lacking.

Strengthening exercises should focus on the main stabilizers of the glenohumeral joint – the rotator cuff muscles – and the scapular stabilizers (Figure 6.9). It should be noted that the shoulder exercises traditionally used in the weight training program for volleyball players – bench press, pull-down and pull-over – actually are more likely to increase rather than reduce the risk of shoulder injury if used in isolation. This can be explained by the fact that isolated strengthening of the deltoid, pectoralis major, and latissimus dorsi is likely to increase arm speed and torque, and therefore put additional strain on the glenohumeral stabilizers. These exercises must therefore be combined with a program aimed at improving rotator cuff strength and scapular control.

Finally, warming up prior to repetitive overhead use of the shoulder is critical to prevent shoulder injury. The warm-up program should include exercises designed to increase core temperature first, followed by stretching. Warm-up then finishes with exercises with the ball, hitting first at low intensity and then progressing to full-intensity spiking.

Role of the medical staff

The traditional role of the medical staff has been to diagnose and treat injury and illness. However, there is a need to redefine the role of the team physician and physical therapist. As stated in the introduction to this chapter, their responsibility does not stop at treating injuries – there is also an obligation to prevent injuries. This requires a thorough
understanding of injury patterns, injury mechanisms, and risk factors, in addition to close cooperation between the coaching and medical staff. Both groups must simultaneously acknowledge each other’s expertise while assuming an active partnership role in the other’s area. The coaching staff need to involve the medical team when planning the training program, and medical personnel need to involve the coaching staff in the rehabilitation of injured players. The value of medical staff involvement has previously been shown conclusively in soccer. In cooperation, medical and coaching staff can introduce a comprehensive injury prevention program taking the skill level, practice and game schedule, injury status of the team, and other factors into consideration (Box 6.1).

Although the cost-benefit ratio of the preparticipation medical exam in mass participation sports may be questioned, for the team physician the preseason exam is an essential part of the injury prevention process. It is important to conduct this exam as early as possible before the actual start of the competitive season, so as to allow sufficient time to implement special conditioning programs before the start of the season. For the same reason, it may even prove beneficial to perform a postseason exam to survey injury status in preparation for the next season. The purpose of the medical examination, which ideally should be a joint effort between the team physician and physical therapist, is to get to know the player and to identify risk factors for injury. The main risk factor for injury is previous injury and minor present injuries that might progress. The examination should therefore include an evaluation of all previous injuries, with special attention to passive and active stability of the knee, ankle and shoulder joint.

**References**


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**Box 6.1 A comprehensive injury prevention program.**

<table>
<thead>
<tr>
<th>General</th>
<th>Warm-up and stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preseason medical screening to assess status of previous injuries</td>
</tr>
<tr>
<td></td>
<td>Have adequate first aid equipment (at least ice and elastic wrapping) available at all times</td>
</tr>
<tr>
<td>Ankle</td>
<td>Include drills to improve take-off and landing technique for attackers and blockers in warm-up routine</td>
</tr>
<tr>
<td></td>
<td>Introduce a restrictive centerline during practice and scrimmages games</td>
</tr>
<tr>
<td></td>
<td>Include a 10-week balance board training program for players with previous ankle sprains</td>
</tr>
<tr>
<td></td>
<td>Use taping and bracing for previously injured players who have not undergone an adequate balance training program</td>
</tr>
<tr>
<td>Knee</td>
<td>Gradual increase in training load</td>
</tr>
<tr>
<td></td>
<td>Introduce weight training and plyometrics gradually into training program</td>
</tr>
<tr>
<td></td>
<td>Prompt and adequate rehabilitation of new episodes of patellar tendon pain</td>
</tr>
<tr>
<td>Fingers</td>
<td>Teach proper finger positioning and timing when blocking</td>
</tr>
<tr>
<td></td>
<td>Taping of injured fingers</td>
</tr>
<tr>
<td></td>
<td>Do not wear rings</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Gradual increase in training load, particularly spiking and serving</td>
</tr>
<tr>
<td></td>
<td>Shoulder strengthening and stretching, with particular attention to rotator cuff and scapula stabilizing exercises</td>
</tr>
</tbody>
</table>


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**Recommended reading**


Chapter 7

The periodic health evaluation/preparticipation evaluation

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University of Calgary Sport Injury Prevention Research Centre, Calgary, Alberta, Canada

Introduction

Historically, the role of the sports medicine professional has been to diagnose and treat sport-related injuries. Over the past decade, there has been an ideological shift within sport medicine emphasizing the prevention of illness and injury. To this end, the periodic health evaluation (PHE) has become an essential tool to document health status and to facilitate injury prevention in athletes.

As with any health screen, the goal of the PHE is early detection of pathological conditions in the hope that there will be an opportunity for timely and effective intervention, and a resultant reduction in morbidity (or mortality). Through regular use of the PHE, it is also possible to identify those athletes who are at increased risk of injury or illness, and may therefore benefit from efforts to prevent health problems before they begin.

The International Olympic Committee (IOC) has developed a standardized form to document the PHE, which should include a detailed personal and family medical history, as well as a comprehensive physical exam. Based on the information gathered in these steps, further laboratory investigations such as blood and urine analyses, radiographs, electrocardiogram, etc. may be warranted. A PHE should be completed by a sport medicine physician, in a medical setting that assures the privacy of the athlete’s personal information. Ideally, the PHE is initially completed in the athlete’s off-season, allowing for the management of identified concerns well before the start of the season or any significant competitions. Additional follow-up evaluation throughout the season would then allow for an assessment of the athlete’s health adaptations compared to preseason levels. An understanding of the common injuries and the day-to-day physiological demands of volleyball can aid a sport medicine physician in the completion of a thorough PHE. It is therefore ideal that the sport medicine physician has a history of involvement in the sport and frequent interactions with the team and coaching staff in both training and competition settings.

It is becoming increasingly common for teams at the elite level to require their athletes to consult with an experienced sport medicine physician during the preseason, before any engagement by the athlete with the team or league. Under such circumstances, the evaluation is termed a preparticipation exam (PPE). In the interest of full disclosure, and in fairness to the athlete, it is essential that prior to the PPE/PHE, the athlete be fully informed regarding the role of the physician in the process: whom the physician represents, what the physician’s responsibilities are to the team and what the potential ramifications of any finding could be. Furthermore, if there is the expectation that results of the exam will be given to a third party, the athlete should provide their authorization...
to permit such disclosure of protected personal information. Unless otherwise requested, the physician’s response to the question of whether the athlete is currently fit to participate in the specific sport should be limited to a dichotomous YES or NO.

Ideally, the process of obtaining clearance to compete through the PPE or PHE allows the athlete to establish an ongoing relationship with a physician who can provide periodic assessments to optimize athlete care and preventive services. As stated, the PHE is intended to capture the dynamic health changes associated with sport involvement, and any evidence of serious medical risk identified during the course of care should be reported to the athlete. The athlete should be discouraged from future sport participation until the necessary follow-up testing and therapeutic interventions have been completed.

The following recommendations regarding the PHE/PPE are based on current medical evidence specific to volleyball. Moderately strong evidence is available for the distribution of specific injuries within an adult volleyball population. The determinants of common volleyball injuries vary greatly by injury type. Finally, specific focus has been given to the use of diagnostic tests with strong positive and negative predictive values when possible.

**Cardiovascular assessment**

The strongest scientific evidence for the completion of a PHE comes from the potential detection of risk factors for sudden cardiac death (SCD). The combination of cardiovascular disease and concentrated physical activity can result in cardiac arrest. Although physical activity is not the cause of SCD, it acts as the triggering mechanism in the presence of underlying cardiovascular disease (Corrado et al. 2003). Furthermore, SCD in athletes can occur without prior symptoms, placing great significance on the PHE as a method of detecting known risk factors of cardiovascular disease. The screening for cardiovascular disease should begin with a questionnaire documenting personal and family cardiovascular medical history followed by a physical examination (see Appendix at end of chapter).

The cost-efficiency of performing a 12-lead ECG examination as part of every athlete’s PHE has been debated by numerous international professional societies (La Gerche et al. 2011; Maron et al. 2014). An ECG assessment has been shown to be abnormal in up to 90% of individuals with hypertrophic cardiomyopathy and up to 80% of individuals with arrhythmogenic right ventricular dysplasia/cardiomyopathy. Development of a tool permitting categorization of ECG changes associated with SCD has reduced the false-positive rate to 4.2%, while improving sensitivity to 91% and specificity to 94% among athletes. Although making a case for a mandatory 12-lead ECG within a volleyball-specific PHE is beyond the scope of this chapter, the IOC Consensus Statement recommends that a 12-lead ECG be performed as part of the elite athlete PHE.

Screening for Marfan’s syndrome carries particular cardiological significance in a volleyball population. Several of the physical traits of Marfan’s syndrome are desirable for volleyball athletes, including tall thin stature, long arms, long legs, and long fingers. Thus, there may be some self-selection for Marfan’s among volleyball players. Individuals diagnosed with Marfan’s are at increased risk for cardiovascular disease, including aortic root enlargement (which in turn places them at increased risk for aortic dissection). Thus, if the athlete exhibits some of the physical traits/risk factors for Marfan’s, it may be reasonable to include echocardiography as part of the PPE.

The management of identified cardiovascular concerns should follow accepted protocols such as those outlined by the Bethesda Conference #36 and European Society of Cardiology (Pelliccia et al. 2008). This may include further evaluation, education of risk and informed participation, or exclusion from participation. It is of paramount importance in the cardiac assessment (or any specific aspect of the PHE system review) that the athlete be referred for specialty level care if the examining physician is not specifically trained and experienced in that discipline of medicine.
Noncardiac assessment

Noninjury-related medical conditions affecting systems other than the cardiovascular system occur frequently in elite athletes: pulmonary, gastrointestinal, hematological, dermatological, urological, immunological, endocrine, and ophthalmological conditions all occur with reasonable frequency. Musculoskeletal conditions are most commonly encountered, and can occur at any time throughout the season. Most injuries are self-limited, healing without specific treatment. When indicated, appropriate treatment optimizes the anticipated outcome and minimizes morbidity. The IOC’s recommended PHE questionnaire and physical exam guide (see Appendix) provide a systematic method of documenting these noncardiac conditions.

Musculoskeletal assessment

The IOC Consensus Statement on use of the PHE outlines one method by which the exam can be tailored to different sports, focusing on the most prevalent musculoskeletal injury types and their corresponding risk factors (Ljungqvist et al. 2009). Volleyball-specific conditions will be discussed below and are summarized in Table 7.1.

The most common injuries in volleyball are acute injuries of fingers and ankles, and overuse injuries of the knee, shoulder, and lower back (Aagaard and Jørgensen 1996). Although less than many other sports, the burden of injury in volleyball is significant, with overuse injuries being more common and resulting in as much athletic impairment as acute traumatic injuries (Aagaard and Jørgensen 1996; Bahr and Reeser 2003; Lian et al. 2005; Verhagen et al. 2004a). In general, however, time loss injuries are relatively rare. Recent research that attempted to capture all medical complaints showed that volleyball has a high prevalence of overuse conditions, frequently resulting in self-management without full withdrawal from participation (Clarsen et al. 2013). For this reason, it is crucial that the musculoskeletal assessment of the PHE captures the athlete’s current health status and is sensitive enough to identify potential injuries that have previously gone unreported. While identification of such conditions during the competitive season may provide the athlete with management techniques that permit them to keep playing, any chronic issues should be addressed during the off-season. This allows for optimal recovery and modification of selected risk factors, with the ultimate aim of limited recurrence.

Prior injury

It has been consistently demonstrated across multiple sports that the greatest predictor of future injury is prior injury of the same body part (Verhagen et al. 2004a). For example, a strong predictor of future ankle sprains in volleyball is having previously sprained the same ankle. However, there is evidence to suggest that full rehabilitation can return the athlete to his/her baseline (pre injury) level of risk (Verhagen et al. 2004b), thereby

<table>
<thead>
<tr>
<th>Body position</th>
<th>Concern</th>
<th>Diagnostic test</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle</td>
<td>Dynamic balance</td>
<td>Modified star excursion balance test</td>
<td>Poor = bilateral difference in anterior direction &gt;4 cm</td>
</tr>
<tr>
<td>Knee</td>
<td>Dynamic knee valgus</td>
<td>Vertical drop jump</td>
<td>Visual assessment of valgus at lowest moment of flexion</td>
</tr>
<tr>
<td>Knee</td>
<td>Ankle dorsiflexion range of motion</td>
<td>Weighted lunge</td>
<td>Poor = dorsiflexion angle &gt;45°</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Scapular malposition and dyskinesis</td>
<td>SICK scapula</td>
<td>Poor = overall score &gt;3</td>
</tr>
<tr>
<td>Lower back</td>
<td>Thoracic mobility</td>
<td>Seated thoracic rotation</td>
<td>Poor = visually evident bilateral differences or &lt;45° from frontal plane</td>
</tr>
</tbody>
</table>
underscoring the importance of taking an accurate medical history which does not omit any details.

Preseason identification of residual effects from past injuries may provide an opportunity for targeted rehabilitation. All previous injuries should be assessed to determine the current state of healing and if any (mal)adaptive/protective responses have manifested themselves (e.g. reduced range of motion). The assessment can include assessments of joint laxity or range of motion, muscular strength, and/or functional ability. The assessment is often conducted with the use of the uninjured limb or joint as a control. This complicates head, neck, and trunk assessments, and bilateral injuries. The use of the contralateral (uninjured) limb as a functional comparison is also confounded when large bilateral differences are expected, such as the shoulder assessment of volleyball players.

**Ankle injuries**

Ankle injuries are the most common acute injury affecting volleyball players, accounting for up to half of all reported volleyball injuries (Aagaard and Jorgensen 1996; Bahr and Bahr 1997; Verhagen et al. 2004a). Interestingly, recurrent ankle sprains have been found to occur more frequently than first-time sprains. The risk of reinjury is particularly high in the initial 12 months following a sprain (Verhagen et al. 2004a). To help reduce the rate of injury recurrence, athletes should be instructed in a program of neuromuscular and proprioceptive rehabilitation following the initial injury (Bahr et al. 1997; Verhagen et al. 2004b). Additionally, it is advised that athletes tape or brace the affected joint for 6–12 months post injury. In order to provide optimal protection, a brace that limits ankle inversion and eversion (without restricting ankle plantar- or dorsiflexion) should be prescribed.

In addition to previous injury, the other common risk factor for ankle injuries is impaired dynamic balance (Plisky et al. 2006). A good functional assessment tool for dynamic functional stability is the modified star excursion balance test (Figure 7.1). The modified version of the original eight-point test reliably assesses balance in three planes (anterior, posteromedial, and posterolateral)

![Figure 7.1](image)

**Figure 7.1** The modified star excursion test permits assessment of dynamic functional balance in multiple planes: (a) anterior; (b) posterolateral; (c) posteromedial.
Periodic health evaluation/preparticipation evaluation

Knee injuries

Volleyball-related knee injuries are frequently divided into two primary categories based upon the mechanism of injury. There are acute traumatic knee injuries and knee injuries caused by overuse. The most common acute knee injury among female volleyball players is a rupture of the anterior cruciate ligament (ACL) (Ferretti et al. 1992; Hootman et al. 2007). Meanwhile, jumper’s knee is the most common volleyball-related knee injury caused by overuse. Jumper’s knee is diagnosed more commonly among male than female volleyball athletes (Lian et al. 2005).

Anterior cruciate ligament injuries have been documented to occur at a rate of 0.09 injuries per 1000 player exposure hours among NCAA female volleyball players. Although incidence is not as high as that recorded in other women’s sports (women’s soccer = 1.3/1000 hours, women’s basketball = 1.15/1000 hours), the burden of ACL injuries is significant, with long-lasting consequences. Research has shown that athletes with higher ground reaction forces and larger valgus angles at the knee when performing a vertical drop jump (VDJ) (Figure 7.2) are at higher risk of ACL injury (Aerts et al. 2013). Although an assessment of ground reaction forces is beyond the scope of a standard PHE, an assessment of dynamic knee alignment is feasible. A VDJ test for the functional assessment of dynamic knee angle is recommended for all female athletes, or at a minimum any athlete with a history of knee injury. The assessment of knee valgus should occur at the lowest moment of the landing phase of the VDJ. The video capabilities of a smartphone or tablet device may be employed to enhance visual inspection (slow-motion replay is particularly useful), and to provide real-time feedback to the athlete. An athlete who has visually obvious valgus collapse during the VDJ assessment should be referred to a physiotherapist to develop knee stability and proper landing techniques.

The most common overuse knee injury diagnosis amongst volleyball players is jumper’s knee. The prevalence of jumper’s knee has been found to be 45% in an elite male volleyball population (Lian et al. 2005). Male volleyball players have been found to have twice the odds of anterior knee pain as females (van der Worp et al. 2011). The causal mechanism is believed to be a repeatedly failed healing process following mechanical overload of the knee joint. For this reason, it is imperative that any prior history of anterior knee pain be identified and the athlete’s response to incremental loading...
be incorporated in any decision regarding return to play, whether it be practice or game participation. Athletes will frequently attempt to self-manage these types of conditions without reducing their training load or volume. The establishment of a pain-free training volume should be targeted prior to any increase in sport participation.

Another modifiable risk factor is ankle dorsiflexion range. It is theorized that athletes with a greater ankle range of motion will use a softer landing technique, therefore reducing the eccentric load on the patellar tendon during the landing phase of a jump (Bisseling et al. 2007, 2008). A measure of ankle dorsiflexion while performing a weight-bearing lunge should be incorporated in the PHE. This test has been found to have high inter- and intrarater reliability (ICC = 0.97). Athletes found to have an ankle angle measure greater than 45° from the horizontal should be considered to have poor range of motion, and therefore provided with an intervention to address the limited range of motion. It is important to ensure that ankle braces that restrict ankle inversion/eversion do so without reducing dorsiflexion. Such braces allow for protection from lateral and medial ankle sprains, while permitting the soft landing techniques that are encouraged for the prevention of overuse knee injuries.

### Shoulder injuries

Shoulder injuries amongst volleyball players are predominantly overuse in nature and have been found to affect up to 32% of British and 24% of American elite volleyball players (Mjaanes and Briner 2005; Wang and Cochrane 2001). As has been measured in other overhead “throwing” sports, such as tennis and baseball, volleyball athletes with overuse shoulder complaints have significant lateralizing range of motion and strength differences. Volleyball athletes playing positions associated with a high frequency of attacking (outside hitters and middle blockers) are at greater risk than setters or liberos. The most common specific diagnosis of shoulder problems amongst volleyball athletes is subacromial or rotator cuff impingement (Seminati and Minetti 2013).

A strong predictor of shoulder injury is the SICK scapula score that assesses various anatomical factors that may be associated with shoulder overuse, including Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition, and dyskinesis of scapular motion. Specifically, a SICK scapula score greater than 3 should be considered poor and those athletes should be considered at high risk for developing future shoulder problems related to overuse. Specific instructions for assessment of the SICK scapula score can be found in Table 7.2 and Figure 7.3. Athletes whose SICK scapula score places them at risk for shoulder overuse should be given rehabilitation exercises to address the specific limitations noted on their current assessment. A reduction in training volume may be required to allow for shoulder adaptation to the prescribed exercises without promoting further overuse.

#### Table 7.2 Derivation of the SICK scapula score.

<table>
<thead>
<tr>
<th>Subjective pain history</th>
<th>Objective pain history</th>
<th>Scapular position</th>
<th>0 cm</th>
<th>1 cm</th>
<th>2 cm</th>
<th>3 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coracoid, Y/N</td>
<td>Coracoid, Y/N</td>
<td>Infera</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>AC joint, Y/N</td>
<td>AC joint, Y/N</td>
<td>Lateral protraction</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Periscapular, Y/N</td>
<td>Superior medial angle, Y/N</td>
<td>Scapular abduction</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Proximal lateral arm, Y/N</td>
<td>Impingement, Y/N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radicular symptoms, Y/N</td>
<td>Scapular assistance test, Y/N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOS symptoms, Y/N</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>


The SICK scapula score is derived from summing responses to questions regarding the existence of subjective symptoms at the areas indicated (1 point for each yes), the existence of tenderness or a positive response to the tests listed in the objective areas (1 point for each yes), and a numerical score based upon the magnitude of the measures of scapular malposition. The maximum score is 20.

AC, acromioclavicular joint; SICK, Scapular malposition, Inferior medial border prominence, Coracoid pain and malposition, and dyskinesis of scapular movement; TOS, thoracic outlet syndrome.
Lower back injuries

According to Seminati and Minetti (2013), roughly 20% of volleyball players have experienced trunk and back pain. Professional athletes have a higher prevalence of low back pain than recreational volleyball players (Seminati and Minetti 2013). The most commonly reported injury is a strain of the muscles of the lower back, a nonspecific diagnosis commonly ascribed to overload of the lumbar musculature. Similar to overuse shoulder injuries, positions associated with a high frequency of attacking (outside hitters and middle blockers) appear to be at greatest risk of developing back pain.

Potentially, the best way to reduce stress in the lumbar spine musculature is through the adjustment of volleyball spiking technique. When attacking and serving, volleyball athletes repeatedly flex, extend, and rotate the lumbar and thoracic spine. Imbalance between these areas may precipitate back discomfort, and thus one recommendation is for athletes to reduce the amount of extension while increasing their thoracic rotational range of motion. Measurement of thoracic rotational range of motion is therefore recommended as part of the volleyball-specific PHE. A simple seated rotation technique can be employed to assess range of motion and bilateral differences with good reliability (Figure 7.4). Visually evident differences between sides or ranges less than 45° from the frontal plane should be considered poor and warrant additional exercises in the attempt to improve thoracic range of motion.

The review of spiking technique in athletes with low back pain is one example of how the PHE provides an opportunity for meaningful review of injuries with the coaching staff and correlation of measurable technical aspects with the athlete’s performance, particularly at the elite level.

Summary

A volleyball-specific PHE should target the musculoskeletal conditions discussed in this chapter (see Table 7.1). It is important to recognize that the assessment methods described in this chapter reflect...
the current body of sport-specific knowledge. As further assessment methods are developed and validated, they should be incorporated, with specific emphasis on tests with strong predictive value.

Finally, it is important to view the PHE not just as a simple screening tool but rather as an opportunity to establish a relationship with the athlete and identify both injury- and performance-related concerns. Ideally, medical care delivered to athletes (including completion of the PHE) should be conducted with a focus on the athlete's long-term health and well-being.

**References**


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**Recommended reading**

Athlete PPE/PHE Form

Available online at: www.olympic.org

Appendix 1

MEDICAL HISTORY

Demographic

Personal Information

Last Name: __________________ First Name: __________________
Address: Street: __________________ City: __________________ Region: ____________
Postal Code: ____________ Country: __________________
Preferred Language: __________________
Birthday: yyyy-mm-dd
Sex (M/F): __________________
Phone: Home: __________________ Mobile: __________________
Emergency Contact 1: Name: __________________ Relationship: __________________ Phone: __________________
Emergency Contact 2: Name: __________________ Relationship: __________________ Phone: __________________
Health Care Insurance (company number): __________________
Family Physician (name, phone number): __________________

Background

The following questions ask for information regarding your personal background

What is your main sport? (sport, event, position)?

Have you participated in other sports in the past (include those sports you have done competitively)? No ☐ Yes ☐

What is your ethnic origin? __________________

Do you have any religious convictions that could affect your medical treatment? No ☐ Yes ☐

When was the last time you had a complete physical examination? __________________

Have you ever failed a pre-participation examination for sports, or has your doctor ever stopped you from participating in sports for any reason? No ☐ Yes ☐

In total, how many days have you missed practice or competition in the past year because of injury or illness? __________________

Heart

Have you ever had any of the following heart or circulation related problems?:

- Chest pain, discomfort, tightness or pressure with exercise? No ☐ Yes ☐
- Unexplained fainting or near fainting or passed out for no reason DURING or AFTER exercise? No ☐ Yes ☐
- Excessive or unexplained shortness of breath, lightheaded, or fatigue with exercise? No ☐ Yes ☐
- Do you get more tired or short of breath more quickly than your friends during exercise? No ☐ Yes ☐
- Does your heart race or skip beats (irregular beats) during exercise? No ☐ Yes ☐
- Heart murmur, high blood pressure, high cholesterol, heart infection or inflammation, rheumatic fever, heart valve problems, or any other heart related problem? No ☐ Yes ☐
- Have you ever had an unexplained seizure? No ☐ Yes ☐
- Any tests for your heart (for example, ECG or EKG, echocardiogram)? No ☐ Yes ☐

Breathing

Have you ever had any of the following respiratory or breathing problems:

- Do you have asthma? No ☐ Yes ☐
- Do you have any other symptoms of respiratory (lung) disease including wheezing, cough, postnasal drip, hay fever, or repeated flu like illness? No ☐ Yes ☐
- Do you cough, wheeze or have more difficulty breathing than you should during or after exercise? No ☐ Yes ☐
- Have you ever used asthma medication (such as an inhaler)? No ☐ Yes ☐
- Have you ever had bronchitis, pneumonia, tuberculosis, cystic fibrosis or other respiratory or other breathing problem? No ☐ Yes ☐

Heat

The following questions are about exercise in the heat:

- Have you ever become ill while exercising in the heat? No ☐ Yes ☐
- Have you ever been diagnosed with heat exhaustion, heat stroke or hyperthermia? No ☐ Yes ☐
- Do you get frequent muscle cramps while exercising? No ☐ Yes ☐
- Have you ever had electrolyte (salt) or fluid imbalance? No ☐ Yes ☐

Medical

Do you have any ongoing medical conditions or illness? No ☐ Yes ☐

Do you have, or have you ever had any symptoms of medical problems such as:

- Infectious mononucleosis (mono), flu like symptoms or viral illness within the past month? No ☐ Yes ☐
- Disease of the ears (infections, hearing loss, pain), nose (sneezing, itchy nose, sinusitis, blocked nose) or throat (sore throat, hoarse voice, swollen glands in the neck)? No ☐ Yes ☐
- Blood disorders such as anemia, low iron stores, sickle cell trait or sickle cell disease, abnormal bleeding or clotting disorder, blood clot (embolus), or other blood disorder? No ☐ Yes ☐
- Immune system including current infections, recurrent infections, HIV/AIDS, leukemia, or are you using any immunosuppressive medication? No ☐ Yes ☐
- Skin problems such as rashes, infections (tungus, herpes, MRSA) or other skin problems? No ☐ Yes ☐
- Kidney or bladder disease, blood in the urine, loin pain, kidney stones, frequent urination, or burning during urination? No ☐ Yes ☐
- Gastrointestinal disease including heartburn, nausea, vomiting, abdominal pain, weight loss or gain (> 5kg), a change in bowel habits, chronic diarrhea, blood in the stools, or past history of liver, pancreatic or gallbladder disease? No ☐ Yes ☐
- Nervous system including past history of stroke or transient ischemic attack (TIA), frequent or severe headaches, dizziness, blackouts, epilepsy, depression, anxiety attacks, muscle weakness, nerve tingling, loss of sensation, muscle cramps, or chronic fatigue? No ☐ Yes ☐
Metabolic or hormonal disease including diabetes mellitus, thyroid gland disorders, or hypoglycemia (low blood sugar)? Yes ❑ No ❑

Infections such as meningitis, hepatitis (jaundice), or chicken pox? Yes ❑ No ❑

Arthritis or joint pain, swelling and redness not related to injury? Yes ❑ No ❑

Were you born without, or are you missing a kidney, an eye or any other organ? Yes ❑ No ❑

An injury to the any internal organs such as your liver, spleen, kidney(s) or lung? Yes ❑ No ❑

Have you ever had surgery? (explain) Yes ❑ No ❑

Do you get motion sickness (car, air or sea sickness)? Yes ❑ No ❑

Do you have any other medical problems? Yes ❑ No ❑

Family

Do any of your family members have a history of any of the following conditions (in male relatives < 55 years, female relatives < 65 years):

- Sudden death for no apparent reason (including drowning, unexplained car accident, or sudden infant death syndrome)? No ❑ Yes ❑
- Unexplained fainting, seizures, or near drowning? No ❑ Yes ❑
- Died before age 50 due to heart disease? No ❑ Yes ❑
- Disability or symptoms from heart disease before age 50? No ❑ Yes ❑
- Other heart problems including electrical problems (arrhythmia) or heart enlargement, cardiomyopathy, heart surgery, pacemaker or defibrillator? No ❑ Yes ❑
- High blood pressure or high blood cholesterol? No ❑ Yes ❑
- Marfan’s Syndrome? No ❑ Yes ❑
- Bleeding disorder, Sickle cell trait or sickle cell disease? No ❑ Yes ❑
- Tuberculosis or Hepatitis? No ❑ Yes ❑
- Anaesthetic reaction or problem? No ❑ Yes ❑
- Other condition such as stroke, diabetes, cancer, arthritis (describe)? No ❑ Yes ❑
- Are you unsure of your family history? No ❑ Yes ❑

Medications

The following questions are about medications and supplements you are taking, or have taken in the past month:

Medications that have been prescribed by a doctor (include insulin, allergy shots or pills, sleeping pills, anti-inflammatory medications etc.)? No ❑ Yes ❑

Non-prescription medications (include pain killers, anti-inflammatories, etc.)? No ❑ Yes ❑

Vitamin or mineral supplements or herbal medicines? No ❑ Yes ❑

Other substance to improve your athletic performance (include substances like creatine, weight gain products, amino acids, etc.)? No ❑ Yes ❑

Have you ever been offered or encouraged to use banned performance enhancing drugs? No ❑ Yes ❑

Allergies

Do you have any allergies to:

- Medication? No ❑ Yes ❑
- Anything else, such as foods, pollens, stinging insects, any plant material or any animal material? No ❑ Yes ❑

Immunization

Indicate which immunizations you have received:

- Tetanus/ Diphtheria (Td or Tdap)? No ❑ Yes ❑
- Measles / Mumps / Rubella (2 shots)? No ❑ Yes ❑
- Chicken Pox (Varicella)? No ❑ Yes ❑
- Meningitis (Meninumone or Menactra)? No ❑ Yes ❑
- Hepatitis A (2 shots)? No ❑ Yes ❑
- Hepatitis B (3 shots)? No ❑ Yes ❑
- Malaria? No ❑ Yes ❑
- Have you had a TB Test (PPD)? No ❑ Yes ❑ Result? ______________

Have you had any other immunizations? No ❑ Yes ❑ Explain: ______________

Female

These questions are for females only:

- Have you ever had a menstrual period? No ❑ Yes ❑
- What was your age at your first menstrual period? ______________
- Do you have regular menstrual cycles? No ❑ Yes ❑
- How many menstrual cycles did you have in the last year? ______________
- When was your most recent menstrual period? ______________
- Have you had a stress fracture in the past? No ❑ Yes ❑
- Have you been identified as having a problem with your bones such as low bone density (osteopenia or osteoporosis)? No ❑ Yes ❑
- Are you presently taking any female hormones (estrogen, progesterone, birth control pills)? No ❑ Yes ❑
- Have you ever had a sexually transmitted disease such as gonorrhea, syphilis, venereal warts, chlamydia or other infection? No ❑ Yes ❑

Male

These questions are for males only:

- Do you have two normal testicles? No ❑ Yes ❑
- Have you ever had a hernia or swelling around the testicle (varicocele, hydrocele)? No ❑ Yes ❑
- Have you ever had an injury to a testicle? No ❑ Yes ❑
- Have you ever had surgery for an undescended testicle, testicular injury or problem? No ❑ Yes ❑
- Have you ever had a sexually transmitted disease such as gonorrhea, syphilis, venereal warts, chlamydia or other infection? No ❑ Yes ❑

Head & Neck

- Have you ever had any of the following problems related to your head or neck?:
- Eye injury, or other problems with your vision? No ❑ Yes ❑
- Headaches with exercise? No ❑ Yes ❑
- Have you ever had numbness, tingling or weakness in your arms and legs or been unable to move your arms or legs after being hit or falling? No ❑ Yes ❑
- Do you have, or have you been x-rayed for, neck (atlantoaxial) instability? No ❑ Yes ❑
- Have you had an injury to your teeth? No ❑ Yes ❑
- Do you have any other decayed, missing or filled teeth? No ❑ Yes ❑
- Do you have a dental prosthesis or appliance? No ❑ Yes ❑
- Have you had your wisdom teeth removed? No ❑ Yes ❑
Chapter 7

Injury
Have you ever had an injury to your face, head, skull or brain (including a concussion, confusion, memory loss or headache from a hit to your head, having your "bell rung" or getting "dinged")? No ☐ Yes ☐

Have you had a problem or an injury like a sprain, strain, muscle or ligament tear, or tendonitis, broken bone, stress fracture or joint injury (that caused you to miss a practice or competition) to any of the following areas of your body?
- Neck or spine (including a "stinger," or "whiplash") No ☐ Yes ☐
- Upper back (thoracic spine) No ☐ Yes ☐
- Lower back (lumbar spine) No ☐ Yes ☐
- Chest and ribs No ☐ Yes ☐
- Shoulder area (including collar bone) No ☐ Yes ☐
- Upper arm No ☐ Yes ☐
- Elbow No ☐ Yes ☐
- Lower arm (forearm) No ☐ Yes ☐
- Wrist No ☐ Yes ☐
- Hand or fingers No ☐ Yes ☐
- Pelvis, groin or hip (including sports hernia) No ☐ Yes ☐
- Thigh (including hamstrings and quadriceps) No ☐ Yes ☐
- Knee No ☐ Yes ☐
- Lower leg (calf or shin) No ☐ Yes ☐
- Ankle No ☐ Yes ☐
- Foot, heel or toes No ☐ Yes ☐

Other Tests - If not already mentioned above, have you had any other tests, for any injury or condition including blood tests, X-rays, MRI, CT scan, Bone scan, Ultrasound, Electroencephalogram (EEG), Electromyogram (EMG), Nerve conduction studies (NCS), Electrocardiogram (ECG/EKG), Echocardiogram (Echo), Exercise stress test or other tests? No ☐ Yes ☐

Treatment - If not already mentioned above, have you ever received any of the following treatments for any condition?
- Surgery? No ☐ Yes ☐
- Been prescribed a brace, sling, cast, walking boot, orthotic, crutches or other appliance? No ☐ Yes ☐
- Cortisone injection? No ☐ Yes ☐
- Been prescribed other rehabilitation or therapy? No ☐ Yes ☐
- Have you ever spent the night in a hospital or been admitted to a hospital as an inpatient or outpatient? No ☐ Yes ☐
- Been referred to a medical specialist (cardiologist, neurologist or other medical person) for any condition not already mentioned? No ☐ Yes ☐

Equipment
- Do you wear eye glasses or contact lenses? No ☐ Yes ☐
- Are you currently using any of the following protective equipment? No ☐ Yes ☐
- Do you use protective eyewear? No ☐ Yes ☐
- Special equipment (pads, braces, etc.)? No ☐ Yes ☐
- Mouth guard for sports? No ☐ Yes ☐

If you wear a helmet for sports, how old is it? No ☐ Yes ☐

Nutrition
The following questions are about nutrition:
- Do you worry about your weight or body composition? No ☐ Yes ☐
- Are you satisfied with your eating pattern? No ☐ Yes ☐
- Are you a vegetarian? No ☐ Yes ☐
- Do you lose weight to meet weight requirements for your sport? No ☐ Yes ☐
- Does your weight affect the way that you feel about yourself? No ☐ Yes ☐
- Do you worry that you have lost control over how much you eat? No ☐ Yes ☐
- Do you make yourself sick when you are uncomfortably full? No ☐ Yes ☐
- Do you ever eat in secret? No ☐ Yes ☐
- Do you currently suffer or have you ever suffered in the past with an eating disorder? No ☐ Yes ☐
- What is your current weight? No ☐ Yes ☐
- How tall are you without shoes? No ☐ Yes ☐

Discuss
Do you have any other concerns that you would like to discuss with a doctor? No ☐ Yes ☐

Explain "YES" answers here:

I hereby state that, to the best of my knowledge, my answers to the above questions are complete and correct.

Signature of athlete: _____________________________

Signature of parents or legal representative (when needed): _____________________________ Date ____________
### PHYSICAL EXAMINATION

Date of Examination: ______________

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<td>Heart rate (after 5 Minutes rest)</td>
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<td>Presence of Worn, Broken or Loose/Mobile teeth:</td>
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<td>Dental appliances (bridge, plate, braces or orthodontic appliance):</td>
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### Musculoskeletal

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<td>Elbow/forearm</td>
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<td>Wrist/hand/fingers</td>
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<tr>
<td>Hip/thigh</td>
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<tr>
<td>Knee</td>
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Chapter 7

Leg/ankle

Foot/toes

Investigations

12 Lead ECG

- Normal / no changes
- Common and training-related ECG changes
- UnCommon training-unrelated ECG changes

Details:

Blood Tests

- Haemoglobin
- Haematocrit
- Erythrocytes
- Thrombocytes
- Leukocytes
- Ferritin
- Sodium
- Potassium
- Creatinine
- Cholesterol (total)
- LDL Cholesterol
- HDL Cholesterol
- Triglycerides
- Glucose
- C-reactive Protein

Other:

Clinical Evaluation Outcome

The athlete does not present apparent clinical contraindications to practice the following sport(s)

1 (specify): No • Yes •

If the answer to question 1 is “No”, it is recommended that the athlete:

- avoids participating:
  - in training (explain) No • Yes •
  - in competition (explain) No • Yes •

- respects the following restrictions:
  - during training (specify) No • Yes •
  - during competition (specify) No • Yes •

- undergoes further examinations (specify):

Examining physician

Name: __________________________ Phone Number: _______________________
Address: ________________________ Email ________________________
Chapter 8
Shoulder injuries in volleyball
Ann M.J. Cools and Jonathan C. Reeser
1 Department of Rehabilitation Sciences and Physiotherapy, Ghent University, Ghent, Belgium
2 Marshfield Clinic Research Foundation, Marshfield, Wisconsin, USA

Introduction

Shoulder injuries due to overuse occur frequently in “overhead” sports such as baseball, tennis, swimming, and volleyball. The shoulder joint is designed for mobility rather than stability, and is therefore susceptible to injury when subjected to the athletic demands of these sports. Volleyball-specific skills such as spiking and serving place a tremendous load on the shoulder girdle. To avoid injury, this load must be absorbed and dissipated by the stabilizing mechanism of the shoulder, which consists of both static stabilizers (including the glenohumeral joint, the glenoid labrum, and the ligamentous shoulder capsule) and dynamic stabilizers (the four muscles of the rotator cuff: the supraspinatus, infraspinatus, teres minor, and subscapularis).

Although differences clearly exist, the kinematics of volleyball spiking and serving resemble those of throwing a ball. These overhead skills subject the dominant shoulder girdle to repetitive stress, which may cause breakdown and injury to the soft tissues. If these stresses are applied at a rate exceeding the rate of tissue repair, such overload can result over time in cumulative damage to the shoulder. Therefore, to better understand the mechanism of overuse shoulder injuries in volleyball athletes, the volleyball medical professional should have a basic familiarity with the kinematics of the volleyball spike and serve.

Like the ball throwing motion, the mechanics of spiking can be divided into three phases: cocking, acceleration, and deceleration/follow-through. The cocking phase may be defined as the period between the preparation for movement and the moment at which the shoulder begins the explosive phase of forward acceleration. This phase has been aptly described as “cocking the hammer.” Initially, the athlete abducts and externally rotates the hitting limb at the shoulder, keeping the elbow flexed. To avoid injury, this load must be absorbed and dissipated by the stabilizing mechanism of the shoulder, which consists of both static stabilizers (including the glenohumeral joint, the glenoid labrum, and the ligamentous shoulder capsule) and dynamic stabilizers (the four muscles of the rotator cuff: the supraspinatus, infraspinatus, teres minor, and subscapularis).

Spikers and jump servers typically combine this movement pattern with truncal rotation and lumbar extension, while “float” servers tend to maintain a more neutral trunk position. The acceleration phase actually begins with lumbar flexion and trunk derotation. The momentum thereby generated is funneled up through the scapula to the shoulder girdle and on to the wrist and hand (the most distal links in the kinetic chain). As the upper limb moves forward, it accelerates through a combination of flexion, adduction, and internal rotation. At the moment of contact with the volleyball, the upper limb is typically abducted to 150–180° (i.e. nearly vertical), slightly flexed (so as to contact the ball out in front of the body), and extended at the elbow (to permit contact with the ball at the highest point possible). This position maximizes
the moment arm of the upper limb, resulting in a faster arm swing and a more powerful spike.

After the ball is contacted, the deceleration phase begins. The primary purpose of the deceleration/follow-through phase is to dissipate the energy accumulated during acceleration, while minimizing stresses about the shoulder. Follow-through occurs via a combination of upper limb adduction and shoulder internal rotation, and is mediated by the eccentric action of the rotator cuff. If not for the dynamic stabilizing action of this group of four muscles, the shoulder joint would anteriorly sublux or dislocate after every spike or jump serve!

Thus, the spiking or overhead serving motion takes the shoulder through a wide active range of motion at high speed. Significant forces are generated in the upper limb, placing the structures of the shoulder girdle at great risk of injury. Furthermore, it has been estimated that the elite volleyball athlete will perform 40,000 spikes in one season of competition (Kugler et al. 1996). Given this volume and load, it should not be too surprising to learn that the most common volleyball-related shoulder injuries are overuse in character.

Most chronic shoulder overuse injuries present clinically with symptoms of impingement (Cools et al. 2008). Impingement occurs when the physical space available to a structure becomes restrictive, as a result of either pathological anatomical change (e.g. tissue swelling) or functional maladaptation (e.g. muscle imbalance). Impingement can therefore be thought of as a final common pathway of adaptive pathology that results from a variety of shoulder conditions, including rotator cuff tendinopathy, shoulder instability, scapular dyskinesia, biceps pathology, SLAP (superior labrum anterior-superior) lesions, and GIRD (glenohumeral internal rotation deficit) (Figure 8.2).
Two principal types of shoulder impingement have been described: internal (or posterior-superior glenoid) impingement and external (or subacromial) impingement. External impingement occurs when the soft tissues in the subacromial space (e.g. bursa, rotator cuff tendons) are mechanically compressed between the humeral head and the acromial arch. This “primary” encroachment tends to occur in the midrange of motion, and often causes a painful arc of motion during active abduction. Internal impingement occurs when the rotator cuff tendons, particularly the tendons of the supraspinatus and infraspinatus muscles, are restricted between the greater tubercle of the humerus and the posterior-superior rim of the glenoid. Internal impingement is a secondary phenomenon that tends to occur during the late cocking phase of spiking or serving. Internal impingement is thought by many to be the primary cause of chronic shoulder pain in the overhead athlete.

It is therefore important for the sports medicine clinician to be able to distinguish between internal and external impingement, both historically and on the physical exam. Understanding that impingement may occur as a feature of any one of several types of a shoulder dysfunction will enable the clinician to diagnose and treat the underlying pain generator with greater accuracy and effectiveness.

### Rotator cuff dysfunction

#### Pathophysiology and biomechanics

The etiology of rotator cuff tendinopathy is multifactorial, and has been attributed to both extrinsic and intrinsic mechanisms (Seitz and Michener 2011). Extrinsic factors that encroach upon the subacromial space (subacromial impingement) or against the postero-superior rim of the glenoid (internal impingement) may include structural factors, such as anatomical variants of the acromion, or functional alterations in scapular or humeral kinematics, postural abnormalities, rotator cuff and scapular muscle performance deficits, and decreased flexibility of the pectoralis minor or the posterior shoulder girdle. Intrinsic factors that can contribute to rotator cuff tendon degradation with tensile/shear overload include alterations in biology, mechanical properties, morphology, and vascularity. Cook and Purdam (2009) described a three-stage continuum of tendon injury...
that includes reactive tendinopathy, tendon disrepair (failed healing), and degenerative tendinopathy.

Clinical scenario and diagnosis

The volleyball athlete with rotator cuff tendinopathy complains of pain with overhead activities. Skills performed at <90° of abduction are usually pain free. On examination, there may be tenderness at the point of humeral insertion of the supraspinatus and/or infraspinatus tendons. Active movement may reveal a painful arc of abduction between approximately 70° and 120°. Symptoms can be reproduced with impingement tests and in the apprehension position, and external rotation against resistance may be painful. The investigation of choice in rotator cuff tendinopathy is MRI. In experienced hands, ultrasonography of the shoulder can also be a useful diagnostic tool.

Therapeutic considerations

Treatment of rotator cuff tendinopathy should be divided into two stages. The first stage involves symptomatic treatment of the tendinopathy. The patient should avoid aggravating activity and apply ice locally. There is no high-level scientific evidence to support prescription of NSAIDs, ultrasound, interferential stimulation, laser, magnetic field therapy or local massage. A corticosteroid injection into the subacromial space may reduce the athlete's symptoms sufficiently to allow commencement of an appropriate rehabilitation program. However, the long-term effects of corticosteroids on rotator cuff tendons are still unknown. In choosing a management plan, clinicians should consider patient preference, availability of practitioners, and other healthcare use. If a patient prefers a more active or self-management approach, manual physical therapy and gentle (isometric) rehabilitation exercises should be prescribed. If the patient prefers a corticosteroid injection, its effectiveness, safety profile, and potential need for additional healthcare should be discussed (Coombes and Vicenzino 2014).

The second phase of treatment consists of active rehabilitation exercises for the rotator cuff. Several kinds of exercises can be prescribed; the selection depends upon the irritability of the tendons, the goal of the program, and the specific sport in which the athlete is involved. Special attention needs to be paid to the external rotators, since weakness of this muscle group is often present as a volleyball-specific (mal)adaptation. In addition, eccentric training of the rotator cuff may be implemented (Holmgren et al. 2012; Maenhout et al. 2013).

Glenohumeral instability

Pathophysiology and biomechanics

Injury to either the static or dynamic stabilizers of the shoulder can result in an unstable shoulder and secondary impingement (Cools et al. 2008). Shoulder instability can be classified based on the frequency (first time versus recurrent), etiology (traumatic versus nontraumatic), direction (anterior versus posterior versus inferior), and severity (subluxation versus dislocation) (Kuhn 2010). Clinically, however, athletes often present with combined patterns of structural as well as functional instability (based on muscle patterning deficiencies). Taking into account the cause, direction, and typical clinical presentation of instability, patients may be divided into three groups.

- TUBS (Traumatic Unidirectional instability with Bankart lesion, for which Surgery is often needed).
- AIOS (Acquired Instability due to Overstress Syndrome).
- AMBRI (Atraumatic Multidirectional instability with Bilateral laxity, in which Rehabilitation is mandatory, but in case of failure Inferior capsular shift surgery is performed).

In volleyball, as in other sports requiring repetitive upper extremity activities, recurrent glenohumeral subluxation can occur even in the absence of discrete trauma. Presumably, the repetitive abduction and external rotation of the upper limb during serving and spiking result in gradual distension of the anterior capsular structures. This capsular laxity permits the humeral head to sublux anteriorly. Players with transient anterior subluxation may complain of severe pain that causes the arm to go “lame” or “dead” when attempting a hard spike, service, or other overhead skill.
Clinical scenario and diagnosis

It is important to determine the injury mechanism, particularly traumatic onset of symptoms. External rotation combined with abduction in the face of anterior laxity promotes anterior subluxation/dislocation. The neurovascular structures traveling through the thoracic outlet are vulnerable to damage with an anterior dislocation. In chronic shoulder pain, the athlete may not be able to recount the inciting mechanism. The athlete’s symptoms should be interpreted in relation to the load on the shoulder (timing in the season, position played, etc.). Recurrent functional shoulder instability and impingement symptoms are often related to fatigue, aberrant sporting biomechanics, or a sudden increase in training or competition volume (Wilk et al. 2009).

During the clinical examination, the clinician should identify both the degree and direction of the instability, and look for concomitant pathologies like rotator cuff tendinopathy or tears, labral pathology such as SLAP lesions, and symptomatic involvement of the biceps brachii muscle (Cools et al. 2008). In addition, the cervical and thoracic spine should be carefully evaluated for any nerve root or structural abnormality, and the kinetic chain should be tested to determine its strength and integrity.

Clinical tests of shoulder instability may be divided into provocative tests and tests of laxity. Commonly used provocative tests for instability are the apprehension and relocation tests (Figure 8.3). If the shoulder is unstable, these tests will provoke responses to the instability, such as apprehension and guarding. Laxity tests assess humeral translation with respect to the glenoid fossa. For anterior laxity, the load and shift test (Figure 8.4) may be used. Inferior laxity will provoke a sulcus sign upon distraction of the upper limb (Figure 8.5), and posterior laxity will result in the posterior subluxation sign (Cools et al. 2008) (Figure 8.6).

Therapeutic considerations

Anterior glenohumeral instability can be treated conservatively or surgically. Conservative treatment is indicated in the early stages of anterior instability in the overhead athlete, after the initial episode of traumatic dislocation, and as a preliminary approach to atraumatic multidirectional instability. The surgical procedure may be open or arthroscopic. Recurrence rates are relatively low, ranging from 2% to 11%. Elite volleyball athletes
The load and shift test is one of several tests that may be used to assess for anterior glenohumeral instability.

The sulcus sign is indicative of inferior glenohumeral instability.

A positive posterior subluxation test suggests posterior glenohumeral instability.
Shoulder injuries in volleyball

requiring shoulder surgery for the treatment of instability may not be able to return to their preinjury level of performance. Return to competition following surgical repair may take 6 months or longer, and athletes who undergo surgery may experience a slight to moderate restriction of external shoulder rotation.

During postsurgical rehabilitation, a step-wise program may first endeavor to reestablish proprioceptive control of the shoulder and rotator cuff, then initiate low load closed chain exercises (e.g. wall slides). The program then progresses to closed chain exercises with increasing load (prone bridging, side bridging), and concludes with a graded functional open chain exercise program, consisting of rotator cuff strengthening, scapular muscle training, and functional exercises. It is important that the athlete's functional progression through their rehabilitation program be based upon individualized goals. A recent qualitative investigation of return to sport after arthroscopic Bankart repair revealed that fear of reinjury, mood, social support, and self-motivation greatly influenced the timing of return to sport (Tjong et al. 2015).

SLAP lesions and biceps-related pathology

Pathophysiology and biomechanics

Pathological disorders of the biceps complex can be divided into three categories:

- inflammatory/degenerative conditions and partial tears of the long head of the biceps
- instability of the biceps tendon in the bicipital groove
- Superior Labrum Anterior to Posterior (SLAP) lesions (Braun 2009).

The three categories of disorders may all present with impingement-related shoulder pain, and although they differ widely in patient populations and pathogenesis, there is significant overlap between the diagnoses.

The glenoid labrum is a cartilaginous rim of tissue that serves to deepen the glenoid, making the glenohumeral joint more stable. The biceps tendon originates from the labrum, and therefore rapid eccentric activation of the biceps can place traction on the labrum, resulting in a tear and an unstable shoulder. Repetitive overhead activity has also been hypothesized to be a common mechanism for producing biceps-related shoulder pathology. Although the pathomechanics are debated, the torsional compressive force on the base of the biceps during the cocking position, as well as the high eccentric activity of the biceps muscle during follow-through phase of throwing and the impingement of the biceps tendon underneath the acromial arch during overhead activities, are believed to contribute to the irritation, dysfunction, and eventual failure of the superior labral and biceps tendon complex (Kibler et al. 2013).

Clinical scenario and diagnosis

Patients with biceps or SLAP lesions complain of pain localized to the posterior or posterior-superior joint line, especially in abduction. Pain in the shoulder is exacerbated by overhead and behind-the-back arm motions. The athlete may also complain of popping, catching or grinding sensations within the shoulder.

On examination, there may be tenderness over the anterior aspect of the shoulder and pain on resisted elbow flexion. Although numerous SLAP tests exist in the literature, no current SLAP lesion test is able to guarantee sufficient diagnostic value to merit being used as a stand-alone test. Consequently, an interpretation of “best-test combinations” is advised in the clinical diagnosis of SLAP lesions. The apprehension, compression rotation, O’Brien (Figure 8.7), speed and biceps load II tests seem to have sufficient sensitivity and/or specificity to be used in a test combination for SLAP diagnosis.

Therapeutic considerations

Recent clinical guidelines suggest that the vast majority of overhead athletes with suspected SLAP lesions and biceps-related shoulder pain should be initially treated nonoperatively (Braun 2009). Only certain diagnoses, such as traumatic injuries with documented structural damage, warrant earlier and
Figure 8.7  The O’Brien test. (a) Shoulder internally rotated. (b) Shoulder in neutral/external rotation. The test is considered to be positive for a SLAP lesion if pain provoked by resisted internal rotation is relieved by externally rotating the upper limb at the shoulder.
Shoulder injuries in volleyball

more aggressive operative intervention. However, only a few studies have examined the results of conservative treatment of SLAP lesions. Edwards et al. (2010) showed that 50% of the conservatively treated athletes returned to play, with a similar rate of return to sports as those who had surgery. Fedoriw et al. (2014) concluded from their case series that nonsurgical treatment correcting scapular dyskinesia and GIRD had a reasonable success rate in professional baseball players with documented SLAP lesions. Arthroscopic repair of SLAP lesions resulted in good to excellent results in patients who were not involved in sports. Unfortunately, the result of surgery in overhead or throwing athletes is much less predictable, with successful return to prior level of play ranging between 20% and 94% (Fedoriw et al. 2014). In particular, the prognosis for full return to sports seems to be rather low for baseball pitchers.

Rehabilitation of biceps-related shoulder pain and SLAP lesions (whether representing conservative management or postoperative rehabilitation) should follow a phased progression of rotator cuff exercises, scapular exercises, and stretching. However, tension on the long head of the biceps should be implemented cautiously and increased gradually, with early protection of the site of the injury. In addition, in postoperative rehabilitation programs after SLAP repair, biceps activity needs to be controlled during the first 12 weeks following surgery, with no resisted biceps activity during the first 8 weeks to protect the healing of the biceps anchor, and no aggressive strengthening of the biceps for 12 weeks following surgery (Wilk et al. 2009).

Recently, a progressive program consisting of selected rotator cuff and scapular exercises with low to moderate loads on the biceps (based on surface EMG activity) was proposed, giving the clinician the opportunity to select the appropriate exercises based on the goal and the desired load on the biceps (Cools et al. 2014a). In the advanced stages of rehabilitation, higher loads are needed to strengthen the biceps brachii in order to prepare the athlete to return to sport. This is achieved by performing eccentric exercises in throwers (Figure 8.8) or pull-up exercises in gymnasts or pole jumpers.

**Scapular dyskinesis**

**Pathophysiology and biomechanics**

Full upper limb elevation requires coupled movement of the scapula and the clavicle in a 2:1 ratio. The scapula must also rotate upwards, tilt posteriorly, and rotate internally or externally in order to provide adequate clearance for the greater tuberosity of the humerus as it moves beneath the

Figure 8.8 This prone catching exercise is a plyometric exercise designed to train the rotator cuff.
coracoacromial arch, thus avoiding potential impingement. Scapular control also enhances joint stability at greater than 90° of abduction by placing the glenoid fossa under the humeral head, where stability is assisted by the action of the deltoid muscle. In view of the limited ligamentous constraints between the scapula and the thoracic wall, the scapulothoracic muscles play the most important role in dynamic scapular stability.

Scapular dyskinesis, defined as abnormal scapular positioning and/or movement, is thought to play a role in the pathophysiology of shoulder pain, although the causal relationship remains the subject of some debate (Struyf et al. 2014). Scapular dyskinesis has been found to be related to shoulder instability, impingement, and stiff shoulders, and is identified as a primary risk factor for shoulder injury in rugby and handball players (Clarsen et al. 2014; Kawasaki et al. 2014). In particular, shoulder pain seems to be associated with insufficient upward rotation and posterior tilting of the scapula (Ludewig and Reynolds 2009), as well as strength and activation deficits of the lower trapezius and serratus anterior (Cools et al. 2014b). Other findings that may contribute to abnormal scapular control include weakness of the upper trapezius and tightness or stiffness of the pectoralis minor and levator scapulae (Cools et al. 2014b).

**Clinical scenario and diagnosis**

It is incorrect to state that scapular behavior should be symmetrical in overhead athletes. Scapular asymmetry has been well documented in volleyball players at rest (Oyama et al. 2008; Ribeiro and Pascoal 2013). Asymmetry should not automatically be seen as a pathological sign, but rather an adaptation to the demands of overhead sports and extensive use of the upper limb. Tests of scapular involvement can be used to determine if the observed scapular malpositioning or scapular asymmetry is associated with shoulder symptoms. The scapular assistance test (SAT; Figure 8.9) examines whether shoulder pain is correlated to a lack of smooth scapular upward rotation and posterior tilting, whereas the scapular retraction test (SRT; Figure 8.10) explores a lack of scapular stability into retraction during resistance tests of the shoulder (Cools et al. 2008). Scapular upward rotation may be objectively measured using an inclinometer and strength using a hand-held dynamometer.

**Therapeutic considerations**

Once deficits and imbalances in scapular behavior are assessed, a rehabilitation program to restore symmetry of scapular muscle performance should follow. The main goals are (a) to restore flexibility of the soft tissues surrounding the scapula, in

![Figure 8.9](image-url) The scapular assistance test. Relief of pain produced by an unassisted scapula suggests scapular involvement.
particular the pectoralis minor, levator scapulae, and rhomboid muscles, and (b) to improve periscapular muscle performance, focusing on either muscle control and inter- and intramuscular coordination or muscle strength and balance.

In the early stage of scapular training, conscious muscle control of the scapular muscles may be necessary to improve proprioception and to normalize scapular resting posture. In the intermediate phase of scapular rehabilitation, exercises may be selected based on the specific deficits and demands of the patient (Cools et al. 2014a). Specific exercises are described for activation of the serratus anterior, lower and middle trapezius, and upper trapezius. In particular, in case of combined flexibility deficits, exercises should be selected based not only on high activity in the targeted muscle group, but also on low activity in the underactive muscles. In the third stage of scapular rehabilitation, the treatment goal is to exercise advanced scapular muscle control and strength during sport-specific movements, and special attention is given to integrating the kinetic chain into the exercise program. In order to prepare for return to play, emphasis is placed on plyometric and eccentric exercises. By the conclusion of treatment, scapular control should be automatic and integrated into all sport-specific exercises.

**Loss of glenohumeral internal rotation range of motion**

**Pathophysiology and biomechanics**

Glenohumeral Internal Rotation Deficit, often referred to as GIRD, is a sport-specific adaptation of the posterior shoulder structures to chronic overload. Several theories have been advanced to explain the development of GIRD, ranging from adaptive contracture with shortening of the posterior capsule to bony response to repetitive excessive torsion resulting in bone remodeling. A third hypothesis regarding the cause of GIRD is hypertonus of the external rotators due to excessive eccentric loading. GIRD may cause aberrant glenohumeral kinematics and thus result in impingement symptoms.

**Clinical scenario and diagnosis**

The assessment of GIRD is performed by measuring glenohumeral internal rotation range of motion, preferably in supine position with the shoulder abducted 90° and the scapula stabilized against the table (Figure 8.11). A side-to-side difference of 20° is considered diagnostic for GIRD. However, in view of a possible
shift in rotational range of motion due to bony adaptations, GIRD may be associated with a gain in external rotation ROM. It is important to measure internal as well as external shoulder rotation, permitting calculation of the total range of motion (TROM).

**Therapeutic considerations**

The clinical impact of GIRD on shoulder kinematics and the risk of injury appears to be sport specific. For example, a deficit of glenohumeral internal rotation of 18–25° has been demonstrated to be a risk factor for shoulder injury in baseball players (Shanley et al. 2011; Wilk et al. 2011). However, in volleyball athletes a statistically significant side to side difference in glenohumeral internal rotation does not correlate with the risk of shoulder pain. Both the cross-body stretch (Figure 8.12a) and the sleeper stretch (Figure 8.12b) can be recommended to decrease posterior shoulder tightness. It has been shown that a 6-week daily sleeper stretch program (3 reps of 30 seconds) is able to significantly increase the acromiohumeral distance in the dominant shoulder of healthy overhead athletes with GIRD (Maenhout et al. 2013). Tyler et al. (2010) showed symptom relief after a stretching program in a population of overhead athletes with impingement-related shoulder pain.

**Suprascapular neuropathy (aka infraspinatus syndrome or volleyball shoulder)**

Volleyball shoulder is a condition uniquely common in volleyball athletes. It is defined as a frequently painless atrophy of the infraspinatus muscle caused by suprascapular neuropathy (Reeser et al. 2013) (Figure 8.13). This syndrome, which occurs relatively rarely in athletes participating in other overhead sports, has been estimated to occur in 12.5–45% of high-level volleyball players (Ferretti et al. 1998).

There are two potential anatomical sites where the suprascapular nerve (SSN) may become compromised: the suprascapular notch and the spinoglenoid notch (Figure 8.14). Entrapment at the suprascapular notch results in palsy of the common trunk of the nerve with marked atrophy of both the supraspinatus and infraspinatus muscles and weakness of shoulder abduction and external rotation. Proximal entrapment of the suprascapular nerve theoretically may result in greater discomfort than would more distal involvement of the nerve at the spinoglenoid notch, since beyond the spinoglenoid notch the nerve is a pure motor nerve. Spinoglenoid entrapment causes a focal...
Shoulder injuries in volleyball

Palsy of the terminal branch of the SSN, resulting in isolated infraspinatus atrophy and loss of strength in external rotation. Isokinetic testing has revealed that individuals with suprascapular neuropathy are on average 22% weaker in the affected arm during external rotation when compared with the unaffected limb. Despite this difference, these elite athletes often fail to notice significant deterioration in their sport performance.

The diagnosis of suprascapular neuropathy requires a high index of suspicion. On examination, there will be noticeable atrophy of the infraspinatus (and possibly the supraspinatus) on the dominant side, although the overlying bulk of the trapezius may obscure the muscle wasting if it is mild. The affected shoulder will be weaker in external rotation. The athlete may be tender to palpation at the site of impingement, and cross-body

**Figure 8.12** The cross-body stretch (a) and the sleeper stretch (b) both address posterior shoulder tightness that is characteristic of GIRD.
adduction of the upper limbs may be somewhat provocative of pain. The diagnosis may be confirmed by electromyography, which will demonstrate injury potentials in the affected muscle(s). MRI is warranted (particularly in elite athletes) to rule out compressive lesions such as ganglia, which, if present, might prompt consideration of early surgical decompression. Note that bilateral supraspapular neuropathy has been reported.

Most commonly, there is no identifiable etiology for the onset of supraspapular neuropathy. However, it has been speculated that the unique kinematics of volleyball-specific skills may result in SSN compromise in anatomically predisposed individuals. In particular, spiking and serving result in greater shoulder abduction and horizontal adduction at the end of the cocking phase when compared to other overhead sport-specific skills such as pitching a baseball or serving a tennis ball (Reeser et al. 2013).

Supraspapular neuropathy usually represents a benign condition, producing minimal disability in the short term. It should be noted, however, that the long-term consequences of supraspapular neuropathy are not entirely clear. The infraspinatus muscle also functions as a major depressor of the humeral head, acting in concert with the other muscles of the rotator cuff to dynamically stabilize the glenohumeral joint. Loss of infraspinatus function creates a potential imbalance in the force couple formed by the deltoid and rotator cuff. Such an imbalance might lead, over time, to a secondary impingement syndrome. For this reason, the volleyball medical professional should be careful to thoroughly assess complaints of shoulder pain by an athlete with known infraspinatus deficiency, and encourage concentric and eccentric external rotator strength training, even in the absence of symptoms.

Although surgical treatment is rarely indicated in volleyball players with infraspinatus atrophy, several surgical procedures have been developed to release the nerve at the supraspapular notch or at the spinoglenoid notch. Athletes who continue to have pain despite conservative treatment may benefit from surgical release of the nerve at the site of entrapment. Despite clinical improvement in pain and strength, recovery of infraspinatus atrophy is seldom observed after surgery.

Integration of the functional kinetic chain in shoulder stabilization exercises

It is important to involve the kinetic chain early in the shoulder rehabilitation process. While the shoulder is recovering from the injury or surgery,
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Leg and trunk exercises can be prescribed so that when the shoulder is ready for rehabilitation, the base of the kinetic chain is also ready for linked activity and functional movement patterns.

The kinetic chain in which the athlete functions is highly sport specific, and needs to be reconsidered for every athlete. In ground-based sports, like baseball, tennis or cricket, all the activities of the shoulder work within a kinetic chain linkage from the ground through to the trunk, mostly in a diagonal pattern. These athletes benefit from diagonal patterns in a closed chain for the lower extremities, e.g. shifting body weight to the contralateral leg during the exercise or performing movements in unilateral stance on the contralateral leg. In addition, research has shown that performing shoulder exercises (rowing) standing on the contralateral leg enhances scapular muscle activity (Figure 8.15). Volleyball players load their shoulders most during spiking, when their feet are off the ground. They should train the spiking and decelerating capacity of their shoulders with minimal input from the ground (for instance on an unstable surface, such as a wobble board). It is important to correct any inflexibilities of the hamstrings, hip, and trunk; weakness or imbalances of the rotators of the trunk, flexors, and extensors of the trunk and hip; and any subclinical adaptations of stance or gait patterns.

**Summary**

Shoulder impingement is a frequent cause of pain and dysfunction related to overuse in the volleyball athlete. Careful examination of the individual with complaints of pain during overhead sport may provide diagnostic clues suggesting the etiology of the impingement (internal or external), and appropriate therapeutic interventions.

**References**


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**Recommended reading**


Chapter 9
Knee and ankle injuries in volleyball

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Introduction

This chapter discusses two particularly troublesome lower limb conditions that cause volleyball athletes, in general, a great deal of inconvenience and discomfort and which, on occasion, can truncate a player’s career. The first of these is jumper’s knee, a condition also known as patellar tendinopathy, patellar tendinosis, and, in the past, patellar tendonitis/tendinitis. The term jumper’s knee is used here because it is well entrenched in volleyball circles and aptly describes the mechanism of injury. Note that clinicians generally use the term “patellar tendinopathy” to refer to this condition, as athletes who participate in sports that are not particularly jump intensive can also suffer from the condition (e.g., soccer players, sprinters, skiers). Jumper’s knee is the most common overuse injury among volleyball players, with a prevalence of nearly 45% (Lian et al. 2005).

This chapter also considers ankle sprains – the single most common acute injury suffered by volleyball players. Volleyball-related ankle sprains result most commonly from landing on the foot of an opponent or teammate during the act of blocking. Ankle sprains account for as many as one half of all acute injuries in indoor volleyball at the national league level, with an incidence of about one sprain per 1000 hours of activity (Bahr and Bahr 1997; Bahr et al. 1994) and about one in four injuries at the international level (Bere et al. 2015).

Both ankle sprains and patellar tendinopathy are less common among beach volleyball athletes than their indoor counterparts. The softness of the sand reduces the load on the patellar tendon during jumping and landing and the fact that there are only two players per team reduces the risk of contact-related ankle sprains. Nevertheless, ankle sprains and patellar tendinopathy account for a significant proportion of injuries in beach volleyball as well. Taken together, these observations should provide ample incentive for physicians and physiotherapists involved in the care of volleyball players to learn how to effectively diagnose and treat both jumper’s knee and ankle sprain injuries.

Jumper’s knee

Clinical scenario

An Olympic volleyball player reports to the team physician with complaints of infrapatellar pain that is aggravated by jumping. The athlete’s pain tends to occur after particularly arduous on-court training, or after activities such as weight training or plyometric jump training. Symptoms improve with rest. The player has previously experienced similar problems. The first instance occurred when...
he was in adolescence and he often notices the pain at the start of a new season. He localizes his pain to the inferior pole of the patella.

**Clinical approach to anterior knee pain**

There are numerous possible causes of pain in the scenario outlined. Box 9.1 lists the more common causes of anterior knee pain. In most instances, however, the volleyball medical professional must distinguish between jumper’s knee and patellofemoral syndrome, as these are by far the most frequent causes of anterior knee pain in this population. In general, distinguishing one from the other is not too difficult if you look for a few key features (Table 9.1). When examining for tendinopathy, the clinician should look for the following three characteristics: localized tendon pain brought on from loading, focal tenderness to palpation, and resultant impaired function (Rio et al. 2014). Even so, the clinical features of these two conditions can overlap, potentially creating some diagnostic confusion. Furthermore, jumper’s knee and patellofemoral syndrome can in rare instances present simultaneously as a result of an underlying biomechanical abnormality or because of excessive training.

**Box 9.1 Common causes of anterior knee pain.**

<table>
<thead>
<tr>
<th>Patellofemoral syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumper’s knee</td>
</tr>
<tr>
<td>Recurrent patellar subluxation</td>
</tr>
<tr>
<td>Osgood–Schlatter disease (younger athlete)</td>
</tr>
<tr>
<td>Fat pad impingement</td>
</tr>
</tbody>
</table>

**Table 9.1 Comparison of the clinical features of two common causes of anterior knee pain. Note that these conditions may co-exist.**

<table>
<thead>
<tr>
<th>Signs</th>
<th>Patellofemoral syndrome</th>
<th>Patellar tendinopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset</td>
<td>Running (especially downhill), steps/stairs, hills, any weight-bearing sport requiring repeated knee flexion/extension (e.g. distance running)</td>
<td>Activities involving jumping and landing (e.g. basketball, volleyball, high jump, netball, bounding, ballet)</td>
</tr>
<tr>
<td>Pain</td>
<td>Vague/nonspecific, may be medial, lateral or infrapatellar</td>
<td>Usually around inferior pole of patella, aggravated by jumping and mid to full squat</td>
</tr>
<tr>
<td>Tenderness</td>
<td>Usually medial or lateral facets of patella but may be tender in infrapatellar region. May have no pain on palpation due to areas of patella being inaccessible</td>
<td>Most commonly inferior pole of patellar tendon attachment</td>
</tr>
</tbody>
</table>

Occasionally in midthenon, rarely at distal attachment to tibial tuberosity.
Extrinsic risk factors identified for jumper’s knee in volleyball players include training load (hours of volleyball training per week) and match exposure (the number of sets played per week). Other factors likely include the playing surface as well as changes or spikes in the acute training load compared to the chronic training load over the preceding weeks. Information on intrinsic risk factors also continues to evolve. Clinically important intrinsic risk factors are likely to exist, since only one in two players develop symptoms of jumper’s knee despite identical extrinsic risk factors. Studies on the dynamic performance of volleyball players suggest that those with a natural ability to jump higher are at a greater risk for developing patellar tendinopathy (Lian et al. 1996a; Visnes et al. 2013). Additional risk factors include decreased ankle dorsiflexion mobility and possible influence from landing mechanics. The right knee is affected more often than the left knee among volleyball players. One reason may be the dynamic biomechanical factors acting upon the leg extensor apparatus during a spike jump with a right-left take-off, since this may be expected to cause higher eccentric-concentric loading of the right knee compared with the left.

**Diagnostic considerations**

Reproducing the patient’s anterior knee pain during clinical assessment is critical to establishing an accurate diagnosis. A double- or single-leg squat will usually provoke the athlete’s typical symptoms. If symptoms are not reproduced on level ground, a series of double- or single-leg squats can also be performed on a decline board to further stress the tendon. Reproducing the athlete’s symptoms is essential both for diagnostic purposes and to provide a baseline in order to determine the effectiveness of treatment. If the athlete is pain free at the time of the examination, he/she should be reexamined after completing a symptom-provoking training session, e.g. with intensive jump training.

The clinician should palpate the anterior knee carefully to determine the site of maximal tenderness. If the athlete has jumper’s knee, tenderness is most often located along the proximal patellar tendon near the inferior pole of the patella (Figure 9.1). To assist with exposing the tendon near the inferior pole of the patella, pressure can be placed with one hand to the superior aspect of the patella to help “tilt” and expose the inferior portion of the patella while the tip of one finger from the other hand palpates the proximal patellar tendon. Palpation should also be conducted along the midportion of the patellar tendon as well as near the tibial insertion.

While jumper’s knee typically refers to pain in the patellar tendon, it is important to note that occasionally volleyball players will present with “jumper’s knee”-like symptoms in their quadriceps tendon proximal to their patella. Palpation of the quadriceps tendon and history from the player will confirm this.

Kinetic chain and biomechanical examination should always be conducted as well to examine the joints proximal and distal to the knee that may have significant deficits leading to increased risk for jumper’s knee symptoms. Specifically, ankle and hip mobility should be cleared and then tested.

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*Figure 9.1 Patellar tendinopathy; typical location of pathology in the posterior aspect of the tendon.*
for strength and stability throughout their respective available range of motions. A passive examination of mobility can be initially performed, but should be repeated in weight bearing and ultimately examined through jumping and landing tasks to see how the individual athlete actually completes the skills required in training.

Radiographic imaging is generally not required to confirm the suspected clinical diagnosis of jumper’s knee. However, real-time ultrasound can be a useful tool. Ultrasound is excellent for detecting structural abnormalities such as tendon thickening and hypoechoic areas within the tendon. In addition to traditional gray-scale used to examine tendon structure, color Doppler settings are often used to detect neovascularization within or near the tendon. However, it must be noted that structural abnormalities such as hypoechoic areas and neovascularization are often observed in about 10% of asymptomatic tendons. This stresses the importance for the clinician to marry the clinical history and presentation of the patient to that which is observed on ultrasound (Cook et al. 1998; Kongsgaard et al. 2009; Lian et al. 1996b) (Figure 9.2).

**Treatment of patellar tendinopathy**

Once an accurate diagnosis has been made, appropriate treatment can begin. Studies on the outcome of treatment for jumper’s knee indicate that some unfortunate players can suffer from prolonged symptoms, ranging from several months to years (Lian et al. 2005) and may require more than 6 months of treatment before they can return to sporting activities (Cook et al. 1997; Schiavone-Panni et al. 2000). Education to manage the athlete’s expectations can play a critical role in building the foundation needed to begin this journey. To tackle this challenging problem, practitioners usually combine treatments that include self-care, medical management and an exercise prescription. If multiple bouts of conservative treatment fail and the athlete has been unable to return to sport, then surgical intervention may be considered. Unfortunately, surgical intervention for jumper’s knee is unpredictable (Coleman et al. 2000) and the only randomized controlled trial available on open surgery showed no better outcome compared with conservative treatment (Bahr et al. 2006).

Volleyball players must recognize that jumper’s knee is potentially a very serious condition requiring

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**Figure 9.2** Ultrasound evaluation of the athlete with symptoms of patellar tendinopathy may show the presence of hypoechogenicity (a), while MR imaging can reveal high signal abnormality (b).
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a long period of rehabilitation. Thus, players should not defer seeking appropriate medical attention. There is evidence to suggest that early diagnosis and treatment of patellar tendinopathy helps to minimize the need for time off from volleyball. Early diagnosis provides an opportunity to make early adjustments to training load and number of jumps, while beginning the appropriate treatment to address the underlying condition.

Ice massage may provide some pain relief. Ice can be applied over the affected tendon several times a day for up to 15 minutes per session.

The issue of whether a player should be treated with nonsteroidal antiinflammatory medication (available without prescription in many countries) is somewhat controversial. Historically, the most common pharmaceutical agents used to treat patellar tendinopathy have been nonsteroidal antiinflammatory drugs (NSAIDs) and corticosteroids. Although jumper's knee was originally considered to be an inflammatory disorder (hence the term “tendinitis”), it is now believed to represent a degenerative condition. Thus, there is no biological basis for using antiinflammatory drugs (Jozsa and Kannus 1997; Khan et al. 1999). Nevertheless, these drugs remain the most commonly used symptomatic therapy, but it should be noted that no effect can be expected on healing patellar tendinopathy (Almekinders and Temple 1998). In fact, by masking pain, NSAIDs are often used to be able to continue playing, making matters worse in the long term. It would be reasonable to summarize current medical practice by saying that NSAIDs play a less than prominent role in the management of tendinopathy, particularly in chronic cases (Khan et al. 2002).

For similar reasons that oral antiinflammatory medications appear to be inappropriate in the treatment of tendinopathy, the role of corticosteroids also remains controversial (Fredberg 1997; Shrier et al. 1996). Positive short-term clinical effects following corticosteroid injections have been reported but these effects diminish after 12 weeks and end with poor long-term clinical outcomes. Other injection techniques, such as of high-volume saline (including local anesthetics and often also aprotinine or corticosteroids) or sclerosing agents (such as polidocanol), at the interface between the deep surface of the patellar tendon and Hoffa body have been shown to provide some pain relief in the short term (Hoksrud and Bahr 2011).

A prescription of therapeutic exercise with the goal of decreasing pain and improving load tolerance of the patellar tendon is the treatment of choice for athletes with patellar tendinopathy. Two exercise programs have been studied, which both provide promising results. An exercise program emphasizing eccentric loading of the knee extensors is the treatment most studied and well documented. This eccentric exercise program often focuses on a series of single-leg squats (Figure 9.3a) consisting of three sets of 15 repetitions performed twice daily on a decline board and with progressive loading (Visnes and Bahr 2007).

The second exercise program is one laid out by Kongsgaard et al. that uses heavy slow resistance (HSR) exercises (Figure 9.3b,c,d). Many clinicians are moving away from daily decline squat exercises towards this HSR exercise program which consists of a series of squats, hack squats and leg presses performed three times weekly. It seems easier to motivate players to perform what they perceive as “real” strength training three times weekly rather than the rather monotonous, low-intensity decline squat program two times daily. Each exercise is performed for 3–4 sets and with gradual increases in load from 15 repetition maximum in week 1 and progressing up to 6 repetition maximum by weeks 9–12. Athletes are instructed to take 2–3 minutes of rest between sets and perform each repetition slowly with 3 s for the eccentric phase and 3 s for the concentric phase of the exercise. Use of the HSR program has yielded good short- and long-term clinical outcomes.

Some athletes with very irritable patellar tendons may not tolerate either of these programs. They may respond best to a program focusing on isometric exercises designed to help manage pain. Combined with appropriate load management, including reduction in training drills that require jumping and landing, athletes perform a midrange quadriceps exercise of 5 repetitions of 45 s isometric holds. These can be done on a leg extension machine or with an exercise called a Spanish squat and can be performed 2–3 times per day. A four-step program that includes isometric exercise for
pain management initially and progresses to a modified HSR program before preparing an athlete for return to sport has been described by Malliaras et al. (2015).

With all the exercises outlined above, it is worth noting that it is permissible for the athlete to perform the exercises with some pain. Possibly the more important criterion is to test for pain and see how they feel 24 hours after performing the exercises. This could be done with a single-leg decline squat or with any other activity that reproduces symptoms. An increase in pain from doing the exercise is permissible as long as their pain does not continue to increase day by day. In fact, the expectation is that after a few weeks of training, pain will subside, first when not training and eventually also during training.

As the athlete progresses, the exercise prescription can be made more challenging and functional by increasing the load and speed of the exercises. Endurance can subsequently be introduced once the athlete can perform these exercises well. Thereafter, combinations of load (weight), speed, and/or height (e.g. jumping exercises) can be added (Cook et al. 2000). These end-stage eccentric exercises can provoke tendon pain and are recommended only if the athlete's sport demands intense loading (and then only after the athlete

Figure 9.3 Exercises used to treat jumper’s knee. (a) Eccentric decline squats, (b) leg press, (c) squat, and (d) hack squat. All exercises should be conducted to a 90° knee angle. Note that the exercises used in the Kongsgaard program (bc,d) are performed bilaterally, while eccentric decline squats (a) should be performed on one leg at a time. Source: Kongsgaard et al. (2009). Reproduced with permission of John Wiley & Sons.
has completed a sufficiently long rehabilitation period). Eccentric training programs and HSR programs, performed under close supervision and adjusted as needed, have been shown in clinical trials to be effective in improving or even eliminating symptoms associated with jumper’s knee. Jump training and evaluation of landing mechanics are also essential components of a comprehensive rehabilitation program. Ice may be used to cool the tendon after exercise training to minimize postexercise pain.

Of course, conservative treatment is not uniformly successful. There are numerous potential reasons why an eccentric strength training program might fail to produce the desired clinical outcome, including excessively rapid progression through the rehabilitation program, inappropriate loading (e.g., insufficient strength or speed work, eccentric work started too early or too aggressively, insufficient single-leg work), excessive reliance on passive treatments (such as electrotherapeutic modalities), insufficient focus on kinetic chain and biomechanical deficits and inadequate monitoring of the patient’s symptoms both during and after therapy.

Surgical intervention for jumper’s knee is generally reserved for symptomatic volleyball players who have not improved after at least 6 months of conservative management. A variety of surgical techniques have been described but the outcome of surgery remains rather unpredictable. In addition to the traditional open technique, where access is through the anterior tendon, new techniques for arthroscopic surgery have been developed, where access to the patellar tendon is from its posterior aspect and where arthroscopic shaving and ultrasound (plus Doppler) examination are performed simultaneously. Using this technique, the tendon and the areas with structural tendon changes and high blood flow can be demonstrated in the operating field. In this way, the shaving procedure can be more exactly addressed to the area of interest on the dorsal surface of the tendon and trauma to the Hoffa fat pad and the anterior healthy part of the tendon is minimized. However, there are few randomized controlled studies to guide treatment choice.

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### Ankle Injuries

#### Clinical scenario

A volleyball player reports to the team physician or therapist after suffering a sprained ankle. The sprain occurred when she landed on the opposing attacker’s foot after a block. She experienced immediate pain in the lateral aspect of the ankle and noticed local swelling beginning only a few minutes later. Fortunately, she had been given immediate first aid, including application of an ice bag and local compression to minimize swelling. At the time of the physician visit, the player was limping noticeably, reluctant to bear full weight on the affected limb. This was her third lateral ankle sprain involving the same ankle.

#### Clinical approach to ankle sprain injuries

When a volleyball player presents after suffering an ankle sprain, the practitioner must first determine which structures have been injured and to what extent. In most cases, a lateral ankle sprain injures one or more of the lateral ankle ligaments, but other structures may also be involved (Table 9.2). The most important objective is to distinguish between ligament injuries and fractures. Fractures are rare among adolescents and young adults, but fractures of the lateral malleolus and fifth metatarsal do occur relatively frequently among older recreational athletes. Since they may require early surgery, it is important to rule out injuries to the syndesmosis, often referred to as a “high ankle sprain,” as well as growth plate injuries in children. Syndesmotic injuries result in damage to the ligaments between the tibia and fibula. A careful history should be taken, since the mechanism of injury is an important clue to establishing an accurate diagnosis. A precise examination will reveal whether it is necessary to submit the patient to a radiographic examination to rule out a possible fracture. If a fracture is suspected, x-rays should be obtained without delay. Surgery for an acute fracture, if necessary, should be performed within 6 hours (before the onset of significant swelling).
Injury situation

The typical scenario that leads to an ankle sprain in volleyball is when a player who is blocking lands on the foot of an opposing attacker underneath the net. This can happen when the attacker is forced to play a ball tight to the net because of a bad set. Alternatively, the attacker may have simply chosen a poor trajectory to play the ball and as a consequence lands partially into the opponent’s court (while still remaining partially over the centerline.) Another common scenario leading to ankle sprains is when one blocker, typically the middle blocker, is late to close the block with a teammate. The middle will drift laterally and land late into a densely populated area of the court that has been termed “the conflict zone.” Ankle sprains have also been observed when a backrow attacker lands on a front row teammate.

Pathophysiology

Video analysis of ankle sprains sustained during the Olympic Games volleyball competition, FIVB World Championships and FIVB World League has revealed that the majority of ankle sprains sustained within the conflict zone share a common mechanism of injury. As the soon to be injured player begins to land from his/her jump, the soon to be injured foot is plantarflexed and preparing to land on the firm, even and predictable court surface. The player continues his/her descent towards the court as the ankle dorsiflexes towards a neutral, flat foot position. Suddenly, however, the foot has a surprise encounter with another player’s foot and everything changes. As the foot nears this flat foot position, the ankle rapidly inverts as a result of the moment created by the unexpected contact with another player. This inversion moment occurs too quickly for the dynamic musculotendinous ankle stabilizers to compensate and at court contact the load is transmitted to the ligaments that statically stabilize the lateral ankle. As the foot inverts, the overloaded ligaments fail in predictable order. The forces and the tensile strength of the ligaments involved determine both the extent and degree of ligament injury. In about half the cases, there is an isolated tear of the anterior talofibular ligament, while in about 25% there is a combined rupture of the anterior talofibular and calcaneofibular ligaments. Concomitant rupture of the posterior talofibular ligament is rare (1%).

In the unusual event of an eversion mechanism (resulting from the combination of foot pronation and external rotation), injury to the strong medial (deltoid) ligament must be suspected. Medial ankle sprains comprise only 10–15% of volleyball ankle sprains. Thus, if the injury mechanism is atypical, the volleyball medical professional should maintain heightened suspicion for injuries other than the typical lateral ligament injury complex.

Diagnostic considerations

The goal of the initial physical examination is to decide whether the patient has a lateral ligament injury as opposed to a different type of injury that
may require surgery or immobilization. According to the Ottawa ankle rules (Figure 9.4), ankle x-rays are indicated only if there is bony tenderness to palpation or if the athlete is unable to bear weight both immediately following the injury and at the time of the subsequent clinical assessment (Leddy et al. 1998). These guidelines, followed correctly, detect all clinically significant fractures with 100% sensitivity.

Figure 9.4  According to the Ottawa rules, the following four structures should be palpated to reveal bony tenderness: the lateral malleolus, medial malleolus, base of fifth metatarsal, and navicular bone.

Injury to the tibia-fibular syndesmosis can be diagnosed by a number of specific tests (Figure 9.5). The “squeeze test” is performed by compressing the fibula against the tibia about halfway between the knee and ankle. If the syndesmosis is injured, this maneuver will produce local pain in the area of the syndesmosis. The “external rotation test,” performed by externally rotating the foot with the ankle in neutral, is also considered positive if the athlete complains of pain in the region of the syndesmosis. These tests are reasonably specific, i.e. they usually do not cause significant pain if only the lateral ankle ligaments have been injured. A positive test necessitates radiographic evaluation to rule out injury to the syndesmosis.

Medical personnel may have learned that the anterior drawer and talar tilt tests can be used to clinically evaluate whether an ankle is mechanically unstable after a significant lateral ligament injury. From a theoretical anatomic and biomechanical perspective, the anterior drawer test should be positive if the anterior talofibular ligament is torn, while the talar tilt test should be positive if the calcaneofibular ligament is also ruptured. However, these tests have limited diagnostic value in the acute phase of injury, since they do not enable the clinician to distinguish between total and partial ligament ruptures, or between isolated and combined lateral ligament injuries. Furthermore, the treatment of ankle sprains is not dependent on the degree of ankle instability demonstrated on stress radiographic views. Therefore, the talar tilt and anterior drawer tests and stress x-rays have no clinical relevance in the evaluation of acute ankle sprain injuries.

If signs indicate that a fracture may be present according to the Ottawa ankle rules, a routine x-ray investigation is indicated (images obtained should include anteroposterior (AP), lateral and mortise views). Also, the same radiographic investigation is indicated if the physical examination has raised suspicion of a syndesmosis injury. Other imaging studies are usually not indicated in the acute phase.

**Treating ankle sprains**

Conservative management of lateral ligament injuries is recommended, even if there is evidence of a combined injury to the anterior talofibular and calcaneofibular ligaments. Nonoperative, function-based treatments have been shown to result in outcomes rivaling the outcome of surgical repair and/or casting, regardless of degree of lateral ligament injury (Kaikkonen et al. 1996). Functional treatment provides the quickest recovery of full range of motion and return to physical activity, does not compromise mechanical stability any more than other treatments and is safer and less
expensive than surgical intervention. The goals of a functional treatment program are to:
1. minimize the extent and consequences of the initial injury, including swelling and pain;
2. restore range of motion, muscle strength and proprioception;
3. graduate the athlete to a sport-specific exercise program prior to return to competition.

The goal of the on-site treatment of acute ankle sprains is to minimize bleeding and swelling. This may be accomplished by providing immediate Protection, Rest, Ice, Compression and Elevation (PRICE treatment; Figure 9.6). Of these early interventions, compression is probably the most important (so as to limit bleeding), while the main effect of cold therapy is to provide analgesia. The term “relative rest” is often used which encourages early, gentle, pain-free mobility to help with the healing process while activities that cause pain or stress to the area are avoided. If PRICE treatment is initiated immediately following the sprain injury and provided continuously for the first 24–48 hours, it is possible to significantly limit the amount of bleeding or swelling following a ligament injury.

Analgesics can be used to provide pain relief, but acetylsalicylic acid (aspirin) can prolong bleeding and should therefore be avoided. Nonaspirin pain relievers and over-the-counter NSAIDs are reasonable alternatives and may also accelerate recovery by permitting earlier active range of motion and weight bearing.

After the initial bleeding phase is over, the goal of treatment is to regain normal, pain-free range of motion. Increased range of motion can be achieved through passive, active or active-assisted stretching exercises and by submaximal exercise, including use of a cycle ergometer. The exercise program should progress (according to the improvement in function and degree of symptoms) from progressive linear movements, e.g. toe-raises, squats, jogging, jumping in place on two legs, then one leg, skip-rope jumping, to cutting movements, e.g. running figure of 8’s,

Figure 9.5 The squeeze test (a) and external rotation test (b) to detect injury to the anterior tibiofibular ligament (“high sprain”).
Do not bear weight on the ankle – no walking or testing. A quick examination to determine that there is lateral injury is all that is needed at this stage. Mix the contents of an ice bag by crushing the inner bag and shaking the bag carefully.

Place the ice bag with the center over the tip of the lateral malleolus. Fasten the proximal end of the ice bag with an elastic wrapping.

Fasten the distal end of the ice bag – continue fastening the ice bag with the elastic wrapping to apply firm compression using the ice bag as a compression tool.

Place the patient with the ankle elevated as much as possible and the cold/compression bandage on for at least 30 minutes.

Avoid weight bearing when the patient needs to be moved – provide crutches if possible. Keep the cold/compression bandage on during transportation even after the cold effect has subsided.

A more complete examination can be done after the initial 30-minute PRICE treatment has been completed. Continued compression bandage treatment is continued for the first 48 hours using an elastic wrapping with a felt or paper filling around the malleolus to provide maximum pressure on the injured ligaments.

Cold treatment provides effective pain relief and intermittent cold treatment can be given for 20–30 minutes every 2–3 hours. Cold treatment can be given by simply using cold, running water or dedicated cold therapy equipment as shown here.

Figure 9.6 Initial management of acute ankle sprains.
sideways jumping, sideways hurdle jumps. The goal of these exercises is to gradually progress towards sport-specific exercises.

During the rehabilitation period, it is important to protect the ankle from new or recurrent injury by taping or bracing. Tape or a semi-rigid brace should be worn during both daily and sporting activities which pose an increased risk of reinjury (e.g., walking over uneven terrain). The athlete should protect the injured ankle with an orthosis until a proprioceptive training program has been completed.

Reestablishing neuromuscular control of the injured ankle through a program of balance exercises is an important goal in the successful rehabilitation of an ankle sprains. Proprioceptive function is impaired in patients with residual functional instability after previous sprains (Konradsen and Ravn 1991) and can be improved by a variety of balance exercises such as through the use of balance boards (Gauffin et al. 1988). Such programs can reduce the risk of reinjury to the level of a previously uninjured ankle (Tropp et al. 1985). A program of proprioceptive training is described in detail in Chapter 6. Proprioceptive training should be carried out for 6–10 weeks after an acute injury.

“Problem ankles” – persistent pain or instability

While most patients with a lateral ligament injury seem to do well following functional treatment, some athletes will develop residual symptoms and persistent complaints. The prevalence of chronic ankle problems following sprain injury has ranged between 18% and 78% in different studies (Karlsson and Lansinger 1993; Shrier 1995). It is therefore important to instruct athletes during the acute phase of rehabilitation to follow up with their physician if they have persistent problems after completing a program of functional rehabilitation.

Patients with residual complaints can be broadly classified into two groups: those complaining of pain, stiffness and residual swelling and those with recurrent sprains and episodes of ankle instability. The cause of pain, stiffness and residual swelling is often chondral or osteochondral injury of the ankle joint. Such lesions are more common after high-energy injuries, such as when landing after a maximal jump, and may therefore be expected to occur more often in volleyball players than in some other sports. Focal uptake on a bone scan may indicate that there is an osteochondral injury. A CT or MRI scan can be used to differentiate between subchondral fractures and chondral fractures with or without separation and/or displacement. Patients with persistent symptoms and chondral injuries should be referred to an orthopedic surgeon. Pain may also result from impingement of scar tissue, particularly in the anterolateral corner of the ankle joint.

Ankle instability may be described as either mechanical or functional in etiology. Mechanical instability can occur after complete ligament tears if the scar tissue is lengthened and provides inadequate mechanical support, while functional instability results from inadequate sensorimotor control of the ankle joint. Some patients can suffer from both mechanical instability and loss of sensorimotor control. Subtalar instability may also result from ankle sprains and the sinus tarsi pain syndrome may occur as a sequela of a lateral ankle sprain injury.

The anterior drawer and talar tilt tests are useful to assess the mechanical stability of the ankle joint in such chronic cases and stress x-rays are used by some clinicians to quantify and document the degree of instability. However, the large variability in talar tilt values in both injured and noninjured ankles precludes the routine use of these diagnostic tests. A simple functional balance test may be used to estimate sensorimotor control, although the predictive value of the test has not been properly documented. The patient is instructed to stand on one leg for 1 minute with arms held across the chest, eyes fixed forward and the opposite leg straight down. The test is said to be normal if the patient can complete 1 minute on one leg and during at least 45 s of this time avoid having to adjust balance other than at the ankle (i.e. using the knees, hips or shoulders to keep balance). The test result is supranormal if the patient can complete an additional 15 seconds with their eyes closed.
Patients with persistent instability symptoms should complete at least 10 weeks of intensive proprioceptive training as studies examining myriad interventions have found neuromuscular training to be the most effective intervention for chronic ankle instability at the present time. The affected ankle should also be taped or braced to prevent reinjury during this period. Figure 9.7 shows a theoretical relationship between neuromuscular training and external support in an attempt to provide optimal ankle stability and future ankle sprain prevention. If instability episodes persist even after an adequate sensorimotor training program has been completed, the patient should be referred to an orthopedic surgeon for further evaluation and management.

References


Recommended reading


Chapter 10
Other injuries in volleyball

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Introduction

As discussed in previous chapters, the most commonly occurring volleyball-related injuries are acute ankle sprains and overuse injuries of the knee extensor mechanism. However, the volleyball athlete is also at risk for developing a host of other injuries and painful conditions, such as low back pain. Trauma to the thumb and fingers is quite common, as are direct injuries of the hip girdle and indirect injuries of the limb muscles. It is also important to note the increasing incidence of concussion in volleyball.

Stress fractures

Stress fractures are overuse injuries of bone and, like most overuse injuries, are typically multifactorial in etiology (Bennell 1999). Thus, if a volleyball athlete has been diagnosed with a stress fracture (or if a stress injury is suspected), it is important to try to determine what factors precipitated or contributed to the injury. Details of the athlete’s training history should be noted, in terms of both volume and intensity. Intensive, prolonged muscular activity may itself result in bone strain and overload. Muscle fatigue, perhaps due to poor conditioning or as the result of overtraining, can attenuate the shock-absorbing capacity of the muscular system and thereby result in greater ground reactive forces transmitted to the lower limb. Structural malalignments (e.g. leg length discrepancies) or biomechanical inefficiencies (e.g. excessive subtalar pronation) can result in increased loads on the tibia, eventually precipitating a stress injury. Poor bone health, perhaps due to hormonal or dietary causes as seen in the relative energy deficiency in sport (RED-S) syndrome, can weaken bone and make it more susceptible to injury. These and other intrinsic and extrinsic risk factors for the development of stress fractures are summarized in Table 10.1.

The most salient historical feature in the diagnosis of stress injury is the insidious onset of activity-related pain. Early on, the pain is typically mild and occurs towards the end of the inciting activity. Subsequently, the pain may worsen and occur earlier during sporting activity, limiting participation. While rest may transiently relieve symptoms in the early stages, as the stress injury progresses the athlete’s pain may persist even after cessation of the activity. Night pain is a frequent complaint, but this is a nonspecific symptom as it may be associated with osteoid osteoma (among other diagnoses).

Stress fractures of the lower limb are among the most frequently encountered stress injuries among volleyball athletes (Ha et al. 1991). In addition, volleyball players appear to be at increased risk for developing stress fractures of the pars interarticularis...
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of the vertebral bodies of the lower lumbar spine (Soler and Calderon 2000). This condition is known as spondylolysis. Spondylolysis typically affects a single level of the lumbar spine, most commonly the fourth or fifth lumbar vertebral body (L5 > L4). Spondylolysis, which usually affects the pars bilaterally, is most commonly seen among athletes who participate in sports demanding repetitive lumbar hyperextension, truncal rotation, or axial loading, all of which describe the kinematics of spiking and jump serving (Figure 10.1). Once considered to be a congenital variation in spinal anatomy, the current thinking is that in most cases spondylolysis is an acquired condition. However, genetic predisposition undoubtedly plays a role in its development. Studies suggest that the prevalence of spondylolysis among athletes at risk for developing the condition (including beach volleyball players, track and field athletes, gymnasts, and weight lifters) ranges anywhere from 1.5 to 8 times the 3–7% rate found among the general population (Soler and Calderon 2000).

Although the individual with spondylolysis may be asymptomatic, more likely he/she may complain of mechanical low back pain. Males and females appear to be equally affected, although females are more likely than males to have associated spondylolisthesis. The incidence of pars fractures among Caucasians is greater than in African Americans, perhaps reflecting the generally higher bone density among African Americans (Bennell et al. 1999; Soler and Calderon 2000).

The symptomatic individual with a pars fracture will typically complain of localized axial (nonradicular) low back pain. On physical examination, the individual will withdraw upon palpation or percussion of the affected area. Inspection may reveal localized swelling and possibly erythema. A thorough assessment of the athlete’s flexibility, lower limb alignment (including leg lengths), foot structure (cavus versus flat feet), and motor function (evaluating for strength imbalances) should be performed. The pain associated with an acute pars fracture may be provoked by lumbar extension, particularly while bearing weight on the ipsilateral lower limb. Hamstring inflexibility is a common finding among individuals with spondylolysis.

The clinical diagnosis of stress fracture may be confirmed radiographically. Plain films are often unrevealing but if present, the fracture line is best visualized on oblique views. Incomplete or recently

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<thead>
<tr>
<th>Table 10.1</th>
<th>Risk factors for stress fracture.</th>
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<tr>
<td><strong>Intrinsic risk factors</strong></td>
<td><strong>Extrinsic risk factors</strong></td>
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<tr>
<td>Low bone mineral density</td>
<td>Excess volume or intensity of training</td>
</tr>
<tr>
<td>Lower limb malalignment</td>
<td>Change in training surface (density or topography)</td>
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<td>Muscle fatigue or weakness</td>
<td>Worn-out training shoes</td>
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<td>Genetic predisposition</td>
<td>Cigarette smoking</td>
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<td>Musculoskeletal irregularities</td>
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<td>Inadequate nutrition (calories or calcium)</td>
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<tr>
<td>Relative energy deficiency in sport syndrome</td>
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![Figure 10.1](image-url) The mechanical loading of repetitive jump serving and spiking places the volleyball athlete at risk for developing stress fractures of the lumbar spine, a condition known as spondylolysis. Source: FIVB Photo Gallery. Used with permission of FIVB.
completed stress fractures of the pars may be detected on bone scan imaging (Anderson et al. 2000). Single photon emission computed tomographic (SPECT) views are considered the most sensitive imaging modality (Figure 10.2a,b). Magnetic resonance imaging (MRI) is also an excellent diagnostic imaging procedure (Bergman and Fredericson 1999) which permits concurrent evaluation of the lumbar intervertebral disks as well as other potential pain generators in the spine (Figure 10.2c).

The recommended treatment for acute spondylolysis has evolved considerably over the years but remains somewhat controversial. As with other stress fractures, the central tenet in such cases is relative rest with appropriate activity modification. Although some clinicians recommend bracing to minimize extension and resultant shear forces across the affected spinal segment, the prevailing opinion appears to be that bracing is only necessary for those individuals who remain symptomatic despite limiting their activity or who require a physical/tactile reminder to avoid provocative activities. Once the individual’s symptoms subside, they should begin a rehabilitation program of flexibility training and dynamic lumbar spinal stabilization exercises. The program should emphasize pain-free functional progression, and once the athlete can perform sport-specific skills without symptoms, they may return to training and competition.

Radiographically documented pars interarticularis defects that are “cold” on bone scan probably represent remote injuries and have little chance of bony union. If symptomatic, these individuals can be treated with antiinflammatories or other analgesics and should be instructed in a program of ongoing home exercises designed to strengthen the muscles that dynamically stabilize the lumbar spine. Note that the goal of treatment in such situations is alleviation of symptoms, rather than achieving bony union.

Injuries to muscle

Muscle injuries are among the most prevalent injuries in sports (Kibler 1990). Contusions, defined as direct trauma to skin and the underlying soft tissues, are quite common among volleyball players. Defensive play in particular is associated with contusion injuries, as the defender may “dive” onto the playing surface in an effort to prevent the volleyball from contacting the flooring or ground (Figure 10.3). Contusions that prevent the athlete from playing without pain should be treated acutely with relative rest and ice massage within the first 48 hours. In the immediate postinjury phase, compression and elevation may limit hemorrhage and bruising of the affected area. After the first 2 days, warm compresses may provide symptomatic relief and facilitate restoration of tissue flexibility and range of motion. Early range of motion should be encouraged, and as soon as the athlete’s pain is diminished, he/she may begin (or resume) strengthening the affected muscle group(s) (Herring 1990). Deep bruises may precipitate heterotopic ossification (HO) of muscle, and this diagnosis should be considered if the athlete experiences a delayed increase in pain with associated warmth, swelling, and localized erythema over the contusion site. Whereas plain radiography may not detect HO until the onset of calcification, ultrasound and MRI are more sensitive and may permit earlier detection of HO.

Indirect injuries to muscle may result in functional or structural deficits. Structural injuries (tears) typically result from forcible stretching of eccentrically activated muscle. Long muscles with a parallel or fusiform architecture, and those that cross two joints (such as the hamstrings and rectus femoris), are most vulnerable to indirect injury. Fatigued muscles are also less resistant to eccentric overload (Mair et al. 1996). Perhaps not surprisingly, muscles with a greater percentage of fast-twitch (type II) fibers are more susceptible to indirect injury than are slow-twitch (type I) fiber-predominant muscles.

Following a distraction injury, the affected muscle is weaker (and thus at increased risk of further injury) (Garrett 1996). Shortly after the injury, an inflammatory response occurs at the site of tissue damage, characteristically at the myotendinous junction. The inflammatory response subsides and the muscle regains the majority of its force-producing capacity within 7–10 days following the injury. However, the muscle’s tensile strength
Figure 10.2 Radiographic features of spondylolysis. A three-phase bone scan with SPECT imaging (a,b) is considered the “gold standard” in detecting areas of stress reaction. However, MRI (c) is increasingly useful in detecting areas of bone edema due to stress injury (arrow) in addition to demonstrating other anatomical details of the athlete’s spine. These studies document a case of acute unilateral spondylolysis involving the pars interarticularis of the fifth lumbar vertebral body.
recovers more slowly, apparently in concert with the repair of muscular architecture. The initial treatment of indirect structural muscle injuries consists of protection, relative rest, ice, compression, and elevation. Acute-phase interventions include early range of motion and isometric exercises, before rehabilitating the athlete through a functional continuum. An adequate warm-up period has been shown to reduce the incidence of indirect injuries, possibly by enhancing muscular extensibility (Garrett 1996).

Two examples of exercise-related indirect muscle injuries are delayed onset muscle soreness (DOMS) and medial tibial stress syndrome. DOMS is a self-limiting condition characterized by delayed-onset soft tissue pain and stiffness. Precipitated by (predominantly) eccentric exercise of uncommon duration or intensity, DOMS has been shown to result in temporary disruption of the myofibrillar architecture of skeletal muscle cells. Symptoms of DOMS will generally spontaneously resolve within 7–10 days without specific intervention.

Medial tibial stress syndrome (also commonly referred to as “shin splints”) is a painful overuse condition involving the deep calf musculature (the soleus and tibialis posterior muscles at their origin on the medial aspect of the tibia). Exercise-related symptoms localize to the posteromedial border of the tibia at the junction of the middle and distal third. Bone scintigraphy is a sensitive means of ruling out stress fracture from the differential diagnosis. The cornerstone of treatment is relative rest followed by gradual, controlled resumption of athletic activity.

The role of antiinflammatory medications in the treatment of contusions and indirect structural injuries is somewhat controversial. Although these medications are used liberally by most healthcare professionals and indeed are generally available for purchase without a physician’s prescription, there is evidence to suggest that their use may interfere with the inflammatory response that is essential to the normal tissue repair process (Almekinders 1999). The antiplatelet effect of many nonsteroidal antiinflammatory drugs (NSAIDs) may also increase the amount of bleeding associated with the injury, possibly increasing the risk of developing HO. Thus, a prudent approach would be to limit the use
of NSAIDs following muscular injury, particularly during the first 48–72 hours. Acetaminophen (Tylenol) or other nonaspirin pain relievers may be used during the early stages of treatment to control pain and permit the athlete to better participate in range of motion and other therapeutic rehabilitative exercises.

**Injuries to the upper limb**

It has been estimated that the hand is moving at a speed of 20 m/s at the moment of contact with the volleyball when spiking. Furthermore, at the elite level, a spiked volleyball can travel at speeds approaching 150 km/h. Trauma to digits of the upper extremity can therefore occur while spiking or more commonly while blocking (Figure 10.4) (Bhairo et al. 1992). Blocking is a skill generally performed with the digits spread and fully extended. This renders the digits, particularly the thumb and small finger, vulnerable to sprains or other ligamentous disruption involving the metacarpophalangeal and/or interphalangeal joints. Most injuries to the digits do not result in significant time lost from training or competition. Many elite volleyball players attempt to prevent acute ligamentous injury to the digits by reinforcing the interphalangeal joints with adhesive athletic tape. Fractures and dislocations of the phalanges can also occur but with less frequency. A defender who successfully “digs” or passes a hard-driven ball must absorb the impact either with the forearm or the hands. In the latter instance, the hands are typically extended and radially deviated at the wrist as the volleyball is received, and then quickly flexed and ulnarly deviated as the defender reflects the ball toward a teammate. The maneuver resembles a “set” but is referred to as an “open-handed dig” in this defensive situation.

Performed repetitively, either in defense or when setting, this motion can lead to overload of the carpal bones, triangular fibrocartilage, and ligamentous structures of the wrist. Fatigue (stress) fractures of the carpal bones have been reported among volleyball players (Israeli et al. 1982), as have neurapraxic injuries of the ulnar nerve in the region of the hypothenar eminence. Appropriate orthopedic intervention typically results in favorable clinical outcomes.

There is evidence in the literature to suggest that volleyball players are at risk for overuse-related circulatory disturbances as well as peripheral nerve entrapment syndromes of the upper limb (van de Pol et al. 2012). Elevated vascular perfusion pressures over the proximal interphalangeal joints of volleyball players have been measured when compared with healthy nonvolleyball-playing control subjects. The clinical significance of this finding is unclear (McDougall et al. 1998). Noninvasive ultrasound screening of the forearm vasculature of professional volleyball players has revealed evidence of predominantly asymptomatic aneurysms of the ulnar palmar arteries as well as lesions of the digital palmar...
arteries on the dominant side in approximately one-third of athletes examined (Rosi et al. 1992).

Traumatic aneurysmal dilation of the posterior circumflex humeral artery (PCHA) as it passes through the quadrilateral space in the upper limb has also been documented among volleyball athletes. This can result in recurrent embolization to the distal arm and hand with repeated spiking or serving (Reekers et al. 1993). In one study, nearly 40% of the volleyball players enrolled reported experiencing cool, cyanotic fingers on their hitting hand (van de Pol et al. 2012.)

In addition to the PCHA, the axillary nerve also passes through the quadrilateral space, within which either the nerve or the artery may potentially be compressed when the athlete abducts and externally rotates the ipsilateral upper limb at the shoulder (Figure 10.5). Axillary neuropathy appears to be far less common among volleyball athletes than suprascapular neuropathy (Paladini et al. 1996). The athlete with axillary neuropathy may complain of vague shoulder girdle pain in addition to positional numbness over the deltoid muscle. The athlete may also demonstrate mild weakness of abduction of the upper limb at the shoulder (deltoid) and/or weakness of external rotation (teres minor). Injury to the long thoracic nerve on the dominant side (Distefano 1989) has been described. This nerve supplies the serratus anterior muscle, one of the principal scapular stabilizers. Injury to the long thoracic nerve therefore may result in scapular dysfunction and predispose the athlete to impingement syndrome and shoulder pain.

**Concussions in volleyball**

Once dismissed as essentially irrelevant to noncontact sports, concussions are being diagnosed with increasing frequency among female collegiate volleyball players. Whether the increased incidence is the result of growing awareness of the diagnosis (also referred to as mild traumatic brain injury), or if concussive head injuries are becoming more common is not clear. Data collected by the National Collegiate Athletic Association through their Injury Surveillance System indicate that concussions occur most frequently in matches as opposed to practice (roughly four concussions per 10,000 match exposures, compared to one concussion per 10,000 practice exposures). The most common mechanism of injury involves a libero hitting her head on the playing surface while attempting to make a defensive play. Approximately 90% of concussed collegians were restricted from playing for 3 or more days following their injury. It has also been observed that athletes who have sustained a concussion are at increased risk of developing a musculoskeletal injury to the lower limb within the 90-day postinjury period, presumably due to impaired neuromotor control. Clearly, ongoing study is required.

**Overtraining syndrome**

There is compelling evidence to indicate that optimal strength and fitness are protective of both acute and overuse injuries in sport. Strength and fitness also typically correlate positively with improved athletic performance. Consequently, strength training and conditioning programs have become essential to the development of elite athletes. However, training volumes below an optimal level do not generate sufficient stimulus to promote the desired physiological adaptation. Thus, coaches and the athletes themselves often push harder in an effort to run faster, jump higher, and become stronger.

Unfortunately, when athletes push (or are pushed) too hard, their risk of overuse injuries and acute overload injuries may increase. Training programs can therefore result in the desired positive effect of improved performance, but may also have potential negative effects. Over time, athletes who train excessively may develop sequelae of the overtraining syndrome (Box 10.1). This syndrome, which has been described in both endurance- and strength-trained athletes, is characterized by a constellation of symptoms and signs including deteriorating performance, loss of motivation, fatigue, myalgias, sleep and mood disturbance, and immunological deficits (Kentta and Hassmen 1998).
Figure 10.5  (a) Angiographic appearance of the posterior circumflex humeral artery (PCHA) in a young volleyball player who reported shoulder pain when spiking or serving. With the arm at rest by the athlete’s side, the vessel appears unremarkable (a). When the upper limb is abduced at the shoulder, however, the PCHA becomes occluded within the quadrilateral space (arrow) (b). The quadrilateral space (aka the quadrangular space) is defined by its borders, which include the teres minor, teres major, humerus, and long head of the triceps. (c) The athlete underwent a surgical procedure to relieve the position-dependent compression of the PCHA.
Other injuries in volleyball

Other terms used to describe overtraining include athlete “staleness” or “burnout” but overtraining per se should not be confused with the more transient effects of acute “overreaching.” Generally, an athlete who fails to recover from a workout within 72 hours should be considered to have overreached. If symptoms persist despite appropriate modifications in the training program, the athlete may have overtrained. Biochemical, hormonal, and physiological markers of the overtraining syndrome have been described, and the interested reader is referred to the references at the end of the chapter for additional information.

What is clear is that the beneficial effects of training are maximized when the athlete is given sufficient time to recover. What is less clear, and often becomes apparent only in retrospect, is the appropriate balance between training and recovery for an individual athlete. Individual variation in exercise capacity, ability to recover, and tolerance for both physical and psychosocial stressors probably accounts for the varying degree of “staleness” experienced by athletes participating in identical training programs. Sports medicine professionals should maintain a reasonable degree of clinical suspicion for the overtraining syndrome, particularly in athletes who suffer multiple or recurrent injuries or who develop diffuse somatic complaints.

Treating the overtraining syndrome effectively depends on accurate identification of the different physical and psychological stressors involved and intervening appropriately. Most often, the critical areas of intervention are nutrition and hydration, sleep, psychosocial status, and a sufficient quantity of low-volume/low-intensity activity (“active rest”) to restore an appropriate athletic balance between training stress and recovery.

Prevention of overtraining begins with individualized, structured (periodized) training programs which incorporate varied activities and which adjust training loads in anticipation of concurrent nonathletic stressors, including travel or academic demands, which might push the athlete beyond their unique threshold for successful adaptation to stress.

Illnesses

Although the emphasis of this chapter has been on musculoskeletal conditions affecting volleyball players, athletes are also at risk for other ailments. Viral upper respiratory illnesses occur commonly and may easily be transmitted among team members, particularly if they share living quarters. Gastrointestinal complaints are not uncommon, especially while traveling. Although competitive athletes at the collegiate and international levels are generally in good health, sports medicine practitioners should be aware of the potential impact of sports participation on chronic conditions. This is particularly relevant for the older competitive athlete with underlying medical conditions who may be at risk for exacerbating those conditions through intensive physical exertion. For example, there is one case report of a recreational volleyball player who suffered a heart attack after being struck directly in the chest by a spiked ball (Grossfeld et al. 1993). The authors speculate that the impact caused an acute thrombus to form at an atheromatous plaque in one of his coronary arteries, precipitating the myocardial infarction. Thus, medical personnel who care for volleyball athletes but who may not have training to provide specialty medical care should be prepared to triage nonmusculoskeletal conditions to an appropriate healthcare provider who can attend to these individuals acutely and ultimately assist their return to health and to sports participation.

Box 10.1 Selected clinical features of the overtraining syndrome.

| Deteriorating performance |
| Fatigue                     |
| Headaches                  |
| Impaired concentration     |
| Lack of motivation; depressed mood |
| Loss of appetite           |
| Menstrual dysfunction      |
| Myalgias                   |
| Sleep disturbance          |
| Susceptibility to colds and viral illnesses |
References


Recommended reading

Chapter 11

Principles of rehabilitation

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²Marshfield Clinic Research Foundation, Marshfield, Wisconsin, USA

Introduction

Injuries are an unavoidable consequence of sporting participation, and can result in considerable pain, dysfunction, and time lost from the sport. Injuries may be classified as acute, suggesting a single defined mechanism that occurs suddenly, or as overuse, which suggests repeated subclinical tissue irritation leading to mechanical adaptation throughout the entire kinetic chain. While an acute injury typically results in a defined tissue injury, overuse injuries typically result in a spectrum of musculoskeletal changes including both protective adaptations and maladaptions to the soft tissues involved. Both acute and overuse injuries require comprehensive treatment in order to reduce symptoms, minimize recovery time, shorten time away from sport, and reduce the risk of repeated injury.

The goal of rehabilitation is the restoration of optimal function. Optimal treatment consists of making an accurate diagnosis, identifying the mechanism of injury, and designing and continuously updating a rehabilitation program. In order to obtain optimal outcomes, medical providers require a detailed understanding of the symptomatic, anatomical, and functional consequences of the specific injury. They should also identify the athlete’s modifiable intrinsic and extrinsic risk factors for injury. Advanced imaging should be used if it can help direct the treatment plan.

The tissue injury cycle

The tissue injury cycle, as described by Kibler et al. (1998), provides a means of understanding the factors involved in overuse injury, and also describes the possible sequela of an untreated (or inadequately treated) acute injury (Figure 11.1). The injured athlete may present with a variety of complaints, including pain (either with activity, at rest, or both), swelling, erythema, bruising, stiffness, or simply an inability to perform at their usual level. Collectively, these observations may be referred to as the injured athlete’s “clinical symptom complex.” This constellation of signs and symptoms results from underlying tissue damage. The anatomical changes can be referred to as the “tissue injury complex.” As a direct result of the injury or as a consequence of the abnormal movement patterns that result from the injury, other tissues and structures may be placed under increased physiological demand and/or anatomical stress. These affected structures may be collectively referred to as the “tissue overload complex.”

In practice, the underlying overload results in changes in the athlete’s technique and biomechanics,
collectively referred to as the “functional biomechanical complex.”

Subconsciously, the athlete may substitute new or altered mechanics in an attempt to compensate for a decrement in performance or to avoid further pain/dysfunction. Unfortunately, the change in mechanics can lead to additional tissue overload, injury, symptoms, biomechanical deficits, and further maladaptions. As seen in Figure 11.1, these “subclinical adaptations” are a result of the injury, but also feed forward, resulting in further dysfunction.

To reduce the risk of progressing toward a self-perpetuating vicious cycle, a comprehensive rehabilitation program should emphasize restoration of balanced strength, flexibility, and neuromuscular control (proprioception), in addition to proper technique and endurance. Attempting to return to play before all components of the injury paradigm have been addressed could promote progression of the cycle instead of breaking the cycle. Return to competitive sport should only happen once the athlete has returned to symptom-free performance and has addressed the modifiable risk factors that may have originally contributed to the injury.

**Phases of recovery**

Although not all injuries should necessarily be treated in the same way, there is some general consistency in the healing process. Treatment of and recovery from an injury can be divided into three successive phases: the acute phase, the recovery phase, and the functional phase. During each phase, there are associated goals and directives depending on the physiological steps of healing (Table 11.1). Using this structured approach facilitates recovery, but also helps communicate appropriate goal setting for both the athlete and coach. This helps to keep the athlete motivated during a physically and psychologically challenging time, while helping to keep the athlete’s and coach’s expectations for recovery realistic.

During the acute phase, possibly even before the diagnosis is made and full extent of injury is understood, the athlete’s clinical symptoms are addressed. The initial treatment of most injuries, whether acute or overuse in nature, usually focuses on management of pain and swelling, restoration of range of motion, and prevention of secondary
complications. Common interventions include analgesic medications, thermal modalities (ice and, in appropriate circumstances, heat), and protection and relative rest of the injured body part. Relative rest permits the injured tissues to begin healing while minimizing the deleterious effects of inactivity on the athlete as a whole by potentially reducing joint loss of motion, deconditioning, and disuse atrophy. Invasive treatment options such as aspiration and/or injection may help to accelerate completion of the acute phase.

During the recovery phase, the emphasis of treatment shifts to providing appropriate stimulation to initiate and facilitate gradual restoration of the affected body part and associated structures, treating the entire functional biomechanical complex. Typically, this involves a program of progressive strengthening and conditioning, emphasizing flexibility and proprioceptive training throughout the kinetic chain. Biomechanical analysis of motion through the injured area should be considered, and early neuromuscular reeducation should be employed to reduce the strain on the injured area and retrain technique to avoid stress. At completion of the recovery phase, the athlete should be able to progress to sport-specific functional exercises, culminating in eventual return to play.

Finally, the functional phase of rehabilitation focuses on prevention of reinjury and “prehabilitation” of future injury. With this focus in mind, it is clear that the injured athlete should always be rehabilitated beyond the mere absence of symptoms. For this reason, some clinicians refer to this final phase as the “maintenance” phase of care. Relieving pain can be accomplished quickly, but full rehabilitation includes optimization of function and maximization of technique and movement efficiency. This phase can be challenging for all those involved, but should not be abbreviated despite pressure for earlier return to play.

Although the phases of recovery overlap, progression through the stages requires continuous reevaluation and identification of barriers for successful return to play.

### Barriers to rehabilitation

As discussed earlier, the components of rehabilitation include restoration of range of motion, strength, endurance, neuromuscular control, and proprioception. However, these factors are interconnected and can therefore affect one another. Understanding of the interactions helps to move rehabilitation in a positive direction. In contrast, disregarding them may hinder clinical advancement.

A sports medicine provider should be aware of the basic anatomical and physiological functions of the structures involved in the injury and adjust the rehabilitation program accordingly. One well-studied example of this concept is the

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**Table 11.1 The stages of rehabilitation.**

<table>
<thead>
<tr>
<th>Phase of rehabilitation</th>
<th>Goals</th>
<th>Modalities</th>
<th>Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute</td>
<td>Pain control, swelling</td>
<td>Protection</td>
<td>Isometric</td>
</tr>
<tr>
<td></td>
<td>Range of motion</td>
<td>Relative rest</td>
<td>Cardiovascular</td>
</tr>
<tr>
<td></td>
<td>Prevent 2° complications</td>
<td>Ice/cooling</td>
<td>Uninjured areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compression/massage</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>Full range of motion</td>
<td>Electric stimulation</td>
<td>Isokinetic/isotonic</td>
</tr>
<tr>
<td></td>
<td>Gradual strengthening</td>
<td>Ultrasound</td>
<td>Active assisted</td>
</tr>
<tr>
<td></td>
<td>Restore normal function</td>
<td>Laser</td>
<td>PNF patterns</td>
</tr>
<tr>
<td></td>
<td>Begin neuromuscular reeducation</td>
<td>Injection/invasive options</td>
<td>Stabilization/control</td>
</tr>
<tr>
<td>Functional</td>
<td>Correct biomechanical deficit</td>
<td>Neuromuscular stimulation</td>
<td>Multiplanar motion</td>
</tr>
<tr>
<td></td>
<td>Optimize movement efficiency</td>
<td>Video analysis</td>
<td>Agility</td>
</tr>
<tr>
<td></td>
<td>Prevent recurrence/future injury</td>
<td>Heat prior to activity</td>
<td>Sport-specific skills</td>
</tr>
<tr>
<td></td>
<td>Endurance</td>
<td>Kinesiotaping</td>
<td>Eccentric strengthening</td>
</tr>
</tbody>
</table>

PNF, proprioceptive neuromuscular facilitation.
importance of the vastus medialis muscle in patellar tracking. The core, hips, and quadriceps musculature all play a role in lower limb kinematics, with the vastus medialis assisting in anchoring the patella medially. Efficient firing of this muscle can improve patellar control. However, the muscle only fires maximally in the last 20–30° of extension, especially in open chain situations like quad sets (Escamilla et al. 1998). If an injury to the knee has resulted in joint swelling, effusion or contracture, the joint may not be able to achieve full motion, thereby preventing the efficient firing of the vastus medialis. Consequently, attempts to strengthen the vastus medialis without first restoring knee range of motion would be inefficient. Therefore, aiming for restoration of normal passive range of motion in the involved limb is typically an early goal to permit proper restoration of the mechanics of the structures involved.

Similarly, neuromuscular function can be affected by the physiological changes that result from injury. Pain, swelling, effusion, and ecchymosis can cause true neurological inhibition of the muscles acting upon the injured area. Consider the supraspinatus muscle in rotator cuff impingement and tendinosis. The humeral head must be mechanically depressed in order for effective and pain-free overhead motion to occur, and to minimize external impingement of the muscles of the rotator cuff between the acromial arch and humeral head. With pain or dysfunction, the supraspinatus is actively inhibited via neural pathways and cannot effectively contribute to humeral head depression. Consequently, further mechanical impingement may occur, with worsening pain and deteriorating glenohumeral function. Unless the muscle can be retrained to contract prior to active overhead motion, progress towards the rehabilitation goals may be delayed. Typically, a rehabilitation program will include isometric or limited isokinetic motion to ensure proper firing of the involved muscle(s) before functionally challenging the area.

Again, all the components described above contribute to normal mechanical patterns in the musculoskeletal system. Although range of motion, strength, endurance, and neuromuscular control are all essential for optimized performance, they are not independent factors in function. Their interdependent nature should be considered when directing a rehabilitation program. A plateau in progress may require reanalysis of the area involved to identify if the structures are interacting properly with each other. Concurrent communication with the entire rehabilitation team can help troubleshoot any barriers to progression.

**Therapeutic interventions**

Therapeutic interventions can include any treatment with a goal of encouraging the healing process of the acute phase and reducing the clinical symptom complex. The treatments commonly available are numerous, but the evidence base justifying their use is sparse. This dichotomy makes it very difficult to standardize treatments, especially considering the wealth of possible injuries and combinations of treatments.

Treatment options can be categorized in many ways, but typically they are loosely divided into medications, thermal modalities, manual therapies, electric modalities, invasive options, and strengthening regimens. Although a comprehensive review of all the options is beyond the scope of this chapter, we will touch on some of the high-yield points.

Medications are commonly used for pain control and to possibly reduce inflammation. The fact that many volleyball athletes are minors makes recommendation of medications challenging. Medications should be used cautiously, with a specific goal in mind. Acetaminophen is a common analgesic, but has no antiinflammatory properties. Nonsteroidal antiinflammatory medications such as ibuprofen do have antiinflammatory properties, but evidence has shown that this function is only achieved at higher doses. Therefore, only pulsed doses of NSAIDs should be taken, under medical supervision. NSAIDs are cleared by the kidneys and can result in renal damage. There are many formulations of topical antiinflammatory medications now available. Their efficacy in controlling pain and inflammation is as yet unproven. In addition, there are some supplements that have been suggested
for bone and joint issues, like curamin, but the evidence is nonexistent. Providers should be aware if the athletes under their care are choosing to take supplements. Unintentional doping is always a possibility, due to the unregulated manufacture and distribution of these nutraceuticals.

Heating and cooling modalities are traditionally employed in treatment and rehabilitation protocols to minimize pain and swelling and to promote healing. Cooling modalities such as ice, cold whirlpools, and vapo-coolant sprays are well established as part of the treatment of acute injuries. The practice is so universally accepted that ice is a cornerstone of the PRICE acronym for the treatment of acute sports injury (protection, rest, ice, compression, and elevation). Although ice does seem to help minimize pain, the effect on healing is debatable. In addition to reducing swelling and lymphatic flow, cold therapy has been shown to reduce transmission of muscle spindle firing and may reduce spasm, allowing greater motion. In contrast, the application of heat can increase blood flow to an area, improve elasticity and theoretically aid in healing after the conclusion of the acute phase. Typical application is with heat packs, or warm baths, but therapeutic ultrasound can be used for deep heating up to a depth of about 5 cm. Although attempts have been made to use ultrasound to “drive” medications into the injured soft tissues, such efforts have never been shown to improve healing more than ultrasound alone.

Similar to deep heating, electric modalities are used to create an environment that promotes healing by increasing blood flow and encouraging transmission of nutrients across membranes. Neuromuscular stimulation can provide a variety of benefits depending on the current intensity, waveform, duty cycle, and placement of electrodes (Figure 11.2). Transcutaneous electrical nerve stimulation (TENS) may provide local analgesia after trauma, and functional electrical stimulation can assist in muscle reeducation and maintenance of tone during recovery. Iontophoresis is the combination of electric stimulation with a topical steroid to further reduce inflammation, but the depth of penetration and practical success rate have been questioned. Finally, some are using laser treatment to promote healing, although the effectiveness of laser therapy is still unproven.

Manual therapy can facilitate tissue healing, recovery, and proper activation of muscle patterns. Massage therapy, for example, includes a variety of techniques to alter the flow of blood and lymph, reduce adhesions, and decrease spasm (Figure 11.3). The functional outcome from massage is difficult to quantify, but massage is typically appreciated and utilized by most athletes in some form.

Compression can be included in manual therapies to reduce swelling using either massage or
compression wraps/supports/garments. Contact with the athlete’s skin can provide biofeedback and encourage neuromuscular reeducation. In addition, biofeedback can be enhanced during functional movement with the aid of taping (e.g. using kinesiotape) or bracing (Figure 11.4).

There are several invasive means of diagnosing and treating musculoskeletal injuries. Injection of anesthetic or corticosteroid into the injured tissue is a long-standing therapeutic measure (Figure 11.5). Most injuries, including chronic injuries, include some component of inflammation. Not all inflammation is deleterious, however. Inflammation brings a host of cellular and molecular elements to the injured area, and is a critical component of normal healing. Therefore, anti-inflammatories, such as NSAIDs or corticosteroids, are not typically recommended in the early stages of injury in order to avoid inhibiting the normal healing process.

Even though research suggests that the inflammatory component of chronic or overuse tissue injury is minimal, there may be some indication for use of corticosteroids in such situations. Chronically injured tissues have been shown via histological study to demonstrate increased mucoid substance, intratendinous degeneration, and collagen disorganization, in addition to a 10–20-fold increase in

Figure 11.3 One of many types of massage, in this case including instrument-assisted soft tissue mobilization of adhesions and realignment of tendon fibers.

Figure 11.4 Use of kinesiotape to encourage proper patellar motion during functional activity.
calcium concentration (Tsikopoulos et al. 2016). Instead of acting on inflammation, steroid injections may serve two useful purposes: disrupting the vicious cycle of pain and confirming the identity of the pain generator through accurate placement of the injection. Although an occasional injection can be helpful, there is some suggestion that multiple steroid injections can have deleterious effects in the long term (Coombes et al. 2010). Therefore, although they may provide a short-term window of opportunity for symptom control and progression in the rehabilitation program, corticosteroids should be used judiciously. These powerful (and in some cases prohibited) medications should only be used under a physician’s directed care, with complete (and documented) understanding of the risks involved with such therapy.

Other invasive procedures that have been used, with varying degrees of success, include platelet-rich plasma injections, hyaluronic acid injections, prolotherapy, and stem cell therapy.

Selected needle techniques have the potential to stimulate the normal healing process and disrupt the pathological changes described in tendinosis above. For example, percutaneous tenotomy may effectively restart a healing process that has plateaued and become refractory to standard interventions. Typically performed under ultrasound guidance, a needle is used to puncture the tendon or fascia in an identified area of tendinosis (Figure 11.6). The goal is to elicit inflammation and bleeding, and to promote the influx of growth factors. The normal healing process is restarted, which may permit the area to heal completely. A host of factors contribute to the variability in this emerging tenotomy technique, including the selection of anesthetic, the addition of therapeutic ultrasound, utilization of supplemental platelet products and growth factors, as well as the possible inclusion of stem cells. The ideal treatment protocol has yet to be agreed upon and therefore the full effectiveness of this technique is unknown. Certainly, there is inherent risk, as there is with any invasive treatment option.

Yet another treatment option is dry needling of the muscles themselves to address muscle spasm and cause reflexive relaxation of the area. Usually, a provider locates the area of maximal tenderness
and places a small gauge needle into the contracted muscle until there is a referral of pain or muscle twitch indicating a true trigger point. The area is treated until the spasm relaxes. Again, effectiveness and reproducibility are difficult to determine based on variability in timing, number of areas treated, and difficulty in determining the completion of treatment. Techniques continue to evolve and new invasive options will continue to become available. They should always be paired with a thorough and comprehensive rehabilitation program for optimizing function and performance.

Therapeutic exercise represents the cornerstone of a complete rehabilitation program. The goal is to reestablish normal strength and range of motion in the affected area (tissue injury complex), the secondarily affected structures (tissue overload complex), and the body as a whole. A typical program includes resistance training, flexibility training, and neuromuscular reeducation (Figure 11.7). Different combinations of these may be used during different phases of rehabilitation. For example, in the acute phase, joint range of motion is a priority. Strengthening is typically initiated with isometric exercises in order to prevent atrophy of muscles acting upon a joint. During the recovery phase, neuromuscular reeducation should be a priority to emphasize proper and efficient movement patterns. The injured athlete gradually transitions to isokinetic and possibly isotonic strengthening. Finally, the functional phase of rehabilitation should emphasize progressive multiplanar strengthening with an emphasis on eccentric, high-intensity, and sport-specific strengthening (Figure 11.8).

Eccentric muscle activation is defined as a lengthening of force-generating muscle. Generating more force per cross-sectional area than concentric muscle activity, eccentric activation produces considerable tensile strain on muscle and the actin-myosin cross-bridges. Although excessive eccentric training can result in delayed-onset muscle soreness and (in extreme cases) rhabdomyolysis, eccentric training is more physiological than other types of muscle activation, and if performed in a controlled manner, it promotes tissue remodeling and adaptation (Figure 11.9).

Eccentric muscular activity is critical to the sport-specific function of several essential muscle groups. For example, the muscles of the rotator cuff act eccentrically to decelerate the upper limb during

Figure 11.6 An ultrasound image showing severe Achilles tendinosis consisting of a thickened heterogeneous tendon.
Figure 11.7  A neuromuscular reeducation program for the scapula encourages scapular control, especially with the lower trapezii. Tactile biofeedback from an athletic trainer helps to emphasize proper technique.

Figure 11.8  A sport-specific drill for volleyball emphasizing control and proprioception of the ankle during the functional phase of rehabilitation.

Figure 11.9  Box jumps are an advanced option for training eccentric strength before return to play.
follow-through after a spike or serve, and the quadriceps of the thigh act eccentrically to limit knee flexion upon landing from a jump. Eccentric muscle activation is essential for sport, but forces or repetitions that exceed the athlete's capacity can place the joint(s) about which the muscles act at increased risk of ligamentous sprain injury or chronic tendinosis at the muscle insertions (Mair et al. 1996).

While graded progression during recovery can help to more efficiently return the athlete to sport, progressing too quickly beyond the athlete's tolerance may lead to further injury. In general, once the recovering athlete can perform volleyball-specific skills involving the affected body part without pain and with good technique, they can return to training and competition.

Effectively and comprehensively treating and rehabilitating volleyball injuries is a complex process. The ability to rehabilitate the athlete beyond the absence of symptoms requires a sound understanding of the structure and function of the affected body part in a volleyball-specific context.

Injury-specific examples of progression through the phases of rehabilitation follow herewith, in Boxes 11.1, 11.2, and 11.3.

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**Prevention of reinjury**

Although appropriate treatment and rehabilitation of injuries permit the athlete to return to play as quickly as possible, the ideal situation would be to prevent injuries entirely. The above discussion suggests that one way to prevent overuse injuries is to attend to the strengthening and conditioning of

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**Box 11.1 Rotator cuff tendinopathy.**

Rotator cuff injuries are typically overuse injuries. Of the four muscles comprising the rotator cuff, the supraspinatus is the most frequently injured. As alluded to previously, the explanation for this observation is principally anatomical – the supraspinatus tendon travels in the space beneath the acromion and coracoacromial ligament to insert on the humeral head and can become injured/inflamed as it is cyclically compressed with repetitive overhead motion (external impingement). The mechanism by which the tissue injury occurs can be a primary phenomenon, wherein the rotator cuff simply deteriorates with time, age, and overuse. In athletes, however, tissue injury is typically a secondary phenomenon due to scapular dysfunction, inefficient neuromuscular control, and the resultant dynamic instability of the glenohumeral joint (Meister 2000a,b). By the time the athlete complains of symptoms, the supraspinatus tendon shows little histological evidence of inflammation and thus it is probably more appropriate to diagnose the athlete with tendinosis or tendinopathy rather than tendinitis per se.

If, through repetitive overload or acute trauma, the shoulder’s well-coordinated system of static and dynamic glenohumeral stabilization is compromised (tissue injury complex), the athlete will begin to substitute altered movement patterns in an effort to minimize symptoms and maintain performance (subclinical adaptation complex). This may in turn lead to imbalances in flexibility (functional biomechanical deficit complex). One nearly universal sign of disturbed shoulder girdle mechanics is scapular dysfunction. Clinically, this is manifest by abnormal scapular kinematics and restricted range of motion. As a result of this scapular dysfunction, glenohumeral control from all the shoulder muscles is typically impaired. Increased anterior translation of the humeral head in the glenoid fossa creates, in effect, a “functionally unstable” shoulder and places the athlete at risk for impingment of the supraspinatus tendon and attrition of the glenoid labrum (Levine and Flatow 2000). Given its crucial role in shoulder function, therefore, the scapula should not be overlooked when evaluating the volleyball athlete who complains of anterior shoulder pain with overhead activity. Indeed, early rehabilitation of rotator cuff injuries should emphasize scapular motion and proper strengthening in order to provide a sound, stable “base” for upper limb function.

Acute-phase management of rotator cuff tendinopathy also focuses on relieving the athlete’s pain (through medication and the judicious use of thermal modalities, such as ice, ultrasound, and electrical stimulation). The goal is to provide an environment that permits tissue healing, while minimizing the deleterious effects of rest and time off from competition. Once the athlete has minimal pain through a full range of motion and full neuromuscular function, they can progress on to the recovery phase of rehabilitation. This stage emphasizes strengthening, range of motion, and progressive scapular control.

Spiking and serving are reintroduced in the functional phase of rehabilitation. Just before, and during this third and final stage, the physician or physiotherapist should seek to identify and correct any underlying biomechanical deficits and subclinical adaptations elsewhere within the kinetic chain that might have precipitated the rotator cuff injury. The legs and back generate 85% of the energy required to spike or serve a volleyball. Therefore, when a proximal segment of the kinetic chain is inefficient, the more distal segments often attempt to “make up” the deficit so as to maintain performance, thereby placing these structures at higher risk of overload injury. Thus, an athlete with low back pain or stiffness may attempt to compensate for a drop-off in spike velocity by altering their spiking mechanics, which in turn may overload the shoulder girdle and precipitate an episode of shoulder pain. Because of the fine coordination needed throughout the entire kinetic chain to perform volleyball-related overhead skills, optimum shoulder function is dependent on maintaining balanced strength and flexibility, not only in the shoulder girdle but in the hips and trunk as well. Once the athlete can perform sportspecific skills through a pain-free range of motion without significant postpractice soreness, they can return to play.
Box 11.2 Jumper’s knee (patellar tendinopathy).

Jumper’s knee is probably the most common overuse injury suffered by volleyball athletes; by some estimates, approximately 40% of volleyball players experience symptoms of jumper’s knee. The knee joint must withstand high forces during jumping that render it vulnerable to overload and injury. The patella plays a critical role in the biomechanics of the knee and in jumping ability. By lengthening the moment arm on which the quadriceps acts, the patella increases knee extensor torque and enhances the mechanical advantage of the quadriceps muscle group, increasing extensor force production by approximately 50%. Komi has estimated that the knee extensors contribute in excess of 50% of the force required to produce a forceful jump (Luhtanen and Komi 1978). Thus, jumping ability would appear to be highly dependent on the patella’s role in amplifying the force-producing capacity of the quadriceps.

Some of the force generated during activation of the quadriceps is directed through the patella toward the knee joint’s center of rotation. The patellofemoral joint reaction force is a measure of the compression of the patella against the femur, and is dependent on the angle of knee flexion and the load applied. In general, with increasing knee flexion there is greater contact between the patella and femur, serving to distribute the increasing force which, with a deep knee bend, can approach eight times the body weight. Maximal patellofemoral joint reaction force occurs at 60–90° of knee flexion. Not surprisingly, research has shown that there is a correlation between knee joint kinematics and jumper’s knee; in one study, those volleyball athletes with the deepest knee flexion angle during landing from a spike jump were more likely to experience symptoms of jumper’s knee (Richards et al. 1996).

Epidemiological studies have shown that patellar tendinopathy is related to repetitive loading of the knee extensor mechanism; the prevalence of jumper’s knee increases with the frequency of jump training, and is higher among players who train or compete on hard, unforgiving surfaces. Research has also shown that athletes with superior jumping ability may be at increased risk of developing patellar tendinopathy (Lian et al. 1996). As the study attempted to control for the volume of jump training, it seems unlikely that this association is simply due to a training effect. Rather, there may be intrinsic structural and biomechanical properties of the lower limbs that are unique to athletes who jump well, particularly in regard to the athlete’s ability to eccentrically activate the knee extensors.

It is also important to note that weakness of the hip external rotators may be seen in athletes with jumper’s knee, as can tightness of the hip flexors, tensor fascia lata and iliotibial band, hamstring, and gastrocnemius–soleus complex. Again, it is not clear whether these inflexibilities should be considered causal or secondary in relation to the pathomechanics of patellar tendinopathy. Inspection of the entire kinetic chain may reveal evidence of prior lower limb injury, or other predisposing factors, including a rigid, cavus foot. Insufficiency of the medial quadriceps can predispose the athlete to abnormal patellar tracking, as can excessive pronation or a tendency for dynamic valgus positioning at the knee with motion.

More recently, attention has focused on the role of the pelvis and the athlete’s “core” strength and dynamic stability as intrinsic risk factors for knee injuries, an idea proposed in the literature by Sommer (1988). Rehabilitation should therefore focus on correcting strength and flexibility imbalances throughout the trunk and entire lower limbs. Strengthening exercises should initially be performed at knee flexion angles that minimize patellar loading, beginning with isotonic exercises and progressing through a functional continuum emphasizing eccentric strength training. Attempting to correct abnormal patellar tracking through bracing or taping can be a useful therapeutic adjunct to control symptoms while rehabilitating the knee. Theoretically, refractory symptoms could be treated with a proinflammatory treatment such as percutaneous tenotomy.

Box 11.3 Lateral ankle sprains.

The lateral ankle sprain is the most common acute volleyball-related injury. The true ankle joint consists of the tibiofibular talar joint, but in a functional sense the “ankle” also includes the subtalar joint. The typical volleyball-related ankle sprain mechanism of injury involves net play, most often a blocker landing on a teammate’s foot or on the foot of the opposing spiker who has crossed over the centerline. As the blocker lands, their feet are typically plantarflexed in anticipation of accepting and dissipating the ground reaction force associated with landing. This is an anatomically disadvantageous position for the ankle, since when the foot is plantarflexed there is inherently greater laxity in the true ankle joint. When landing on an uneven surface, unless the dynamic (muscular) ankle stabilizers can maintain the joint in a stable alignment, the ligaments that passively stabilize the ankle are suddenly overloaded. As the foot inverts and the subtalar joint over-supinates, a predictable pattern of ligamentous loading occurs which can lead to failure of one or more of the lateral ankle ligaments. The anterior talofibular ligament (ATFL) fails initially, followed by the calcaneofibular ligament, and then the posterior talofibular ligament. In mild (grade 1) sprains, the ATFL may be simply stretched. In more serious (grade 2) injuries, one or more ligaments may be partially disrupted, while a grade 3 injury indicates complete diastasis of one or more lateral ankle ligaments.

The athlete who has suffered an inversion ankle injury usually recalls a definite mechanism of injury with immediate functional disability proportional to the severity of the injury. The athlete may have felt or even heard a distinct “pop.” On early examination, the amount of swelling typically correlates with the severity of the injury. The athlete will be tender over the ligaments involved. Palpatory examination should include the entire leg and foot to rule out associated proximal fibular (maisonneuve) fractures or avulsion injuries of the peroneal tendons off their insertion onto the lateral aspect of the fifth metatarsal.

Grade 1 and 2 injuries are more common than grade 3 injuries, and can be treated nonoperatively with aggressive early weight bearing and range of motion, progressing to strengthening and proprioceptive retraining exercises prior to return to play. Studies have demonstrated that proprioceptive training reduces not only the risk of reinjury but also the incidence of acute lateral ankle sprains if used prophylactically (Bahr et al. 1997). Furthermore, there is evidence that chronic ankle instability might place volleyball athletes at higher risk of eventually developing arthritic changes in the ankle (Gross and Marti 1999). Thus, a comprehensive rehabilitation program should include proprioceptive retraining. Use of an ankle-stabilizing orthosis can provide protection during early ambulation, and in some cases may actually reduce the risk of reinjury, particularly within the first 12 months following an ankle sprain injury (Thacker et al. 1999).
muscle groups routinely overloaded by the sport. Such an approach has been termed “prehabilitation.” Flexibility is also a key factor in optimizing muscle function and joint motion. Endurance is a critical component of athletic fitness; there are several studies that suggest that fatigue results in abnormal muscular activation patterns, thereby placing the joint(s) acted upon by those muscles and the muscles themselves at increased risk of injury. Thus, in order to achieve maximum performance and reduce the risk of injury, the volleyball athlete should participate in a structured, volleyball-specific training program, periodized to minimize the risk of overtraining, with appropriate attention to nutrition and rest.

References


Recommended reading


Chapter 12

The young volleyball athlete

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Introduction

The rate of youth participation in organized sport in the United States and in many other countries around the world has increased exponentially over the past 50 years. Whereas youthful pastimes used to consist largely of unstructured free play, recently the trend has been for children to become involved in competitive sports programs as early as age 5. In the United Kingdom, nearly 80% of children aged 5–15 participate in organized sport. Perhaps more significantly, 11% of those took part in “intensive training” (Bruns and Maffulli 2000). In the United States, it has been estimated that up to half of boys and 25% of girls aged 8–16 participate in organized sport annually. Approximately 75% of male and 50% of female secondary school students in the USA compete in an organized sport.

Volleyball has enjoyed explosive growth over the past half century. Nowhere has the growing popularity of the sport been more evident than among the youth. Over the last two decades, the number of junior and youth athletes registered with USA Volleyball has increased 22-fold to more than 100 000 participants. Approximately 70% of the membership of USA Volleyball is 20 years of age or younger. Most (nearly 94%) of these young athletes are female. Note that these figures do not reflect the numbers who participate in volleyball recreationally, or through school-based physical education curricula (for example, an estimated 426 814 secondary school-age athletes in the United States participated in organized volleyball in 2000, more than 90% of whom were female). In response to the increasing popularity of volleyball among the youth, many national volleyball federations now sponsor youth and junior-level championship competitions for both genders. In addition, the FIVB currently holds biannual youth and junior world championship competitions for both males and females. (Note that “junior” is defined by the FIVB as younger than age 21 for males and age 20 for females, while “youth” is defined as younger than age 19 for males and age 18 for females.) Although there are many potential benefits from such a programmatic approach to youth sports, a number of potential drawbacks exist as well, not the least of which is the dramatically increased incidence of pediatric athletic injuries. For example, in Wales from 1983 to 1998, the rate of sport-related injury among girls more than doubled, while the risk of injury among boys more than tripled (Jones et al. 2001). In addition, adolescents appear to be at higher risk for sport-related injuries than are preadolescents and children, a fact which reflects that maturing athletes grow bigger, stronger, and faster, and may be more likely to participate in year-round training and competition.
Epidemiology of injuries in youth volleyball

Although data remain somewhat limited, recent studies have added to our understanding of the extent and distribution of injuries that befall young volleyball athletes. A 3-year prospective study published 20 years ago revealed an injury incidence rate of 3.0 per 1000 hours, ranking volleyball eighth among sports for athletes aged 14–20 years (de Loes 1995). However, since that study was published, participation rates in volleyball have consistently risen. From 2009–2010 to 2013–2014, the number of girls playing high school volleyball rose by 6% to over 400,000, making it the third most popular sport among secondary school females in the USA (Reeser et al. 2015). Pollard’s two-decade review of pediatric volleyball-related injuries treated in US hospital emergency departments revealed an estimated 692,024 volleyball-related injuries to children younger than 18 years (Pollard et al. 2011).

The High School RIO™ (Reporting Injuries Online) surveillance system and the National High School Sports-Related Injury Surveillance project have bolstered the epidemiological data available regarding US high school athletes since their inception in 2005. Reeser et al. (2015) compared representative data collected by HS RIO to injury data collected by the National Collegiate Athletic Administration’s injury Surveillance System (NCAA ISS), in order to compare and contrast the injury profiles characteristic of youth players with those of collegiate athletes. The authors found that the average rate of time‐lost injuries over the study interval (injuries sufficiently severe to warrant missing a day or more of training or competition during a 4-year period from 2005–2006 through 2008–2009) among collegians was more than three times higher than was observed among the younger high school athletes (40.6 versus 12.4 per 10,000 athlete exposures (AE)). The documented annual injury rate declined in both the collegiate and high school populations over the study interval, although the prevalence of concussions increased slightly. Ligament sprain was the most common diagnosis made in either cohort (49.2% of HS RIO injuries compared to 28.8% of NCAA ISS injuries.) The vast majority of ligament sprains were acute lateral ankle sprains, which represented the most common specific injury. The knee was the second most frequently injured body part, followed by the hand, shoulder, and lower back. The frequency of anterior cruciate ligament (ACL) injury among high school athletes was roughly double that of collegiate athletes, while overuse knee injuries were twice as common in the NCAA ISS as among HS RIO. In general, young athletes sustained more acute injuries such as fracture (likely stemming from the skeletal immaturity of pubescent athletes), while overuse injuries (such as tendinosis) were infrequently diagnosed among younger athletes. It was noted, however, that concussions occurred with similar frequency in both age groups.

In a study of middle school female basketball, soccer, and volleyball players, volleyball had the second highest overall rate of injury (3.68 per 1000 AE; soccer 6.66, basketball 2.86) (Barber-Foss et al. 2014). Overall, middle school athletes showed a similar pattern of injury to their high school counterparts. Interestingly, volleyball was the only sport that had a higher incidence of injury in practice sessions than in games (5.55 versus 0.75 per 1000 AE). Of the 38 injuries documented in the study, 35 (92.1%) occurred during practice. Similar to basketball and soccer, the most common body part injured was the knee (81.6%), followed by the ankle (7.9%), the shoulder (7.9%), and the wrist (2.6%). The most common types of injury seen in this study of volleyball players were pain/inflammation (71.1%), sprain/subluxation (15.8%), and strain/tendinopathy (10.5%). The most common diagnoses in order were patellofemoral dysfunction, Osgood–Schlatter disease, Sinding–Larsen–Johansson patellar tendinosis, ankle sprain/fracture, knee plica, shoulder inflammation, knee contusion, knee fat pad, patellar subluxation, shoulder subluxation, and wrist sprain.

Although the data are somewhat limited, as a non-contact sport volleyball remains relatively safe for youth when compared with other “major” sports. It should be noted that due to the predominance of females among this segment of the volleyball-playing population, the injury pattern characteristic of younger male volleyball athletes remains relatively
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poorly defined. Currently in the USA, only 42,000 boys play high school varsity volleyball in 22 states (www.teamusa.org/USA-Volleyball).

**Pediatric physiology and the risk of injury**

Although youth sports remain an overall positive endeavor, significant concerns exist regarding the effect of intensive, year-round training on the unique anatomy and physiology of young athletes. One of the biggest differences between young and adult athletes is the presence of skeletal growth plates, also known as physes. The physes are vulnerable to both acute and repetitive (or chronic) overload.

In children, the “long” bones of the body (the humerus, radius, and ulna in the upper limb and the femur, tibia, and fibula in the lower limb) are still growing. The areas of longitudinal growth (termed the physeal plates) are located at the ends of the long bones and are quite vulnerable to injury, particularly fracture. As a result of these areas of relative skeletal weakness and immaturity, children (particularly preadolescents) who suffer acute joint-related trauma are at increased risk of fracture along the physeal growth plate compared to adults. Imbalances in neuromuscular control (balance), strength, and flexibility also contribute to the risk of physeal injury (Colvin and Lynn 2010; Loud and Micheli 2001; Shanmugam and Maffulli 2008). During the period of rapid growth commonly seen in puberty, the physes are said to be “open” and these areas of bony growth are more prone to injury compared to adults (who have “closed” physes) (Cuff et al. 2010). Between the ages of 6 and 14 years, the increase in limb mass is double the corresponding increase in limb length, which may result in a force imbalance and decreased lower extremity control, placing the physes at increased risk of injury (Colvin and Lynn 2010; Ford et al. 2010a,b; Hewett et al. 2006a; Quatman et al. 2006). In addition, during adolescence muscles and tendons grow proportionately slower than bones, altering the forces on the long bones during this phase of rapid bone growth (Franklin and Weiss 2012). Therefore, any child who suffers a sprained ankle should undergo radiographical evaluation to rule out a fracture that might require casting or operative intervention. The Salter–Harris classification system (Figure 12.1), which describes fractures involving the growth plate, has proven to be clinically useful in prognosticating the outcome of such fractures.

Areas of bony growth at sites of musculotendinous insertion are termed apophyses, and are potential sites of injury. Apophyses are vulnerable to traction injury, particularly when unequal rates of skeletal and muscular growth predispose the adolescent athlete to inflexibility. “Traction apophysitis” refers to a painful condition related to repetitive overload of the tendon inserting at the involved apophysis. Osgood–Schlatter disease, a common apophysitis involving the knee extensor mechanism at the tibial tubercle, is contrasted with other common overuse conditions affecting the upper and lower limbs of young athletes in Table 12.1. Osteochondritis dissecans is an ischemic condition of the articular cartilage and subchondral bone of a joint, typically affecting the knees, ankles, and elbows. Young baseball pitchers who, through repetitive throwing, subject their dominant elbow to recurrent valgus stress are thought to be predisposed to osteochondritis dissecans of the elbow joint (also known as “Little League elbow”). Research has demonstrated that young baseball players who limit the number of maximal throws to fewer than 300/week have a lower risk of developing elbow problems (Micheli et al. 2000). Although no studies have been performed investigating the optimal number of spikes for young volleyball players, it seems reasonable to empirically limit the number of repetitions to avoid structural fatigue and overload. Children who are routinely given insufficient time to recover between training bouts are at risk for developing stress injury of weight-bearing bones.

**Treatment of overuse injuries**

The general principle underlying treatment of overuse conditions is to provide the young athlete with an appropriate amount of relative rest to permit
recovery and healing of the involved tissues. Unequal
rates of skeletal and muscular growth and develop-
ment can lead to inflexibility and relative weakness
of the soft tissues (muscles, tendons, and ligaments)
surrounding the child’s skeleton. Consequently,
temporary structural malalignments are not infre-
frequent in children and can render the pediatric ath-
lete more susceptible to overload injuries. Regaining
and maintaining balanced strength (particularly
core and scapular stability) and flexibility is therefore
an integral part of the rehabilitation of these injuries.
It is equally important to assess the biomechanics of
the athlete’s sport-specific skills in an effort to
identify and correct any flaws in technique which
could be contributing to tissue overload (Hawkins
and Metheny 2001). The importance of a thorough
annual preparticipation examination by a well-
trained sports medicine provider familiar with
pediatric development and the demands of volleyball
should not be overlooked either (Metzl 2000).

Figure 12.1  (a) Long bones grow longitudinally from the physis, or growth plates, located at both the proximal
and distal ends of the bone. (b) The Salter–Harris classification system for physeal injury describes five common
injuries involving the growth plate and surrounding bone. Type 1 and type 2 injuries do not involve the joint
surface, and represent relatively benign fractures with typically good outcomes from treatment. Types 3 and 4
include involvement of the joint surface. These are less common than types 1 and 2 but are potentially more
dangerous, with less favorable outcomes unless treated appropriately. Reduction and surgical fixation may be
required to correct displacement. If substantial injury to the growth plate occurs, future bone growth may be
affected. This is particularly problematic in type 5 injuries, which are difficult to detect acutely on radiographs since
they are crush injuries. Both acute and chronic physeal injuries can have a long-term impact on the growth and
performance of young athletes. Proper recognition and response starts with understanding the common causes of
these injuries and the basic anatomy that makes these athletes unique.
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Other implications of developmental physiology

In addition to the musculoskeletal differences between children and adults, other physiological differences may contribute to the risk of injury among pediatric athletes. Specifically, children are mechanically less efficient than adults, and as a result have a higher energy cost for athletic performance. Children suffer from heat illness in the same way that adults do but may be less likely to be aware of symptoms or to speak up if they occur. Appropriate precautions should therefore be taken to safeguard young athletes from heat stress when practicing or competing in hot and humid conditions. Children also have reduced anaerobic capacities compared with adults (although when corrected for weight, they do not differ significantly), potentially making them even more susceptible to muscular fatigue and cramping. Finally, it is important to remember that neuromuscular coordination (and consequently skill acquisition) typically improves with age (and with practice). The motor control ability of a young athlete influences their risk of both acute traumatic and chronic overuse injuries. For example, bad timing when blocking may result in finger injuries, poor take-off or landing technique when jumping may result in an increased risk of ankle sprain (to both the attacker and the opposing blocker), and faulty arm swing technique may excessively overload the shoulder and low back.

The nutritional needs of young athletes are not well understood, as limited research has been conducted in this area (Thompson 1998). It is evident, however, that adolescent athletes are in general poorly educated about the importance of proper nutrition. They may be susceptible to peer influence and misinformation. For example, studies have shown that as many as 11% of male and 2.5% of female pediatric athletes admit to taking anabolic steroids (American Academy of Pediatrics 1997). Use of “nutritional supplements” occurs on a similar scale and appears to be motivated by a desire for improved performance and concern over appearance. Like adults, young athletes should be encouraged to eat a varied and well-balanced diet. Coaches and parents should also be attentive to signs of disordered eating. Preoccupation with weight control and aesthetics among female athletes may begin as early as age 5–7 in some sports. Although volleyball may not typically be included among the “aesthetic sports,” females do wear very tight-fitting uniforms. Youth volleyball athletes should therefore be thought of as at risk for developing maladaptive eating behaviors, with potentially dangerous consequences.

Psychological concerns

Childhood and adolescence can be a difficult period of change and development. Sports bring both additional risk and protective factors in relation
to mental well-being. Unfortunately, a large stigma still exists around mental health which affects both the demand for and availability of services. The NCAA, IOC, and other medical organizations have recently taken a stance that mental health is not separate from but rather is an integral part of athlete health (Brown et al. 2014). It is critical that athletic staff and sports medicine professionals understand and support the overall concept of student-athlete wellness, both physical and psychosocial. Previously, the same type of response has not been provided to young athletes facing mental health issues, such as anxiety, depression, disordered eating, and drug and alcohol abuse, as was provided to athletes for physical issues such as concussion or musculoskeletal disorders.

Approximately one in every 4–5 youths in the US experiences impairment during his/her lifetime as a result of a mental health disorder. The prevalence of many emotional and behavioral disorders in children and adolescents is higher than that of some well-known physical ailments, such as asthma and diabetes. Nearly one in three adolescents (31.9%) met the criteria for anxiety disorder, 19.1% were affected by behavioral disorders, 14.3% experienced mood disorders, and 11.4% had substance use disorders (Merikangas et al. 2010). The early onset of major classes of mental disorders has been documented (Substance Abuse and Mental Health Services Administration 2012). Of the affected adolescents, half experienced symptoms of their anxiety disorder by age 6, their behavioral disorder by age 11, their mood disorder by age 13, and their substance use disorder by age 15. Co-morbidity rates of affected individuals have been reported at 40%, and 22.2% described having a mental disorder with severe impairment or distress that interfered with daily life (Merikangas et al. 2010).

A National Athletic Trainer Association-led interassociation work group has developed recommendations for high schools on how to recognize such issues and help student-athletes get treatment (Neal et al. 2015). The proposal encourages schools to have a plan that focuses on education, early recognition of potential problems and effective referral to the mental health system to help student-athletes, along with a plan to recognize and address potential crisis situations.

In addition, certain circumstances can heighten risk, especially in an athlete already prone to an underlying condition (i.e. anxiety, depression, ADHD, etc.). These include bullying and hazing, injuries where their identity as an athlete is threatened and diminished team interaction occurs, and year-round sport participation with the additional stressors of performance expectations, reduced recovery time, and impaired sleep.

**Pediatric injury prevention**

Prevention efforts should be based on and guided by quality epidemiological information such as the frequency, severity, and etiology of injuries. Volleyball is a jump-intensive sport with corresponding predisposition to lower extremity injuries. In general, volleyball athletes have been shown to be most at risk for acute ankle injuries and overuse conditions of the knee and shoulder. The high numbers of these injuries argue strongly for the integration of evidence-based preventive measures into youth volleyball training programs.

Although not specific to volleyball, level 1 studies by McGuine et al. (2011, 2012) have demonstrated the value of lace-up ankle braces and proprioceptive exercises to reduce the incidence of ankle sprain injury. An examination of high school football as well as boys’ and girls’ basketball showed that lace-up ankle braces, independent of shoe type, taping, and field surface, led to a lower incidence of acute ankle injuries for both first-time injuries and those who have a history of a prior sprain. The degree of sprain severity was unchanged and there was no secondary effect on other lower extremity injuries (McGuine et al. 2011, 2012). Meanwhile, the group that used a balance training program had an injury rate of 6.1% versus 9.9% in the control group (McGuine and Keene 2006). In addition, there was a 50% risk reduction if an athlete had a prior sprain and performed the intervention (McGuine and Kenne 2006). Bahr was able to reduce incidence of ankle sprains in both male and female amateur Norwegian volleyball players through a multifaceted intervention program that included technical training (proper spike approach,
take-off and landing technique, block movement drills) along with balance board training and injury awareness education (Bahr et al. 1997).

Female athletes have anywhere from a twofold to 10-fold increased risk of certain injuries, such as ACL tears and the development of patellofemoral pain in the collegiate and high school settings (Fulkerson 2002; Fulkerson and Arendt 2000; Hewett et al. 2006b; Robinson and Nee 2007). Previous injury surveillance research in the high school setting determined injury rates for female athletes in the sports of basketball, soccer, and volleyball to be 4.4, 5.3, and 1.7 per 1000 AE, respectively (Powell and Barber-Foss 1999). Neuromuscular training programs have proved to be effective in reducing knee and some ankle injuries, especially when implemented in the adolescent female population (Abernethy and Bleakley 2007; Hewett et al. 2006b). Optimized when they include a preseason conditioning program and a structured warm-up in-season, neuromuscular prevention strategies result in a number needed to treat of 4–10 for minor/moderate injuries and 66 for serious injury such as ACL tear (Abernethy and Bleakley 2007; Hewett et al. 2006b).

Risk factors for overuse knee injuries include the playing surface, training volume, and jump/landing mechanics. Therefore, teaching fundamentals and form along with minimizing the volume of jump training on hard surfaces can minimize cumulative load on the knee. Knee extensor eccentric training exercises can be used prophylactically to prevent anterior knee pain (Reeser et al. 2006). In addition, addressing deficits in core strength and functional imbalances may help to prevent lower limb injuries (Sommer 1988).

With regard to overhead training, programs that focus on scapular and dynamic glenohumeral stabilization, core strength, stretching the posterior capsule, and proper mechanics are key. Addressing form, fundamentals, and training load is also likely beneficial. However, no volleyball-specific prevention studies have been performed to date in this area.

The incidence of concussions has increased, although the increasing frequency of diagnosis may simply be a matter of increased awareness by medical personnel or family members. Causes include contact with the playing surface and contact with the net/pole. Ensuring that protective padding covers all volleyball poles and protruding hardware should help to prevent impact-related injuries, including concussions (Pollard et al. 2011).

Finally, incomplete recovery from a prior injury is a leading risk factor for reinjury. Therefore, appropriate and complete rehabilitation is a crucial step toward prevention efforts.

### Goals of youth volleyball

As alluded to earlier, there are many potential benefits for enrolling youth in organized volleyball programs. Ideally, sport promotes a healthy lifestyle and fosters a sense of teamwork and fair play. Reasons why children participate in sport include “having fun,” but in many instances this innocent motivation is cast aside by well-meaning but overzealous parents and coaches. Overly structured athletic programs may in many instances stifle long-term interest in fitness and athletics by children as they mature. Rather than focusing on skill development and enjoyable physical activity, many regimented youth athletic programs have overemphasized winning, which has been postulated to account for the rather dramatic decline in athletic participation as children age. Consequently, the American Academy of Pediatrics has concluded that “reasonable goals for children and preadolescents participating in organized sports include acquisition of basic motor skills, increasing physical activity team, learning good sportsmanship, and having fun” (American Academy of Pediatrics 2001).

Increasing youth participation has helped to “grow the game” of volleyball worldwide. These youth feed the athlete developmental pipeline that produces talented volleyball athletes and which enables nations to sustain (or develop) competitive excellence in the sport. The youth of today may bring Olympic glory in the future and consequently there has been considerable interest in trying to identify the characteristics that contribute to volleyball proficiency and success. Anthropometric studies have been published which profile the body...
morphotype, height, jumping ability, and other physical and physiological traits of the elite volleyball athlete (Gualdi-Russo and Zaccagni 2001; Kioumourtzoglou *et al.* 2000). Not surprisingly, the elite adult volleyball athlete tends to be tall, lean (ecto- or mesomorphic/leptosomatic), and jumps well. However, no features have been identified which consistently and accurately predict future volleyball success at the international level.

**Nature and nurture**

So the question remains: are champions born or made? Certainly, features such as physical size and an athlete’s physiological potential are genetically predetermined and contribute greatly to sports success. There is also undeniably a trainable component of sports talent. Increasingly, however, there is concern that starting sport-specific training at too young an age may prove detrimental in the long term. Intense physical training combined with premature sports specialization may not only jeopardize the developing athlete’s health but also detract from their advancement as a volleyball player. Research has demonstrated that there are potential adverse physiological consequences from intense physical training, including delayed menarche in females and an increased risk of overuse injuries to immature musculoskeletal systems (American Academy of Pediatrics 2000). The International Federation of Sports Medicine (FIMS), in conjunction with the World Health Organization, examined the issue and concluded that “there is growing evidence that excessive and intensive training may increase the rate of overuse and catastrophic injuries” (FIMS 1997).

Recent research on talent identification, profiling, and athlete development suggests that the best athletes are those who are exposed to a variety of different sporting experiences in their youth. It is thought that this breadth of exposure stimulates not only visual perceptual skills such as anticipatory timing, but also motor development and neuromuscular control in addition to a generalized appreciation for the tactical aspects of ball games and sport in general. There is therefore ample evidence to support the contention that sport specialization should be avoided before 10 years of age in favor of broader sporting experience.

How, then, does one create a youth program that at once attracts children to the sport while providing opportunities for promising athletes with aptitude to develop their talent? First and foremost, the program should encourage participation. Youth should be encouraged to contact the ball as many times as possible in both skill-enhancing structured drills and during unstructured “play time.” Children learn best by playing, and the early emphasis should be on learning the basic skills of the game. Youth also learn a great deal by imitating the skills of more skilled athletes they see on television or in the sporting arena. Coaches should capitalize on this innate mimicry and encourage novice volleyball players to repeat skills such as setting and spiking that have been demonstrated for them. USA Volleyball has developed pictographic instructional guides that provide novice players with a model upon which they can pattern their skill-specific movements and kine-matics (Figure 12.2).

For children aged 9–13 years who demonstrate an interest in the game and wish to play it competitively, a developmentally appropriate version of volleyball has been invented. Called mini-volleyball, the game is tailored to preadolescent athletes and permits them to learn the essential elements and skills of the sport in a safe environment. Play is co-educational, with three boys and/or girls to a team. Employing a smaller court (9×6m total dimensions), a lower net height (2.1 m), and developmentally appropriate equipment and rules (e.g. larger and lighter weight volleyball), mini-volleyball is not only fast-paced and fun but by design it minimizes the wear and tear on developing skeletal structures that would otherwise occur from playing with adult equipment and rules. Transition to a regulation volleyball court and equipment is recommended only after 14 years of age. As the athlete progresses through the youth and junior stages, appropriate progression is made in technique and strategy, as well as physical training and conditioning.
USA Volleyball, the national governing body for the sport in the United States, has developed a series of eight pictograms illustrating the specific movement patterns of the fundamental volleyball skills. These can be used by coaches and players alike to better appreciate the kinematics of the sport. (a) Blocking. (b) Digging. (c) Jump-setting. (d) Passing. (e) Serving. (f) Setting. (g) Spiking. (h) Underhand serving. Source: USA Volleyball. Reproduced with permission of USA Volleyball.
Summary

In conclusion, it is apparent that education is perhaps the most vital ingredient in youth volleyball. Nurturing young volleyball talent requires knowledge of developmental physiology and age-appropriate strengthening and conditioning techniques. Youth coaches should be familiar with developmental sports psychology, and both coaches and parents should have realistic expectations of both the physical and emotional abilities and limitations of young athletes. Sports medicine personnel working with young athletes must remember that they should place the health and well-being of the child before the needs of the team or the expectations of coaches or parents. Working together, concerned and knowledgeable adults can create an environment conducive to personal and athletic growth and development that will foster a life-long love for the great sport of volleyball among the world’s youth.

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**Recommended reading**


Introduction

While the gender breakdown of participants internationally is not known, in the United States significantly more females participate in organized volleyball than do males. Nearly half a million girls (compared to approximately 50,000 boys) play competitive volleyball during secondary school in the USA. National Collegiate Athlete Association (NCAA) participation data suggest that over 27,000 females competed at the collegiate level during the 2015–2016 season, compared to fewer than 3,000 males. It is therefore important to consider sports medicine issues that pertain specifically to female athletes. Although the majority of injuries and ailments for which the female athlete is at risk are similar to male athletes, there are several issues that apply uniquely to female athletes that are deserving of separate discussion.

Sports injuries

Sports injuries result from a complex interaction of intrinsic and extrinsic risk factors. They are largely a consequence of the type of sport in which one participates and one’s fitness level. With only a few exceptions, sports injuries sustained by female athletes are no different from those sustained by males.

Nevertheless, sex specificity of injuries in sport has been much researched in recent years. Published studies support the following observations.

• Women report injuries differently than do men.
• Women are capable of equal efficiency and aerobic metabolism compared with men.
• There are sex differences in upper body strength, power, and endurance and lesser (but significant) differences in lower limb fitness parameters.
• A greater number of knee injuries are reported among female athletes than male athletes. In particular, an increased rate (2–10-fold) of noncontact anterior cruciate ligament (ACL) injuries has been observed for women compared with men in the same sport, particularly where abrupt deceleration, jumping, and pivoting are demanded (Arendt and Dick 1995).

Epidemiological studies of collegiate women’s volleyball injuries reveal that ankle sprains and knee injuries are the most common, with injury rates slightly higher in game situations than during practice. Knowledge about pediatric female volleyball players is limited, but one prospective study (Barber-Foss et al. 2014) in middle school female athletes (age 6–14) reported that knee injuries predominated (81.6%), followed by shoulder and ankle (7.9% each).
Knee injuries

The knee is at considerable risk of injury in volleyball athletes. The most common volleyball-related knee injuries are overuse injuries involving the extensor (patellofemoral) mechanism. The incidence of acute internal derangement of the knee joint is relatively low among female volleyball players, particularly when compared with such high-risk sports as women's basketball. Data from the NCAA Injury Surveillance System (ISS) best illustrate the magnitude of the disparity between volleyball and other collegiate sports for women. Common clinical and historical features of ACL injury include:

- ACL injuries occur four times more frequently among females than males
- the most common mechanism of ACL injury in volleyball is the offensive skill of hitting (spiking), with most injuries occurring during the landing phase of a jump
- most ACL injuries are noncontact in nature.

Sport injury epidemiological data have conclusively demonstrated a sex-specific difference in the rates of noncontact ACL injury. Reasons for this sex-specific difference have been reviewed in detail elsewhere (Arendt and Dick 1995), and appear to include the female athlete's unique hormonal environment and gender variation in neuromuscular control of lower limb function.

It has been hypothesized, but not definitively proven, that estrogens and/or other sex hormones may contribute to increased joint laxity in women, or that ligaments may be intrinsically weaker in females than in males. Nevertheless, despite a number of studies and significant speculation, there is no consensus on the cause-and-effect relationship of hormones and sex-specific musculoskeletal injuries. More rigorous studies must be performed before one can accept any relationship between hormone environment and injury as causal, to say nothing of understanding the mechanism of such a relationship.

Currently the most intriguing modifiable risk factor for acute knee injuries in females is the athlete’s neuromuscular control of the lower limb, particularly the proximal lower limb during jumping and landing maneuvers. Strengthening programs that promote proximal hip control (mediated through gluteus medius and proximal hamstring activation in a closed chain fashion) and appropriate landing technique are thought to be beneficial in injury prevention. A strengthening program consisting in part of plyometrics and skill training, particularly in landing and pivoting maneuvers, should be encouraged. A metaanalysis of six different studies of neuromuscular intervention programs found that the preseason addition to regular training of three key interventions of plyometric training, balance and core training, and strength training with resistance exercises resulted in a 72% reduction in noncontact ACL injuries in comparison with untrained controls (Griffin et al. 2006; Hewett et al. 2006).

Shoulder pain

Upper limb overuse injuries occur frequently among volleyball players. Whether there is gender predisposition to upper limb injury in general and shoulder girdle injury in particular is difficult to determine based on the available injury incidence data (the NCAA ISS unfortunately does not include incidence data for male collegiate volleyball). Factors contributing to the prevalence of shoulder pain syndromes in female athletes include poor upper body strength and repetition of a given upper limb activity or skill without adequate torso strength. Faulty technique in sports skills performed with the upper limbs is also likely to play a role. For example, to perform an overhead volleyball serve or spike, glenohumeral motion needs to be coupled with scapulothoracic motion. Improper body mechanics, including motor function of the torso and pelvis, can lead to overuse of the shoulder girdle musculature. Rehabilitation of shoulder injuries as well as preconditioning for volleyball activity should focus on strengthening the muscles of the rotator cuff and the scapular stabilizers, in addition to evaluation and management of any mechanical issues noted while hitting.
Anemia

Multiple factors can potentially contribute to the development of anemia in female athletes. Inadequate dietary iron intake is a major causative factor, and vegetarian athletes, with diets typically lower in available iron, may therefore be at greater risk. Female athletes with recognized eating disorders not only have a diet deficient in energy, but one that is likely deficient in iron as well. Potential causes of iron loss in female athletes include menstruation, gastrointestinal disorders, hemolysis, and urinary and sweat losses. Menstrual bleeding accounts for the majority of iron losses. On average, 34 mL of blood is lost per menstrual period; the average eumenorrheic female athlete must therefore consume an additional 0.55 mg iron/day over the course of 1 month to compensate for menstrual losses. Newer research also suggests that impairment of iron uptake is regulated through the peptide hormone hepcidin, which increases in response to inflammation, peaking 3–6 hours after an acute exercise bout (Clénin et al. 2015).

Appropriate treatment of iron deficiency anemia (defined as hemoglobin concentration <120 g/L for women) is dependent upon understanding the etiology of the blood loss. In most cases involving female athletes, nutritional deficiency is superimposed upon menstrual losses. Dietary modification and iron supplementation (recommended dosage 40–60 mg of elemental iron daily) are therefore appropriate therapies. Simultaneous ingestion of vitamin C on an empty stomach increases gastrointestinal absorption of supplemental iron. When athletes fail oral therapy, intravenous therapy should be considered, but it is important to rule out malabsorptive syndromes such as celiac disease.

The clinician must also be aware of “pseudoanemia,” a condition caused by dilution of the athlete’s hemoglobin concentration as a result of the volume expansion induced by endurance training. One can differentiate pseudoanemia from true anemia by evaluating both the athlete’s iron stores and a reticulocyte count. Laboratory assessment of the athlete’s iron stores and reticulocyte count should be normal in pseudoanemia, but will be abnormal in true anemia.

Not infrequently, an elite athlete may have a low ferritin level (reflective of iron stores) but a normal hemoglobin and hematocrit. Ferritin levels below 15 μg/L are specific for empty iron stores, and values of 15–30 μg/L correspond to low iron stores, with 30 μg/L being suggested as a reasonable cut-off for athletes. It is possible that many athletes with “normal” hemoglobin and low ferritin actually have experienced a relative decrease in hemoglobin concentration, but nevertheless remain within the normal reference range. This relative deficiency can be appreciated only after adequate iron supplementation has succeeded in increasing the hemoglobin concentration. However, iron is also a key component of the enzymatic system of the respiratory chain, and important for oxidative capacity. Iron supplementation may be of benefit in such cases.

Thyroid disorders

Thyroid disorders are often ignored when addressing conditions of the female athlete. It is well known that thyroid disease affects women more than men. This difference is felt to be secondary to sex steroids and local cytokines. Hypothyroidism is the most common thyroid disorder, affecting 0.6–5.9% of women, depending on the diagnostic criteria and the population surveyed. Hypothyroidism may be primary (most commonly) or secondary in etiology. Primary thyroid failure can result from autoimmune disease, iodine deficiency, prior radiiodine treatment, or thyroid surgery. Secondary hypothyroidism may derive from pituitary or hypothalamic tumors, cranial radiation, or head trauma. Whatever the cause, the symptoms of hypothyroidism can include fatigue, weakness, weight gain, constipation, cold intolerance, depression, muscle cramps, and menstrual irregularities.

Hyperthyroidism affects 0.54–2.0% of women, and is 10 times more common among females than males. The most common cause of hyperthyroidism is Graves’ disease, an autoimmune disorder in
which antibodies are produced that bind to the thyrotropin receptor. Symptoms of hyperthyroidism include palpitations, heat intolerance, weight loss, dyspnea, tremor, hyperdefecation, muscle weakness, and menstrual irregularities.

Since thyroid disorders are more common among females, and can produce symptoms such as fatigue, menstrual irregularities, and weight loss, thyroid dysfunction must be considered when evaluating a female athlete with amenorrhea, an eating disorder, and/or fatigue. Generally, hypothyroidism is treated with thyroid hormone replacement and hyperthyroidism is treated with medical management, radioiodine ablation of the overactive thyroid, or surgical resection.

Fatigue

Fatigue can result from a multitude of causes, including anemia, thyroid dysfunction, sleep disorders, fibromyalgia, jet lag, and the overtraining syndrome, to name but a few. Calorie malnutrition can also precipitate fatigue, especially in the face of excessive energy expenditure as seen in those athletes who are overtraining. Although not gender specific, overtraining is a significant cause of fatigue among athletes.

Pregnancy

A detailed discussion of the effects of pregnancy on athletic performance is outside the scope of this chapter. However, all healthcare professionals caring for female athletes must be aware that pregnancy can cause amenorrhea and fatigue and therefore should be included in the differential diagnosis when evaluating these complaints. Although no volleyball-specific studies regarding the pregnant athlete have been published, the Canadian Academy of Sport and Exercise Medicine published a Position Statement on exercise and pregnancy which concludes: “The current data suggest that a moderate level of exercise on a regular basis during a low risk pregnancy has minimal risk for the fetus and beneficial metabolic and cardiopulmonary effects for the exercising pregnant woman” (http://casem-acmse.org/wp-content/uploads/2013/07/Discussion-Paper-Pregnancy.pdf). The IOC has recently convened a group of experts to review the evidence surrounding guidelines for exercise in pregnancy in recreational and elite athletes (Bø et al. 2016).

Pelvic floor dysfunction

The pelvic floor is the term given to the muscles that create the inferior part of the muscular base of the abdomen, which together form the “core.” The anterior half of the core consists of the abdominal wall musculature, the posterior half is composed of the thoracolumbar paravertebral muscles, and the superior cap is formed by the diaphragm (Figure 13.1). The transversus abdominis, iliopsoas, and gluteal muscles also contribute to the core. Together, these muscles work to modulate intraabdominal pressure (IAP), which in turn helps stabilize the lumbar spine, providing a solid base of support for the upper torso and limbs.

The pelvic floor also functions as a sphincter for the urethra and anus. Dysfunction of the pelvic floor can precipitate loss of voluntary sphincter control, resulting in urge and stress incontinence of both urine and stool. Prevalence of pelvic floor dysfunction (PFD) resulting in incontinence is estimated to range from 15% to 50% of elite female athletes. Risk factors for PFD include participation in jumping sports (such as volleyball) and/or strength training. Pregnancy may also play a role in the incidence of PFD.

Prevention of PFD consists of training the pelvic floor musculature to increase its inherent stiffness and ability to resist exercise-related elevations in IAP. Treatment of urinary incontinence consists of bladder training, pelvic floor muscle training (Kegel exercises), biofeedback, or (in persistent cases) surgery. Absorbent products and devices designed to prevent urinary leakage can help to mitigate the consequences of PFD.
Nutrition is a critical component of many of the conditions that can affect female athletes. Poor nutrition can contribute to anemia, osteoporosis, and fatigue, among other things. Females are at greater risk of nutritional disorders than male volleyball athletes. For a number of reasons, the true prevalence of disordered eating and low energy availability in female athletes is difficult to ascertain. Certain individual sports that are judged subjectively (such as gymnastics and ice skating), and which place a premium on leanness and appearance, are thought to foster disordered eating behaviors among their participants to a greater extent than team sports (such as volleyball). Although volleyball is not considered a “high-risk” sport, it does rank in the top of the second tier of sports in which eating disorders occur (after such high-risk sports as ballet, figure skating, gymnastics, and diving). Intuitively, female beach volleyball athletes must feel even more pressure to maintain a lean appearance than do their indoor counterparts (Figure 13.2), because of the skimpiness of their uniforms (bikinis). These are actually mandated by FIVB Rules to be a certain size/measurement, including a maximum of 7 cm for the side seam of the bikini bottom, while the male players wear longer shorts and tank tops. Interestingly, however, there have been recent advances in the regulations to allow additional options such as long-sleeved tops and pants, or short-sleeved tops and shorts, to allow for players’ religious and/or cultural beliefs. The longer uniforms are also beneficial in cold environments.

Anorexia nervosa and bulimia nervosa are perhaps the two most publicly recognized eating disorders, and are characterized by typical behaviors and attitudes towards eating and body image (Box 13.1). The *Diagnostic and Statistical Manual of Mental Disorders V* (American Psychiatric Association 2013) has had substantial changes from previous versions. Notably, amenorrhea was removed from the diagnostic criteria for anorexia, and Binge Eating Disorder (BED) was approved for inclusion as its own category of eating disorder, whereas it was previously diagnosable using the catch-all...
phrase EDNOS (eating disorder not otherwise specified). The latter has been replaced with two new categories: Other Specified Feeding or Eating Disorder (OSFED) and Unspecified Feeding or Eating Disorder (UFED). These new categories are intended to more appropriately recognize and categorize conditions that do not more accurately fit into Anorexia Nervosa, Bulimia Nervosa, BED, or the other eating and feeding disorders. Clinically, however, it is important to identify and treat any athlete who exhibits pathological eating behavior, rather than focusing only on those who fulfill the formal criteria for a specific diagnosis.

Identification of an individual with an eating disorder usually results from concerns voiced by teammates, coaches, and family members. Less commonly, health questionnaires administered as part of the preseason physical examination can detect disordered nutrition. If an eating disorder is suspected, a longer standardized questionnaire such as the EAT-26 or EDI-2 can be used to screen for disordered eating, although these questionnaires are limited in several respects, and usually a clinical interview is needed to establish the diagnosis. The reliability of these instruments is dependent in large measure on the extent to which the athlete’s confidentiality is maintained. Furthermore, the “defense mechanism” of denial is common among those who suffer from disordered eating. Thus, questionnaires and interviews may not be sufficient to uncover states of disordered nutrition, particularly in the early stages of the condition.

Box 13.1 Characteristics of anorexia nervosa and bulimia nervosa (from DSM-5).

**Anorexia**
1. Restriction of energy intake relative to requirements leading to a significantly low body weight in the context of age, sex, developmental trajectory, and physical health.
2. Intense fear of gaining weight or becoming fat, even though underweight.
3. Disturbance in the way in which one’s body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or denial of the seriousness of the current low body weight.

**Bulimia**
1. Recurrent episodes of binge eating characterized by BOTH of the following:
   - Eating in a discrete amount of time (within a 2-hour period) large amounts of food.
   - Sense of lack of control over eating during an episode.
2. Recurrent inappropriate compensatory behavior in order to prevent weight gain (purging).
3. The binge eating and compensatory behaviors both occur, on average, at least once a week for 3 months.
4. Self-evaluation in unduly influenced by body shape and weight.
5. The disturbance does not occur exclusively during episodes of anorexia nervosa.

Box 13.2 SCOFF questionnaire (from Luck et al. 2002).

S Do you make yourself sick because you feel uncomfortably full?
C Do you worry you have lost control over how much you eat?
O Have you recently lost more than one stone (6.35 kg) in a 3-month period?
F Do you believe yourself to be fat when others say you are too thin?
F Would you say food dominates your life?

Another quick screening tool is the SCOFF Questionnaire, which consists of five questions that are designed to clarify suspicion of an eating disorder, rather than to make a definitive diagnosis. The questions can be delivered either verbally or in written form (Box 13.2).

True eating disorders are extremely difficult to treat. Patient denial, underlying depression, and the inherent complexity of the problem may complicate the clinician’s ability to effectively treat the female athlete with disordered nutrition. It is recommended that athletes be referred to a multidisciplinary team, which may include a clinician experienced in the treatment of athletes with eating disorders, a certified athletic therapist, a registered dietitian, a mental health professional, and at times an exercise physiologist and/or a strength coach. The athlete (and coach) should also be educated regarding the detrimental effects of poor nutrition on sports performance. Coaches must be made aware that they have a powerful influence on athletes and that they should therefore not be
advising athletes to lose weight without a legitimate reason. One study revealed that 13–17% of elite female adolescent volleyball players felt pressured by their coaches or parents to achieve or maintain a particular body weight (Beals 2002). This study also showed this group to be at risk for menstrual dysfunction and have energy and nutrient intakes placing them at risk for nutritional deficiencies and compromised performance.

If weight loss is indicated, it should be undertaken through an appropriately monitored, nutritionally sound program. In addition to the more immediate physiological and medical problems that accompany disordered eating, the long-term impact on the female reproductive system and bone mineral density (BMD) are potential additional long-term concerns.

### Menstrual dysfunction

Menstrual dysfunction exists in several forms. Amenorrhea, defined as the absence of menstruation, can be classified as either primary or secondary in etiology. Primary amenorrhea is the absence of menses in a 15 year old with normal secondary sex characteristics, or within 5 years after breast development if that occurs before the age of 10 years. Secondary amenorrhea is the absence of three or more consecutive menstrual periods after menarche. Oligomenorrhea is defined as menstrual cycles lasting longer than 35 days. A woman may also suffer from shortened luteal phase (less than 10 days) or anovulatory cycles, in which “regular” menstrual bleeding still takes place but the normal fluctuations of the ovarian hormones estrogen and progesterone are altered or missing.

There are numerous potential causes of amenorrhea (Box 13.3), one of which is pregnancy. When evaluating primary amenorrhea, it is also important to note that menarche is typically delayed in athletes compared to nonathletes. Secondary amenorrhea can result from reduced energy availability and/or stress, in which case it is termed functional hypothalamic amenorrhea (FHA). FHA is characterized by the absence of menses due to suppression of the hypothalamic-pituitary-ovarian axis, without an identifiable anatomical or organic cause. Energy availability (EA) is defined as the amount of energy available for physiological processes and activities of daily living after subtracting out the energy used for exercise training: (dietary energy intake – energy expenditure)/kg fat-free mass (FFM). One can lower the energy availability and affect energy balance by decreasing energy intake (as seen with eating disorders, disordered eating or inadvertent poor nutrition), or by increasing energy expenditure (e.g. through increased volume or intensity of exercise) without a compensatory increase in caloric intake.

The “energy drain” hypothesis suggests that it is the inadequate energy intake relative to energy expenditure (i.e. not the stress of exercise) that then leads to menstrual dysfunction and amenorrhea by altering the levels of reproductive hormones, including gondadotropin-releasing hormone (GNRH) (with subsequent reduction of estrogen secretion) and luteinizing hormone (LH). The latter is secreted in a pulsatile fashion, and is the first to be altered (Loucks et al. 2003). The negative energy balance has been implicated as the principal mechanism by which training predisposes

<table>
<thead>
<tr>
<th>Box 13.3 Potential causes of amenorrhea.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamic</td>
</tr>
<tr>
<td>Space-occupying lesions</td>
</tr>
<tr>
<td>Functional disturbances of the hypothalamic-pituitary axis</td>
</tr>
<tr>
<td>Pituitary</td>
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<tr>
<td>Hypopituitarism</td>
</tr>
<tr>
<td>Prolactin-secreting tumor</td>
</tr>
<tr>
<td>Ovarian</td>
</tr>
<tr>
<td>Gonadal dysgenesis</td>
</tr>
<tr>
<td>Tumor</td>
</tr>
<tr>
<td>Polycystic ovaries</td>
</tr>
<tr>
<td>Resistant ovary syndrome</td>
</tr>
<tr>
<td>Uterine or vaginal</td>
</tr>
<tr>
<td>Absence of uterus</td>
</tr>
<tr>
<td>Complete or partial absence of vagina</td>
</tr>
<tr>
<td>Imperforate hymen resulting in hematocolpos</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Pregnancy</td>
</tr>
<tr>
<td>Congenital adrenal hyperplasia</td>
</tr>
<tr>
<td>Hypothyroidism or hyperthyroidism</td>
</tr>
<tr>
<td>Debilitating chronic disease (liver/kidney disease)</td>
</tr>
<tr>
<td>Eating disorders</td>
</tr>
<tr>
<td>Medications</td>
</tr>
<tr>
<td>Oral contraceptive pills, chemotherapy, antipsychotics, anti-depressants, corticosteroids</td>
</tr>
</tbody>
</table>
female athletes to menstrual dysfunction, which in turn has a detrimental effect on bone health, as discussed in further detail later. Other hormonal changes can include elevated cortisol and decreased total and free triiodothyronine levels, increased growth hormone, ghrelin and peptide YY levels and low leptin and insulin-like growth factor 1.

**Bone health**

Maintenance of bone health through a woman’s active, athletic years is critical to maintenance of functional capacity in later life. The greatest accretion of bone mass (>50%) happens during puberty, between the ages of 11 and 14 years in girls. Factors that contribute to the bone health of the female volleyball athlete include nutritional status and menstrual history, and the volume of ground reactive forces that must be dissipated as the result of repetitive jumping. Female athletes in general have BMD 5–15% higher than the general population, and fortunately, female volleyball athletes appear to maintain higher bone mineral densities of the lumbar spine and bones of the lower limb (femur, tibia, calcaneus). One possible explanation is that regular participation in such weight-bearing exercise may cause the principal skeletal structures exposed to the recurrent ground reactive forces to adapt to the imposed demands by laying down new bone in accordance with Wolff’s law. Thus, the regular jumping that is part of the sport may help to offset any adverse skeletal effects of hypoestrogenism in the female volleyball athlete.

Bone mineral density is normally measured with dual-energy x-ray absorptiometry (DEXA) scans. Assessment of BMD status in premenopausal woman is based on Z-scores instead of T-scores to determine low bone density for age and osteoporosis. The International Society for Clinical Densitometry (ISCD) defines BMD within the expected range as a Z-score >–2 SD below the average value for age-, sex-, and race-matched controls, and BMD below the expected range for age as a Z-Score ≤–2 SD. The authors of the 2007 Position Statement of the American College of Sports Medicine (ACSM) on the Female Athlete Triad (Nativ et al. 2007) recommend a slightly different classification, defining low BMD as a Z-score of –1 to –2 with secondary clinical risk factors for fracture (e.g. chronic malnutrition, eating disorders, hypogonadism, glucocorticoid exposure, previous fractures), and osteoporosis as a Z-score ≤–2 with secondary clinical risk factors for fracture.

The long-term consequences of delayed menarche on developing bone, particularly when coupled with exercise at a young age, are unknown. However, there are a few studies in the literature that implicate osteopenia, stress fractures, and scoliosis as potential complications of delayed menarche. Low BMD also puts these women at risk for suboptimal peak bone mass acquisition, leading to an increased risk of premature osteoporosis (and the potential for stress fractures as well). In adulthood, a 10% decrease in BMD is associated with a two-to threefold increase in fracture risk.

In addition to the effects of lower estrogen on the menstrual cycle and subsequent bone health, a low Body Mass Index independently correlates with low BMD. Unfortunately, treatment of estrogen deficiency alone may not be enough to reestablish normal bone mineral density. Research has shown that improvement in bone density was found only when estrogen replacement was coupled with weight gain.

Universally accepted guidelines for the treatment of low BMD or premature osteoporosis secondary to hypoestrogenic menstrual irregularity have not yet been established. Appropriate interventions would include proper nutrition (including adequate calories, calcium, and vitamin D intake), restoring the athlete to a positive energy balance and encouraging modest weight gain among underweight athletes. Hormone replacement may be necessary if dietary measures are not sufficient, but there are an inadequate number of well-designed studies investigating the effects on BMD in this population.

However, despite this lack of prospective longitudinal data, estrogen replacement is frequently prescribed. The Committee on Sports Medicine of the American Academy of Pediatrics (AAP) recommends that amenorrheic athletes within 3 years of menarche should be counseled on improving their nutritional status and decreasing the intensity of
exercise, to restore menses. According to the published AAP recommendations (1989), estrogen supplementation, such as the use of combined oral contraceptives or the oral contraceptive pill (OCP), may be considered for hypoestrogenic amenorrheic athletes who are 3 or more years post menarche. More recent studies suggest that this will not replenish BMD, and in fact may be detrimental to accrual of maximal bone mass. There is also the clinical concern of masking amenorrhea with the OCP, prior to proper assessment and diagnosis of the cause. These older athletes should also undergo an analysis of their nutritional status/energy balance.

Transdermal estrogen, in contrast to OCP, maintains or increases insulin-like growth factor 1, a bone trophic hormone essential for bone formation and remodeling. It has been successfully used in populations of anorexic patients, and is being investigated for use in athletes. The use of oral bisphosphonates (such as alendronate and risedronate) to treat low bone mass in the premenopausal female remains controversial, because of their long half-life in bone and possible teratogenic effects. Other pharmacological therapies are still under investigation for this population.

**Nutrition and bone health**

Lifelong healthy eating habits, including adequate dietary intake of calcium, help to maximize bone health, in addition to regular physical activity. The amount of dairy products consumed during childhood and adolescence is directly related to achieving satisfactory bone density in later life. Vitamin D intake is also essential, with positive effects on bone tissue, including stimulation of osteoblast activity, increased calcium transport, and decreased parathyroid hormone secretion. In addition to adequate daily calcium (up to 1500 mg) and vitamin D (up to 800 IU), macronutrients are important in adequate bone health. Protein, fat, and carbohydrates are the nutrients from which energy can be metabolically derived. Protein comprises most of the nonmineral composition of bone, and its intake is essential for synthesis of the bone matrix. Indeed, there is a positive correlation between protein intake and bone mass gains in children. Low energy availability has also been identified as a determinant of bone health due to both energy-related (suppression of bone formation and upregulation of bone resorption) and estrogen-related (increase in bone resorption) factors (Ihle and Loucks 2004).

**Stress fractures**

Stress fracture represents the ultimate consequence of bone exposed to a persistent increased load to which it cannot accommodate through normal repair and remodeling.

The diagnosis of stress fracture in a mature female athlete should alert the clinician to the possibility of concomitant osteopenia or osteoporosis, as well as underlying menstrual dysfunction. Amenorrheic athletes have 2–4 times greater risk for stress fracture than their eumenorrheic counterparts. An association between stress fractures and menstrual irregularity has also been observed. Stress fractures are also associated with low body weight and reduced lean body mass. Bone mineral density studies should be considered in those athletes with recurrent stress fractures, and for those with concomitant risk factors for osteoporosis such as amenorrhea and disordered eating, or simply low energy availability.

Treatment of stress fractures involves identifying and modifying the underlying cause(s) of the stress fracture, including accelerated training programs, suboptimal fitness level, and potential nutritional deficiencies. Menstrual irregularity may be treated with hormonal replacement, if appropriate, but only after nonpharmacological therapies, including improved energy availability, have been attempted.

**The Female Athlete Triad and Relative Energy Deficiency in Sport (RED-S)**

The term “Female Athlete Triad” was initially coined in 1997 to bring attention to the marked interrelatedness of amenorrhea, osteoporosis, and
disordered eating among female athletes. In 2007, the ACSM renamed the three components as menstrual function, bone mineral density (BMD), and energy availability (EA), and described each entity as existing on a continuum from health to disease (Figure 13.3), emphasizing that the athlete may move along the different axes in different directions and at different speeds. For example, changes in EA happen over hours or days, while menstrual dysfunction may ensue over days or weeks, with significant alterations in BMD taking months or years. An athlete may present with any or all of the component diagnoses of the triad. Increased awareness of the triad by healthcare providers has resulted in improved clinical recognition of its component parts.

Identification of the Female Athlete Triad requires an increased level of clinical suspicion. Ideally, screening for the components should occur regularly, such as during the annual preparticipation exam. Regrettably, screening practices for both Canadian collegiate (Rumball and Lebrun 2005) and US National Collegiate Athlete Association Division 1 athletes (Mencias et al. 2012) are notably insufficient. The Female Athlete Triad Coalition (a consortium of organizations) has proposed a 12-item questionnaire, containing eight questions about disordered eating, three regarding menstrual dysfunction, and a question about stress fractures. Eight of these specific questions are also contained in the Female Athlete section of the form from the PPE monograph (4th edition) (Box 13.4). More recently, the 26-item Low Energy Availability in Females Questionnaire (LEAF-Q) has been found to have an acceptable sensitivity (78%) and specificity (90%) in screening for triad disorders (Melin et al. 2014).

Clinical detection of one component of the triad should prompt an evaluation for the others. Inadequate energy availability is usually the principal underlying factor, and there can be other significant health and performance consequences besides menstrual dysfunction and altered BMD. For example, low levels of estrogen in amenorrheic or oligomenorrheic athletes have also been shown to cause endothelial dysfunction, resulting in
Chapter 13

Elevated low-density lipoprotein levels and an increased risk of cardiovascular disease (Temme and Hoch 2013). There are many physiological processes that may be affected by low EA, including metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular and psychological health. For this reason, when the IOC Medical Commission revised and updated its Position Paper on the Female Athlete Triad, a newer, more inclusive term was introduced: Relative Energy Deficiency in Sport (RED-S) (Mountjoy et al. 2014). The diagnosis of RED-S subsumes (but does not replace) the Female Athlete Triad, and expands upon the complex interrelationships between various conditions that can potentially affect female athletes, which appear to have as their root cause a deficit of energy availability (Figures 13.4, 13.5). Male athletes can be affected by RED-S as well.

Features of the clinical examination and the necessary diagnostic laboratory investigations of the associated RED-S disorders are beyond the scope of this chapter, as are specific treatments. The Female Athlete Triad Coalition has proposed a cumulative risk stratification system, based on presenting symptoms and physical findings, to aid in guiding further testing and treatment, as well as in clearance of the athlete to return to play (Joy et al. 2014).

In general, RED-S should be suspected when BMI is less than 18.5 for women age over 18 years and below the fifth percentile for other age groups. Optimal energy availability is thought to be at least 45 kcal/kg FFM/day. At levels lower than 30 kcal/kg FFM/day, changes in the pulsatile release of LH start to occur.

The underlying principle of care is to restore a positive energy balance by either increasing the athlete’s dietary intake or decreasing their energy expenditure. The initial target intake is at least 30 kcal/kg of fat-free mass per day. However, because RED-S may result in serious sequelae that may prove refractory to treatment, prevention of RED-S represents the goal. Education of athletes, coaches, parents, and healthcare providers, combined with early identification, will have the largest impact on the reproductive and long-term bone health of female athletes. The RED-S Clinical Assessment Tool (RED-S CAT) is a screening tool which has been translated into many languages and is freely available online (Mountjoy et al. 2015) (www.bjsm.bmj.com). Large-scale epidemiological studies identifying the incidence and prevalence of RED-S in various athletic populations (including males) have yet to be done but it is hoped that the RED-S concept will help medical professionals better understand and recognize some of the conditions that affect the female volleyball athlete.

**Box 13.4 Female Athlete Triad Coalition’s recommended screening questions for the Female Athlete Triad (from Joy et al. 2014).**

<table>
<thead>
<tr>
<th>Question</th>
<th>Included on the Fourth-Edition PPE Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you worry about your weight or body composition?</td>
<td>✓</td>
</tr>
<tr>
<td>2. Do you limit or carefully control the foods that you eat?</td>
<td>✓</td>
</tr>
<tr>
<td>3. Do you try to lose weight to meet weight or image/appearance requirements in your sport?</td>
<td>✓</td>
</tr>
<tr>
<td>4. Does your weight affect the way you feel about yourself?</td>
<td>—</td>
</tr>
<tr>
<td>5. Do you worry that you have lost control over how much you eat?</td>
<td>—</td>
</tr>
<tr>
<td>6. Do you make yourself vomit or use diuretics or laxatives after you eat?</td>
<td>—</td>
</tr>
<tr>
<td>7. Do you currently or have you ever suffered from an eating disorder?</td>
<td>✓</td>
</tr>
<tr>
<td>8. Do you ever eat in secret?</td>
<td>✓</td>
</tr>
<tr>
<td>9. What age was your first menstrual period?</td>
<td>✓</td>
</tr>
<tr>
<td>10. Do you have monthly menstrual cycles?</td>
<td>✓</td>
</tr>
<tr>
<td>11. How many menstrual cycles have you had in the last year?</td>
<td>✓</td>
</tr>
<tr>
<td>12. Have you ever had a stress fracture?</td>
<td>✓</td>
</tr>
</tbody>
</table>
Figure 13.4  Health consequences of RED-S. Source: Mountjoy et al. (2014). Reproduced with permission of BMJ Publishing.

Figure 13.5  Potential performance effects of RED-S. Source: Mountjoy et al. (2014). Reproduced with permission of BMJ Publishing.


**Recommended reading**


Chapter 14

The elite indoor volleyball athlete

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Artro Clinica de Ortopedia, Curitiba, PR, Brazil

Introduction

Competing at the highest level of international volleyball is both physiologically demanding and psychologically stressful. International indoor volleyball players usually compete for their club team from October to April. Currently, the most competitive leagues are found in Russia, Turkey, and Poland. The national team season starts towards the end of April and continues into early to mid-autumn. The final competition of the season for club teams is the club championships, while the ultimate contest of the national team calendar cycles between the Grand Champions Cup, the World Championships, the World Cup, and the Olympic Games.

The elite volleyball athlete “lives on the edge,” as we can see in Figure 14.1. Constantly striving for optimal performance, the elite volleyball athlete is subject to physical wear and tear, mental fatigue, and social stressors. The level of medical care offered to elite athletes often differs from the care made available to recreational athletes, particularly in terms of timing and the willingness to pursue testing or imaging in an effort to promptly arrive at a comprehensive understanding of the injury and appropriate treatment options.

In this chapter, I will endeavor to describe my experience as a team physician for the Brazilian national women’s team from 1997 to 2000, and subsequently with the Brazilian national men’s team from 2001 to the present. During this period, these teams matured from teams used to finishing in “the middle of the pack” to teams that consistently earned a position on the medals stand in major competitions.

The staff: roles and responsibilities

During my first international competition in 1998, the Brazilian national women’s team traveled with the head coach, two assistant coaches (one of whom was in charge of the video editing), one athletic trainer, one doctor (who was also in charge of overseeing physical therapy), and the head of the delegation. By contrast, during our most recent road trip with the men’s national team, our entourage consisted of the head coach, three assistant coaches, two statisticians, one trainer, one physical therapist, one massage therapist, one doctor, and the head of the delegation. Awaiting return of the team to Brazil was a sports nutritionist, a second orthopedic surgeon, and an internist.

More important than the number of personnel, however, is the respect that all the staff have for each other. As a result, the staff work very well together. For example, when practicing during a road trip, everyone chips in to shag balls so that the practice time can be more productive.
During some years, I kept statistics while sitting on the bench, and at other times this work has been done by the physical therapist. All of us are willing to work outside our comfort zones for the good of the team.

Even though everyone on the staff functions in multiple roles, and frequently gives opinions in areas other than their specialty, the coaching staff have always respected the medical decisions made by the team medical personnel. During my 20 years of working with the Brazilian national teams, when it comes to medical issues my decisions have always been respected as the final word.

**Cooperation between national and club teams**

The national team (NT) season begins when the club leagues around the world end, usually in late spring. Since different leagues end at different times, some athletes may have very little time off from the demands of the sport. Eventually, the elite NT athletes all arrive at our training center in Saquarema. With little time off, this transition can be very stressful for the athlete. One source of possible stress for the medical team is effective

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**Figure 14.1** The elite volleyball athlete places him or herself at risk of injury simply by taking the floor.
communication with the health providers that supervised each athlete’s medical care during the just completed club season. During this transition between commitments, it is vital that communication between medical personnel is clear to all parties involved. Essential details about those athletes who are (or have been) injured must be clearly transmitted so that the athlete can continue to receive prescribed treatment. Occasionally, there may be disagreement between the two medical staffs regarding the diagnosis or the appropriateness of therapy. This can strain relationships with the club medical staff. At these times it is best to remember that the goal is to work for the health and well-being of the athlete, and to “do no harm.” In such situations, it might prove helpful for the medical staffs to arrange consultations prior to initiating treatment so that all can agree on the optimal course of action. When the NT season has concluded, we send a report on every athlete who has been under our supervision to the appropriate club medical staff. In complicated cases, or when there is an important injury or problem not to be missed, we speak personally with the club doctor.

### The pre-season assessment

An assessment of the athlete’s injury history and a physical examination are performed on each athlete prior to the start of the season. In 2014, 230 indoor athletes underwent precompetition evaluation as part of the indoor national team program (Table 14.1, Boxes 14.1, 14.2).

As part of these precompetition evaluations, all players undergo odontological, ophthalmological, orthopedic, and gynecological (women) examinations. After a detailed history and system review, we proceed to a physical examination in all relevant areas, then collect relevant laboratory analyses. Among other things, we test the pH of the saliva, test for gingival bleeding and conduct an oral cytological exam for bacteria and fungi. Panorex and bite wing x-rays screen the athlete for dental decay. Routinely, every 2 years, we test visual acuity, extraocular muscle function, tonometry, and direct fundoscopy. If there are any complaints or any findings in the clinical, orthopedic, gynecological or specialty tests, we conduct the appropriate exams. The laboratory analyses performed are shown in Box 14.3.

After we finish all these screening exams, as well as any others that may be indicated, we have an understanding of the current issues for every athlete.

<table>
<thead>
<tr>
<th>Table 14.1 Brazilian indoor volleyball athletes evaluated in 2014.</th>
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<tbody>
<tr>
<td><strong>Category</strong></td>
</tr>
<tr>
<td>Under 15 female</td>
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<tr>
<td>Under 15 male</td>
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<td>Under 17 female</td>
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<td>Under 19 female</td>
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<td>Under 29 male</td>
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<td>Adult female</td>
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<td>Adult male</td>
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<td><strong>TOTAL</strong></td>
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### Box 14.1 Healthcare specialties involved in evaluation and care of Brazilian national team athletes, 2004–2014.

**Medicine**
- Internal medicine
- Sports medicine
- Clinical cardiology
- Cardiology (echocardiography)
- Orthopedics
- Clinical pathology
- Ophthalmology
- Radiology
- Gynecology
- Genetics
- Odontology
- Surgeon

**Nutrition**
- Sports nutritionist

**Physical education**
- Professor

**Technicians**
- Laboratory medicine
- Radiology
- Nursing auxiliary
As a medical team, we begin to address each issue identified by the periodic health evaluation (PHE). Once the process is completed, we are ready to begin training.

**Box 14.2 Diagnostic and laboratory testing performed on Brazilian national team athletes.**

- Odontology
- Ophthalmology
- Clinical
- Orthopedics
- Gynecology
- Laboratory (clinical pathology)
- ECG (at rest and with effort)
- Echocardiogram with Doppler
- Pulmonary function
- Dietary analysis
- Kinematic analysis
- Anaerobic testing (Wingate test)

**Box 14.3 Examples of tests obtained by Brazilian national team physicians.**

- **Blood work**
  - Blood type ABO
  - Rh factor
  - Hemogram
  - Iron
  - Ferritin
  - Vitamin B12, folic acid
  - Vitamin D3, C, and A
  - Transferrin, albumin, and globulins
  - Glycosis
  - Total cholesterol
  - HDL and LDL cholesterol
  - Triglycerides
  - Creatine phosphokinase
  - Uric acid
  - ALT, AST, γ-GT, bilirubinase
  - Alkaline phosphatase
  - Urea
  - Creatinine
  - NA, Cl, K, Mg, Ca, P, Cr, Se, Zn
  - TSH, T4, cortisol, testosterone
  - FSH, LH, progesterone, estradiol
  - Serology for hepatitis A, B, and C
- **Urinalysis**
  - Urine culture
- **Fecal analysis**
  - Parasitology

**Sport-specific training**

Generally, we begin by training in the sand. This permits the athletes to recover somewhat from the rigors of the club season by minimizing ground reactive forces and thus reducing the load on the lower limbs. After this short period, we start practicing indoors and lifting in the fitness center. The adult national team, when out of competition, stays in our training center from Monday to Saturday morning, practicing on the court two periods per day, for approximately 2 hours per session. One of the two daily sessions is devoted to fitness and strength training. Between those periods, the players who need it receive physical therapy treatment, in addition to receiving recovery treatment at the conclusion of the day (e.g. soaking in an ice bath).

The elite volleyball player needs to diligently prepare for playing sport at the highest possible level throughout the entire year. Maintaining fitness throughout the entire season enables the athlete to achieve peak performance year round, and to be ready when called upon.

In 2001, we embarked on a novel, virtually revolutionary strength and conditioning program with the Brazilian men. Observing that many of the athletes exhibited imbalances of muscle strength and had significant proprioceptive deficit (predominantly at the knee and shoulder), it was decided that the physical preparation should focus on improving muscular strength with balance between agonist and antagonist muscles and that could impact on proprioceptive performance. Strict control over the intensity of the effort was key to the success of this strategy. Moreover, this strategy allowed training of vertical jump skill through plyometric exercises. With an established muscular base, volleyball technical skills could be trained without premature impairment of motor coordination due to muscle fatigue. Flexibility training, both dynamic and static, was emphasized during physical conditioning drills. With a muscle strength base established, we began the interval training sessions by emphasizing technical skills and tactical strategies. This strategy has improved the aerobic and anaerobic endurance specific to the demands of the game.
Injuries and returning to play

Injury is the biggest fear of any athlete, but particularly professional athletes since playing the sports they love is the way in which they earn their salary. According to the literature, the kind of injuries sustained by recreational and elite athletes is similar, but the approach to treating elite athletes has to be totally different. If a recreational player comes to my office with a grade 1 ankle sprain, he will stay out of competition for 3 weeks, receive physical therapy 1 hour a day, and if he returns to play in 4 weeks he will be happy. If, on the other hand, a national team athlete sustains the same type of injury, treatment will be much more aggressive. Advanced radiographic imaging will be obtained early to rule out fracture and, depending on which portion of the season it is, the athlete will receive physical therapy around the clock. Aggressive pain management will permit early ambulation. In less than 1 week the athlete will return to play. Although we must respect the biology of healing when determining when an athlete may return to play, sometimes the elite player’s schedule will force the medical staff and player to “push the envelope of risk” somewhat.

Four brief cases will illustrate the way in which medical care for elite athletes can differ from the way in which recreational athletes are typically treated. Coincidentally, two of these athletes suffered injuries requiring surgery 4.5 months before the Olympic Games. Figure 14.2 demonstrates the rotator cuff tear suffered by a member of our national team prior to the Athens games. Figure 14.3 shows an anterior cruciate ligament (ACL) lesion suffered by one of our athletes prior to the Beijing Olympics. The normal recovery time from a shoulder surgery is 6–9 months, for an ACL tear 9–12 months. These two athletes underwent surgery, and each, somewhat miraculously, was capable of playing in the Olympics. Achieving this goal required the agreement and concerted effort of the athletes and the medical staff. The other two cases are from the 2014 World Championships in Poland. In Figure 14.4, there is a grade 1 muscle lesion. Normally, a thigh contusion such as this would keep a player out of competition for at least 10–15 days. Because of the important role played by this athlete and the importance of the competition, he attempted to return to competition in 3 days. Despite intensive physical therapy treatment and the use of a compression bandage, his performance was not up to his usual standard. Figure 14.5 shows the knee MRI.

Figure 14.2  This member of the Brazilian national team sustained a tear of his supraspinatus 4.5 months before the 2004 Olympic Games in Athens. He underwent surgical repair and was subsequently able to play, winning a gold medal.
of a player who experienced chronic pain in the quadriceps tendon. Despite this discomfort, he was able to play in all the important games of the tournament.

Figure 14.3 An ACL lesion sustained 4.5 months before Beijing 2008. The athlete underwent reconstruction with a hamstring tendon allograft. He played in the Games, winning a silver medal.

Figure 14.4 A grade 1 thigh muscle lesion sustained during the 2014 World Championships. The player returned to play in 3 days, but did not perform at his best.

Supplements and other therapies

Medical doctors who work with elite teams must keep up to date on all new therapies, medications, and supplements that claim to enhance performance, treat and prevent injuries, and decrease pain. When injured, athletes want nothing more than to recover as fast as possible. Occasionally, this will prompt the athlete to look for a “miracle cure” so we have to try and ensure that the athlete does not believe everything he may hear or read regarding the effect of these interventions.

Due to the repetitive loading and weight bearing of their knees, the majority of professional players will sooner or later develop degeneration of their knee joint cartilage. Based upon our experience, we advise those athletes to take supplemental glucosamine and chondroitin. Intraarticular hyaluronic acid is also beneficial in the management of degenerative joint disease, but since it is an invasive therapy, we try to avoid it if possible.

The use of PRP is very controversial in the literature, and since we do not have abundant proof of its effectiveness we do not use it, either for chondral lesions or for muscle injuries. In selected cases of patellar or Achilles tendonitis that are refractory to traditional methods (such as physical therapy), a trial of PRP may be considered as the last chance intervention, prior to going to surgery.
Supplements such as whey protein, creatine, and amino acids are popular with athletes. We determine on a case-by-case basis whether or not such supplements might be beneficial to the athlete. We advise the players to drink as much water or sports drink as they need to stay hydrated. We find carbohydrate gel helpful to maintain physical performance during competition. Of course, doping control is the responsibility of the team doctor as well. All players should be advised to check with the team doctor to verify that all medicines prescribed are not on the Prohibited List, and reminded that ultimately they are responsible for all products ingested.

**Traveling around the world**

The national team spends a great part of each season (at least 2 months) in foreign countries. This presents a considerable stress for the team and staff. Frequently, travel will be complicated by a significant time difference (3+ hours) between the point of departure and the destination. The resulting jet lag leads to sleep dysfunction, and the resultant fatigue can negatively affect individual and team performance. In the past, we have administered melatonin to the athletes in an effort to regulate sleep, but we found it generally ineffective. We have had more success with shifting the body clock and synchronizing meals, activities, and sleep to coordinate with the corresponding time at our destination. Maintaining adequate hydration during travel and avoiding alcohol are also important in minimizing the effect of crossing several time zones.

In a foreign country, the accommodations and menu might be substantially different from what we are used to in Brazil, so if our inquiries and inspections fail to reveal an adequate variety and selection of food, we take it upon ourselves to shop for items that will be palatable and nutritious. Since we are away from home for weeks at a time, the comfort of the hotel is another concern. Small details such as having access to reliable internet service can make a huge difference to team morale if the athletes are able to maintain communication with their families back home.

Also at issue when we are on the road is access to medical facilities should we need them. In competitions such as the Olympics, all manner of imaging modalities and clinical care are available, but for smaller or less well-structured events, or for events held in countries that may not have all the medical equipment we might need, another issue would be where we should take the players if they require prompt medical care. Team doctors not only attend to sprained ankles and sore shoulders, but also must diagnose and treat medical illnesses such as flu, common colds, diarrhea, sore throats, stomach aches, headaches, etc. We always carry medications for the most common diagnoses that might affect the players, since at times it becomes a challenge to identify a local doctor to provide the athlete with a prescription. We also have supplies for a small surgery, should stitches be necessary to close a wound. The physical therapist who travels with us brings all his equipment as well, since the majority of the players need his help daily. We may also visit local healthcare practitioners if we think their services would be helpful (like an acupuncturist when in Asia).
Lastly, it is advisable to have a “disaster plan” in case an athlete’s injury requires prompt intervention that is unavailable or inadvisable in the host country. I recall that in my first official match as a team doctor for the men’s national team, one of our athletes ruptured his patellar tendon, necessitating his prompt return to Brazil to facilitate surgical repair (Figure 14.6).

In conclusion, matches and championships are often decided in the details, so taking care to provide the best conditions for the team can make a big difference in the final result.

Brazilian volleyball: the Diamond Generation

Getting to the top is difficult, but remaining there is even more difficult.

(Bernardo Rezende, Brazilian national men’s team coach)

In the 1980s, the Brazilian national men’s team experienced their best results ever. However, winning silver medals in the 1982 World Championship and the 1984 Los Angeles Olympic Games in 1984 proved to be a mere prelude to the team’s success in the 1990s through 2010. In 1992, the Brazilian men won the gold medal at the Olympic Games in Barcelona, thus becoming known as the “Golden Generation.” Between 2001 and 2010, Brazil won three World Championships, eight World League titles, two World Cup trophies, and three Olympic medals (two silver and one gold). This group of athletes became known as the “Diamond Generation” (Figure 14.7).

What is the difference between a team or an athlete who wins repeatedly (such as the Diamond Generation) and a team or an athlete who always comes up short of the medals stand? Athletes can be born with the DNA that provides the blueprint for the physical capacity to play volleyball. But it is only when ability is mixed with determination and hard work, in an environment that pushes athletes and teams to succeed, that special talents are created. Those who would be the best are the athletes who are driven to succeed, and are willing to put in the effort to improve year after year. Some players burst upon the scene from nowhere, but they do not commit to improving and growing with the team, and so they fail to progress to elite status.

If a team can attract players with all the desired qualities, and has a coach who works tirelessly day and night considering every detail on and off the court and is respected by his/her staff and the players, then that team will definitely be successful once they develop the intense focus and concentration required. Those traits are what distinguished Brazilian volleyball from other programs, and ultimately led to the legend of the Diamond Generation.

In Brazilian volleyball, we had two other cases where we could reach the gold standard in winning competitions. Our national women’s team became part of world elite volleyball in the 1990s, winning medals but facing an extraordinary Cuban team that won everything back then. After struggling at the beginning of the current century, and failing in the decisive moments, the team was able to recover, mainly in the mental aspect, and now is
The elite indoor volleyball athlete is unique. He or she competes year round and is vulnerable to multiple stressors. It is important to provide the elite athlete with state-of-the-art medical care, including injury prevention, treatment, and rehabilitation. The national team physician may also be responsible for prescribing proper medication, managing doping-related issues, counseling the athlete on nutrition and the use of dietary supplements, and attending to travel-related issues. It is of critical importance to build an experienced support staff around the team in which all members are open to the suggestions of others and work cooperatively. In doing so, the international volleyball athlete can concentrate fully on the core goal of any elite athlete: winning games and competitions!

**Recommended reading**


Chapter 15
Adapted volleyball for the athlete with an impairment

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Introduction

The Paralympic sporting movement has its roots in post-World War II England where a physician by the name of Ludwig Guttmann conceived of sport as a means of enhancing the rehabilitation of spinal cord-injured soldiers being treated at the Stoke Mandeville Hospital. Guttmann subsequently organized the first International Wheel Chair Games to coincide with the 1948 London Olympic Games. The Wheel Chair Games evolved into the Paralympic Games, which were first held in 1960 in conjunction with the Rome Olympics. Since then, the Paralympic movement has grown to include athletes with many types of physical impairment and disability. Over this intervening half-century, several sports have been adapted to allow a growing number of impaired individuals the opportunity to participate and compete.

In the mid-1970s, the World Health Organization published the International Classification of Impairments, Disabilities, and Handicaps (ICIDH). The ICIDH established a concept of disability which first defines the level of functional impairment suffered by the individual as a result of injury or disease, and then proceeds to evaluate the resulting disability and handicap caused by the impairment. The ICIDH therefore provides a conceptual framework that has improved our ability to accurately communicate the extent to which an individual with an impairment may be functionally limited.

The ICIDH defines the following terms.
1. Impairment: *is any loss or abnormality of psychological, physiological, or anatomical structure or function.* An example would be a volleyball player with a transtibial (below-knee) amputation.
2. Disability: *is any restriction or lack of ability (resulting from an impairment) to perform an activity in the manner or within the range considered normal for a human being.* An example would be the ability of the aforementioned volleyball player to ambulate without a prosthesis or other assistive device.
3. Handicap: *is a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment of a societal role that is considered normal (depending on age, sex, and social and cultural factors) for that individual.* For example, the individual with the trans-tibial amputation would be expected to be handicapped with regard to sports participation.

However, volleyball has been adapted in several ways to permit participation by individuals with impairments, thereby eliminating the role-specific handicap. The various forms of adapted volleyball may be played by individuals with a variety of physical and mental impairments and disabilities, including (but not limited to) limb amputation, neuromuscular disorders, and hearing loss (deafness). As a result, the impaired individual may be disabled...
but, thanks to a modification of the sport, may not be handicapped with regard to participation in volleyball.

In order for competition between individuals with various impairments to be fairly contested, there are accepted international standards which must be met for the athlete to be eligible for competition. For example, for an athlete to be eligible for the World Games for the Deaf, she/he must demonstrate a hearing loss of 55 dB or greater in both ears (a standard established by the Comité Internationale des Sports des Sourdes – CISS). Individuals with mental retardation (defined as an IQ of less than 70) can participate in the volleyball competition of the Special Olympics International World Games. To participate in adapted volleyball internationally, an individual must have a physical disability.

The two forms of volleyball that have been most recently contested during the Paralympic Games are sitting volleyball and standing volleyball. Only sitting volleyball is included on the current Paralympic calendar.

### Sitting volleyball

Sitting volleyball, considered by some to have evolved from a fusion of volleyball with the German game of “sitzball,” was developed in the Netherlands where the first competitive match was played in 1957. Sitting volleyball has subsequently grown into the most popular form of adapted volleyball for individuals with physical impairment.

Sitting volleyball varies from conventional volleyball in three obvious ways:

1. the court is smaller (10 × 6 m total dimension, compared to 18 × 9 m for the standing game)
2. the net is lower (1.15 m for men/1.05 m for women versus 2.43 m for men/2.24 m for women in regular volleyball) (Figure 15.1)
3. participants must remain “seated” during competition (the rule stipulates that it is obligatory for a player’s buttock or part of the athlete’s torso to remain in contact with the floor at all times) (Figure 15.2).

![Figure 15.1 Sitting volleyball is played on a smaller court, with a lower net, than is able-bodied volleyball. Source: World ParaVolley. Used with permission of World ParaVolley.](image-url)
Adapted volleyball for the athlete with an impairment

To participate in international competition, the sitting volleyball athlete must meet a “minimum standard of disability” as defined by World ParaVolley (WPV), the international governing body for sitting and standing volleyball (Figure 15.3). This means that the athlete’s impairment may appear minimal but nonetheless prevents the individual from competing in the conventional version of the sport. The process by which athletes with an impairment are evaluated for qualifying disability is referred to as “classification.” Classification evaluates the extent to which individuals with physical impairments are capable of moving and performing the physical actions demanded by the sport, i.e. classification defines their sport-specific level of functional limitation. Sitting volleyball classification is based on the “Amputee and Les Autres” system used by the International Sports Organization for the Disabled (ISOD). In general, classification is conducted utilizing one or more of the following measures: the level of amputation, muscle strength, joint range of motion, and differences in limb length.

Furthermore, there are minimum team standards which must be met in an effort to ensure that fair functional balance is maintained between teams. “Class allocation” refers to the process of quantifying the amount of disability that results from the qualifying impairment. In sitting volleyball, there are only two recognized categories: minimal disability (MD) and disabled (D) (Figure 15.4). WPV regulations for international competition require that of the six people who comprise a sitting volleyball team (i.e. the athletes on the court at the same time), only one may carry a “minimal disability” classification. In many countries, sitting volleyball is also enjoyed recreationally by mixed teams featuring both able-bodied and impaired persons, making sitting volleyball truly an integrated sporting pastime at the grassroots level.

Standing volleyball

A “standing” version of adapted volleyball for athletes with physical impairments has also gained considerable popularity around the world. Standing volleyball is not presently contested in

Figure 15.2  The rules for sitting volleyball stipulate that the athlete’s buttocks or torso be in contact with the playing surface at all times. Source: World ParaVolley. Used with permission of World ParaVolley.
the Paralympic Games, having last been on the schedule during the 2000 Paralympics in Sydney.

Originally developed in Great Britain, standing volleyball is played by individuals with congenital or acquired limb deficiency (“amputation”) or other neuromuscular limb impairment. The rules for disabled standing volleyball are modified only slightly from those of the Fédération Internationale de Volleyball (FIVB). Court size and net height are unchanged, as are the basic rules governing scoring and ball handling. The only significant difference is that each athlete must meet a minimum level of disability as defined by the classification system endorsed by World ParaVolley. This system considers level of amputation, loss of motor function, and restricted range of motion, in an effort to group athletes with similar movement potential together. Based on their disability classification, players are assigned to one of three classes: A, B, or C. In general, athletes with greater functional limitations are assigned to class C, while those with minimal degree of impairment are assigned to class A (class B is intermediate). During sanctioned international competitions, each standing

Figure 15.3  World ParaVolley is the international governing body for the adapted forms of volleyball that are competed throughout the world. Source: World ParaVolley. Used with permission of World ParaVolley.
Classification Figure for International Sitting Volleyball

The below diagram is a guideline for international classification. The classification below does not prevent other athletes from competing at community, club and national levels.

Shoulder
- No movement (cannot raise above 90 degrees)
  Classification: FULL DISABLED

Upper limb
- One limb shorter by more than 1/2
  Classification: FULL DISABLED

Amputee above elbow
Classification: FULL DISABLED

Amputee below elbow
Classification: FULL DISABLED

Amputee above knee
Classification: FULL DISABLED

Amputee below knee
Classification: FULL DISABLED

Lower limb
- One limb shorter by more than 1/3
- Paralysis of limb
  Classification: FULL DISABLED

Upper limb
- Weakness or paralysis of limb
- One limb shorter by up to 1/2
  Classification: MINIMAL DISABLED

Elbow (no movement)
Classification: MINIMAL DISABLED

Wrist (reduced movement)
Classification: MINIMAL DISABLED

Hand and fingers
(7+ digits missing or not functional)
Classification: MINIMAL DISABLED

Hip (replacement joint)
Classification: MINIMAL DISABLED

Lower limb
- Weakness of limb
- Decreased range of motion due to injury (eg. severe ACL tear)
- One limb shorter by up to 1/3
  Classification: MINIMAL DISABLED

Ankle (fused or decreased motion)
Classification: MINIMAL DISABLED

Foot (amputation above toes)
Classification: MINIMAL DISABLED

Figure 15.4 For international sitting volleyball competitions, athletes must be classified prior to any participation. Athletes will be classified as either minimal disability (MD) or full disabled. Teams can only have two MDs on the roster and one MD on the court at any given time. Source: World ParaVolley. Used with permission of World ParaVolley.
team must have no more than one class A player on the court and at least one class C player on the court at all times.

**Adapted beach volleyball**

With the growing popularity of the beach game, an effort has been made to adapt sand volleyball to provide persons with physical impairments the opportunity to enjoy the sport and compete on the beach. The two versions (sitting and standing) follow a combination of the rules of able-bodied beach volleyball, and World ParaVolley sitting and standing volleyball. Sitting beach volleyball is played with three players on a team, on a court measuring 4 x 4 m. Standing beach volleyball is played on a regulation 8 x 8 m court with three players per team. For purposes of classification, only one minimal disability athlete may be included per team (the equivalent of a class A standing player). The remaining two players (no substitutions allowed) must be the equivalent to a standing class B or C rating. At present, sitting and standing beach volleyball are not contested in the Paralympics, nor is standing indoor volleyball.

**Injury patterns**

Volleyball, in virtually all its forms, has developed into a sport of explosive, powerful skills. These skills place enormous demands on the musculo-tendinous and ligamentous structures of the shoulders, low back, hips, knees, and ankles, and consequently these structures are at increased risk for injury. Since congenital and acquired limb deficiencies, combined with the use of prosthetic limbs, may result in significant biomechanical alterations of how sport skills are performed, to say nothing of how loads are absorbed and dissipated, soft tissues along the kinetic chain may be at even greater risk of overload and overuse injury compared to the able-bodied athlete (Stewart 1983). On the other hand, the biomechanical demands of adapted sport may be significantly different from those of the able-bodied version. It would be reasonable to speculate, then, that volleyball athletes with impairments may be at increased risk for injury when compared to their able-bodied counterparts. Unfortunately, there is scant published research on this topic in the world literature.

Ferrara and Petersen (2000) and Nyland *et al.* (2000) have studied the injury trends among athletes with physical impairment, but their studies did not focus on adapted volleyball specifically. Although it might appear reasonable to determine the risk of volleyball injuries based upon research focusing on other forms of adapted sport, most of the recent sport literature focuses on wheelchair athletics and on adapted alpine skiing, sports that do not share common equipment movement patterns or physiological demands with volleyball (Busconi and Curtis 1995; Shephard 1988). Ferrara *et al.* (1991) retrospectively studied injury prevalence among several disabled sports groups and concluded that disabled athletes had injury rates comparable to able-bodied athletes. However, the sport-specific injury patterns of impaired athletes understandably differed from those of able-bodied athletes competing in similar sporting disciplines.

Other researchers, however, have concluded that disabled athletes are “more vulnerable to stress and fatigue” (Jackson and Fredrickson 1979), and have suggested that “there is a need ... for better training of disabled athletes” (Calmels *et al.* 1994). These factors might be hypothesized to present a significant problem for standing volleyball athletes, in view of the fact that most are limb amputees and the use of a prosthesis involves considerable metabolic cost. Studies have demonstrated that an individual with a below-knee amputation expends between 15% and 55% more energy during ambulation than does a nonamputee (Gailey *et al.* 1997).

Only three studies have been published that investigate the injury history of disabled volleyball athletes. In their survey of injuries occurring among 1992 British Paralympians, Reynolds *et al.* (1994) reported that 90% of the volleyball team members were treated for injuries suffered during
Adapted volleyball for the athlete with an impairment

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Training or competition—the highest percentage among any of the 15 British disabled sports teams that participated in the Barcelona Paralympic Games. Unfortunately, the authors did not specify if these were standing or sitting volleyball players, nor did they provide a sport-specific or diagnosis-specific breakdown of the different injuries sustained and treated. The second study investigated the incidence of osteoarthritis in the sound lower limb among male lower limb amputees who also play volleyball (Melzer et al. 2001). The authors found that amputees have a higher prevalence of knee joint arthritis in the sound limb than in matched healthy controls.

The third study was a self-reported retrospective review of the injury history of disabled standing volleyball athletes participating at the 1996 Atlanta Paralympic Games (Reeser 1999). Based on the athletes' own estimation of the number of volleyball exposures (practices or competitions) within the preceding year, a time-lost injury rate of approximately 8.5 per 1000 athlete exposures was calculated. The most frequently injured body parts were (in rank order): the ankle/foot, shoulder, wrist/hand, and knee. The most common diagnoses were sprain, strain, tendinitis, and bursitis. The majority of injuries reported by the standing volleyball Paralympians who participated in the study were described as new (60%) and occurred during practice or warm-up more often than during competition (64% versus 36%). These percentages are similar to those documented by the Injury Surveillance Program for women's collegiate volleyball in the United States (Datalys, Indianapolis, IN). As with able-bodied volleyball players, skills involving jumping, such as blocking and spiking, were identified most frequently as the activities leading to injury. Furthermore, 80% of the ankle/foot injuries were reported as being caused by contact with another player. The majority of reported injuries involved the lower limb (58%), comparable with the NCAA ISS data (61%). The residual limb or prosthesis was involved in less than half of the lower limb injuries, and in none of the upper limb injuries reported. Fifty-six percent of the time, the athlete returned to participation within 6 days, compared to 73% of the time reported for NCAA women's volleyball during the 1995–1996 season.

However, more time off was taken for injuries occurring earlier in the season than was taken for injuries occurring later in the season. This observation may reflect injury severity, or simply indicate the reluctance of Paralympians to miss important season-ending competitions.

Comparison between the injured and noninjured groups revealed no significant difference between the estimated number of athlete exposures per year. Those athletes who reported injuries were more likely to have lower limb impairment as a cause of their disability. However, there was no relationship between the nature of the athlete's impairment and the body part injured, diagnosis, or severity of injury (as gauged by time off from training or competition). Lower limb injuries were associated with a longer time off for healing compared with upper limb injuries. Injured athletes were less likely to participate in strength and conditioning programs during the season than were uninjured athletes. Finally, players who remained healthy throughout the year were somewhat more likely to have played volleyball prior to becoming disabled, or have had a congenital disability, than were players in the injury subgroup (57% versus 43%).

The estimated injury rate for elite disabled volleyball players reported in this study is over twice as high as the injury rates reported in other studies of able-bodied volleyball players. Unfortunately, due to differences in study design, meaningful comparison of these data with other existing studies is not possible. The results suggest, however, that disabled standing volleyball players sustain similar kinds of injuries, involving similar etiological factors, as their fellow able-bodied athletes. Disabled volleyball players with lower limb impairment do appear to be at an increased risk of injury when compared to their teammates with upper limb impairment. Adaptive biomechanical alterations or substitutions occurring during performance of volleyball-specific skills involving jumping may contribute to the increased injury incidence in this subgroup (Kibler et al. 1992; Molnar 1981), and may also contribute to an increased risk of osteoarthritis in the sound tibiofemoral joint. This suggests that unique, individualized training and conditioning programs should
be designed for athletes based on their impairment to minimize the risk of injury and to facilitate their rehabilitation from injury.

Finally, the data indicate that players who remained healthy were more likely to have a congenital impairment or have learned to play volleyball prior to their disability. While not statistically significant, this observation raises questions regarding motor learning of sport-specific skills following a disabling injury or illness. From a coaching standpoint, it would be prudent for coaches of disabled athletes to pay particularly close attention to form and technique when teaching new volleyball skills to minimize the risk of overuse pathology brought on by subclinical biomechanical adaptations or substitutions.

**Summary**

As the Paralympic movement attests, disabled sport has evolved from therapeutic recreational activities introduced by Ludwig Guttmann into intensely competitive international sport (McCann 1996). As these elite athletes strive to become stronger, run more swiftly, and jump higher, their risk of injury increases (Webborn and Emery 2014). Although much research needs to be conducted, the limited work that has been published appears to demonstrate that disabled volleyball athletes may have an increased risk of injury compared with their able-bodied counterparts. As adapted volleyball continues to grow in popularity, it may be that future volleyball competitions will feature greater integration of disabled and able-bodied athletes. It would therefore behoove all volleyball coaching and sports medicine personnel to understand the injury patterns of disabled athletes so that they receive the optimum care they deserve. Clearly, further prospective studies are needed to improve our understanding of the natural history of injuries among volleyball players with an impairment. In particular, research is needed in the area of sitting volleyball. Because sitting volleyball attracts athletes with different impairments than does standing volleyball, it follows that injury patterns may differ between the two forms of adapted sport.

**References**


Recommended reading

Introduction

What makes competition fair? Is it comparable age? Equal strength? Is there a minimum IQ that results in fairness? What of socioeconomic status? The best answer to the question is probably “All of the above” since there are undoubtedly competitions in which an unequal distribution of any of these traits could systematically influence the competitors’ chance of victory. In sport, one consistent answer is sex.

Postpubertal males typically outperform females of similar developmental status due to superior physical traits (on average) whose expression is (in part) developmentally regulated by testosterone. In fact, testosterone and many other genes participate in a tightly orchestrated process whose outcome is an individual’s trainable phenotype that includes size, strength, and speed. Consequently, to ensure fair competition, it has always stood to reason that males should compete against males, and females should compete against females.

This seems intuitively obvious, and as long as sex is reliably a dichotomous condition, the paradigm of competing against members of the same sex makes sense. But what happens when the relationship between sex and elevated levels of endogenous androgens becomes disconnected? How do we maintain the promise of fair and equitable athletic competition in the face of variable hormone levels, or indeed variable sexes?

The process by which a fertilized egg becomes a female or a male is a multistep process that is much more complicated than the simple chromosomal paradigm XX=female and XY=male would suggest. At every step along this complicated, genetically determined developmental pathway, there exists the possibility that a statistically improbable event will occur that will influence the degree and timing of the physiological response to endogenous androgens. In fact, a continuum of states has been described. These were once termed “intersex” but have more recently been identified by the descriptive nomenclature [46,XY Disordered Sex Development]. “Issues of sexual identity” also seems an appropriate way to characterize the struggle that these athletes encounter.

Although volleyball is (as far as we know) no more or less affected by issues of sexual identity than any other sport, it seems appropriate to discuss the potential impact of both disordered sex development (DSD) and transsexuality (TS) on the sport, including our ability (or inability) to guarantee freedom from issues of sex bias and resultant phenotypic inequality in sport. As we shall see, these “statistically improbable events” have the power to challenge long-established paradigms of what constitutes fairness on the athletic pitch or volleyball court.
Disorders of sex development

Disorders of sex development is a catch-all phrase that collectively describes the morphological and functional outcomes of a variance in the sex determination pathway (Box 16.1). One cause is insensitivity to androgens due to a faulty androgen receptor, despite the presence of an XY karyotype. Other possible etiologies of DSD in XY individuals include genetic mutations leading to 5-alpha reductase deficiency, 17-alpha reductase deficiency, or C17 hydroxylase deficiency, all of which may profoundly virilize at puberty with activation of alternative pathways. In XX fetuses, defects in the pathway leading to production of cortisol and compensatory ACTH secretion result in congenital adrenal hyperplasia with variable, at times profound, virilization.

Depending on the exact cause of the DSD, the phenotypic consequence is typically apparent at birth. The newborn infant may demonstrate a variety of phenotypes ranging from that of a “normal” female (but with undescended testes) to hermaphroditic with a rudimentary vaginal orifice and distinct clitoral hypertrophy. This genital ambiguity makes it difficult for the obstetrician and parent(s) to designate the infant as definitively male or female. Thus, the descriptive phrase “disorders of sex development” (or differences, as some advocates prefer) has gained favor to describe these “intersex” phenotypes that lie somewhere in the middle of our traditional binary concept of sex as either male or female. From a practical standpoint, in most instances of DSD the individuals are raised as females even though they may have a Y chromosome.

Historical perspective

In the mid-1960s, the International Olympic Committee (IOC) and the International Amateur Athletics Federation (IAAF, the international governing body for track and field) encountered a rash of female athletes who were decidedly masculine. Among the possible explanations entertained to explain this influx of females with male characteristics (who also happened to be very good athletes) was that men were masquerading as females. In order to discourage misrepresentation of identity and to ensure that “athletes are competing on an equal basis considering their physical status,” it was decided to require sex verification tests of all athletes registered to compete in female contests.

Regrettably, the first attempts at sex identification were clumsy and unquestionably demeaning to the competitors. In 1966 at the European Track and Field Championships and in 1967 at the Pan American Games, female athletes had their genitals directly examined by a panel of physicians.

| Box 16.1 Examples of “disordered sexual development.” |

Athletes with conditions that afford no advantage over females should be allowed to compete as females.

1. Complete or almost complete androgen insensitivity (previously known as “testicular feminization”). These individuals are genetically male, with XY sex chromosomes, but they are not responsive to testosterone. As a result they develop as phenotypic females, and do not gain any performance advantage from circulating testosterone.

2. Gonadal dysgenesis, in which individuals also develop female external genitalia, are genotypically XY. They have streak gonads which cannot produce sex hormones and do not experience puberty. Streak gonads are typically surgically removed at the time of diagnosis and exogenous female hormones are administered.

3. Turner syndrome is a condition affecting females in which one of the sex chromosomes is absent or partially missing. These individuals have a 45X or 45X0 genotype, and distinct physical features. They likewise do not secrete sex hormones and one aspect of treatment is often estrogen and progesterone replacement.

There are other conditions that may accord some theoretical advantage but have not been proven to enhance performance over other females. Athletes with these conditions should also be allowed to compete as females in most situations.

1. In congenital adrenal hyperplasia, genetic females’ adrenal glands secrete greater than normal amounts of adrenal hormones and may secrete androgens. However, this has not been conclusively shown to enhance performance.

2. Androgen-producing tumors may result in elevated testosterone levels, but have not been demonstrated to result in a definite enhancement of athletic performance.

3. Anovulatory androgen excess or polycystic ovarian syndrome do not confer any competitive advantage.

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3. Anovulatory androgen excess or polycystic ovarian syndrome do not confer any competitive advantage.
microscopic analysis of the presence of a Barr body in epidermal cells collected by a buccal smear (Figure 16.1). This represented a more “scientific” means of confirming female sex (defined by an XX karyotype), but the test lacked specificity. In fact, it was never a valid test for its stated purpose. It excluded women without significant physiological advantage over their competition, such as XY females with complete androgen insensitivity, while it missed XX women with congenital adrenal hyperplasia or androgen-secreting tumors who might have had a theoretical competitive advantage. In fact, from the time sex testing was introduced through to its formal discontinuation, no male was ever caught misrepresenting a female. There were accusations that a male participated on a female Asian volleyball team competing in the 1972 Munich Olympic Games, but this remains unproven.

While Barr body testing could not “level the playing field”, it did effectively devastate the personal life and careers of many unsuspecting female athletes. The first athlete to be disqualified due to absence of a Barr body was Polish sprinter Ewa Klobukowska. During a trial of the testing procedure at the 1967 European Cup, Ms Klobukowska was found to have “an extra chromosome” and “internal, male-like characteristics.” María Patiño was the Spanish national hurdles champion and in fact had been previously awarded a “certificate of femininity” (Figure 16.2) when she was screened out of competition by a test conducted prior to the 1985 World University Games. She was subsequently found to have complete androgen insensitivity. After suffering the shock and public humiliation of this disqualification on the athletic stage, Ms Patiño became the first woman to be reinstated after protesting her disqualification.

The demise of sex testing

After two decades of experience, geneticists were aware of some of the shortcomings of the karyotype test, but despite their collective protest, IOC and IAAF procedures remained unchanged. During these years, athletes who tested as “not XX” could either quietly withdraw from competition or submit to an extensive gynecological and clinical examination to decide whether they should be banned or allowed to compete. A very few followed Ms Patiño’s lead. Eduardo Hay, former chair of the IOC Medical Commission, estimated that “one or two women” were found to have DSD during each Olympic Games, beginning with Mexico City in 1968 and culminating at Calgary in 1988. Although the exact number is not known with any accuracy, over the years it seems probable that many female athletes may have disqualified themselves because of misunderstanding of the procedure or to avoid embarrassment over possible results. Others may have been screened out prior to the Olympics.

Now sufficiently concerned about the impact Barr body testing was having on its female athletes, in 1990 the IAAF convened a group of expert
physicians, scientists, and athletes to address the issue. The panel arrived at three conclusions. First, that individuals with intersex states and raised as females have no unfair physical advantage and should not be excluded from competing as females or stigmatized. No longer would females having nondrug-induced masculinization, such as those with 21-steroid hydroxylase and 5-alpha-steroid reductase deficiency, incomplete androgen insensitivity or chromosomal mosaicism, be restricted from competition. Second, that gender screening based upon identification of Y chromosomal material should be abandoned. Third, only males masquerading as females should be excluded from female competition. Despite point two above, IOC medical officials decided to retain a deterrent to sex subterfuge and adopted a more advanced buccal screen employing polymerase chain reaction (PCR) technology to detect (supposedly) male-specific SRY genetic sequences. Some felt that the IOC had missed the point in simply mandating another genetic screen, but there was optimism that the PCR test would succeed where the Barr body test had failed.

It did not. Despite the less than hoped for result, the PCR testing mechanism remained in effect through the 1996 Atlanta Summer Olympics. In Atlanta, eight of 3387 female athletes tested positive for male genetic material. Of these eight, seven had the androgen insensitivity syndrome (three complete and four incomplete). Six of the eight had had previous gonadectomy. None of the eight was excluded from competition, and there were no males caught masquerading as females. This positive test rate of 0.24% was consistent with the prior Olympics (Albertville, Barcelona, Lillehammer) for which PCR data were available. The fact that this screening resulted in no disqualifications argued against the utility of screening. Others voiced concern regarding the time, effort, and cost of this questionable endeavor. In Atlanta, for example, 58 professionals donated from 18 to 90 days of their time, and the lab testing alone cost more than $150 000.

Figure 16.2  Maria Patiño’s certificate of femininity issued prior to the World Championships in 1983. Two years later, she forgot to bring the card with her to the World University Games. Karyotype analysis on that occasion demonstrated her to have an XY genotype, resulting in her suspension from competition.
While the goal of sex testing was reasonable in theory, in practice it was difficult to justify the testing being performed. By 1999, after more than 30 years of maintaining a policy of mandatory female sex identification, the IOC was ready to accept the recommendation of medical experts and its Athlete Commission and it discontinued blanket sex testing prior to the 2000 Sydney Olympic Games.

For over a decade, there was no compulsory sex testing for females. Then Caster Semenya, a South African middle distance runner, recorded a dominant performance in winning the 800 m at the Women’s World Track and Field Championships in 2011. Her masculine physique sparked fears that elevated endogenous testosterone concentrations characteristic of DSD could provide an unfair performance advantage. Subsequently, the IOC and IAAF hurriedly established regulations prohibiting participation by female athletes if their serum testosterone concentrations exceeded 10 nmol/L, which represents the lower limit of the male testosterone reference range. Adopted in time for implementation at the 2012 London Olympic Games, it wasn’t long afterwards that an Indian sprinter named Dutee Chand challenged the regulation in court. In 2015, the Court of Arbitration for Sport (CAS) ruled that endogenous testosterone, even at concentrations within the male range, had not been indisputably proven to provide females with a significant athletic advantage compared to those with a lower concentration of testosterone. The court did allow that such evidence may yet be forthcoming, and granted the IAAF an opportunity to present new data at a future time. For now, however, by court order no sex testing or performance screening is being conducted. In fact, at the time of this writing, as a result of this CAS ruling, there are no plans to screen athletes competing as females in the 2016 Rio de Janeiro Olympic Games for hyperandrogenism.

Nearly 40 years after the first sex testing was performed, we have seemingly come full circle. In the end, the IOC’s desire to promote fair and equitable competition for its female participants has made us wiser regarding the continuum of human sexual development, and how we define male and female sex. The experience has led to an understanding that genetic based sex testing has distinct limitations that challenge its utility, and that phenotype is as important a consideration as genotype.

Transsexual athletes

Transsexuality exists when a person identifies strongly with the sex opposite their birth sex, and seeks to adopt a new sexual identity and phenotype. This process is referred to as transitioning between sexual phenotypes, and is made possible through manipulation of sex hormones and sex reassignment surgery.

The timing of the transitioning process influences the posttransition phenotype, and conceivably may leave the transsexual athlete with an “unfair” performance advantage, and thus the IOC has taken steps to regulate the Olympic participation of transsexuals. Currently, the regulations are in flux, but for many years the Stockholm Consensus served to guide Olympic participation by transsexuals. These guidelines stipulated that in order to be eligible for the Olympics in one’s acquired sex, the transsexual athlete must have undergone sex reassignment surgery and have completed a minimum of 2 years of appropriate hormone therapy. Recently, the requirement that the transsexual athlete undergo sex reassignment surgery was dropped by the IOC with the requirement that testosterone levels be maintained <10 nmol/L for a minimum of 12 months before competition. It is too soon to know what effect this decision will have on the participation of transsexuals at the Olympic level.

Timing and direction of transition

An increasing number of cases of transsexuality are diagnosed before puberty. Puberty is a time during which young men and women begin to explore their sexuality. It is also a time during which males acquire the androgen-dependent traits that generally give them competitive advantages compared to women. Some of these traits become immutable (e.g. height) while others are more malleable (e.g. muscle mass). Thus, puberty serves as a developmental landmark...
that guides the extent of intervention necessary to manipulate sex, depending on the direction of the transition to be effected (Box 16.2).

**Females who identify as males**

Although the typical volleyball female phenotype has evolved over the years, the average female volleyball athlete is shorter and less powerful than the average male volleyball athlete. Thus, there is little concern that the female who transitions to a male (FtM) will have gained a substantial competitive advantage, regardless of the timing of transitioning. For this reason, the FtM transsexual athlete need only document their legal identity as a male to be eligible to compete as a male. However, FtM athletes receiving androgen therapy as part of their ongoing phenotype maintenance should be aware that excessive supplementation may lead to a doping violation.

**Males who identify as females**

*Prepubertal transitioning, male to female (MtF)*

If a prepubertal male can be appropriately diagnosed and evaluated, and undergoes appropriate treatment prior to onset of puberty, the developmental effects of testosterone should be negligible. If sex reassignment surgery with gonadectomy is performed prior to the onset of puberty, then the youth should be permitted to compete as a female without restriction from that point forward. If surgery is not included and only hormonal suppressive therapy is prescribed, then the MtF transsexual will need to periodically document the ongoing success of suppression therapy (see Box 16.2).

**Pubertal and postpubertal transitioning, male to female (MtF)**

Males who transition after the onset of puberty must maintain hormonal treatment designed to induce and maintain their adopted phenotype so as to minimize differences between competitors. Surgery is not mandated, but hormone levels must be maintained for a sufficient length of time in order to minimize any residual androgenic performance advantage (see Box 16.2).

**Summary**

While cases of transsexual or intersex athletes are fairly infrequent in volleyball, undoubtedly there will be instances in which competitive questions may arise. Governing bodies will do best in dealing with these situations if they have a mechanism in place to address such questions prior to being confronted with them. Cases, when they do occur, must be evaluated confidentially on an individual basis. As this chapter suggests, the purpose and mechanism of evaluating an athlete's genotype and phenotype have changed over the years. Ultimately, however, the steps taken to ensure fair and equitable competition for female athletes have proven to be overly cautious. Sporting competition seeks to determine which team or athlete has greater skill and ability at a given moment. The legendary talents of a Karch Kiraly or Lang Ping are undoubtedly (to some extent) heritable, but they were also developed and polished by long hours, indeed years, of practice. In many respects, there is no difference
between the randomness of these athletes excelling at volleyball and an athlete who has been conferred a unique phenotype by virtue of issues of his/her sexual identity.

**Pronoun dysphoria**

So, what is the correct way to refer to a transgender athlete? This can be a vexing question for medical providers, coaches, and even teammates. It demonstrates the difficulty that we as a society have in dealing with these issues. Even medical providers may experience discomfort when confronted with “intersex” conditions. Some faced with this situation may try to avoid using any pronoun at all. Others attempt to dodge the issue by using the gender neutral plural “they” or “them” to refer to an individual. It may not be easy, especially for those who have previously known the athlete as a member of the opposite sex, but the answer to this question is that it is correct to refer to each individual in accordance with the sex with which they identify. “He” or “him” if they identify as male. “She” or “her” if they identify as female.

**Recommended reading**


Chapter 17

Ergogenic aids, doping, and anti-doping

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Introduction

Doping may be defined as the illegal use of biochemical substances or methods in an effort to improve or maximize athletic performance. Fortunately, there is very little evidence to suggest that deliberate doping is common in the sport of volleyball. Very few positive cases have been recorded in international volleyball since doping tests were started. Although systematic doping does not seem to be a problem, it is nonetheless important for players, coaches, and medical staff to be aware of the anti-doping regulations of the Fédération Internationale de Volleyball (FIVB).

According to the FIVB medical and anti-doping regulations, doping “contravenes the ethics of both sports and medical science, can be harmful to the health of the athlete, and constitutes a clear attempt to cheat in sports competition.” The FIVB definition of doping is restricted to the use of certain pharmacological agents, as well as selected doping methods.

The official FIVB prohibited list is based on the list of banned substances published by the World Anti-Doping Agency (WADA). The WADA prohibited list represents the standard to which all volleyball players participating in international competition are held accountable.

This chapter will discuss accidental doping, with particular attention given to compliance with the doping rules. It will also review the anti-doping programme of the FIVB. To avoid accidental doping, it is, of course, essential to confirm that substances legitimately prescribed by the athlete’s personal or team physician are not on the prohibited list. The WADA prohibited list, which is updated continuously, is available at www.wada-ama.org. The FIVB also publishes the prohibited list on its website (www.fivb.com), but it is important to note that the list of banned substances and methods published by WADA is not exhaustive in its content. Rather, it contains only selected examples of substances from the different pharmacological classes in order to illustrate which types of agents are banned. Substances belonging to a banned class of pharmaceuticals cannot be used for medical treatment except in specific, preapproved situations. This applies to all agents within a drug class, even those not specifically enumerated in the published list. For this reason, the phrase “and related substances” is emphasized throughout the list of banned substances. This term refers to and legally encompasses all drugs that belong to the class by virtue of their pharmacological action(s) and/or chemical structure.

If a banned substance is detected in the doping laboratory, the relevant sports authority will act to sanction the athlete. This is normally the IOC during the Olympic Games, the FIVB during other international competitions, or the national federation – also referred to as the national governing
body or NGB – during national competitions. It should be noted that the mere presence of the prohibited substance in the urine or blood constitutes an offence, irrespective of the route of administration, unless a therapeutic use exemption (TUE) has been granted. If an athlete is prescribed medication by a physician or uses an over-the-counter preparation, it is ultimately the athlete's responsibility to make certain that the substance(s) taken is not itself, or does not contain ingredients, on the prohibited list. In such situations, it is important to check with competent medical personnel that the product is safe from a doping standpoint.

Many, if not most, of the substances found on the prohibited list have a therapeutic indication. Frequently, it is the side effect of the agent that results in its inclusion on the prohibited list. Acknowledging this, certain agents can be used to treat illness or disease if permission is granted by the supervising authority. Up to 30 days prior to the competition, the athlete can apply for a TUE which, if granted, permits the athlete to use the agent for reasons of specific medical treatment. Note that while most common illnesses can be treated with medications that do not contain prohibited substances, the TUE permits athletes whose complex or chronic condition may be well controlled with a specified agent to continue their ongoing treatment.

Therapeutic use exemption applications should be submitted to the sport regulatory agency appropriate to the level of competition (e.g. the FIVB for international competition). The application will be reviewed by the TUE committee to evaluate the legitimacy of the intended use of the agent. For example, certain medications used in the treatment of asthma and other respiratory disorders are also powerful stimulants and are therefore banned as doping agents. Other agents may be approved with dose thresholds or restricted methods of administration. For instance, treatment of asthma with the inhaled corticosteroids salbutamol or formoterol may be allowable as long as the dosage does not result in drug concentrations that exceed specified thresholds.

Banned substances may be included in many different formulations, making the status of a product particularly confusing. Antitussive preparations have proven to be especially problematic for athletes in this regard. The most fool-proof approach to avoiding a doping violation is the simplest: never take or prescribe a product for upper respiratory symptoms, common cold symptoms, sore throats, cough, or the flu without first checking with a physician or pharmacist who has special expertise in the area of doping control.

### Nutritional supplements

Professional athletes and amateurs alike are in constant search for new methods that will enable them to achieve better sport results in a shorter time. An analysis of co-medication on the occasion of doping controls shows that a high percentage of elite volleyball players use dietary supplements. A vast array of nutritional supplements is available to athletes. These products all claim to improve physical performance, often in unique ways. However, there is little to no scientific evidence to support the majority of these claims.

Generally, athletes cite three principal reasons to justify their supplement use: to compensate for less than adequate diets or lifestyles; to meet unusual nutrient demands induced by heavy exercise; and to produce a performance-enhancing (i.e. ergogenic) effect. In the following discussion, nutritional supplements (also referred to collectively as “nutraceuticals”) will be classified either as dietary supplements or nutritional ergogenic aids (Burke et al. 2000).

### Dietary supplements

According to one proposed definition (Burke and Read 1993; Burke et al. 2000; Kreider et al. 2010), a dietary supplement should:
- contain nutrients in amounts generally similar to the recommended dietary intakes and similar to the amounts found in food
- provide a convenient or practical means of ingesting these nutrients, particularly in the athletic setting
- permit or facilitate the attainment of known physiological or nutritional requirements in athletes
Box 17.1 Supplements that meet the definition of dietary supplements (Burke et al. 2000; Kreider et al. 2010).

Sports drink
Sports gel
High-carbohydrate supplement
Liquid meal preparation
Sports bar
Vitamin/mineral supplement
Iron supplement
Calcium supplement
Protein supplement

Box 17.2 Nutritional ergogenic aids classified according to the scientific evidence for their efficacy in sports (Burke et al. 2000; Kreider et al. 2010).

With scientific support
Creatine
Caffeine
Bicarbonate

With mixed scientific support
Antioxidant supplements
Protein and amino acids
Glycerol

Lacking substantial scientific support and/or dangerous
Ginseng and related herbal products
Carnitine
Co-enzyme Q10
Inosine
Chromium picolinate
Medium-chain triglycerides
Smilax officinalis
Isoflavones
Glutamine
Prohormones
Chromium
Tribulus terrestris
Boron

- contain nutrients in large amounts for use in treating a known nutrient deficiency
- have been shown to meet a specific physiological or nutritional need that improves sports performance or treats a nutrient deficiency
- be generally acknowledged as a valuable product by sports medicine and science experts.

Agents that meet the definition of dietary supplement are summarized in Box 17.1.

It is important to appreciate that dietary supplements do not improve sports performance per se. Rather, the use of a dietary supplement may help the athlete achieve a specific sports nutrition goal that in turn creates an environment that permits optimal performance. In most cases, the use of a supplement should be part of a larger plan of optimal sports nutrition or the clinical management of a nutritional problem. This means that education is important to highlight the general importance of optimal nutrition for athletes, and to insure that dietary supplements are only used when they are beneficial to the player.

Nutritional ergogenic aids

The second category of supplements, nutritional ergogenic aids, is described by the following characteristics (Burke and Read 1993; Burke et al. 2000; Kreider et al. 2010).

- They contain nutrients or other food components in amounts greater than the recommended daily allowances, or the amounts typically provided by food.
- They claim to have a direct ergogenic (work-enhancing) effect on sports performance, often through a pharmacological rather than a physiological mechanism.
- They often rely on anecdotal support rather than documented evidence from scientific trials.
- They are generally not supported by sports nutrition experts, except where scientific trials have documented a significant ergogenic effect.

Well-conducted scientific trials have produced evidence that some ergogenic aids can enhance sports performance (Kreider et al. 2010; Russell and Kingsley 2014). The evidence available for some ergogenic aids is summarized in Box 17.2. It should be noted that each ergogenic aid works in a specific and narrow set of exercise situations, and thus may not have any effect on (or could conceivably prove to be detrimental to) the volleyball athlete’s performance.

There are three nutritional ergogenic aids for which there is some credible scientific support: creatine, caffeine, and bicarbonate.
Creatine is a high-energy muscle fuel. Stored primarily in skeletal muscle, there is some evidence to show that the oral intake of large doses of creatine can increase muscle stores of phosphocreatine. Since phosphocreatine provides a rapidly available, but transient, source of cellular energy, it appears to increase performance during repeated maximal efforts of 5–10 s duration in laboratory tests. In other words, volleyball players may experience a performance-enhancing effect from creatine loading. However, it is important to note that about 30% of individuals appear to be nonresponders. Creatine loading consistently leads to a weight increase of 1–3 kg, probably as a result of water retention within muscle. Such an increase in body weight is clearly detrimental to the jumping athlete. Furthermore, the published studies have not been conducted with elite athletes, nor are the protocols and performance outcome measures directly relevant to volleyball. Reports have also suggested that creatine use can precipitate compartment syndrome in the lower limbs. For these and other reasons, including the lack of large-scale long-term studies, a cautious approach to creatine use seems warranted.

Caffeine stimulates the central nervous system as well as cardiac muscle, and promotes both diuresis and epinephrine release and activity. There is no clear mechanism to explain the “beneficial” effects of caffeine supplementation. Whereas caffeine has been shown to increase performance during steady-state endurance exercise (such as running and swimming), studies examining its effect on sports like volleyball, which require intermittent maximal performance, are lacking. The few studies available on short-term maximal exercise generally show no effect from caffeine supplementation. Moreover, since caffeine is a nonrestricted substance according to the doping rules, it is included in a so-called monitoring program to detect patterns of misuse in sport.

Bicarbonate increases the buffering capacity of muscle, and there is some evidence that bicarbonate supplementation may increase an athlete’s anaerobic capacity. A positive effect on performance might therefore be expected in athletes who participate in events of medium duration that demand maximal effort, such as the 800 m race in track and field (or other predominantly anaerobic sporting events). There is therefore no reason to expect that bicarbonate loading would be physiologically beneficial to the volleyball athlete. Furthermore, many athletes suffer from gastrointestinal distress and nausea after sodium bicarbonate loading.

In conclusion, with the possible exception of creatine, there is no evidence to support the use of nutritional ergogenic aids among volleyball players.

**Accidental doping through nutritional supplementation**

Nutritional supplements are very popular among athletes, being used by up to 90% of participants in different athletic disciplines (Braun et al. 2009; Huang et al. 2006; Tscholl et al. 2010). As stated earlier, it is vitally important for athletes, coaches, and sports medicine personnel to understand that nutritional supplements and herbal medicines may contain banned substances. These nutritional supplements are generally produced by a (poorly) self-regulated industry of food manufacturers and marketers in which product labeling and advertising are often purposely incomplete or misleading. Consequently, sports nutritional supplements may contain banned substances and inaccurate labeling information (Catlin et al. 2000; de Hon and Coumans 2007; Geyer et al. 2004; Judkins and Prock 2012). There are several documented cases in volleyball and other sports of athletes testing positive after consuming nutritional supplements or herbal medication that, unbeknown to the athlete, contained a banned substance that had not been identified in the list of ingredients.

Moreover, since supplements purchased via international mail order, through internet sales, or by personal marketing schemes are not subject to any scrutiny in the country of destination, it is important to have a global understanding of the regulation of supplements. In many countries, there is only minimal regulation of production and marketing. When considering the enthusiasm and emotive nature of the advertising claims made, it is important to realize that such advertising is not regulated either. This is especially the case with
products that target the bodybuilding or resistance training industry, where testimonials and multi-level marketing “rackets” abound.

Consequently, the use of nutritional supplements or herbal medication in connection with sports is strongly discouraged without careful consideration, including one-on-one nutritional counseling with a sports nutritionist. If, after thoughtful deliberation, the athlete and their support personnel decide to proceed with supplement use, it is advisable to select products from large companies that also manufacture conventional dietary supplements such as vitamins and minerals. It is reasonable to expect that companies involved in the preparation of “mainstream” pharmaceutical products are likely to demand and achieve better quality control than would be expected from less invested companies. To protect athletes against an accidental positive doping test, the Netherlands (www.dopingautoriteit.nl/nzvt), Germany (www.koelnerliste.com), and several other countries (AUS, NOR, SUI, USA, etc.) have developed programs to minimize the risk of contamination and inadvertent doping. All the products listed there are tested for known stimulants and anabolic steroids. However, it should be noted that contamination of the product or falsification of records cannot be definitively excluded (Geyer et al. 2008). Thus, any athlete who uses these products assumes a significant risk in doing so.

**World Anti-Doping Agency (WADA)**

The World Anti-Doping Agency was founded in 1999. The WADA is responsible for the World Anti-Doping Code, adopted by more than 500 sports organizations including international federations, national anti-doping organizations, the International Olympic Committee, and the International Paralympic Committee.

**World Anti-Doping Code**

The Code is a document aiming to harmonize anti-doping regulations across all sports and countries. It publishes an annual list of prohibited substances and methods that sport persons are not allowed to take or to use. The first World Anti-Doping Code was implemented in 2004. Code revisions were adopted in 2009, 2013, and 2015 (see www.wada-ama.org).

The FIVB is a signatory to the World Anti-Doping Code. To fulfill its responsibility to the Code, it is obligatory that the FIVB:

- conducts doping controls in volleyball and beach volleyball (in international competitions as well as out of competition testing)
- defines and maintains registered testing pools of international players
- defines the sport risk assessment
- collects whereabouts information
- follows the Code sanctions policy
- establishes an anti-doping education program.

**WADA prohibited list**

The prohibited list identifies substances and methods that are prohibited in competition and out of competition.

**Substances prohibited both in and out of competition**

- S0 Non-approved substances
- S1 Anabolic agents
- S2 Peptide hormones, growth factors, related substances, and mimetics
- S3 β-2 agonists
- S4 Hormone and metabolic modulators
- S5 Diuretics and masking agents

**Methods**

- M1 Manipulation of blood and blood components
- M2 Chemical and physical manipulations
- M3 Gene doping

**Substances prohibited in competition**

- S6 Stimulants
- S7 Narcotics
- S8 Cannabinoids
- S9 Glucocorticoids

Alcohol and β-blockers are prohibited in some sports, but not in volleyball and beach volleyball.

The list is revised at least once a year. The new prohibited list usually comes into effect on January
1 each year. The list in force is available at all times on www.wada‐ama.org. The prohibited list also includes a so-called monitoring program for substances that are not on the prohibited list, but which the WADA wishes to monitor in order to detect patterns of misuse in sport (e.g. caffeine).

The WADA has also introduced the athlete biological passport to track personal use of prohibited substances. In 2009, the hematological module was launched and in 2014 the steroid module was introduced. Currently in use by the FIVB, any athlete who has a urine test entered into the Anti-Doping Administration and Management System (ADAMS) is issued a steroid passport. A single test may be sufficient for targeted testing or immediate expanded urine analyses, although two or three urine tests are necessary for longitudinal analysis. The review of sample data is conducted by an Athlete Passport Management Unit (APMU) which is responsible for the administrative management of athlete passports, advising the FIVB on intelligent target testing, liaising with the Expert Panel, and compiling and authorizing an ABP documentation package.

**FIVB anti-doping program**

**Education**

A frequent complaint of an athlete caught violating the anti-doping rules is: “I did not have any education or sufficient information concerning the danger of doping.” Therefore, educating and transmitting information on medical and anti-doping matters are major tasks in the anti-doping program of the FIVB. The education programme includes different components.

**FIVB Play Clean program**

This is a web-based, interactive education program aimed at athletes, coaches, and other support personnel. There are seven modules available in different languages (http://playclean.fivb.org). The program is mandatory for all international beach volleyball and volleyball athletes, as well as for coaches, team managers, team doctors, and therapists.

The modules are:
- doping control procedures
- consequences to health
- therapeutic use exemptions
- breach of anti-doping regulations
- the prohibited list
- dietary supplements
- whereabouts.

When all modules are successfully completed, a certificate is issued. This certificate is used to confirm that all FIVB requirements are fulfilled and authorizes the player to take part in FIVB competitions. Some national federations have also made this a requirement at the national league level.

Through 2014, more than 7000 users completed the FIVB Play Clean program. More than 4000 international beach volleyball and volleyball athletes have been educated and moved from being passive to become active players in the field of education and in the fight against doping. Detailed information for athletes, coaches, and team managers can be found at medical@fivb.org or www.wada‐ama.com (Education and awareness).

**FIVB Outreach program**

In 2013, the FIVB joined the WADA Outreach campaign, the inaugural event of which was the boys’ U19 World Championship in Mexico. This campaign focuses especially on young players and their entourage. The goal of the program is to provide education regarding all matters concerning anti-doping, particularly the risks of doping. The FIVB, in collaboration with the national anti-doping organizations (NADO) and the national federations, organizes the Outreach program mainly during youth and junior events, but also in many other competitions. The WADA provides a variety of informational handouts and materials, including a starter kit. The FIVB Medical Department (medical@fivb.org) supports local organizers if they wish to provide such an activity during an international competition.

**New media**

In 2014, the FIVB launched a Twitter account, @ FIVBMedical, to broadcast relevant information on sports medicine and anti-doping news on a daily basis. In addition, the medical section of the FIVB
website and the FIVB YouTube channel will post all relevant information about athlete health, the referee Health Management Program, anti-doping, future FIVB medical congresses, and the most recent edition of the medical and anti-doping regulations.

**FIVB testing program**

**Doping tests**
The extensive anti-doping program in volleyball and beach volleyball coordinates responsibility for testing between the national federations and confederations, and the FIVB. The national federations are responsible for testing in national competitions (with their local NADOs), the continental confederations are responsible for continental competitions, and the FIVB for international competitions and the FIVB testing pool. In- and out-of-competition doping tests are executed by the respective NADOs and the FIVB. Under the supervision of the FIVB medical delegate, several doping control officers from independent sample collection providers, such as International Doping Tests and Management, Professional Global Services, Sports Physicians of Latin America and Caribbean, and NADOs are in charge of collecting samples in accordance with the WADA requirements and guidelines.

In addition to in-competition testing, out-of-competition testing is a priority in the FIVB anti-doping policy. The objective is to have approximately 50% of doping tests done in competition and 50% out of competition (Figures 17.1, 17.2). The majority of tests are urine tests, including testing for erythropoietin. In 2013, blood tests were introduced into the FIVB anti-doping program (Figure 17.3) to extend the testing profile of doping substances to include human growth hormone. The FIVB adopted this testing plan according to the WADA Technical Document for Sport Specific Analysis.

In beach volleyball, the top five players of each gender are included in the registered testing pool, requiring individual whereabouts information to be reported annually. In volleyball, 16 players from the Club World Championships, World League, and World Grand Prix provide individual whereabouts information and the top 20 teams provide their team whereabouts information from May to October.

In 2014, 703 players were tested in FIVB competitions. Together with the anti-doping program of the confederations, 1337 tests were conducted by the FIVB (Figure 17.4).

**Anti-doping rule violations**

In 2013 and 2014, the WADA reported collection of 4375 and 4532 samples in volleyball and beach volleyball, respectively. Of the nearly 9000 samples, only 30 adverse analytical findings (AAFs) were detected (approximately 0.3% of all tests conducted). All blood samples were negative. This rate of AAFs is low compared to other Olympic sports, for which the rate of AAFs is roughly 1.0% on average.

![Figure 17.1](image_url)  
*Figure 17.1* Number of in-competition anti-doping tests performed by the FIVB.
Figure 17.2  Number of out-of-competition anti-doping tests performed by the FIVB.

Figure 17.3  Fraction of urine and blood tests performed by the FIVB as part of its anti-doping program.

Figure 17.4  Number of anti-doping tests performed by the FIVB and its confederations.
Conclusion

In conclusion, the FIVB is fully compliant with the WADA Code. The FIVB anti-doping program is both effective and successful. Efforts to educate athletes regarding the hazards of doping and the risk of accidental doping must continue, as the science of performance enhancement is always evolving. The FIVB wants to protect the disciplines of volleyball by continually encouraging its athletes to “play it clean.”

References


Introduction

Competitive sports are played mainly on a five-and-a-half-inch court; the space between your ears. (Bobby Jones, golfer, four time winner of the US Open)

The application of sport psychology is often overlooked in favor of the more familiar training of physical abilities and technical volleyball skills. Sport psychology interventions are too often perceived as the last call for help if all else has failed to generate success. However, sport psychology is much more than picking up the pieces after a defeat. It should be regarded as a very useful tool in all stages of the training and coaching process.

The present chapter will outline the broad variety of contexts in which sport psychology can be used to foster team function, including goal setting and establishment of expectations at the beginning of the season, developing athlete leadership skills and motivational coaching ability during practices and games, and dealing with interpersonal conflicts. It will also offer practical tools to assist the coach in creating a team that has the capacity to function autonomously and is therefore able to positively withstand stressors, even without the constant supervision of the coach. As such, we argue that the various aspects of sport psychology are not a one-time technique for the coach to employ when conflicts arise, but are consistently valuable to foster, indeed to train, team effectiveness.

Motivation – the key to success

Passion is a huge prerequisite to winning. It makes you willing to jump through hoops, go through all the ups and downs and everything in between to reach your goal. (Kerri Walsh, 2004, 2008, and 2012 Olympic gold medalist, beach volleyball)

Passion fosters optimal sport performance and motivates the athlete to strive to achieve his or her goals. We can distinguish between two types of motivation: intrinsic and extrinsic. Volleyball players are intrinsically motivated when their actions are driven by their interest in and enjoyment of the sport itself. In contrast, extrinsically motivated athletes do not participate in practices and games out of pleasure, but rather to derive some kind of reward that is external to the volleyball game itself. Common examples of extrinsic motivation include praise from the coach, avoidance of physical or mental punishment by the coach if an individual or the team does not give their best effort, or parental pressure to play volleyball. It can be intuitively assumed that more intrinsically motivated athletes put forth more effort, demonstrate greater persistence, and
are less likely to drop out compared to extrinsically motivated athletes. Several studies have indeed shown that intrinsic motivation, in contrast to extrinsic motivation, leads to a variety of positive outcomes, ranging from greater attention, creativity, positive emotion, and satisfaction to more persistence and enhanced performance (Vallerand and Ratelle, 2002).

It should be noted that professional volleyball is by nature characterized by several extrinsic motivations, such as salary, praise from the fan base, and enhanced media attention. These extrinsic motivational factors are not inherently problematic, but they can be. Coaches should be aware that these factors can undermine an athlete's intrinsic motivation, and as a consequence lead to decreased effort, poor attitude, less perseverance, and (eventually) drop-out. Thus, it is vitally important that the coach fosters his/her players’ intrinsic motivation in addition to providing extrinsic motivational factors.

Knowing that intrinsic motivation is the goal to aim for is one thing. The key question, however, remains: how do we get volleyball players to be intrinsically motivated for their sport? Coaching style is without a doubt a critical factor in players’ motivation and commitment. In this regard, recent research has demonstrated that the perceived justice of the coach (i.e. the extent to which players perceive their coach’s behavior and decisions to be fair) is an important determinant not only for team cohesiveness but for individual athletic effort as well (de Backer et al. 2011). Research has also shown that an autonomy-supportive rather than a controlling coaching style fosters a more stable perception of the fairness of a coach, which is crucial for optimal team functioning.

Particularly in elite sport, it is rare for a coach to adopt an autonomy-supportive style (i.e. one in which open two-way communication exists between coach and player and players can participate in the decision-making process). In competitive situations, there is frequently no time for consultation or discussion between coach and player, and as a result, coaches in these situations often adopt a more controlling approach (i.e. the decisions are made by the coach in an authoritative way without any input from the athletes). However, on other occasions an autonomy-supportive coaching style may be more effective and appropriate.

For example, it has been shown that a directive controlling coaching style is better accepted by players when the team has together established its ambitions and goals, and has agreed upon the way to reach these goals. Furthermore, the effectiveness of game communication can be improved by involving players in tactical decision making during practice, as a result of which players obtain more tactical insight, take initiative, and demonstrate problem-solving behavior (Vande Broek et al. 2011). In this chapter, we will demonstrate in which situations the coach can profit from a more autonomy-supportive coaching style, thereby allowing athletes to have voice in certain aspects of the decision-making process.

The provision of voice is not the only important determinant for athletes’ intrinsic motivation. The self-determination theory postulates that intrinsically motivated behavior can be fostered by supporting three basic needs that are inherent to each individual: autonomy, competence, and relatedness. Autonomy refers to the need to feel in control of one’s own behaviors and goals, while competence represents the feeling that the athlete is competent in the tasks assigned to them. Finally, relatedness refers to a sense of belonging and attachment to teammates and coach. In the following sections, we will discuss how the coach can satisfy these three basic needs and thus foster the players’ intrinsic motivation in different facets of the coaching job:

- the coach as goal setter
- the coach as facilitator of shared leadership
- the coach as catalyst to foster group dynamic processes
- the coach as conflict manager to create highly resilient teams.

The coach as goal setter

If I look at the three stages to coaching, the thing I do first is I know the process of reaching a goal. Second I know the route towards the goal. The third thing is, players whom I select I have to trust! (Joop Alberda, coach of the Dutch men’s national volleyball team, 1996 Olympic gold medalists)
Goal setting is much more complex than simply postulating a goal. As Alberda stated, knowing how to reach the goal is at least as important as setting the goal. In this regard, there are some important boundary conditions which must be met if the goal-setting process is to effectively influence the team’s functioning. As Kerri Walsh has demonstrated throughout her career, passion for the sport is an important prerequisite to successfully facing the challenges encountered on the way to your goal. As discussed, this passion is an example of intrinsic motivation. As previously noted, a need-supportive coaching style, in which the coach is able to satisfy players’ need for autonomy, competence, and relatedness, is critical to fostering a volleyball player’s intrinsic motivation to reach her goals.

In a team sport like volleyball, it is important to initiate the goal-setting process at the individual level. Individual goals should then be incorporated into more general team goals, thereby enhancing the players’ commitment and motivation for the shared team goals. The need-supportive coaching style is one way in which challenging but feasible team goals may be constructed and endorsed by the entire team. We propose five key rules that underpin the effectiveness of the goal setting process, at both the individual and the team level.

**Rule #1: Autonomy support fosters goal clarity, goal acceptance, and goal commitment**

It is not uncommon for the coach to single-handedly decide on the goals to aim for and thereafter impose these goals on the players. However, this situation carries considerable risk that the athletes will not share the coach’s vision, which will seriously thwart their motivation to achieve these individual or collective goals. Without this motivation, the likelihood of obtaining the goal is practically zero. Autonomy support by the coach (i.e. giving the players a voice in setting their objectives) will foster player motivation, and as such their willingness to work towards their goals.

In this regard, it is a good idea for the coach to hold a meeting with each athlete on the team, to discuss the athlete’s individual goals and anticipated contributions towards the team goals. Such a conversation provides goal clarity; having clear and consistent information regarding role responsibilities has been suggested to lead to greater athlete acceptance of those responsibilities. The provision of voice, leading to a joint discussion of team goals, further increases the likelihood that the athletes will accept those goals. In addition to goal acceptance, the autonomy support provided by the coach also creates shared responsibility, which as a consequence makes the team much more committed to work toward team and individual goals.

Goal acceptance and goal commitment have been shown to enhance the team climate and positively impact team performance. On the other hand, failure to accept the appointed roles (e.g. as a consequence of the coach imposing the roles instead of providing voice to athletes) violates team rules, which in turn causes negative emotions and interpersonal conflicts.

**Rule #2: Support the players’ need for competence by setting feasible goals**

An important requisite of providing athletes with voice in the goal-setting process is the ability of the athletes to set appropriate goals. A frequently employed method in this regard is the SMART principle, which stipulates that goals should be Specific, Measurable, Attainable, Relevant, and Timely. In the previous section, we saw how an autonomy-supportive coaching style can contribute to goal clarity (i.e. specific, measurable goals) and goal commitment (goals become more relevant for the athletes because they had a voice in the decision process).

In this section, we will outline how competence support by the coach fosters attainability of the goals. More specifically, competence feedback by the coach is crucial in teaching athletes how to form a realistic self-image. Athletes who are able to accurately assess their own performance will be better able to set feasible individual goals. Meeting those goals will satisfy their need for competence, thereby increasing their intrinsic motivation to aim for the next goal. In contrast, without regular feedback from the coach on the players’ performance, players might overrate their performance. This in turn may prompt athletes to set unrealistic, unachievable
mediate goals will provide players with competence, and goal commitment (Box 18.1). The interaction between the player, it will foster goal clarity, goal acceptance, and goal commitment. Doug Beal, head coach of the 1984 USA men’s Olympic gold medal team, stated: “To have a successful program, you must be able to develop an overall plan or blueprint of the goal. You then do your best to break down that ideal image into building blocks useful for laying the foundation of a winning program.”

If the goal setting happens by mutual agreement with the player, it will foster goal clarity, goal acceptance, and goal commitment (Box 18.1). The intermediate goals will provide players with competence feedback throughout the learning process, thereby allowing them to more consciously gain control of their own learning. The acquired competence feedback, together with the autonomy support of the coach, will motivate players to engage in deliberate practice (i.e. highly structured exercises, not inherently enjoyable but specifically aimed at improving performance through self-regulated feedback). Examples include multiple repetitions of a float service, in which the player consciously considers the different technical aspects of good performance, and is able to adjust his/her performance through self-regulated feedback. Research demonstrated that deliberate practice and intrinsic motivation are directly related: more motivated athletes engage in more deliberate practice, and greater deliberate practice results in more intrinsically motivated athletes.

### Rule #3: Emphasize the road towards the goal to motivate players to engage in deliberate practice

It is one thing to clearly visualize the goal to aim for; it is another thing altogether to know how to get there. Given the crucial importance of meeting goals, coaches have a significant responsibility to point out the means by which athletes may achieve their goals. One means to this end is to help the athlete subdivide the larger goal into manageable chunks. Doug Beal, head coach of the 1984 USA men’s Olympic gold medal team, stated: “To have a successful program, you must be able to develop an overall plan or blueprint of the goal. You then do your best to break down that ideal image into building blocks useful for laying the foundation of a winning program.”

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### Rule #4: Select mastery goals instead of performance goals to enhance effort and strengthen team cohesion

The specific content of the established goals is often closely connected with the team climate. In this regard, two types of climate have been distinguished: (1) a **task-involving** (or **mastery**) motivational climate and (2) an **ego-involving** (or **performance**) motivational climate. Mastery goals closely connected with the team climate. In this regard, two types of climate have been distinguished: (1) a **task-involving** (or **mastery**) motivational climate and (2) an **ego-involving** (or **performance**) motivational climate. Mastery goals...
climate (Ntoumanis and Vazou 2005). The mastery goals that are set in a task-involving climate focus on intrapersonal (or intrateam) progression. Examples include learning a new technique like a jump float service or increasing your own scoring percentage against the same opponent. The performance goals that are set in an ego-involving climate, on the other hand, emphasize interpersonal comparison and competition with teammates (or competing teams). Examples include becoming a starting player (instead of a substitute player) or, at the team level, winning the championship.

One significant difference between the two types of goals is the perceived locus of control in attaining them. The locus of control varies from a belief that through his effort the athlete can completely influence the attainment of the goal (i.e. internal locus of control) to the belief that it is entirely outside his ability to influence the outcome (i.e. external locus of control). While most players do feel capable of attaining mastery goals (i.e. intrapersonal progression), meeting performance goals is frequently susceptible to uncontrollable external factors (e.g. progression of teammates, level of competing teams, or referee decisions). Therefore, a task-involving climate (having mastery goals) is usually associated with positive motivational outcomes such as enjoyment, interest, performance improvement, performance satisfaction, and team cohesion. In contrast, an ego-involving climate (with performance goals) has been linked with feelings of anxiety, reduced effort, less cohesive teams, and other maladaptive outcomes.

**Rule #5: Prioritize the team goals – towards goal clarity and a shared vision**

When setting team goals, an approach similar to that used for individual goals can be adopted. At the team level, it is important for coaches to provide adequate autonomy support to the team and to decide in mutual agreement with the players on the common goals for the team, as well as the norms and values that are necessary to reach these goals. In this way, a shared vision can be obtained. The more team members internalize the team’s goals as their own, the more a shared accountability is established, and as a result the players are more strongly committed to these goals. Team competence feedback is critical to inform the team of their progression towards the overall goal as well as towards the identified intermediary goals.

Although performance goals (such as winning the championship, attaining the cup final, or avoiding play-downs) are sometimes imposed by the club management, it is important as a coach to emphasize mastery goals, which are focused on the progression (individually or as a team) in order to provide players with an internal locus of control.
In a team sport such as volleyball, in which each player has individual goals but together all players aim for common team goals, it is crucial to find the right balance between both. It might be a useful strategy for coaches to identify two types of goals for each athlete: priority aims (P1-aims) and secondary aims (P2-aims). The P1-aims are oriented to the individual contribution of each player towards the common team goal, while the P2-aims are the individual goals that each player has in recognition of his/her long-term progression as a volleyball player. To optimize the team’s functioning, it is important to communicate the P1-aims of every individual player in the whole team, which further improves role clarity. This open communication fosters a task-involving climate, in which players are focused on developing together as a team, rather than outplaying their teammates. Furthermore, this approach delineates the accountability of each individual player and allows players to reprimand teammates if they do not attain their priority aims. This open communication climate and the willingness to help teammates reach their goals will result in stronger task cohesion.

The coach as facilitator of shared leadership

Talent is important. But the single most important ingredient after you get the talent is internal leadership. It’s not the coaches as much as one single person or people on the team who set higher standards than that team would normally set for itself …

(Mike Krzyzewski, head coach of the United States men’s national basketball team, 2008, 2012, and 2016 Olympic gold medalists)

When it comes to leadership, athletes, fans, media – even those who have no real interest in sports – will identify the coach as the leader of the team. It is important to realize, however, that team members can fulfill important team leadership roles within a team. (For an overview of athlete leadership, see Cotterill and Fransen 2016.) Fransen et al. (2014) distinguished between four leadership roles that athletes can occupy:

- **task leader**, who gives his/her teammates tactical advice when necessary
- **motivational leader**, who encourages his/her teammates to perform at their best when on court
- **social leader**, who develops a good team atmosphere outside the competitive environment
- **external leader**, who handles communication with club management, media, and sponsors.

When examining athlete and team leadership, it is important to move beyond the formal leadership role of the team captain. In fact, it has been demonstrated that the informal leaders (players who emerge as natural leaders in the team without formal leadership recognition), rather than the team captain, were perceived as the real athlete leaders of the team (Fransen et al. 2014). In 44% of the teams, the captain did not fulfill any of the four leadership roles. The captain was thus not perceived as best leader on the field (neither as task leader, nor as motivational leader), nor as best leader off the field (neither as social leader, nor as external leader). Recent research further confirms that most sports teams establish a shared leadership paradigm: while coaches and athlete leaders were seen as equally good leaders on the task and external leadership role, the athlete leaders were perceived as better leaders than their coaches on the motivational and social leadership role (Fransen et al. 2015a).

Several studies have confirmed the importance of athlete leadership by demonstrating that higher quality athlete leadership in each of these four leadership roles resulted in greater team identification and stronger task and social cohesion (Fransen et al. 2014; Price and Weiss 2011). Furthermore, athlete leaders have been shown to be the catalysts in propagating confidence throughout the team. In volleyball, soccer, and basketball, it was shown that the expression of team confidence by the athlete leaders in the team was one of the most important sources of players’ confidence in their team (Fransen et al. 2012, 2015b). Two experimental studies further confirmed that contagion of team confidence emanates from the athlete leader (Fransen et al. 2015c, 2016). More specifically, the findings revealed that athletes had greater team confidence when the leader expressed high confidence.
in the team's success. In addition, the results indicated that when team leaders expressed high team confidence, athletes' performance improved. By contrast, when leaders expressed low confidence, team and individual members' performance decreased. Athlete leaders thus seem to have the capacity to influence collective team confidence (in both positive and negative ways), thereby significantly affecting team members' performance.

Given all these positive outcomes, it is important for the coach to facilitate athlete team leadership. However, before designating the team leadership, it is crucial to have a good insight into the leadership structure within the team. Who are the right leaders for the different jobs? The perception of the coach in this regard might differ from the perceptions of the players. It is the players' perception, however, that is most crucial when it comes to effective athlete leadership: if the coach-appointed athlete leaders are not seen as athlete leaders by their teammates, their guidance will not be followed and effective leadership is a long way off.

Social network analysis (SNA) is a novel diagnostic tool to identify key players for the different leadership roles within the team (Fransen et al. 2015a). This network approach also allows the coach to map the evolution of these leadership structures over time. By using this approach, coaches can appoint task, motivational, social, and external athlete leaders who are supported by the team. A clear delineation of the leadership role, followed by competence feedback along the way, will foster the further development of the leadership qualities and skills of the leader. The fact that athlete leaders realize that teammates support and even expect their leadership will further motivate them to accept their role and engage in high-quality athlete leadership behavior.

Given all the benefits of shared leadership, it is important that the coach not only identifies the athlete leaders on the team but also facilitates and develops team athlete leadership. An autocratic controlling coaching style, in which the coach imposes the rules, norms, goals, and ways of working on his/her players without providing any voice to the athletes, will most likely produce a flock of meek sheep. Such an environment offers very little opportunity to develop effective athlete leadership in the team. By contrary, an autonomy-supportive coaching style provides voice to the players when deciding on the team rules, norms, and goals. This participation leads to higher member accountability and a higher degree of commitment. It can be assumed that a coaching style in which athletes are given autonomy, rather than being controlled, nurtures the development of their leadership abilities.

Despite the established benefits of shared leadership for optimal team functioning, sharing leadership also carries significant risks. For example, if the appointed task leader holds a strongly different view of the optimal playing strategy from the other task leaders or the coach, the contrasting input during a match might lead to confusion and doubt, thereby thwarting optimal team functioning. In order to develop an effective shared leadership structure while avoiding the risks inherent in the process, we suggest three important preconditions that coaches should keep in mind.

**Precondition #1: Aim for role clarity instead of role ambiguity**

In the same way that goal clarity was important for the goal-setting process, the clarity of someone's leadership role is important for effective athlete leadership. As a coach, it is essential to clearly delineate the function and responsibilities attached to a given leadership role together with the athletes. Perceptions of role ambiguity (i.e. the lack of clear, consistent information regarding an individual’s role) have been associated with decreased task cohesion and lowered confidence in their own ability to successfully fulfill the leadership role. On the other hand, if athlete leaders are well informed of the expectations that are connected to a given leadership role, greater role satisfaction should ensue, as should overall athlete satisfaction, leading to better fulfillment of their leadership role.

**Precondition #2: Develop leadership abilities with regard to specific roles**

Knowing what is expected of an athlete leader does not always equate with effectively providing high-quality athlete leadership. Before being able
to provide high-quality athlete leadership, athlete leaders need adequate competence in their leadership role. For example, a task leader needs to have insight into the game tactics, while a motivational leader needs to know how to motivate each of his/her teammates. Undoubtedly, some players need to be incited, while others benefit more from being calmed. Off the court, athlete leaders need to learn specific competencies: the social leader needs to learn how to deal with intrateam conflicts and how to foster the team atmosphere, while an external leader should be trained in communication skills so that the team is well represented before club management, media, and sponsors.

Appointing the right athlete leaders thus is not enough in itself: athlete leaders need to be further developed on their critical task competencies. One of these crucial task competencies is tactical awareness, especially for a task leader. In this regard, it has been demonstrated that it is important to teach the players how to think along with their coach—in setting up norms, values, and goals but also in tactical and strategic reasoning (Vande Broek et al. 2011). The study findings demonstrated that an autonomy-supportive coaching style resulted in increased tactical awareness on the part of the players. Tactical observation and questioning, in which players were asked to independently evaluate their tactical decisions, was a very important tool for coaches to foster team tactical awareness. The autonomy-supportive coaching style, together with players’ improved tactical awareness, will motivate athletes to take on leadership roles and to take the initiative in discussing match strategy. High-quality athlete leadership in this area will result in improved team functioning and better performance (Fransen et al. 2015c, 2016; Price and Weiss 2011).

Precondition #3: Establish a shared vision

Clearly delineating the function of the different athlete leaders and guiding them in becoming better athlete leaders are important boundary conditions for effective shared leadership. The final and perhaps the most important condition for effective shared leadership is the development of a shared vision. Similar to the goal-setting process, a shared vision with regard to what the team is trying to accomplish is essential to getting all the athletes “on the same page.” As Phil Jackson, one of the greatest basketball coaches of all time, once said: “Good teams become great ones when the members trust each other enough to surrender the Me for the We.”

As mentioned earlier, the provision of autonomy and voice in the decision process will lead to higher player commitment and thus more effective athlete leadership. Furthermore, a task-involving team climate, focused on common goals and team development, is the perfect environment in which to develop a shared vision (in contrast to an ego-involved climate, characterized by intrateam comparison). The fact that all players are looking in the same direction and share the same team goals will promote concurring messages from the different athlete leaders and the coach, thereby leading to more optimal team functioning (Box 18.2).

The coach as catalyst to foster group dynamics processes

Coming together, sharing together, leading together, succeeding together.

A common framework for evaluating a team’s development was provided by Tuckman (1965), who identified four stages of team development: forming, storming, norming, and performing. Tuckman further postulated that teams must pass through each of these phases in order to grow, effectively face challenges, negotiate the path towards team goals, and ultimately perform optimally. The competence of the coach as goal setter, facilitator of shared leadership, and conflict manager, while providing players with their basic needs (autonomy, competence, and relatedness), is essential to foster effective group dynamics as described by Tuckman.

First stage of development: Forming

A newly composed team or a team at the start of a volleyball season automatically enters into the first phase of the developmental process: the forming
phase. During this stage, the players get to know each other and their behaviors are guided by the desire to be accepted by their teammates and coach. In this phase, players will avoid any controversy or conflict. The forming stage is a comfortable stage. However, because all players seek to avoid conflict, they behave mainly independently, focusing on themselves. Consequently, players adopt a cautious, wait-and-see attitude, and fail to identify with the team.

To facilitate identification with the team, the coach must provide the players with a voice in discussing individual and team goals. In addition, coaches would do well to stimulate team discussion about team goals, norms, and values. This discussion moves the team toward a shared vision. Autonomy support by the coach is critical for deciding which goals should be prioritized, as well as how these goals should be attained.

### Second stage of development: Storming

Despite the coach’s best planning and expectation, team development does not always proceed smoothly. The storming phase is characterized by players who deviate from the expected behavior or ignore the values, norms, and goals established by the team. In contrast to the first stage, the storming phase is no longer comfortable. Rather, it can be contentious, unpleasant, and even painful for
players who are conflict averse. This phase can even be destructive to the team and its motivation if the behaviors are allowed to progress out of control.

If the coach provides the right support, however, this stage can be very important and valuable in the development of the team. Deviations from the formulated values, norms, or goals cannot be ignored at this stage of team growth. If a player does deviate from the expected standards, it is vital that the coach reminds him/her of the expected behavior for team members. In addition, if a clear structure of athlete leadership has been established, it is essential that the athlete leaders ensure that all players travel the same path towards the common team goals. If not, it is also the responsibility of the athlete leaders to appropriately reprimand their teammates. Players who dare to stand up for their opinion might cause dissension within the team, but it is exactly these discussions that can make players stronger and come together more effectively as a team.

**Third stage of development: Norming**

If the coaches and athlete leaders are able to handle the anticipated intragroup conflicts well, the storming phase will give way to the norming phase. In this phase, the testing of responsibilities and boundaries eases and the players begin to respect each other, perhaps because of the interpersonal differences that exist. Each player begins to settle into his/her individual role in the team. Furthermore, the leadership structure of the team has been established at this point and the roles of the athlete leaders have been accepted by their teammates. In this phase, the team develops and agrees upon a shared vision or goal to which members will be committed and motivated to work together. A task-involving team climate will result, in which players highly identify with their team. A sense of “us” has been created.

**Fourth stage of development: Performing**

When each of the previous three stages has been negotiated, the team will arrive at the performing phase. This is the final stage of team development, in which the group of players becomes one team with a shared vision and a common goal. The team is optimally structured and under the guidance of the coach and the athlete leaders, it works efficiently towards the team and personal goals. In this phase, all players know their role in the team and their resulting responsibility. These high-performance teams are able to function largely independently given their accurate self-knowledge, their ability to adjust their learning process, their motivation for deliberate practice, and their internal leadership. As such, progress can be made quickly and without inappropriate conflict or the need for a directive coaching style. Players can effectively shoulder their responsibilities and use their coach’s competence feedback to further improve their learning process.

As already indicated throughout the different sections, teams that actually reach the performing phase of Tuckman’s cycle are characterized by several strengths. For example, strong team identification in the norming phase will in turn foster players’ adherence to team norms. Favorable effects will also be noted in team confidence, the team’s task and social cohesion, the team’s optimal functioning, and (eventually) in team performance. In addition, an effective structure of shared athlete leadership will promote clarity of understanding of the team goals, norms, and values. This in turn will enhance the athletes’ motivation and their commitment to achieving team goals, thereby enhancing team performance. This focus on achieving team goals, rather than performing better than teammates, is a reflection of the task-involving climate that has been established throughout the development process.

Furthermore, high-performing teams are characterized by enhanced confidence in their team’s abilities and in the team’s chances of achieving their goals. This team confidence in turn positively affects players’ individual performance, as well as their team performance (Fransen et al. 2015c, 2016). As noted earlier, this team confidence, together with team identification, shared leadership structure, and task-involving team climate, will foster the team’s resilience and enable the team to effectively withstand stressors or setbacks.

The performing phase does not last indefinitely. Even the most high-performing teams will go through this cycle many times as the team and its
personnel react to changing circumstances. For example, changes in the coaching staff or athlete leadership (e.g., a new coach is hired or a player with strong leadership abilities is transferred) may cause the team to revert to the storming phase as these new members challenge the existing status quo. It is therefore important for coaches to recognize when teams revert to earlier stages of the development process, so that they can act appropriately and guide the team once more through the different developmental stages.

**The coach as conflict manager to create highly resilient teams**

*It’s not whether you get knocked down; it’s whether you can and will get back up.*

(Vince Lombardi, one of the most successful football coaches in American history, and member of the National Football League Hall of Fame)

Teams that are able to effectively withstand stressors are called highly resilient teams. The resilience of a team is more than the sum of the individual players’ resilience. Morgan et al. (2013) identified four attributes that characterize resilient teams: group structure; task-involving climate; social capital; and team confidence (Figure 18.2). It is important for coaches to foster these characteristics in order for the team to be able to effectively handle both within-team conflicts and external stressors (e.g., repeatedly losing, injuries, etc.).

**Characteristic #1: Group structure**

The first characteristic of highly resilient teams pertains to the creation of an optimal group structure, characterized by collective group norms and values, shared leadership, and an open communication climate. We have already highlighted the importance of these aspects at the beginning of a season, but they will become even more decisive when the team is confronted with obstacles.

![Figure 18.2](image-url)  Attributes that characterize resilient teams.
or intrateam conflicts as the season progresses. First, by providing a voice for the players, the players will be more committed to realize their goals and adopt the team norms and values. Second, if a clear structure of athlete leadership has been established, the athlete leaders can assist their coach in ensuring that all players travel the same path towards the common team goals, and if necessary reprimand their teammates. Mike Candrea, head coach of the USA softball team (2004 Olympic gold medalists), highlighted the importance of such a set of key leaders within the team:

Having great leadership is a big key to success. It’s really the leaders’ team because they are the ones whom the rest of the players, especially the freshmen, look up to when setting the standards. Our team will go as far as our leaders are willing to take us.

Third, discussing such intrateam conflicts in an open communication environment will allow the players to voice their opinions, resolve their differences, and find a common, positive way of interacting with each other.

**Characteristic #2: Task-involving climate**

A second important characteristic of highly resilient teams is a task-involving climate, which focuses on learning and improving together as one team, instead of promoting intrateam comparison. Morgan et al. (2013) established that resilient teams are able to focus on both personal and team development because they can filter out irrelevant cues and isolate what is important. Furthermore, they revealed how resilient teams exhibited a range of effective behaviors to overcome stressors, thereby increasing the likelihood of team progression. For example, thorough preparation for difficult moments was seen as an important factor which could make the difference when encountering difficult match situations.

When conflicts arise or when goals, norms, or values have been deviated from, communication will be crucial. It is the task of the coach, together with the athlete leaders, to clearly outline each player's responsibility and to remind players of the common goals set at the start of the season. Several studies reported that such open communication, which reflects the shared values and emphasizes the common goal, is the most optimal way to resolve conflicts, to get everyone back on the same wavelength, and to enhance the task cohesion within the team.

**Characteristic #3: Social capital**

The third characteristic of highly resilient teams is the existence of high-quality interactions and caring relationships within the team, also called the social capital (Morgan et al. 2013). Resilient teams develop emotional bonds and learn to accept their teammates, regardless of individual differences. Furthermore, this deep emotional bonding and closeness will give players the feeling that they can rely on each other and that teammates would provide assistance if needed.

Trust is the key word here. Mike Hebert, former head coach of the US national volleyball team, emphasized the importance of trust in dealing with conflicts:

As I look back on the conflicts we encountered, it is clear to me that all of us had benefitted from our earlier work together with the concept of trust. They were learning to trust each other when taking on issues. They were freeing themselves of the fear of retaliation that often accompanies such intimate discussions. We were able to arrive at a full awareness of both the problem and a solution without having to waste time tip-toeing around the issue. We trusted each other to refrain from unfairly exposing each other to ridicule. We trusted each other to leave individual agendas behind and to contribute to the dialogue in an open and unselfish fashion. All of this was possible only because sufficient levels of trust were in place.

Regardless of how talented your players are, a positive environment that includes a solid mutual trust among everyone involved with the program is vital for your program both on and off the court. When I am asked to reveal the secret to my past success, I could answer that I was an exceptional skilled trainer, a tactical genius,
a thorough game planner, and a great motivational speaker, but I don’t. Instead, I tell them the truth: I spent most of my time trying to get people to learn how to trust. All of the other elements are important, but trust is the one variable without which the entire program-building effort would collapse.

(Hebert 2014)

To develop trusting relationships between the players, a safety climate should be established, characterized by mutual respect and understanding, in which players dare to freely voice their opinion. Such a climate will emphasize a player’s feeling of being united with his/her teammates, and forms a warm environment in which to deal positively with intrateam conflicts. In addition, it is important to foster players’ team identification: the extent to which players feel connected to the team and to which team membership is important for them. Research has demonstrated that coaches and athlete leaders who were able to strengthen the players’ team identification also strengthened their confidence in the team’s abilities and their confidence in attaining their goals (Steffens et al. 2014). In turn, this stronger feeling of connection with the team resulted in improved performance (Fransen et al. 2015b). Not only the coaches but also the athlete leaders have an important responsibility in being a role model for their team. It was shown that when athlete leaders expressed high confidence in their team, this confidence spread throughout the players. As a result, team member confidence in the ability of the team grew and, as a consequence, performance improved. In contrast, when athlete leaders expressed that they had lost all confidence in their team’s chances, their behavior negatively affected teammates’ confidence and their performance deteriorated (Fransen et al. 2015c, 2016).

**Conclusion**

The four characteristics of highly resilient teams provide valuable tools for coaches to prevent or effectively handle the conflicts which will undoubtedly arise throughout the development process of a team. It is important to remind people that it is not the intragroup conflicts themselves that are by definition positive or negative influences on team development, but rather it is the way in which the team deals with those conflicts that is crucial for team outcome (Martin et al. 2014). For example, it was shown that destructive styles of intragroup conflict resolution (e.g. criticizing those involved or avoiding the problem altogether) negatively impacted the task and social cohesion of sports teams. A potential consequence could be the emergence of various cliques within the team. The development of such within-team cliques has been found to increase athlete stress levels, to be detrimental to team cohesion, and to detract from team performance. Coaches often list “breaking up cliques” as an important strategy to improve team cohesion (Martin et al. 2014). Indeed, quantitative research has confirmed that constructive conflict resolution styles (e.g. mutual disclosure and effort) resulted in stronger task cohesion. Intragroup conflicts thus do not have to be destructive but can be very valuable in the development of a team.
Motivation is the key to success that enables players to get back up after repeated failures and still achieve their goals, as illustrated by the following bit of wisdom: “If you're not willing to learn, no one can help you. If you’re determined to learn, no one can stop you.”

As outlined in the beginning of this chapter, players have three basic needs in order to be intrinsically motivated for their sport: autonomy, competence, and relatedness. We hope we have demonstrated how coaches can support these needs while setting goals, while facilitating shared leadership, while resolving conflicts, and throughout the different stages of the group dynamics development process. When these needs are fulfilled and players feel in control of their own actions (autonomy satisfaction), competent in what they are doing (competence satisfaction), and related to their coach and teammates (relatedness satisfaction), they will be intrinsically motivated to play volleyball. As a result, they will exert more effort during training sessions and games, be more persistent when attempting to overcome obstacles, and demonstrate less drop-out.

However, it is important to note that although this need-supportive coaching style has many benefits, some situations require a more directive coaching style (Chelladurai and Turner 2006). For example, when time is limited (e.g. during a time-out), a decisive coaching style is more appropriate. Also, some decisions are more important than others and therefore vary in the appropriate extent of voice. For example, coaches should take responsibility in selecting the best players for their team and deciding upon the starting players. However, other decisions, such as the selection of a team captain, can be decided by democratic vote. In the latter situation, it is important that players are given a say in electing their captain, since that leader’s effectiveness depends upon the extent to which they are accepted by their team. Furthermore, the style adopted by the coach also depends upon the developmental phase which the team is going through. If the quality of interpersonal relations is limited and team members hold diverse opinions, the participative decision process may further weaken an already fragile team consensus and team spirit.

Our goal in compiling this chapter has been to demonstrate the importance of studying and applying psychological aspects of team building and athlete development. While it is important to consider the physical, technical, and tactical aspects of the sport, by taking into account the psychological aspects of the team development, we are confident that even greater progress (and success) can be achieved on the volleyball court.

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Volleyball was invented in the city of Holyoke, Massachusetts, USA in 1895 by a YMCA instructor by the name of William G. Morgan. Since then, the sport has enjoyed exceptional growth. Over a relatively brief period of years, volleyball matured and the rules became codified. In 1964, volleyball became a member of the pantheon of Olympic sports. In 1996, beach volleyball (the outdoor cousin of the indoor game) also achieved Olympic status. Participation numbers in the sport are increasing worldwide. In fact, by some estimates, volleyball is the second most popular participation sport in the world, trailing only football (soccer).

Concomitant with volleyball’s increasing popularity, sport scientists have demonstrated a growing interest in researching the fundamental questions relevant to the sport. This is perhaps best reflected by the growing number of volleyball-related papers published annually in the peer-reviewed literature. As shown in Figure 19.1, the number of articles identified by the key word “volleyball” that were abstracted by the National Library of Medicine and have been listed by Index Medicus has increased steadily over the past 50 years. Since the article entitled “Typical injuries in volleyball” by H. Berndt appeared in 1956, a total of 1359 articles with the key word “volleyball” have been published (as of 15 July 2016). Of these, nearly 10% were published in 2015 alone.

In that 1956 paper, which described several volleyball-related finger injuries, Berndt suggested that the injury rate in volleyball was comparatively modest. Further epidemiological study has proven Berndt correct: volleyball and beach volleyball are among the safest of all sports. Nevertheless, no sport is without some risk of injury. Indeed, each sport has its own characteristic pattern of injuries, and volleyball athletes at every level assume a risk of injury each time they take the court to practice or compete.

It could be argued that the world’s best athletes are among the greatest risk takers, exchanging their time, energy, and (all too frequently) their health for an opportunity to represent their country in pursuit of victory that is less than certain. Any number of circumstances may conspire to prevent the athlete from excelling or the team from winning. However, an athlete’s greatest fear is sustaining a serious time-loss injury that will compromise his/her ability to compete.

Why do athletes take such risks? The simplest answer is that their desire to compete and to win is greater than their fear of becoming injured. For many athletes in certain sports, however, this is no longer true. Witness the recent rash of retirements among American professional football players who have decided to retire from the sport well before their athletic prime rather than risk developing debilitating central nervous system trauma from repetitive head injuries. Such concerns are not limited to professional athletes, as parents are increasingly prohibiting their children from playing American
football (and other sports) out of fear of permanent sequelae from injury.

Clearly, science and medicine have played and will continue to play a significant role in the evolution of sport. Although the practice of caring for athletes dates back to the ancient Greek physician Herodicus, the term “sports medicine” was coined in the last century. Perhaps the most indelible image of sports medicine is of physicians providing triage and medical care on the sidelines, a practice which began in the 1940s. In those early days of modern sports medicine, “coverage” meant that there was a doctor who had some familiarity with the sport prowling the sideline of the field or court, ready to “patch and go.” Today, sports medicine is a multidisciplinary field that draws upon the expertise of many different specialties to provide the athlete with optimal care, both on the sideline and away from the arena.

Over time, through experience and the cooperative efforts of clinicians and scientists, our understanding of the pathophysiology and biomechanics of sports traumatology has improved. This in turn has led to advances in the treatment and rehabilitation of sport injuries. Some 30 years ago, a handful of sports medicine experts advanced the question of how sport-related injuries might be avoided in the first place. Thus was born the field of sports injury prevention. Research in this discipline has shown that although time-loss injuries cannot be eliminated altogether, the risk of selected injuries can be reduced through implementation of structured prevention programs.

What does the future of sports medicine and science hold? Among the current “hot topics” on the sports medicine research agenda is the optimization of physiological recovery from intensive exercise. Recovery lies at the intersection of sports medicine and sports performance, and advances in this area may prove to be essential to overcoming residual barriers to athletic success. Meanwhile, other scientific disciplines, such as genetics, hold
the promise of revealing the heritable components of elite performance as well as susceptibility to injury. A further challenge will be to fully appreciate the economics of injury and the ethical conundrums that arise in the course of scientific investigation so that we may make future discoveries available and affordable to all.

There is still much to learn. Evidence-based decisions grounded in research and fortified by longitudinal outcome studies and randomized clinical trials will create the gold standard of medical care for our elite and developing athletes as we move forward. Future care plans will no doubt look substantially different from those we currently employ and promote as “state of the art.”

Even though we constantly look to advance the limits of medical intervention available to our athletes, as the discipline of sports medicine inevitably progresses we must continue to be honor bound by the principal tenet of the Hippocratic Oath, to “First, do no harm.” Only if the bonds of trust remain unbroken between physician, scientist, and athlete will the discoveries that have yet to be made result in true progress for those who are dedicated to sport.

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