Introduction

Volleyball is a team sport played by two teams on a court divided by a net. The object of the game is to send the ball over the net in order to ground it on the opponent’s side. Teams are allowed three hits to return the ball over the net. Two competitive forms of volleyball are played around the world; indoor volleyball and beach volleyball.

Indoor Volleyball:
Competitive indoor volleyball uses a player rotation system; the positional duties are a setter, two middles, three outsides, and a backcourt defensive specialist, the libero. There are six athletes on the 9 m x 9 m court at any one time; the libero interchanges into the backcourt for either of the two middles. The demands of a match change with the demands of offensive and defensive duties and an individual’s placement on court (e.g., frontcourt or backcourt in the rotation). The vast majority of jumping in volleyball occurs in the frontcourt, consisting of attacking spike jumps (SPJ) and defensive block jumps (BLJ), with setters also performing jump sets (JS). However, backcourt offensive attacks (i.e., SPJ) are a significant component of play, particularly with men (Polglaze and Dawson 1992; Sheppard and Gabbett 2007; Sheppard et al. 2007; Viitasalo 1991; Viitasalo et al. 1987). Furthermore, defensive diving efforts are a physiological stress that must be considered (Sheppard et al. 2007).

Several published volleyball time–motion analysis studies were conducted on competition prior to several rule changes, including the player substitution rules and the change from service scoring to rally-point scoring in 1999 (Dyba 1982; Polgaze and Dawson 1992). These rule changes appear to have had some minor influences on the specific physiological demands of volleyball matches (Sheppard et al. 2007b). It was determined that 77% of rallies were 12 s or less, whereas the average rally time was approximately 11 s. However, the range of durations included rallies as short as 3 s (ace service) and as long as 40 s. In addition, 44% of rest periods between rallies were 12 s or less, with the average rest time being 14 s in duration. Rest periods were observed to be as short as 4 s and as long as 38 s (contested call or time-out).
Distribution of (A) rally times, and (B) rest between rallies in elite men’s volleyball competition.

Observations of match conditions (Polgaze and Dawson 1992; Sheppard et al. 2007; Viitasalo et al. 1987) reveal that volleyball is characterized by frequent short bouts of high-intensity exercise, followed by periods of low-intensity exercise and brief rest periods. The high-intensity bouts of exercise with relatively short recovery periods, coupled with the total duration of the match (~90 min), suggest that volleyball players require well-developed anaerobic alactic (phosphocreatine) and anaerobic lactic (anaerobic glycolytic) energy systems as well as reasonably well-developed aerobic capabilities (Dyba 1982; Polgaze and Dawson 1992; Viitasalo et al. 1987). Testing results and observation of match conditions also indicate that considerable demands are placed on the neuromuscular system during the various sprints, dives, jumps, and multidirectional court
movements that occur repeatedly during competition (Sheppard and Borgeaud 2008; Sheppard et al. 2008b; 2008c 2009d). As a result, it can be assumed that volleyball players require well-developed speed and muscular power (Sheppard et al. 2007, 2008b; Stanganelli et al. 2008) and the ability to perform these repeated maximal efforts with limited recovery for the duration of the match (Gabbett et al. 2007; Polgaze and Dawson 1992; Sheppard et al. 2007).

Vertical jumping ability is likely the single most important performance indicator in volleyball. Indeed, testing measures such as spike jump (with three- or four-step approach), block jump (countermovement jump with two-arm reach), and countermovement vertical jump (countermovement jump with one-arm reach) are typical of most programs (Gladden and Colacino 1978; Heimer et al. 1988; Marques et al. 2008; Newton et al. 1999; Smith et al. 1987; Spence et al. 1980). The use of these measures is supported by their ability to discriminate between higher and lower performers within the sport (Heimer et al. 1988; Smith et al. 1992; Spence et al. 1980; Viitasalo 1991). Considering the tactical nature and importance of jumping activities and the frequency with which they occur in a typical match, countermovement jump ability (i.e., jump and reach height) and approach jump ability (i.e., spike jump height) are considered critical performance indicators for volleyball and are a feature of the physiological profile of a volleyball player (Sheppard et al. 2008b, 2009a, 2009b; Spence et al. 1980; Viitasalo 1991). However, we have observed large variability in the performance of the block jump, likely due to athletes’ inability to complete the two-arm reach with their hands at the same height consistently. The typical error of this measure, in our experience, is too large to be useful to the practitioner, making it difficult to detect real changes versus changes attributable to alterations in execution of the test by the athlete.

Beach Volleyball:
Beach volleyball has been played since the early 1900s and is primarily based on the game of indoor volleyball. Beach volleyball became an Olympic sport at the 1996 Atlanta summer games. The sport has evolved through a variety of rule and regulation changes made by the international governing body, the FIVB (Fédération Internationale de Volleyball 2009). The sport is played on a court measuring 8 m x 16 m with an 8 m wide net splitting the court into two 8 m x 8 m halves. The net height is different for male and female athletes, with the top of the net reaching 2.43 m and 2.24 m, respectively.

Two opposing teams compete against each other on opposite sides of the net, with each team consisting of two competitors, traditionally one taking on the role of backcourt play and the other frontcourt. A single match follows a best of three set format (first to win two sets). A set is complete when a team scores 21 points or greater and is 2 points clear of the opposition; the third tiebreaker set is won by the first team that reaches 15 points or greater and is 2 points clear of the opposition. In the first and second set, teams will alternate playing from each end, swapping ends every time the total combined score is a multiple of 7. For example, if team A has scored 6 points and team B has scored 8 points, the total combined points equals 14, so the teams will swap ends before commencing play for the next (15th) point. During the third set, teams change sides of the court at every combined multiple of 5.
After winning a point, the winning team has 12 s to return to the baseline and serve the ball to start play for the next point. During the first and second sets (but not the third), there is a 30 s “technical time-out” when the combined scores equals 21. In association with this, each team is allowed to call a 30 s time-out at any stage during the set; this applies in a tiebreaker set also.

Data from the 2009 FIVB world tour indicate that the mean duration of a female two-set match was 38.3 ± 5.3 min and the combined mean total points scored was 74.5 ± 6.1. In a three-set match, mean duration and scores were 55.0 ± 7.0 min and 104.6 ± 6.9 points, respectively. Male two-set matches had a mean duration of 41.5 ± 6.2 min and combined mean total points scored of 75.3 ± 6.7. A three-set match had a mean duration and combined points score of 59.8 ± 7.6 and 105.3 ± 7.9, respectively (www.fivb.org/EN/BeachVolleyball/Competitions/WorldTour/2009x/).

Beach volleyball consists of multiple high-intensity maximal efforts lasting approximately 6 to 8 s broken up by short, low-intensity recovery periods (Homberg and Papageorgiou 1994; Turpin et al. 2008). The ability to reproduce and maintain the quality of these efforts is a key component of performance. Therefore it is suggested that when planning a training session, coaches consider the repeated-effort nature of the sport and ensure that there is a substantial anaerobic bias. To maintain training specificity and develop a conditioning program that challenges the athlete’s ability to perform maximal efforts repeatedly, coaches should vary the duration of effort and recovery periods to stimulate the desired energy system. Like indoor volleyball players, beach volleyball players require well-developed anaerobic alactic (ATP-CP) and anaerobic lactic (anaerobic glycolytic) energy systems as well as reasonably well-developed aerobic capabilities.

At the time of publication the authors were in the process of developing a relevant, reliable, and valid repeated-effort test specific to beach volleyball. The test and related data are not included in this chapter; however, we believed it necessary to suggest this as an important research area. If a valid and reliable test can be developed, it should be included in the test battery for beach volleyball.

In association with the repeated-effort nature of the sport, consideration must be given to the influence of jumping. A major goal for any beach volleyball conditioning program should be to maximize vertical jump height and minimize excessive stress in both takeoff and landing. Two studies highlight the importance of jumping: during the course of play an elite male German beach volleyball athlete averaged 85 maximal jumps per game (Homberg and Papageorgiou 1994), whereas Turpin and colleagues (2008) found that the average number of jumps per team per match was 219 ± 7.4. This is supported by research with the Australian Institute of Sport (AIS) beach volleyball program showing that within an FIVB world tour game, an Australian men’s team performed on average 145 ± 22.1 maximal jumps during the course of play across seven games.

Key performance skills (such as jump serving, spiking, and blocking) in beach volleyball depend on an athlete’s vertical jump ability (Batista et al. 2008; Giatsis and Tzetzis 2003; Grgrantov et al. 2005). The higher an athlete can jump when performing these skills allows for a higher ball contact point and as a result improved hitting angles, a greater range of attacking options, and, in the case of blocking, improved defending options attributable to the greater potential for a reduction in effectiveness of the attacking opponent. From an attacking perspective, Koch and Tilp (2009) demonstrated that despite a high error rate, the jump serve was the most successful serving technique in relation to direct points won and that the crosscourt spike action or hit was the most
used attacking technique by both genders (male 38.9%, female 30.6%). From a defensive perspective, these authors assessed the variations in blocking technique and showed that an active block (block in which the defender reaches over the net and penetrates the opponent’s side) was the most common style of block for both male and female athletes. Giatsis (2001) concluded that blocking accounted for 27% of the total number of jumps throughout a game of beach volleyball.

Because of the sizeable impact of the athlete’s vertical jump ability on performance and some associated major factors influencing beach volleyball players’ jump heights (e.g., somatotype, body composition, ground reaction force characteristics), an important component of athletes’ conditioning is to maximize their power to weight ratio, which requires the athlete to minimize nonessential (fat) mass (Riggs and Sheppard 2009). This can vary between athletes and is dependent on athlete maturation, sex, and training history.

Accordingly, key training outcomes and goals for beach volleyball include maximizing vertical jump reach height, multidirectional acceleration, and repeated maximal efforts.

**Athlete Preparation and Test Environment**

Standardized pretest preparation is recommended to enable reliable and valid physiological data to be obtained. Refer to the AIS Pretest Preparation document for specific information relating to athlete and environment preparation.

It is generally unrealistic to expect that elite athletes can be completely recovered for testing occasions. However, performing tests after a complete rest day, and several days after a player’s last match and international travel, is considered good practice.

For indoor volleyball, vertical jump testing, as well as any repeated-effort or endurance testing, should be performed in the volleyball indoor sports hall, if possible, or a suitable indoor facility with a nonslip surface. A laboratory setting is most suitable for anthropometry testing as well as the assessment of strength qualities (i.e., using a strength laboratory).

For beach volleyball, vertical jump and reach testing, as well as any repeated-effort or endurance testing, should be performed on a beach volleyball court. Environmental conditions can significantly affect test results when beach volleyball athletes are tested in their competition and training environment. Issues like altered compressive characteristics of wet sand versus hot dry sand, air temperature, and wind speed can all alter performance outcome. After rain, the sand on a beach volleyball court will tend to become harder and more compliant, resulting in a surface that provides better energy return compared with hot and dry sand. Consequently, it is important that when conducting physiological testing on beach volleyball athletes, testers record environmental data (temperature, humidity, air pressure, wind speed) and time of testing. It is also relevant to make note of the sand characteristics (e.g., hot, dry, and fluffy or cool, wet, and hard).
Recommended Test Order

It is important that field and strength tests are completed in the same order to control the interference between tests. This order also allows valid comparison of different test occasions. The order is as follows:

<table>
<thead>
<tr>
<th>DAY</th>
<th>TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anthropometry</td>
</tr>
<tr>
<td></td>
<td>Vertical jump</td>
</tr>
<tr>
<td>2</td>
<td>Lower-body speed-strength &amp; strength</td>
</tr>
<tr>
<td>3</td>
<td>Indoor volleyball repeated-effort</td>
</tr>
</tbody>
</table>

Equipment Checklist

**Anthropometry:**
- [ ] Stadiometer (wall mounted)
- [ ] Balance scales (accurate to ± 0.05kg)
- [ ] Anthropometry box
- [ ] Skinfold calipers (Harpenden skinfold caliper)
- [ ] Marker pen
- [ ] Anthropometric measuring tape
- [ ] Recording sheet - refer to anthropology data sheet template
- [ ] Pen

**Vertical Jump Test:**
- [ ] Yardstick® jumping device (e.g. Swift Performance Yardstick)
- [ ] Measuring tape
- [ ] Field marking tape
- [ ] Recording sheet - refer to vertical jump data sheet template
- [ ] Pen

**Lower-Body Speed-Strength & 1RM strength testing:**
- [ ] Lifting platform
- [ ] Squat rack with safety bars
- [ ] Olympic bench press
- [ ] Chin up bar
- [ ] Barbell (Olympic 20kg)
- [ ] Weight plates (2.5-25kg increments)
- [ ] Recording sheet - refer to strength and power data sheet template
- [ ] Pen
Indoor Volleyball Repeated-Effort Test:

[ ] Electronic light gate equipment
[ ] Yardstick © jumping device (e.g. Swift Performance Yardstick)
[ ] 2 Mounted volleyballs on apparatus
[ ] Stopwatch
[ ] Measuring tape
[ ] Field marking tape
[ ] Recording sheet - refer to indoor volleyball repeated effort test data sheet template
[ ] Pen

Test Protocol - Anthropometry

Rationale -
The height of volleyball athletes is a performance consideration and may also influence court position (Sheppard and Borgeaud 2008; Sheppard et al. 2009a, 2009b). Low fat mass is imperative in elite volleyball players and is a major consideration in improving relative strength qualities and jump heights in elite players (Riggs and Sheppard 2009; Sheppard et al., 2009b).

Test Procedure -
Measurement of height, body mass, and skinfolds should be carried out prior to field testing protocols. Skinfolds are recorded over seven sites (triceps, biceps, subscapular, supraspinale, abdominal, front thigh, and medial calf). The individual skinfold measures as well as the sum of the seven sites should be reported. Refer to anthropometry protocols outlined in the AIS Surface Anthropometry document for a detailed description of anthropometric test procedures. Although the description of skinfold measurement procedures seems simple, a high degree of technical skill is essential for consistent results. It is therefore important that these measurements be taken by an experienced tester who has been trained in these techniques. It is also important that the same tester conduct each retest to ensure reliability.

Data Analysis -
Elite volleyball athletes in general appear to be taller than previously reported (Sheppard et al. 2009b). However, height alone does not determine the suitability of a player, and although athletes who play certain positions (e.g., middles) tend to be quite tall, height does not exclude an athlete from consideration for any one position. Generally, height can be used as a talent potential indicator in that tall players who are taught to play well may achieve elite status, and it can also be used to track growth in preelite players.

A useful ratio comparing body mass and sum of seven skinfolds ($\Sigma 7$ skinfolds) can be used to reflect lean mass. The formula of body mass/$\Sigma 7$ skinfolds provides a simple ratio that allows comparison of athletes who are vastly different in height and body mass, in regard to their lean mass. This ratio (e.g., 100 kg/50 mm = 2.0) also provides a useful, straightforward context for educating athletes on the role of lean muscle mass increases while reducing or maintaining skinfold levels.
Normative Data -
The two tables below present anthropometric normative data for Australian female and male indoor volleyball and beach volleyball athletes, respectively.

### Anthropometric data for male and female indoor volleyball players (mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
<th>∑7 Skinfolds (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>183.0 ± 6.4 (173.7-194.2)</td>
<td>73 ± 5 (65-84)</td>
<td>101 ± 21 (81-136) Desired &lt; 60mm</td>
</tr>
<tr>
<td>MALE</td>
<td>200.4 ± 5.0 (187.3-207.5)</td>
<td>95 ± 6 (82-109)</td>
<td>57 ± 9 (40-72) Desired &lt; 50mm</td>
</tr>
</tbody>
</table>

Source: Female - Australian junior (n=9) and senior national (n=2); Male - Australian junior (n=8) and senior national team (n=14).

### Anthropometric data for male and female beach volleyball players (mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Height (cm)</th>
<th>Body Mass (kg)</th>
<th>∑7 Skinfolds (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>183.7 ± 4.3 (175.9-191.1)</td>
<td>71 ± 5 (63-82)</td>
<td>84 ± 22 (53-108) Desired &lt; 55mm</td>
</tr>
<tr>
<td>MALE</td>
<td>195.2 ± 3.76 (190.7-199.7)</td>
<td>90 ± 6 (84-99)</td>
<td>48 ± 13 (33-71) Desired &lt; 50mm</td>
</tr>
</tbody>
</table>

Source: Female - Australian junior (n=5) and senior national (n=4); Male - Australian junior (n=2) and senior national team (n=4).
Test Protocol - Jump Tests

Rationale -
Vertical jump height is likely the single most important measured physical quality in elite volleyball players (Sheppard et al. 2009a, 2009b; Stanganelli et al. 2008). Improving vertical jump height in volleyball players greatly increases their options for angle of attack in spiking as well as their defensive abilities in blocking, two major components of volleyball (Sheppard et al. 2007).
For volleyball, three types of jump tests are implemented. The first is the standing vertical jump (with arm swing and countermovement). Additional tests include the depth jump and squat jump.

Test Procedure -
Vertical Jump:
Standing Reach Height:
i. The athlete should stand with their feet together side-on to the Yardstick jumping device.
ii. Keeping the heels on the floor and looking straight ahead, the athlete reaches upward with their dominant hand as high as possible, fully elevating the shoulder to displace the vanes (e.g., vane 25 is displaced 25 cm).
iii. This is recorded as the standing reach height in centimeters.
i. The absolute standing reach height from the floor may be calculated as the pole setting height (i.e., the height the zero vane is from the floor; either 160, 170, 180, 190, 200, or 210 cm) plus the highest vane displaced. Record this measure in centimeters.

Vertical Jump Height:
i. Move several of the lower vanes away before instructing the athlete to stand close to the Yardstick for their jump.
ii. The athlete uses an arm swing and countermovement to jump as high as possible in order to displace the vanes at the height of the jump.
iii. The takeoff must be from two feet with no preliminary steps or shuffling; however, feet can be comfortably apart.
iv. The athlete performs at least three trials and may continue as long as improvements are being made. The best trial, that is, the highest vane displaced, is recorded as the jump height.
v. The difference between jump height and standing reach height is calculated to give the relative vertical jump result in centimeters.
i. The absolute jump height from the floor may be calculated as the pole setting height (i.e., the height the zero vane is from the floor; 160, 170, 180, 190, 200, or 210 cm) plus the highest vane displaced (e.g., vane 80 = 80 cm). Record this measure in centimeters.
**Depth Jump:**

i. Begin with the athlete standing on top of the drop box with the force plate or contact mat placed approximately 0.5-m in front of the box.

ii. With hands on hips instruct the athlete to step forward off the box without stepping down or jumping up, and upon contact with the ground to jump as high as possible while minimizing time on the ground.

iii. Ensure that the take-off and landing positions are the same for each trial. Common variations include landing with the feet dorsiflexed, and knees or hips flexed.

iv. From the measurement device obtain the jump height and contact times.

v. The reactive strength index (RSI) is calculated as jump height divided by ground contact time.

vi. Repeat the above procedure from boxes of varying heights (e.g. 30, 45, 60 and 75-cm).

**Squat Jump:**

i. Zero the force-platform without the athlete on the platform (i.e. zero-mass).

ii. Instruct the athlete to step onto the centre of the platform, with a bar across the shoulders.

iii. Secure the position transducer cable to the side of the bar, such that the cable runs in parallel with the athletes shoulders, hips, knee, and ankle (i.e. place it in line with the lateral malleolus).

iv. Zero the position transducer to set a reference for the take-off and landing position.

v. Instruct the athlete to lower to achieve the squat position (110 degree knee angle) with a practitioner providing feedback using a handheld goniometer.

vi. When the position is achieved, begin sampling data and instruct the athlete to hold this position for 3 s (i.e. counting down 3-2-1) before jumping maximally vertically.

vii. Upon landing, instruct the athlete to stand in the landing position for 1-2 s to complete the sampling period.

viii. Examine the force-trace for compliance (i.e. ensure no small amplitude countermovement [SACM] was present).

ix. Save data, provide a minimum of 1 min rest, and repeat for 2-4 trials.

**Data Analysis - Indoor Volleyball:**

Jump test results can be used not only to identify potential elite talent but also to track progress and evaluate the effectiveness of training methods in improving volleyball performance (Sheppard et al. 2008c, 2008d, 2008e, 2008f). In volleyball, jump height is a quality that is not optimized but rather needs to be maximized to each athlete’s potential and is likely the single largest discriminator between junior and senior elite players (Sheppard et al. 2009b).

Useful comparisons can be made between the vertical jump (CMJ), drop jump (DJ), and spike jump (SPJ; vertical jump with approach) to gain insight into the training needs of a volleyball player. For example, the jump height difference between SPJ and CMJ provides an indication of the athlete’s ability to use the approach (run-up) to gain greater jump heights (Sheppard et al. 2007). As seen from the table below, on average the SPJ is 8 cm higher than CMJ for females and 14 cm for males.
It is suggested that practitioners consider 6 cm and 10 cm a desired minimum for females and males, respectively. If the difference between SPJ and CMJ is lower than these values, more attention should be paid to approach and jump technique, horizontal to vertical transition, or specific physical qualities (e.g., stretch–shorten cycle [SSC] function).

Comparing DJ and CMJ heights is useful to determine training needs. In general, DJ height should be superior to CMJ height (Bobbert 1990; Bobbert et al. 1986). However, this is not always the case with each individual athlete; the relationship between DJ height and CMJ height is quite sensitive to training activities (Sheppard et al. 2008f), and the DJ height of volleyball players tends to increase with increased training (Sheppard et al. 2009a). It is proposed that if an athlete’s DJ is lower than their CMJ, then training with an increased stretch load (e.g., drop jump training, accentuated eccentric loads) is warranted, because it presents a potential to increase DJ height (Sheppard et al. 2008a, 2008e, 2008f). This approach stands to reason with volleyball athletes, because increases in DJ height are strongly associated with increases in the jumps that occur in volleyball (CMJ and SPJ) (Sheppard et al. 2008d, 2009a).

**Beach Volleyball:**

As discussed for indoor volleyball, to gain insight into the training needs of a beach volleyball player and identify possible weaknesses in their ability to maximize their jump height reach, we must understand the technical and skill demands of the sport. In beach volleyball the skill to perform an effective block has a lot to do with the athlete’s ability to read and assess the opponent early, position themselves early, drop into a deep squat out of the hitting opponent’s field of vision, hold this deep squat, and then jump maximally from this static position without using an arm swing due to hand positioning. Therefore, the need to assess block jump height and the ability to execute a maximal jump from a static deep hold are most relevant. Batista and colleagues (2008) assessed the block jump (BJ) height as well as spike jump height of 38 male beach volleyball athletes, comparing the elite and the subelite players. The investigators identified a significant difference between the two group mean jump heights, and the greatest difference was seen in the block jump height (elite group 8% higher). Well-trained beach volleyball athletes often obtain similar CMJ and BJ heights on both a hard and a sand surface (see tables below). These findings suggest that beach volleyball athletes need to generate force and power from active muscle recruitment more than from heavy reliance on the SSC (Riggs and Sheppard 2009).

In the indoor volleyball section we suggested that the jump height difference between SPJ and CMJ provides an indication of the athlete’s ability to use their approach (run-up) to gain greater jump heights (Sheppard et al. 2008d). For beach volleyball athletes being tested on sand, this appears not to be the case. Results presented in normative data tables demonstrate that scores obtained on sand are less than those obtained on a hard surface and that the difference between the two jump tests is greater on the hard surface. This reinforces the notion that a beach volleyball athlete’s vertical jump ability on sand may not reflect SSC performance but rather reflects their ability to generate force and power through active force recruitment.
Normative Data -
The table below presents vertical jump normative data for female and male Australian indoor volleyball athletes. The following tables present vertical jump normative data for female and male Australian beach volleyball athletes on sand and hard surfaces, respectively.

Vertical jump data for male and female indoor volleyball players
(mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Countermovement Jump (cm)</th>
<th>Depth Jump (from 30cm) (cm)</th>
<th>Spike Jump (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>291 ± 11 (276-308)</td>
<td>292 ± 11 (279-311)</td>
<td>299 ± 12 (284-315)</td>
</tr>
<tr>
<td>MALE</td>
<td>330 ± 5 (318-338)</td>
<td>330 ± 6 (318-340)</td>
<td>344 ± 7 (332-366)</td>
</tr>
</tbody>
</table>

Typical error: Countermovement Jump = 2.1cm; Depth Jump = 2.2cm; Spike Jump = 2.1cm

Source: Female - Australian junior (n=9) and senior national (n=2); Male - Australian junior (n=14) and senior national team (n=12).

Vertical jump data for male and female beach volleyball players on sand
(mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Countermovement Jump (cm)</th>
<th>Block Jump (cm)</th>
<th>Spike Jump (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>293 ± 11 (277-310)</td>
<td>285 ± 12 (268-302)</td>
<td>296 ± 13 (278-312)</td>
</tr>
<tr>
<td>MALE</td>
<td>332 ± 6 (323-338)</td>
<td>317 ± 4 (310-321)</td>
<td>335 ± 4 (330-342)</td>
</tr>
</tbody>
</table>

Typical error: Countermovement Jump = 1cm; Block Jump =2cm; Spike Jump =1cm

Source: Female - Australian junior (n=4) and senior national (n=2); Male - Australian junior (n=2) and senior national team (n=4).
Vertical jump data for male and female beach volleyball players on hard surface
(mean ± SD; range)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Countermovement Jump (cm)</th>
<th>Block Jump (cm)</th>
<th>Spike Jump (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALE</td>
<td>297 ± 13 (278-316)</td>
<td>286 ± 11 (270-303)</td>
<td>303 ± 12 (287-316)</td>
</tr>
<tr>
<td>MALE</td>
<td>331 ± 6 (321-336)</td>
<td>319 ± 5 (310-323)</td>
<td>341 ± 5 (333-349)</td>
</tr>
</tbody>
</table>

Typical error: Countermovement Jump = 2cm; Block Jump = 1cm; Spike Jump = 2cm

Source: Female - Australian junior (n=4) and senior national (n=2); Male - Australian junior (n=2) and senior national team (n=4).

Test Protocol - Lower Body Speed-Strength and Strength Testing

Rationale -
Speed-strength measures, maximal strength (e.g., 1RM squat), and heavy load power (e.g., 1RM clean) are important measures for a volleyball player, because they are associated with direct performance measures such as CMJ and SPJ (Sheppard et al. 2008d).

Test Procedure -
Specific guidelines for the conduct of upper- and lower-body maximal strength tests are contained in the AIS Strength and Power Assessment Protocols document. Typical strength movements tested for volleyball are 1RM squat, clean, bench press, and chin-up. Speed-strength assessment includes the incremental power load profile for jump squats with loads beginning with body mass, body mass + 25%, and body mass + 50%.
A large range of tests are available for coaches to use in assessing strength. Given that muscle imbalances are linked to injury, it is important to assess muscular strength of both the upper and lower body and to assess strength in the anterior and posterior planes bilaterally. Because fatigue accumulates quickly during maximal efforts, the number of tests should be kept to a minimum. Therefore, the squat, bench press, and bench pull are the lifts to be tested.
Although the single repetition maximum (1RM) test is generally considered the most representative of strength, there are concerns about safety, reliability, and the maintenance of technique when using 1RM tests for individuals with low training age (Baechle and Earle 2008). Therefore, 3RM testing is recommended for athletes not specifically trained for strength.
The following general guidelines must be adhered to for all tests:

i. Strength testing should be performed on a separate day from the field tests. Strength and field tests should be separated by 48 h.

ii. The athlete must perform an appropriate warm-up. As a minimum, all athletes are required to perform a trial at approximately 90% of specified repetition maximum for each test. If this is the first test, athlete should perform an initial trial at approximately 90% of weight lifted in training.

iii. Lowering and lifting actions must be performed in a continuous manner. A single rest of no more than 2 s is allowed between repetitions.

iv. A maximum of 5 min recovery between trials is allowed.

v. Minimum weight increments of 2.5 kg should be used between trials. However, increments should be guided by ease of each trial.

vi. The specified RM test should be completed within four trials (not including the warm-up).

vii. If the athlete is unable to complete tests as per protocol, this should be noted on testing results information, and values should not include any mathematical calculations (e.g., average, TE).

viii. A spotter other than the supervising coach should be used when spotting is required.

Normative Data -
The table below presents strength norms for male Australian indoor volleyball athletes.

<table>
<thead>
<tr>
<th>Strength data for male indoor volleyball players (mean ± SD; range)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MALE</strong></td>
</tr>
<tr>
<td>National Senior</td>
</tr>
<tr>
<td>National Junior</td>
</tr>
</tbody>
</table>

Source: Australian junior (n=2) and senior national team (n=4).
**Test Protocol - Lower Body Speed-Strength and Strength Testing**

**Rationale -**
The indoor volleyball repeated-effort test (RET) involves jumping and movement activity that is specific to indoor volleyball, with duration and rest periods that replicate a portion of the most extreme demands of a match (Sheppard and Gabbett, 2007). Research results have demonstrated that the RET is a reliable method of assessing repeated-effort ability in volleyball players, is able to discriminate between higher and lower performers, and is sensitive to specific training interventions (Sheppard et al. 2007, 2008a). As such, the RET is a useful test for practitioners to evaluate volleyball players’ repeated jump and speed movements.

**Test Procedure -**
The RET encompasses spiking, blocking, and lateral movements and was developed to mimic the physical demands of frontcourt play in volleyball. Because frontcourt play generally involves the most activities (jumping and lateral movement), the test was designed to reflect these demands. It was decided that to assess the most extreme demands of volleyball play, the test should include repetitions that reflected the typical rally time and involve rest periods that reflected the most extreme demands of international play (Sheppard et al. 2007). Four repetitions of the RET are performed to reflect these extreme demands, with the repetitions commencing at 20 s intervals to allow approximately 4 to 8 s of rest between each repetition depending on the speed at which the athlete executes each repetition.

As the figure below illustrates, two spike jumps are measured using a vertical jump apparatus, and the timing of movements is measured using a timing light system. The timing of the specific movement is separated from the spike jumping task. In other words, the timing as measured by the timing lights is the movement speed performance measure and represents a portion of the total repetition time (which is fixed for all subjects as a 20 s interval). The block jumps are performed on a specially designed apparatus that is adjustable for height and position, and these movements are included in the time measure on each repetition. The apparatus, which is 2 m wide, is placed on the opposite side of the net from the player being tested. Two volleyballs are secured to 2 separate supports that are mounted onto an aluminum beam and supported by a tripod or other suitable apparatus. The bottom of the ball is 15 cm above the top of the net (258 cm high for males, 239 cm for females), and the side of the ball nearest the athlete is placed 15 cm into the opposing court. To correctly execute a block, the athlete is required to perform a block jump and place both hands on the ball without contacting the net. Any attempts during the execution of the RET in which the athlete does not correctly execute a block is recorded as an error, and this is included in their RET results.

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***Notes: (For right-handed players) The Yardstick is set up in between the net and the 3 m line (1.5 m from each) and 1 m from the side line. A pair of timing lights are set 1.5 m apart, 1.5 m from the side line. Another set of timing lights are set on the 3-metre line, 3 m apart, with the leftmost tripod set 1.5 m from the sideline. An adjustable apparatus that incorporates a large tripod with a 2 m horizontal pole is placed on the opposite side of the net, with the middle of the tripod in the middle of the court. Volleyballs are permanently mounted on the outermost points of the 2 m horizontal pole.

The athletes start 4 m back from the net. The athlete begins by performing a spike jump and registering their maximum effort on the Yardstick. (This is quickly recorded by a tester and the vanes re-set). The athlete must then land at the net and immediately move right along the net (and hence begin timing). The athlete then performs a block jump on each of the two mounted volleyballs, then moves further right until they get their outside foot onto or past a taped line 1 m in from the rightmost boundary. The athlete then reverses the entire process, including the jumps to both volleyballs placed on the tripod. After touching the second volleyball in the reverse direction, the athlete then moves backward and diagonally towards the 3 –m line using an open step typical of volleyball. As they pass the 3-metre line, they stop the second set of timing lights, but then continue to stay in motion, rounding a 2 m high pole-marker, and immediately perform a 2nd spike jump on the Yardstick. This entire sequence constitutes 1 repetition of the 4 repetition test.
Players should be well familiarized with all testing procedures prior to beginning data collection. Practitioners are encouraged to perform the test as a training drill two or more times before collecting data. After a thorough explanation of the test procedures, the data collection session should begin with the athlete’s typical volleyball match-specific warm-up. Following this, one or two trials of one repetition are performed at a submaximal intensity, after which feedback can be provided to the athlete to ensure clarity of instructions and adherence to the test protocol. The athlete then performs one maximal repetition of the test at full intensity. Following 3 to 5 min of rest, the athlete performs the actual test battery, which includes four repetitions of the test. The measured performance outcomes of each of the four repetitions include 2 spike jump scores (cm), lateral movement time (s), and any errors that may have occurred. The first spike jump and the movement time in the first repetition are used as the “ideal jump” and “ideal time” scores. The mean of all spike jumps recorded (total of 8) and the mean of all movement times recorded (total of four) across the four repetitions are used as the actual jump and actual time scores. Errors are recorded if the blocking task, as outlined previously, is not performed correctly (e.g., one hand touching or hand on net).

**Data Analysis -**

Reliability data from a group of junior national team players are presented in the table below (normative data). Reliability of the percentage decrement of time and jump variables calculated from the volleyball RET has resulted in very high TE scores (Sheppard et al. 2007), which is in agreement with previous findings using this calculation (Spencer et al. 2006). With such large TE scores observed for jump and time decrements, it is unlikely that practitioners can find utility in these calculations because extremely large changes would need to occur for practitioners to confidently interpret these changes as being real versus being due to normal variation.

It has been observed that within each group, the fastest athletes on the movement time test and the highest jumpers demonstrated the largest percentage decrement when expressed in relative terms. When expressed in absolute terms, these superior athletes’ scores can be interpreted differently. In other words, when absolute ideal and actual scores are viewed, the superiority of higher-performing athletes is clearly demonstrated despite a higher percentage decrement (see table below), which is also evidenced in comparisons of higher and lower performers (figures above and below). Practitioners are encouraged to forego calculating a percentage decrement for the volleyball RET and instead plot absolute scores across repetitions. This will allow the practitioner to take into consideration the best scores as well as the average scores achieved as a reflection of fatigue. Five major variables are used to evaluate performance in the volleyball RET: ideal jump, actual jump, ideal time, actual time, and errors. Because the actual score for both spike jumps and movement time takes into consideration all of the efforts performed, this score reflects the fatigue resistance of the athlete. This allows the practitioner to evaluate the athlete based on their ideal and actual score as a measure of fatigue resistance. Examining the ideal time and ideal jump results of the repeated-effort test provides the practitioner insight into the
movement speed and jumping ability of volleyball athletes. By comparing the actual time and ideal time, the practitioner can determine the athlete’s fatigue resistance. Finally, an examination of the frequency, type, and progression (over each repetition) of errors allows the practitioner insight into the movement and jump technique of the athlete as well as the influence of her progressing fatigue on technique.

**Mean ± SD of (A) ideal jump height and actual jump height and (B) ideal time and actual time for the national team (N=8) and the development national team (N=8). All measures depicted were observed to have large (> 0.50) effect size differences between groups.**
Mean movement time (A) and mean jump height (B) for the national team (N=8) and the development national team (N=8) across the 4 repetitions of the repeated effort test.

Note: Because there are 2 spike jump measurements per repetition, 8 spike jumps are depicted, whilst there are 4 movement times depicted, corresponding to each of the 4 repetitions. Therefore, a brief rest period took place after even numbers of spike jumps (i.e. 2.1, 3.1 & 4.1 spike jumps were preceded by brief rest periods).

Normative Data -
The first table below provides reliability and normative data for the indoor volleyball RET for junior national team athletes, whereas the two figures above provide normative data comparing junior and senior national team athletes on the RET.

<table>
<thead>
<tr>
<th></th>
<th>Day 1 Scores</th>
<th>Day 2 Scores</th>
<th>TE</th>
<th>%TE</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual time (s)</td>
<td>7.43 ± 0.6</td>
<td>7.27 ± 0.6</td>
<td>0.16</td>
<td>2.24</td>
<td>0.93</td>
</tr>
<tr>
<td>Ideal time (s)</td>
<td>7.15 ± 0.6</td>
<td>6.97 ± 0.7</td>
<td>0.23</td>
<td>3.54</td>
<td>0.87</td>
</tr>
<tr>
<td>Actual jump (cm)</td>
<td>327.76 ± 8.6</td>
<td>328.48 ± 9.0</td>
<td>1.81</td>
<td>0.55</td>
<td>0.96</td>
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<tr>
<td>Ideal Jump (cm)</td>
<td>334.25 ± 10.3</td>
<td>335.25 ± 9.8</td>
<td>3.15</td>
<td>0.95</td>
<td>0.90</td>
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<td>Errors</td>
<td>2.82 ± 2.3</td>
<td>2.91 ± 2.9</td>
<td>1.49</td>
<td>22.08</td>
<td>.57</td>
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<tr>
<td>% Jump Decrement</td>
<td>1.97 ± 0.9</td>
<td>2.06 ± 1.0</td>
<td>1.03</td>
<td>88.01</td>
<td>.15</td>
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<tr>
<td>% Time Decrement</td>
<td>3.94 ± 2.3</td>
<td>4.51 ± 3.5</td>
<td>2.49</td>
<td>82.38</td>
<td>.31</td>
</tr>
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</table>

Results are presented as typical error (TE), relative typical error (%TE) and intraclass correlations (ICC) (n=12).
Comparison of absolute scores and % decrement scores between two athletes

<table>
<thead>
<tr>
<th></th>
<th>Athlete A</th>
<th>Athlete B</th>
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<tr>
<td></td>
<td>Ideal</td>
<td>Actual</td>
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<tr>
<td>Jumps (cm)</td>
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<td></td>
<td>320</td>
<td>316</td>
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<td>Time (s)</td>
<td>6.88</td>
<td>7.12</td>
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<td>8.09</td>
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Traceability Information

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<td>HP_Volleyball_v1.1_2014</td>
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References


