Vertical Jump Assessment on Volleyball: A Follow-Up of Three Seasons of a High-Level Volleyball Team

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ABSTRACT

Borràs, X, Balius, X, Drobnic, F, and Galilea, P. Vertical jump assessment on volleyball: A follow-up of three seasons of a high-level volleyball team. J Strength Cond Res 25(6): 1686–1694, 2011—This is a longitudinal descriptive study whose purpose is to assess the physical state of male volleyball players competing at the international level, comparing their jump heights during 3 different seasons. National team sample relies upon trainer decisions, and it was different every season. There were 23, 15, and 13 players in the first, second, and third years, respectively. Subjects underwent a vertical test protocol consisting of rocket jump, squat jump (SJ), countermovement jump (CMJ), CMJ with arms (CMJa), and spike jump (DJb) at the preparation period of the national team season. In 2007, an extra evaluation was performed during the competitive period. A contact mat was used for the assessment. An increase of jump height was observed over the years, with SJ and DJb increasing significantly ($F_{SI} = 5.4; F_{DJb} = 4.7; p < 0.05$). The elasticity index decreased significantly between 2007 and 2008 ($F_{EI} = 8.5; p < 0.05$), whereas arm utilization index and approach index increased, but this increase was not statistically significant. A significant increase in SJ and DJb was also observed between the 2 tests performed in 2007, whereas a nonsignificant increase was observed for CMJ and CMJa. The results indicate a better performance of explosive strength, elastic–explosive strength, and reflex–elastic–explosive strength and a better use of arms during jumps.

KEY WORDS explosive strength, contact mat, physical conditioning

Introduction

Volleyball is an intermittent sport that combines active and passive phases of play. Exercise performed during the active phase is influenced by court size (9 m$^2$), number of players (6 team players), height of the net (2.43 m for male senior level), velocity of the ball and technique skills. Vertical jump is a fundamental part of the spike, the block, and the topspin and floating serves. At high-level volleyball, jump is also used when setting, because it reduces the flight time of the ball and, as a consequence, increases the complexity of the game. According to Fontani et al. (15), there is a wide range of jumps performed in a 5 set match (from 65 to 136). On average, setters are the players with a higher number of jumps (136 jumps), followed by middle hitters (97 jumps), opposite hitters (88 jumps), and side hitters (65 jumps). Quick displacements are also necessary when defending and receiving to adjust body position to the ball position in a short period of time because the ball takes about 1.2–1.4 seconds to cover from 1 side of the court to the other (15). They are also used previous to a jump when spiking, blocking, and jump serving. Thus, exercise is mainly characterized by quick and short displacements and vertical jumps, in either defensive and offensive actions, requiring the players to have well-developed explosive force and power (16).

Functional assessment is fundamental to determine the player’s physical condition and to enable a better workload program. Vertical jump testing is a common method used by coaches to assess jump height and muscular power (3,6–9,14,15,18,24,31,36,45). Significant correlations have been observed between vertical jump height and cycling power (13), maximal strength and muscular power (6,39), and sprinting (11,30). Markovic et al. (28) have shown that vertical jump testing is reliable and valid for the estimation of explosive muscular power, whereas Slind et al. (41) conclude that it can be used as a measure of power development because of its high reproducibility. It is also a good indicator of the athletes’ performance (48) and sensitive enough to detect changes after a specific training period (23,33,34,42).

The purpose of this study was to assess the physical state of volleyball players competing at the international level,
comparing their jump heights during 3 different seasons to determine reference values for the next drafted athletes and other volleyball teams.

**METHODS**

**Experimental Approach to the Problem**

This is a longitudinal descriptive study that analyzed jump characteristics performed by the Spanish National Volleyball team during 3 consecutive years (2006–2008). All players participating in this study were selected among a pool of Spanish volleyball players by the National Team coaches. They joined the draft after completing their club league season (winter season) and after taking a week’s rest period. The season of the national team (summer season) consists of a European or International League. In 2007, they played the European Cup, and in 2008, they also played the World Cup.

Physical performance of players was evaluated with a vertical jump test at the beginning of the base. In 2007, a second evaluation was performed in the middle of the national team season. This methodology was approved by the Ethical Committee of the Catalan Sports Council.

**TABLE 1.** Number of subjects and mean ± SD of the anthropometric characteristics.*

<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Age (y)</th>
<th>BMI (kg m⁻²)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Fat † (%)</th>
<th>Muscular † (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>23</td>
<td>24.6 ± 3.8</td>
<td>23.5 ± 1.7</td>
<td>88.9 ± 8.2</td>
<td>194.3 ± 7.7</td>
<td>10.3 ± 1.7</td>
<td>49.5 ± 1.7</td>
</tr>
<tr>
<td>2007</td>
<td>15</td>
<td>26.5 ± 4.1</td>
<td>23.4 ± 1.6</td>
<td>87.8 ± 9.9</td>
<td>193.3 ± 8.2</td>
<td>10.5 ± 2.1</td>
<td>49.6 ± 1.4</td>
</tr>
<tr>
<td>2008</td>
<td>13</td>
<td>26.4 ± 3.7</td>
<td>23.6 ± 1.7</td>
<td>86.9 ± 8.0</td>
<td>191.9 ± 7.4</td>
<td>10.4 ± 2.4</td>
<td>49.9 ± 2.4</td>
</tr>
</tbody>
</table>

*BMI = body mass index.
†Drinkwater and Ross method (12).

**TABLE 2.** Description of vertical jumps performed.*

<table>
<thead>
<tr>
<th>Type of jump</th>
<th>Characteristics</th>
<th>Initial position</th>
<th>Execution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocket jump (2)</td>
<td>Jump with no countermovement.</td>
<td>Deep squat with trunk as much vertical as possible. Hands held and arms straight on the back.</td>
<td>Quick extension of legs vertically only legs for impulsion. After 3 s in the initial position and following the command “go,” start the movement upward. Quick movement of knee flexion–extension. Players are instructed to flex legs at 90°, but they freely choose flexion. Hands have to be kept on hips. Arms are moved backward and forward energetically synchronized with leg flexion–extension. movement. Knee bent freely chosen. Three steps approach and arm movement jump simulating a volleyball spike.</td>
</tr>
<tr>
<td>Squat jump (4)</td>
<td>Jump with no countermovement.</td>
<td>Semisquatted position. Knees bent at 90° and hands on hips.</td>
<td>After 3 s in the initial position and following the command “go,” start the movement upward. Quick movement of knee flexion–extension. Players are instructed to flex legs at 90°, but they freely choose flexion. Hands have to be kept on hips. Arms are moved backward and forward energetically synchronized with leg flexion–extension. movement. Knee bent freely chosen. Three steps approach and arm movement jump simulating a volleyball spike.</td>
</tr>
<tr>
<td>Countermovement jump adapted from Bosco (4)</td>
<td>Jump with legs countermovement.</td>
<td>Standing position with hands on the hips.</td>
<td>After 3 s in the initial position and following the command “go,” start the movement upward. Quick movement of knee flexion–extension. Players are instructed to flex legs at 90°, but they freely choose flexion. Hands have to be kept on hips. Arms are moved backward and forward energetically synchronized with leg flexion–extension. movement. Knee bent freely chosen. Three steps approach and arm movement jump simulating a volleyball spike.</td>
</tr>
<tr>
<td>Countermovement jump with arms</td>
<td>Jump with legs countermovement and arm movement.</td>
<td>Standing position with arms extended.</td>
<td>After 3 s in the initial position and following the command “go,” start the movement upward. Quick movement of knee flexion–extension. Players are instructed to flex legs at 90°, but they freely choose flexion. Hands have to be kept on hips. Arms are moved backward and forward energetically synchronized with leg flexion–extension. movement. Knee bent freely chosen. Three steps approach and arm movement jump simulating a volleyball spike.</td>
</tr>
<tr>
<td>Spike jump</td>
<td>Jump with leg countermovement, arm movement and approach.</td>
<td>Standing position with arms extended and 3 step far from the platform.</td>
<td>After 3 s in the initial position and following the command “go,” start the movement upward. Quick movement of knee flexion–extension. Players are instructed to flex legs at 90°, but they freely choose flexion. Hands have to be kept on hips. Arms are moved backward and forward energetically synchronized with leg flexion–extension. movement. Knee bent freely chosen. Three steps approach and arm movement jump simulating a volleyball spike.</td>
</tr>
</tbody>
</table>

*RkJ = rocket jump; SJ = squat jump; CMJ = countermovement jump; CMJa = countermovement Jump with arms; DJb = spike jump.
Subjects
The number of subjects joining the National Team was not constant through the years. This information is shown in Table 1. The table also includes the general characteristics of players in every season. Subjects provided an institution-approved written consent for testing.

Testing Procedures
Vertical jump was measured using a contact mat (ERGOJUMP-Plus BOSCO. SYSTEM® Byomedic, S.C.P., Barcelona, Spain.) consisting of a switch mat connected to a digital timer (±0.001 seconds). This system has been demonstrated to be reliable for the measurement of flight time ($T_f$) (28,43). It derives jump height ($h$) from flight time using the following formula (5):

$$h = g \times \frac{T_f^2}{8}$$

where $g$ corresponds to gravity value.

Athletes were familiarized with the vertical jump protocol and performed jumping exercises periodically in their training sessions. The warm-up for the test included running, specific joint movements, stretching, and submaximal jumps freely performed by the players.

All tests were performed in groups of 4–5 players, during the morning and before the weight training. Participants performed 3 jumps of each type by rounds, which made the full recovering of previous actions possible and the readiness for the following hops. This type of assessment increases the competitive spirit and ensures that the jumps are performed to their maximum.

Jumps performed in 2006 were the rocket jump (RkJ) and the countermovement jump (CMJ), whereas evaluation from 2007 was performed with arms (CMJa) and the spike jump (DJb).
2007 to 2008 consisted of squat jump (SJ), CMJ, CMJ with arms movement (CMJa), and spike jump (DJb). Description of jumps execution is presented in Table 2.

### Performance Parameters

The combination of the vertical jumps described gave us the possibility to assess different manifestations of force (46) calculating some useful indexes of physical performance:

The percentage difference between SJ and CMJ height is defined as the elasticity index (EI) or elasticity rate (47).

\[
EI(\%) = \frac{CMJ - SJ}{SJ} \times 100. \tag{2}
\]

The arm contribution index (AI) describes the percentage difference between CMJa and CMJ heights (45).

\[
AI(\%) = \frac{CMJa - CMJ}{CMJ} \times 100 \tag{3}
\]

and the difference between CMJa and DJb is assessed by the approach index (ApI).

\[
ApI(\%) = \frac{DJb - CMJa}{CMJa} \times 100. \tag{4}
\]

### Statistical Analyses

The statistical analysis of the performance parameters is presented as the mean and SD of the best height reached by the athletes in each type of jump. Intraclass correlation coefficient was used to determine between-subject reliability. The SEM was calculated (Table 3). For the comparison of data over the years, an analysis of 1 factor variance (ANOVA) was applied. The comparison between the 2 tests performed in 2007 was done through a *T*-test with repeated measures. Statistical significance was accepted at \( p \leq 0.05 \) for all analysis.

### Results

Jump height and its evolution are shown in Figure 1. An increase of SJ, CMJ, CMJa, and DJb height was observed over the years. The ANOVA analysis showed a significant difference in jump height for SJ and DJb (\( F_{SJ} = 5.4; F_{DJb} = 4.7; p < 0.05 \)) but no statistically significant difference for CMJ and CMJa (\( F_{CMJ} = 2.1; F_{CMJa} = 1.8; p > 0.05 \)). Subject responses over each year are presented in Figure 2.

Jump indexes for 2007 and 2008 are shown in Figure 3. A 4% difference in the EI was observed between 2007 and 2008 (7.9 and 3.9%, respectively). This difference was statistically significant (\( F_{EI} = 8.5; p < 0.05 \)). Differences for AI and ApI were of 0.7% (20.2% in 2007 and 20.9% in 2008) and 3.6%
Figure 3. Mean and SD of jump indexes.

Data is expressed in %.

* Values are significantly different, p<0.05.

Figure 4. Mean and SD of jump height in the tests performed during 2007.

Data is expressed in cm.

* Values are significantly different, p<0.05.
(15.5% in 2007 and 19.1% in 2008), respectively, but not statistically different ($F_{AI} = 0.1; F_{ApI} = 1.8; p > 0.05$).

An analysis between jump tests performed in 2007 was done using a $T$-test with repeated measures. Three athletes did not repeat the test, and they were ruled out from the analysis (Figure 4). Values for SJ and DJb were significantly different ($T_{SJ} = -3.4; T_{DJb} = -2.7; p < 0.05$), whereas values for CMJ and CMJa were similar ($T_{CMJ} = -0.8; T_{CMJa} = -1.0; p > 0.05$).

### Table 4. Vertical jump height of senior high-level/elite male volleyball players.†

<table>
<thead>
<tr>
<th>Author</th>
<th>SJ</th>
<th>CMJ</th>
<th>CMJa</th>
<th>DJb</th>
<th>System used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobbert et al. (3)</td>
<td>44.7 ± 4.2</td>
<td>48.1 ± 3.6</td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Bosco et al. (6)</td>
<td>37.4 ± 2.7</td>
<td>44.0 ± 2.6</td>
<td></td>
<td>68.8</td>
<td>Contact mat</td>
</tr>
<tr>
<td>Carvalho et al. (8)</td>
<td>41.1</td>
<td>43.5</td>
<td></td>
<td></td>
<td>Contact mat</td>
</tr>
<tr>
<td>Ciccarone et al. (9)</td>
<td>40.3 ± 3.1</td>
<td>45.7 ± 3.4</td>
<td>54.1 ± 4.3</td>
<td></td>
<td>Contact mat</td>
</tr>
<tr>
<td>Cole et al. (10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Ferragut et al. (14)</td>
<td>37.4</td>
<td>37.6</td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Hasson et al. (17)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Hespanholf et al. (18)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Komi and Bosco (21)</td>
<td>37.2 ± 3.7</td>
<td>43.4 ± 5.2</td>
<td></td>
<td></td>
<td>Contact mat</td>
</tr>
<tr>
<td>Kuhlmann et al. (22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3D</td>
</tr>
<tr>
<td>Lian et al. (26)</td>
<td>36.0 ± 4.0</td>
<td>41.3 ± 6.5</td>
<td>63.7 ± 4.0</td>
<td></td>
<td>Contact mat</td>
</tr>
<tr>
<td>Marques et al. (29)</td>
<td>41.9 ± 2.6</td>
<td>42.9 ± 5.4</td>
<td>44.4 ± 1.0 L</td>
<td>46.7 ± 4.3</td>
<td>OH</td>
</tr>
<tr>
<td>McGrow et al. (31)</td>
<td>83.6 ± 5.5</td>
<td>71.5 ± 5.0</td>
<td>51.0 ± 5.0</td>
<td></td>
<td>Force platform</td>
</tr>
<tr>
<td>Newton et al. (34)</td>
<td>68.1 ± 7.0</td>
<td>80.4 ± 6.2</td>
<td>83.0 ± 7.2</td>
<td></td>
<td>Force platform</td>
</tr>
<tr>
<td>Oddsson and Thorstensson (35)</td>
<td>38.0 ± 4.0</td>
<td>44.0 ± 3.0</td>
<td></td>
<td></td>
<td>Force platform</td>
</tr>
<tr>
<td>Ravn et al. (36)</td>
<td>33.7 ± 1.5</td>
<td>36.7 ± 2.5</td>
<td></td>
<td></td>
<td>Force platform</td>
</tr>
<tr>
<td>Shan (38)</td>
<td>44.6 ± 4.1</td>
<td>44.6 ± 4.1</td>
<td></td>
<td></td>
<td>Force platform</td>
</tr>
<tr>
<td>Sheppard et al. (39)</td>
<td>67.6 ± 2.9</td>
<td>85.6 ± 9.1</td>
<td></td>
<td></td>
<td>Similar to Vertec</td>
</tr>
<tr>
<td>Sheppard et al. (40)</td>
<td>61.5 ± 7.3</td>
<td>80.8 ± 6.1</td>
<td></td>
<td></td>
<td>Similar to Vertec</td>
</tr>
<tr>
<td>Vanrenterghem et al. (44)</td>
<td>46.0 ± 3.0</td>
<td></td>
<td></td>
<td></td>
<td>Force platform</td>
</tr>
</tbody>
</table>

*SI = squat jump; CMJ = countermovement jump; CMJa = countermovement jump with arm movement; DJb = spike jump; RkJ = rocket jump; OpH = opposite hitters; MH = middle hitters; L = Liberos; OH = outside hitters; S = setters; 3D = 3-dimensional videography; 2D = 2-dimensional videography.

†Values are given as mean ± SD.

Figure 5. Difference of body position when taking off and landing.
DISCUSSION

A volleyball team is composed of 12 players. In the National Team, the selection of players depends on the trainer’s opinion, and it is influenced by technical decisions, level of performance, and injury state of the players. This is why the number of subjects in this study was not constant through the years. Nevertheless, when looking at Table 1, the sample had a similar body mass index and fat and muscular percentage. In contrast, the age of the players was different. In 2006, they were younger than in 2007 and 2008.

Specificity of force is evaluated through the combination of different types of jumps. Rocket jump and SJ evaluate the concentric muscle contraction; the higher the height of the jump, the higher the manifestation of explosive strength (46). The CMJ assesses the eccentric and concentric muscle contractions and the stretch shortening cycle mechanism, which, following Vittori’s (46) classification, is related to the manifestation of the elastic–explosive strength. The CMJa evaluates the eccentric and concentric muscle contraction plus the contribution of the arm action in the jump. With the spike jump, the stretching reflex is activated during the eccentric phase, and it is possible to assess the manifestation of reflex–elastic–explosive strength (46). Results showed an increase through the years for all evaluated jumps indicating a better performance of explosive strength, elastic–explosive strength, reflex–elastic–explosive strength, and arm use.

Height achieved during the CMJ is greater than that during the SJ or the RkJ. From the physiological point of view, it is explained by the elastic energy storage in the elastic component of the muscle during the stretching phase, which is optimized when eccentric and concentric muscle contractions are properly coordinated (3). By using biomechanics, this is explained by the addition of impulse produced in the eccentric phase that allows the muscle to develop a higher force during the beginning of the concentric phase and an increase of the positive work (3,19,27). Although both SJ and CMJ jumps increased between 2007 and 2008, a significant decrease in the EI was observed, indicating that players had better explosive strength but, in contrast, less elastic–explosive properties. Improvement in AI and ApI indicated a better performance of jumps (CMJa and DJb) that are more related to the technical skills of attack and block (42).

Despite the fact that players obtained better jump performances in 2008, the team achieved the best competitive results in 2007, when they won the European Championship, evidencing the importance of the technique, individual and collective tactics, team strategy, and opponent analysis during a game.

The literature related to vertical jump height of senior high-level male volleyball players is presented in Table 4. Only 1 RkJ reference has been found (35) whose value is below the height achieved by Spanish volleyball players. The lack of bibliography referencing RkJ and the need to compare data with other teams and players led us to decide to change RkJ to SJ after the first season. The values of SJ for Spanish volleyball players are higher than reference values (6,8,9,26), except for Bobbert et al. (3) who obtained a value of height superior to the one reached during the 2007 season.

With respect to CMJ, some literature values are similar to values of season 2006 (9,18,29,44) and 2007 (3,18), but all of them are lower than season 2008. For CMJa, only 1 reference value uses the contact mat as a device of measurement, and its value is similar to our results for the 2007 season (9) but lower than the height achieved in 2008. With respect to DJb, only 1 study used the contact mat as a measurement system, with its value slightly over that of the value obtained in 2007 and slightly below that of 2008 (8). When comparing the tests of 2007, jump height changed during the summer season as it is higher in the competitive period than in the precompetition period.

Vertical jump height should allow one to distinguish between athletes’ physical condition (48). Nevertheless, when comparing with references values, differences because of other causes should be taken into consideration. The jump test has been observed to recognize changes after a specific training (23,33,34,42). Therefore, if the evaluation has been performed in different season periods, it is normal to obtain different height values. The evaluation of the Spanish team was carried out the first days of draft start, after some days of rest but subsequent to the competitive season. This means that the players were in an appropriate physical condition although not necessarily in their best form. Eight of 20 articles cited in Table 3 described the season period where the tests were performed, and in all cases, these periods are different from our study. Ciccarone et al. (9) and Hespanhol et al. (18) evaluated jumps at the beginning of the season, during preparation period; Newton et al. (34) also evaluated the effect of a ballistic training on the preparation period; Lian et al. (26) performed the physical test 2 months after the competitive season. McGrow et al. (31) performed 2 tests, 1 in July, just before the 1984 Los Angeles Olympic Games, and the other in March, but did not inform of the physical state of the players. Kuhlman et al. (22) performed the analysis during a Championship, and Marques et al. (29) that tested players during the second period of the in-season period. Sheppard et al. (40) evaluated jumps during the International season.

The methodology used to evaluate jump height could also be responsible for the differences in the data. The contact mat is highly considered in the coaching community because flight time–based measurements have been reported to produce highly reliable and valid (28,43) results and a very small error of a measurement when compared with video analysis (21). Four references used video analysis to evaluate jump height, obtaining with respect to this study similar values for SJ and CMJ (3), but lower values in DJb (10,22,36).

Vertec (or similar) is another methodology used to evaluate jump height (9,17,34,39,40). It consists of a metal stand and a height scale composed of color-coded vanes that are displaced by the player when jumping. Height is calculated...
by subtracting the highest point reached when standing with arms extended from the height achieved when jumping. Its validity (25) and reliability have been demonstrated (49), and its use is spread in volleyball teams thanks to its simplicity of handling and its economic price. It can be observed that Vertec values are above the contact mat values. This is explained because Vertec is evaluating hand height, whereas the contact mat is based on the center of mass height. Furthermore, evaluation of Vertec is limited to jumps with arm movement.

The last methodology used to evaluate jump height is the force platform. This system is able to derive height either from flight time or by the velocity at takeoff in the impulse–momentum method (27). It has been observed that the flight time method overestimates height about 0.5–2 cm when compared to the impulse–momentum method (20,24,32). As Aguado and González (1) explain, this is because of the difference in body position when taking off and landing (Figure 5). Some authors (1,4) suggest to control landing position, advising the athlete to fall with legs completely straight and feet hyperextended. However, flexing legs while landing is a preventive strategy to reduce injuries because it dissipates ground reaction forces (7).

It is necessary to be cautious when comparing jump height data. The contact mat is best suitable when contrasted with itself, rather than compared with other methodologies, because devices give different measures for a single jump even when height is derived from the same variable (37).

**Practical Applications**

Jumping is a basic activity in most technical skills. It is an activity performed by all players with the exception of the libero but is also determinant in this position because of its correlation with quick displacements (11,30).

This study presents height data of a vertical jump protocol performed on male international volleyball players during 3 different seasons. Its information may be used as a reference for the next National Team seasons to understand and compare the physical performance of players and as a help to the trainer to design training programs individually adjusted.

These results may also be used for top level and lower level teams as an indicator of the physical conditions of their players over the season. Most of the references give values during the preseason (9,18,34) which means that players had been under the transition phase during a while. Our values are acquired after the end of the regular season and 1 week of rest. In 2007, data were also taken during the competitive season.

Two devices are very popular when evaluating jump capacity in volleyball teams, the Vertec and the contact mat. It is necessary to be cautious when comparing data from these devices because they obtain height from 2 different methods.

**Acknowledgments**

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Vertical Jump Assessment


