10 Volleyball (Indoor, Beach)

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10.1 History of Volleyball

Volleyball is a common sport, which is played by approximately 200 million players worldwide [1]. It was firstly introduced in Holyoke, Massachusetts in 1895 by William G. Morgan, physical director of the Young Men's Christian Association (YMCA) (Fig. 10.1). It was initially played and an indoor sport and especially attracted those players who found of basketball too hard to play and traumatic. Morgan himself proposed the first rules which were printed in the first edition of the Official Handbook of the Athletic League of the Young Men's Christian Associations of North America (1897). The game soon became really attractive for players of both sexes in schools, playgrounds, the armed forces, and other organizations in the United States, and it was subsequently introduced to other countries. The first official ball used in volleyball is disputed; some sources say Spalding created the first official ball in 1896, while others claim it was created in 1900 [2]. In 1916, the original rules were revised by the YMCA in conjunction with the National Collegiate Athletic Association (NCAA). In 1920, "three hits" rule and a rule against hitting from the back row were established. The first nationwide tournament in the

Fig. 10.1 William G. Morgan invented Volleyball in 1895

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United States took place in New York City in 1922. Volleyball was then introduced into Europe by American troops during World War I. In that period first national organizations were formed all around the world. The Fédération Internationale de Volleyball (FIVB) was founded in Paris in 1947 and moved to Lausanne, Switzerland, in 1984. International volleyball competitions began in 1913 with the first Far East Games, in Manila. However, in Asia during the early 1900s and until after World War II, volleyball was played on a larger court, with a lower net, and nine players on a team. The FIVB sponsored world volleyball championships for men in 1949 and for both men and women in 1952. Volleyball became an Olympic sport for both men and women at the 1964 Olympic Games in Tokyo.

10.2 The Game

The game is played on 9 m (30 ft) wide by 18 m (60 ft) long court. A center line divides it into two equal playing areas for the two teams. Over this central line, a 2.43 m high net is located for men's competitions, while it is 2.24 m high for women's competition [3]. A vertical tape marker is attached to the net directly above each side boundary line of the court, and, to help game officials judge whether served or volleyed balls are in or out of bounds, a flexible antenna extends 1 m (3 ft) above the net along the outer edge of each vertical tape marker. The ball used is around 260–280 g (9–10 ounces) and is inflated to about 65 cm (25.6 in.) in circumference. A ball must pass over the net entirely between the antennae.

Players may not step completely beyond the center line while the ball is in play. A line is located 3 m (10 ft) away and parallel to the center line on each half of the court, and it divides the players playing in the front row and those playing in the back row. It indicates the point in front of which a backcourt player may not drive the ball over the net from a position above the top of the net. This offensive action is called a spike and is usually performed most effectively and with greatest power near the net by the forward line of players. On the other hand, players in the back row may spike only jumping behind this line. A service area, 9 m (30 ft) long, is outside of each court end line. The service must be made from within or behind this area. A space at least 2 m (6 ft) wide around the entire court is needed to permit freedom of action, eliminate hazards from obstructions, and allow space for net support posts and the officials' stands. A clear area above the court at least 8 m (26 ft) high is required to permit the ball to be served or received and played without interference. In competition, each team consists of six players, three of whom take the forward positions in a row close to and facing the net, the other three playing the backcourt.

Figure 10.2 shows the dynamic of this sports—a moment in the volleyball match where a player is attacking and the opponents are positioned to block.

The 2000 Olympics introduced significant rule changes to international competition. A new player: the libero was introduced. He serves as a defensive specialist and may switch with all players in the back row the libero wears a different color from the rest of the team and is not allowed to serve or rotate to the front line. Another important rule change allowed the defensive side to score, whereas formerly only the serving team was awarded points.

10.3 Biomechanics of Volleyball

Volleyball is a high demanding sport with two major injury scenarios being possible: sprains and overuse syndromes. Ankles, knees, and fingers are mostly affected by traumatic events, while shoulders and knees may undergo overuse syndromes. The precise comprehension of the biomechanics of the specific skills is crucial since it allows better sport performance reducing the risk of injury.

Jumping is the most important action of volleyball since it affects serving, spiking, and blocking and is closely related to landing. The ability of jumping higher leads to increased performances [4]. Individual muscle properties, jumping technique, and playing surface all

Fig. 10.2 Volleyball dynamics of attacking and blocking

influence the height of a jump and must be therefore analyzed when trying to prevent injuries.

The first aspect to take into account is muscle function; the force generated by the muscle is transferred through the tendons to the bones and finally to the ground. These steps are influenced by muscle properties, composition of the tendons, jumping technique, and the playing 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. However, training should be individualized to address and improve any specific neuromuscular system deficiencies: 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. Repetitive jump training is important to improve performance, and it showed to have no negative effects in terms of jump's gesture or intensity among the different game sets [5]. However, this stable performance along with hard training is in opposition with the results by Wnorowski et al. who demonstrated a deterioration of jumping performance during game sets in elite male Polish players [6]. Historic studies have confirmed that explosive plyometric training increases jump height in volleyball players [7]. More recently, Krističević et al. found that completion of a 5-week plyometric training program improved selected vertical jump tests in young female volleyball players [8]. However, they did not find significant changes in spike and block jumps following the plyometric training program.

The second aspect is the jumping technique; several aspects such as a countermovement or the arm swing may have substantial effects on the spike jump (SPJ) height performance. A countermovement, i.e., a lowering of the center of mass just before the beginning of the push-off phase, increases jump height [9].

Spike jump (SPJ) height is generally greater than the height 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 [10].

The reasons for this higher performance 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 [10]. 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. Training is therefore crucial to maximize jump height the SPJ since it is a complex and unique sport gesture. In fact, although it 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 (non-dominant) shoulder hyperextension were significantly related to jumping height. The reason for this is probably that the SPJ is rather asymmetrical.

Sheppard et al. showed that assisted jumping may promote the leg extensor musculature to undergo a more rapid rate of shortening, and chronic exposure appears to improve jumping ability [11].

The third aspect to take into account is the playing surface. 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 sand. In addition, the instability of the sand reduces peak power output due to the differences of body configuration at the lowest body position and lower limb joints' range of motion [12]. Lesiniski et al. found no statistically significant interactions of fatigue by surface condition. They concluded that fatigue impairs neuromuscular performance during rope jumps (DJs) and countermovement jumps (CMJs) in elite volleyball players, whereas surface instability affects neuromuscular DJ performance only. Fatigue-induced changes in jump performance are similar on stable and unstable surfaces in jump-trained athletes [13].

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. Hosseininezhad et al. investigated the effects of polyvinyl chloride outsole (PVC shoe) and styrene-butadiene sole (TPE shoe) on countermovement jump (CMJ) and squat jump (SJ) [14]. They showed that the height of vertical jump in CMJ was higher than SJ regardless the type of sole. The use of PVC shoe with lower hardness resulted in more tensile energy storage and energy return than TPE shoe. Therefore, shoe outsole characteristics such as material and hardness can change the height of vertical jump through affecting on storage and return of energy.

10.4 Epidemiology of Volleyball Injuries

The epidemiology of volleyball injuries is variable according to the level of athletes analyzed. In 2015, the FIVB Injury Surveillance System performed a survey on 2710 reports [15]. In total, 440 injuries were reported, 275 during match play (62.5%), and 165 during training (37.5%). The incidence of match injuries was 10.7/1000 player hours; this was greater for senior players than junior players (RR: 1.32, 95% CI 1.03–1.69), while there was no difference between males and females (RR: 1.09, 95% CI 0.86–1.38). The incidence of injuries during match play was greater for center players than for other player functions. The majority of injuries were minimal to mild, while severe injuries were rare. Ten out 440 injuries led to an absence from training of more than 4 weeks. Of these, 8 occurred during match play, corresponding to an incidence of 0.3 severe injuries per 1000 player hours (95% CI 0.1–0.5). The most common injury type was joint sprain (32.5%, *n* = 143), followed by muscle strains (14.1%, *n* = 62) and contusions (12.7%, *n* = 56).

Overall the ankle was the most commonly injured body part (25.9%), followed by the knee (15.2%), finger/thumb (10.7%), and lumbar/lower back (8.9%). This distribution was almost similar between match play (ankle: 31.3%, knee: 15.6%, fingers/thumb: 10.2%) and training (ankle: 17.0%, knee: 13.2%, lower back: 11.9%). Competition rates did not differ from practice rates among all injuries (7.48 vs. 6.91 per 1000 athlete exposures (AEs)) [16]; in addition, the injury rates in men and women were 4.69 and 7.07 per 1000 AEs, respectively. The injury rate was greater in women than men (IRR, 1.51; 95% CI, 1.19–1.90). Moreover time-loss (TL) injuries (resulting in participation restriction for at least 24 h), rates were 1.75 and 2.62 per 1000 AEs for men and women, respectively [16].

When analyzing sprains, the ankle was the most commonly affected (*n* = 87) (19.8%), followed by finger/thumb (*n* = 26) and knee (*n* = 17). When considering muscle strains, they were mostly located in the lower back (*n* = 19) and thigh (*n* = 10). In total, 23.0% of all injuries (*n* = 101) were the result of traumatic contact between players, while 20.7% (*n* = 91) were overuse injuries, and 17.3% (*n* = 76) were reported as noncontact trauma.

A Survey of Injuries Among Male Players of the Chinese Taipei National Volleyball Team showed that the incidence of injuries increased with the training sessions [17]. The percentage of injuries in the second session was greater than that in the first session when double sessions were performed daily. In the first session, 24%, 16%, 16%, and 16% of all injuries occurred in the knees, waists, fingers, and ankles, respectively. In the second session, knees and waists were the most common injury locations, which accounted for 33.3% and 23.8% of all injuries, respectively. This is the consequence of fatigue, reduced muscle performance and reduced proprioception. Based on the statistics, knee injuries were the most severe and frequent injuries of the lower extremities, which accounted for 33.3% of all injuries, followed by waists (23.8%), ankles (16%), fingers (16%), and shoulders (12%).

A difference has been also recorded according to the different playing phase [18]. The authors reported a total of 178 injuries in 121 out of 144 volleyball players. Most common location was the ankle (23.03%) followed by knee (21.91%), shoulder (11.79%), back (10.67%) hamstring (9.55%), groin (6.74%), finger (6.17%), hand (3.93%), and other (5.61%).

Most common cause for injury was spiking (33.70%), blocking (24.15%), diving (17.41%), setting (11.23%), and others (14.04%). Maximum incidence of injuries affected muscles (32.40%), ligaments (24.71%), tendon (9.55%), bones (factures) (2.80%), braises (6.17%), and other (7.40%).

Among knee injuries, patellar tendinopathy, also known as “jumper’s knee,” is the most common situation having been reported in about 50% of male indoor volleyball players [19, 20]. The rate is slightly inferior in elite players (around 40%) [21] and more frequent in males than females. It is more common in volleyball players who train on hard surfaces [21] and is therefore less common in beach volleyball players [22]. Middle blockers tend to suffer from jumper’s knee more than do players at other positions.

On the contrary, acute trauma leading to anterior cruciate ligament (ACL) trauma is uncommon [23]. The reported incidence is about 0.1 ACL injuries/1000 athlete exposures among female collegiate volleyball athletes in the United States (compared with a rate of 0.4/1000 athlete exposures in soccer and 0.27/1000 athlete exposures in basketball) [24]. These data have been confirmed by retrospective cohort studies from Norway and the Netherlands [25, 26].

10.5 Top Five Sports-Related Injuries

Women generally have a higher rate of overuse injuries while men have a higher rate of ball contact-related injuries [16].

10.5.1 Ankle Sprains

Ankle sprains are the most common acute injury in volleyball, with a reported incidence of up to 41% of all volleyball-related injuries [26]. They usually occur when landing onto another player's foot, often a player from the opposing team, so that they are more common in players of the front row. They often result from a supination trauma with the evidence of injury to the lateral compartment ligaments with swelling and tenderness (Fig. 10.3).

Recurrent sprains are common, with one study showing a 42% risk of resprain in volleyball players within 6 months of the initial sprain [25].

10.5.2 Knee Sprains

The knee is the second most commonly injured body part among NTL injuries (men, 25.5%; women, 16.3%) [16]. However, is the majority of the published they show a considerably higher rate in women than men in landing and cutting sports [27]. In addition to female gender and prior ACL tear, a number of risk factors have been proposed including intercondylar notch width, generalized ligamentous laxity, and increased body mass index [28]. In volleyball, the mechanism for ACL tear usually is coming down awkwardly from a jump or a cutting maneuver.

Fig. 10.3 Lateral compartment swelling and tenderness are extremely common after inversion ankle sprains

10.5.3 Throwing Shoulder and Suprascapular Neuropathy

The exact rate of shoulder injuries is hard to assess. Traumatic events are uncommon, while overuse syndromes are more frequent with a reported incidence of around 12% [17, 18]. The phases of the overhead spike and serve predispose to excessive external rotation, glenohumeral internal rotational deficit (GIRD), internal impingement, labral tears, rotator cuff tears, and neurovascular structures entrapment which may lead to painful syndromes and dysfunction [29–31].

Increased external rotation and GIRD are the initial event [32]. Repetitive abduction and external rotation movement is common in hitters and servers; it increases the laxity of the anterior capsule and at the same time causes retraction of the posterior capsule. There is therefore a static translation of the humeral head into a more anterior and superior position. This trend may aggravate.

Another pathologic condition which is aggravated by this anterior subluxation is the internal impingement. It is caused by the impingement of the deep surface of the supraspinatus tendon rotator with the posterior labrum during the throwing movement [33, 34].

Suprascapular neuropathy occurs from traction and/or compression of the nerve during the extreme motions of the arm during the cocking or follow-through phases of the arm swing while serving and hitting [35, 36]. The nerve can become entrapped at different locations, but it is more common at the spinoglenoid notch. Nerve entrapment causes infraspinatus muscle weakness and atrophy which is reported in 12–30% of top-level volleyball players [37]. Biceps traction leading to a SLAP lesion and pulley pathology are often related to the deceleration/follow-through phase [38].

10.5.4 Low Back Pain

Low back pain is the fourth most common injury seen in volleyball players [18]. One study reported that low back pain is experienced in 63% of volleyball players [39]. More than half of volleyball players experience low back pain during their sports career, but less than 20% of players met with a physical therapist to receive the care they need [18].

Moreover 47.4% of volleyball players with low back pain continued to have low back pain for the rest of their sports career [40]. This constant pain can affect muscle performance, preventing athletes from reaching their maximal potential.

One common reason for low back pain in volleyball players is asymmetries in endurance for muscles that stabilize the low back [41]. Core muscles provide stability to the low back and spine with all movements. If imbalances are present in the core muscles, then players may spike or serve the ball with increased turning and bending in their spine. These extra movements caused by reduced stability in the spine cause increased pressure in the joints of the lower spine. This repetitive pressure over time can lead to low back pain.

Other muscles influence the stability of the spine [42]. The gluteal muscles prevent the trunk and hips from bending too far forward during landing. If gluteal muscles do not have the endurance to perform this motion, then your upper body will bend further forward as you land. This poor landing posture results in decreased stability of the spine and increases the risk of low back pain in volleyball players. Studies have shown that at rest, volleyball players with low back pain stand with an anterior pelvic tilt [43, 44]. It has been shown that there is a correlation between landing with an anterior pelvic tilt and low back pain in volleyball players.

10.5.5 Patellar Tendinopathy

Patellar tendinopathy is an overuse injury; its prevalence has been reported to be 11% in Swedish elite junior volleyball players [45] and 36% in male senior professional volleyball players [46]. The symptoms onset usually occurs gradually after a threshold of cumulative tissue injury has been exceeded. Histological examination on tendon samples reveals degeneration and fibrotic scarring of the tendon, particularly at the bone-tendon junction. The normally parallel collagen bundles are disorganized, and the observed tenocytes display altered morphology [47]. It has been hypothesized that excessive tendon loading induces tenocyte apoptosis (programmed cell death) [48]. An increased incidence of jumper's knee has been reported in athletes who jump highest and in those who develop the deepest knee flexion angle during landing from a spike jump [49]. Another study suggested that valgus knee strain during the eccentric loading phase of the spike jump take-off may contribute to the observed asymmetric onset of patellar tendinopathy [50].

10.5.6 Final Consideration: Concussions

They account for 19.4% and 14.8% of men's and women's volleyball TL injuries, respectively. Because volleyball includes rules to limit the amount of contact, such a finding may be unexpected [51]. However, the most common mechanism of concussion was not due to player contact [52], but rather ball contact, particularly during blocking and digging.

10.6 Prevention of Injuries

10.6.1 Ankle Sprains

Ankle sprains are the most common traumatic event in volleyball. A non-negligible number of players suffer a recurrence within 6 months from the initial trauma. Therefore, it is particularly important to complete a supervised rehabilitation program before returning to play. Balance board training to regain proprioception has shown to be effective in preventing recurrences of ankle sprains in volleyball players as well to prevent initial trauma [53]. Wearing a lace-up ankle brace or taping the ankle for the remainder of the season also may help reduce the incidence of recurrent sprain.

10.6.2 Knee Sprains

One study showed that less than 50% of athletes returned to playing sports at their preinjury level or returned to participation in competitive sport when surveyed 2–7 years after ACL reconstruction [54]. Since several athletes are not able to return to high-level sports after ACL reconstruction, and the risk of osteoarthritis is increased after an ACL tear, there has been considerable interest on prevention programs. There have been numerous studies looking at proprioceptive and plyometric training programs to decrease ACL injury risks in athletes engaging in sports with cutting, jumping, and sprinting, with many showing encouraging results. [27, 55]. One study included female volleyball players and showed that a neuromuscular training program significantly reduced ACL injury [56].

10.6.3 Throwing Shoulder and Suprascapular Neuropathy

Attention to throwing mechanics and appropriate stretching, strength, and conditioning programs may reduce the risk of injury in this highly demanding activity. Early discovery of symptoms followed by conservative management with rest and rehabilitation with special attention to retraining mechanics may mitigate the need for surgical intervention. Prevention of injury is always more beneficial to the long-term health of the thrower than is surgical repair.

It usually consists of selective stretching of the posterior capsule using “sleeper stretches” and reinforcement of the anterior “wall” (subscapularis, latissimus dorsi, and teres major) [57]. In addition, since malpositioning of the scapula can contribute to impingement and weak periscapular muscles can alter shoulder kinematics leading to shoulder pain: therapy of shoulder problems should always include scapular stabilizing exercises.

10.6.4 Low Back Pain

In order to prevent and/or treat low back pain the core muscles should be strengthened. This helps stabilizing the lower spine is stable. In addition, performing an abdominal contraction before any overhead motion (spiking, serving, setting) or landing may be beneficial. During an abdominal contraction, the core muscles rotate the pelvis posteriorly reduces compression in the joints of the lower back. This also prevents players from landing in an anterior pelvic tilt. Strengthening other lower body muscles that attach to the pelvis and provide stability to the spine such gluteal muscles is indicated.

10.6.5 Patellar Tendinopathy

Potential prevention strategies include changes in the jumping technique, training, and rehabilitation.

Changes in the jumping technique in order to prevent valgus strain on the lead knee and to keep knee flexion to a minimum on landing may be advantageous in reducing the rate and severity of patellar tendinopathy. It must be highlighted the importance of the landing phase of the jump since it is the most common reason for knee injuries in volleyball players. In any case, no clear scientific data have been published to support this fact.

Training volume on hard playing surfaces should not exceed the capacity of the patellar tendon to regenerate. However, it is still debated how often and by what percentage the volume of jump training can be safely increased over a given time period. It has been shown that a critical step occurs when young players are promoted from the junior to the senior level. During this passage, players are abruptly moved from a relatively safe training environment to an elite club or sports school that practices daily and has a structured program of weight training. Therefore, great care should be taken to muscle stretching and rest to strengthening. In addition, lack of strength and flexibility in the core muscles [58], and lack of balance or control of the body when jumping and landing has been associated with poor form in the athlete's jumps resulting in injury and reduced performance.

Eccentric training protocols (particularly those using decline squats) have shown to be effective in treating patellar tendinopathy [59, 60]. However, other studies have reported that eccentric training of the quadriceps was ineffective in treating symptomatic jumper's knee in volleyball players during the competition season [61]. There is preliminary evidence that such knee extensor eccentric training protocols, used prophylactically, can effectively prevent sports-related anterior knee pain from patellar tendinopathy [62]. Specific rehabilitation and strengthening of the core muscles may prevent functional imbalances of the lower limbs' weakness contributing to the treatment of anterior knee pain. In addition, when treating jumper's knee, it is important to rehabilitate beyond the absence of symptoms and to avoid return to play before the athlete is adequately rehabilitated, in order to maximize secondary prevention of recurrent injury and thus minimize the risk of chronicity.

Finally, although reports of benefit of external orthoses abound, there is no evidence to support the routinely use of patellar straps (ostensibly designed to redistribute the forces acting on the patellar tendon) in the treatment or prevention of jumper's knee.

Conclusions

Volleyball is one of the most common sports. Although it is a noncontact sport, it is physically demanding. Players may suffer two types of injuries: sprains and overuse syndromes. Among sprains, ankle and knee are usually affected; among overuse syndromes, patellar and Achilles tendinopathy are common. Ankle and knee sprains usually follow landing from a jump. Volleyball is not a contact sport, but players are usually in the air and while landing they can come in contact with teammates or opponents resulting in traumatic events. Overuse syndrome have a gradual onset. They are caused by extrinsic (hard surfaces, shoes, training methods) or intrinsic (muscle performance, jumping technique, core muscle weakness) factors. Prevention is essential to reduce the severity of these injuries; however, when they occur, specific rehabilitation strategies and modifications of training programs are mandatory to achieve good results and comeback to performance.

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