Changes in Strength and Power Qualities Over Two Years in Volleyball Players Transitioning From Junior to Senior National Team

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Abstract

Sheppard, JM, Nolan, E, and Newton, RU. Changes in strength and power qualities over two years in volleyball players transitioning from junior to senior national team. *J Strength Cond Res* 26(1): 152–157, 2012—The purpose of this investigation was to examine the changes in performance indicators as they relate to strength and speed-strength development, over 2 years in a group of volleyball players who successfully transitioned from age group (U21) to senior national team in that time period. Sixteen male subjects (age: 18.5 ± 1.5 years, height: 2.00 ± 0.06 m, and weight: 88.4 ± 7.7 kg) participated in this 2-year longitudinal study. During the 24-month period of this investigation, all the subjects gained professional European contracts and also debuted with at least 1 senior national team match. These included, at a minimum, not only international friendly matches but also senior continental championships, World Championships, and the World Cup. Testing included 1 repetition maximum (1RM) and 3RM for the clean and squat, a maximum effort counter movement vertical jump (CMVJ), depth jump from a 0.35-m box (DJ), spike jump (with approach) (SPJ), and lower body speed-strength assessment with a body weight and body weight + 50% load. Large magnitude increases were observed for CMVJ, DJ, and SPJ over the 2-year period ($d = 0.80$, 0.82, and 0.94, respectively, $p < 0.001$). Unloaded (body weight) and loaded jump-squat performance also exhibited large improvements for all measured parameters, with very large increases in jump height in the unloaded ($d = 1.21$, $p = 0.002$) and loaded jump squat ($d = 1.346$, $p < 0.001$). Very large magnitude changes in 1RM Clean and 3RM Squat ($d = 1.56$ and 2.21, respectively, $p < 0.001$) were observed over the 2-year investigation period, and a large increase ($d = 1.18$, $p < 0.001$) in the lean mass ratio (mass/sum skinfolds). To progress from junior representation to senior national team, volleyball players must increase their CMVJ and SPJ. This is best accomplished through increasing lean mass, reducing fat mass, improving strength and speed strength, and developing high levels of stretch-load tolerance in stretch-shorten cycle activity.

Key Words jump, spike jump, elite, testing, training

Introduction

Volleyball is characterized by short and frequent explosive activities such as jumping, diving, and ball play (4,9). Jumping activities can include both horizontal approach movements (spike jumps [SPJs]) and movements without an approach but generally involving a counter movement (jump setting, jousts, and blocking). Considering the importance of these jumping activities to the performance outcome in volleyball, and the frequency that they occur in a typical match (8), both countermovement vertical jump (CMVJ) ability and SPJ ability are considered important performance indicators in volleyball and are the primary performance indicators that strength and conditioning programs aim to enhance (5,7,12).

Several studies have shown moderate to strong relationships between jump performance and strength or speed-strength (power) measures in volleyball players (7). Sheppard et al. (5) identified that over 1 year in senior national team players, speed-strength performance improvements in loaded jumps squats, and improvements in depth jumping ability, exhibited very strong association with performance improvements in the CMVJ and SPJ. In other words, elite players can likely improve their CMVJ and SPJ performances with improvements in their stretch-load tolerance (depth-jump ability) and speed-strength capabilities (loaded jump-squat performance).

Recent studies have examined the difference between junior and senior elite volleyball players (8), highlighting the importance of developing vertical jump ability in both the CMVJ and SPJ, as a priority. A cross-sectional analysis of junior and senior groups provides performance characteristics and strength and speed-strength data that are useful in

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TABLE 1A: Typical training schedule during training periods of the international season.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Strength & Power	Individual Technical	Strength & Power	Individual Technical	Strength & Power	Strength & Power	
Individual Technical		Individual Technical			Team Tactical	
Team Tactical	Team Tactical	Team Tactical	Team Tactical	Team Tactical		

TABLE 1B: Typical training schedule during competitive touring during the international season.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Travel	Individual Technical	Strength & Power	Individual Technical	Individual Technical	Team Tactical	Rest or Travel
Travel			Strength & Power			
Travel	Team Tactical	Practice Match	Practice Match	Team Tactical	Feature Match	

setting standards and benchmarks for aspiring athletes (7–9,11). However, they do not provide a clear indication of the physical development from junior to senior level that is required to promote the gains in CMVJ and SPJ required to make the senior level. Of great interest to the strength and conditioning coach are the specific strength and speed-strength variables that require development for players to progress from junior to senior elite competition. The purpose of this investigation was to examine the changes in CMVJ, SPJ, because they relate to strength and speed-strength development, over 2 years in a group of volleyball players who successfully transitioned from age group (U21) to senior national team in that time period.

METHODS

Experimental Approach to the Problem

To assess the changes that occurred between junior and senior level volleyball players in jump performance, strength, speed-strength, and anthropometric variables, a longitudinal analysis was performed over a 2-year time period with a cohort of volleyball players who successfully transitioned from junior national team to senior national team competition.

Subjects

Sixteen male subjects (age: 18.5 ± 1.5 years, height: 2.00 ± 0.06 m, and weight: 88.4 ± 7.7 kg) participated in this 2-year longitudinal study. The subject's competitive experience at the beginning of the study included representation on the national team at age group (under 21 and under 18) continental championships. During the 24-month period of this investigation, all the subjects gained professional European contracts and also debuted with at least 1 senior national team match. These included, at a minimum, not only international friendly matches but also senior continental championships, World Championships, and the World Cup.

Table 1 outlines the typical weekly schedule for athletes in this study during the international volleyball season (April–September) for training (Table 1A) and competitive touring (Table 1B) periods. Table 2 outlines the subjects' typical weekly schedule with their professional club.

TABLE 2. Typical training schedule during professional season.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Strength and power	Individual technical	Strength and power		Individual technical	Travel
				Team tactical		Travel
Team tactical	Team tactical	Team tactical	Team tactical	Travel	Match	

Table 3. Changes (mean ± *SD*) in anthropometric variables over 2 years in volleyball players ($n = 16$).*

	Pretest	Posttest	ES (*d*)	Magnitude	Alpha (*p*)†
Height (cm)	200.8 ± 6.8	201.2 ± 7.0	0.06	No change	0.426
Mass (kg)	88.4 ± 7.7	92.3 ± 8.0	0.51	Moderate	0.002
Skinfolds (mm)	59 ± 13.3	51.1 ± 8.1	0.59	Moderate	0.009
LMR	1.5 ± 0.3	1.5 ± 0.3	1.18	Very large	<0.001

*LMR = lean mass ratio; ES = effect size.
†Alpha < 0.05 considered significant.

All the subjects received a clear explanation of the study, including the risks and benefits of participation, and if after this explanation their decision was to not be included in the analysis it did not adversely affect any current or future team selections. All included subjects provided written informed consent for testing and data analysis. Approval for this investigation was granted from the Institutional Human Ethics Committee, and the study conformed to the Declaration of Helsinki for medical research involving human subjects.

Procedures

The subjects performed a maximum effort CMVJ, depth jump from a 0.35-m box (DJ), and an SPJ (with approach) using a vaned jump and reach apparatus that allowed for recording of the maximum height reached to the nearest centimeter (Yardstick, Swift Systems, Lismore, Australia). In the CMVJ, no horizontal approach was allowed, whereas in the SPJ, an approach ranging from 3 to 4 steps was used, based on the athlete's preference. For the DJ35, the subjects stepped off the box, and immediately upon landing, attempted to jump as high as possible. The population-specific intraclass correlation coefficients (ICCs) (%Typical Error in parentheses) of the height of the CMVJ, DJ, SPJ were 0.98 (2.5%), 0.97 (3.0%), and 0.97 (3.2%), respectively.

One repetition maximum (1RM) and 3RM testing were conducted for the Clean and Squat, respectively. Repetition maximum testing was conducted in accordance with typical protocols, and with the National Sport Science Quality Assurance Standards. In brief, these protocols involve the use of certified and calibrated masses and strict adherence to the depth of squat (i.e., hip crease must descend below the top of the patella in squats).

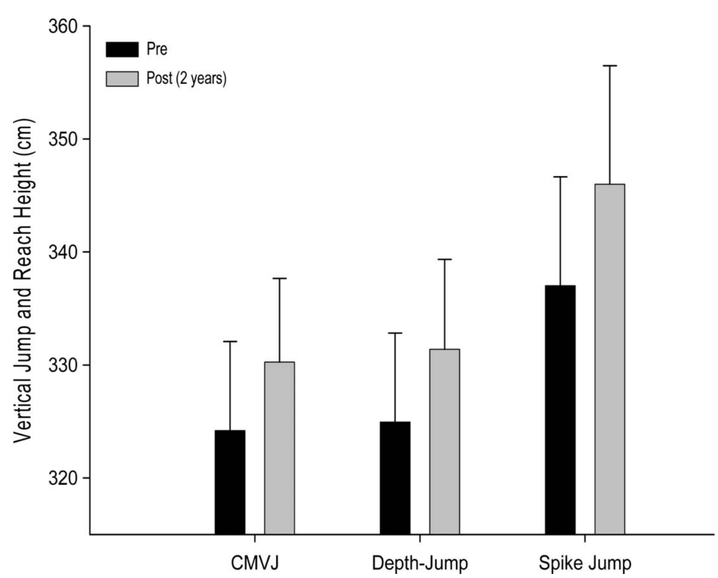

Figure 1. Mean (±*SD*) of 2-year changes in countermovement vertical jump (CMVJ), depth jump, and spike jump of elite male volleyball players ($n = 16$) successfully transitioning from junior to senior national team. All changes are statistically significant ($p < 0.05$).

TABLE 4. Changes (mean ± *SD*) in speed-strength variables over 2 years in volleyball players ($n = 16$) progressing from junior to senior national team.*

	Pretest	Posttest	ES (*d*)	Magnitude	Alpha (*p*)†
Unload jump squat					
Peak power (W)	6,155 ± 684	7,096 ± 844	1.38	Very large	<0.001
Relative peak power ($W\cdot kg^{-1}$)	69.8 ± 6.2	76.9 ± 5.7	1.15	Very large	<0.001
Force (N)	2,044 ± 195	2,155 ± 155	1.04	Moderate	0.019
Jump height (cm)	46.4 ± 4.7	52.1 ± 4.0	1.21	Very large	0.002
Loaded jump squat (+50% BM)					
Peak power (W)	5,226 ± 627	5,941 ± 555	1.04	Very large	<0.001
Relative peak power ($W\cdot kg^{-1}$)	59.9 ± 5.7	64.5 ± 401	0.80	Large	<0.002
Force (N)	2,398 ± 2.9	2,631 ± 203	0.97	Large	<0.001
Jump height (cm)	33.0 ± 2.9	36.9 ± 2.6	1.35	Very large	<0.001

*ES = effect size; BM = body mass.
†Alpha <0.05 considered significant.

Speed-strength jump-squat assessments were conducted with the subjects standing on a commercially available force plate (400 Series Performance Force Plate, Fitness Technology, Adelaide, Australia). A position transducer (PT5A, Fitness Technology) was connected to a 400-g wooden pole (body weight jumps) or weightlifting bar and weightlifting plates (body weight plus 50% of body weight as additional mass) held across the shoulders. Both the force plate and position transducer sampled at 200 Hz and were interfaced with computer software (Ballistic Measurement System, Fitness Technology) that allowed direct measurement of force-time characteristics (force plate) and displacement-time and velocity-time (position transducer) variables.

Before all data collection procedures, the force plate was calibrated using a spectrum of known loads and then assessed against 3 criterion masses. The position transducer was

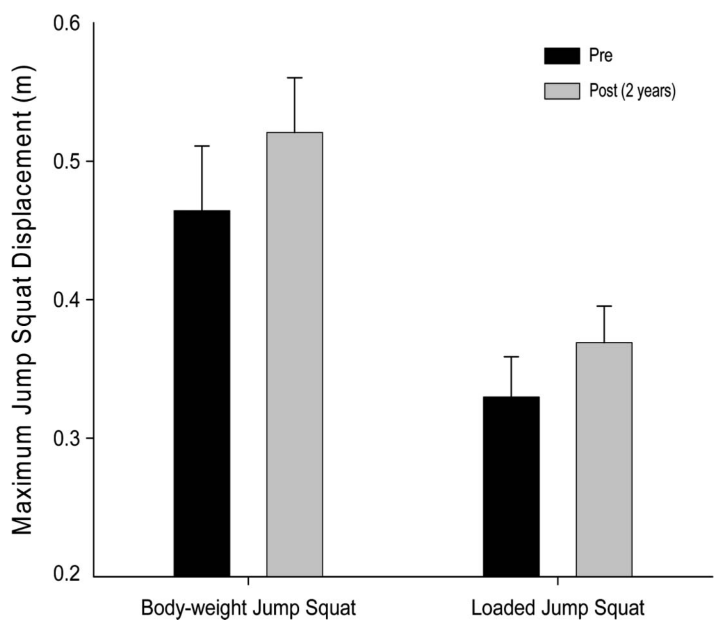

Figure 2. Mean (±*SD*) of 2-year changes in unloaded (body-weight jump squat) and loaded jump-squat (body weight + 50% body weight) performance of elite male volleyball players ($n = 16$) successfully transitioning from junior to senior national team. All changes are statistically significant ($p < 0.05$).

Table 5. Changes (mean ± *SD*) in 1RM clean and 3RM squat over 2 years in volleyball players ($n = 16$) progressing from junior to senior national team.*

	Pretest	Posttest	ES (*d*)	Magnitude	Alpha (*p*)†
1RM clean (kg)	85.7 ± 12.7	98.2 ± 8.0	1.56	Very large	<0.001
1RM squat (kg)	104.3 ± 19.7	134.3 ± 19.7	2.21	Very large	<0.001

*1RM = 1 repetition maximum; ES = effect size.
†Alpha <0.05 considered significant.

calibrated using a known distance of 1 m. The ICCs and %TE of the displacement, force, and power measures used in the assessment methodology, with this population group, were 0.95–0.97 (3.1–3.9%), 0.95–0.97 (3.1–4.0%), and 0.80–0.98 (3.0–9.5%), respectively.

All the subjects were assessed for height, mass, standing reach, and the sum of 7 skinfolds. The sum of 7 skinfolds was determined following measurement of the triceps, subscapulae, biceps, supraspinale, abdominal, quadriceps, and calf skinfold using a Harpenden skinfold calliper (British Indicator, London, United Kingdom). A composite ratio of body mass divided by the sum of 7 skinfolds was then determined to reflect the amount of mass that is made up of lean tissue, termed the lean mass ratio (LMR). All the tests were conducted by a single researcher certified by the International Society for the Advancement of Kinanthropometry. The ICCs and %TE for height, mass, and standing reach were 0.99 (1.5%), 0.99 (1.2%), and 0.98 (2.0%), respectively. The test-retest ICC and %TE for the skinfold assessment was 0.99 (2.2%).

Statistical Analyses

The changes in the mean were used to assess the practical differences that occurred across the investigation time period. Paired *t*-tests were used to assess the changes in the speed-strength, anthropometric, and vertical jump variables over the 24-month period, with alpha set at $p \leq 0.05$. Additionally, Cohen's effect sizes (*d*) were calculated to reflect the magnitude of any changes that may be observed, with the criteria of <0.40: small; 0.40–0.70: moderate; 0.70–1.00: large; >1.00: very large.

Results

Anthropometric changes across the 2-year investigation period are presented in Table 3. Moderate magnitude increases in mass ($d = 0.51$, $p = 0.002$) and reduction in skinfolds ($d = 0.59$, $p = 0.009$) combined to result in a large increase in the LMR ($d = 1.18$, $p < 0.001$).

Jump height for CMVJ, DJ, and SPJ ($d = 0.80$, 0.82, and 0.94, respectively, $p < 0.001$) increased significantly over the 2-year period (Figure 1). Unloaded (body weight) and loaded jump-squat performances also increased significantly for all measured parameters (Table 4), and the very large increases in jump height in the unloaded ($d = 1.21$, $p = 0.002$) and loaded jump squats ($d = 1.346$, $p < 0.001$) are illustrated in Figure 2.

The Very Large magnitude changes in 1RM Clean and 3RM Squat ($d = 1.56$ and 2.21, respectively, $p < 0.001$) across the 2-year investigation period are presented in Table 5.

Discussion

Of great interest to the strength and conditioning coach working with elite programs are the specific variables that require development to progress from junior to senior elite competition. This information is invaluable in decision making and priority setting for optimizing the success rate in transforming junior athletes into senior athletes. Although previous studies have used this concept in rugby league (1), no studies have examined this in volleyball. The results of this investigation are novel in that they examine the changes in CMVJ and SPJ, as they relate to the 2-year development of volleyball players who transitioned from age group (U21) to senior national team during the investigation time-period. This investigation involved assessment of anthropometry (stature, mass, skinfolds), jump-squat speed-strength measures, maximal strength testing, and vertical jump measures. All the involved methods have been demonstrated to be valid in discriminating between higher and lower performers (7,8) and in detecting training-induced change with volleyball players (6). The results of the study provide the strength coach with the basis of a rationale to prioritize (a) increasing lean mass while reducing fat mass; (b) increasing stretch-load tolerance through depth jumping; and (c) increasing strength and loaded speed-strength performance, to increase the likelihood of success in progressing junior national team athletes to those at the senior national team level.

Despite no significant ($p = 0.057$) increase in height, lean mass was increased by a mean of 3.9 kg, with a reduction in total skinfold thickness of 7.8 mm, leading to a very large and significant ($d = 1.18$, $p < 0.001$) LMR increase from 1.5 to 1.8 (Table 3). These results emphasize the importance of increasing muscle mass to accommodate the large increases in the strength observed (Table 5), and the importance of leanness in elite volleyball players. It stands to reason that in a sport where relative power is of primary importance (5–8,10), training should be aimed at increasing strength and speed-strength, while maintaining very low fat mass. In fact, based on current observations and experience with high-performing senior national team members, further reductions in skinfold thickness would be expected of some subjects within this cohort (i.e., <50 mm), with a concomitant increase in LMR (i.e., ~2.0), and increases in maximum strength (i.e., Squat 150–175 kg).

Low fat mass is not only important for jump and relative power considerations but also to reduce stress placed on the musculoskeletal system in the jump-landing and diving demands inherent to volleyball (8). Fat mass places extra stress on the body when landing from a height, because the extra mass increases the kinetic stress upon landing and cannot contribute to absorption or deceleration in the landing activity.

The CMVJ and SPJ tests are widely accepted as the most important performance indicators in volleyball (7,8). During the course of this investigation, the subjects improved their CMVJ and SPJ to 6.1 and 9.0 cm, respectively, considered large, practical, change magnitudes ($d = 0.80$ and $d = 0.93$, $p < 0.001$). These are considerable improvements in this population and further support the justification of the CMVJ and SPJ as being the key performance indicators for elite volleyball, and demonstrating that these performances must be developed to successfully progress from junior to senior representation in volleyball.

Our present results support previous findings that demonstrate the importance of depth-jump ability in volleyball players, and the relationship between developing depth-jump ability and improving both CMVJ and SPJ (5,7,10). In the current investigation, DJ scores improved by 6.4 cm, considered a large magnitude ($d = 0.82$, $p = 0.001$). Considering these results, and others that demonstrate strong association between improving depth-jumping ability and increasing CMVJ and SPJ (1,5,7,10), strength and conditioning coaches should consider improving stretch load tolerance in depth jumping as an important training priority.

Several variables in the unloaded and loaded jump squats improved in the progression of these subjects from junior to senior levels (Table 4). The very large relative peak power increases in both the unloaded ($d = 1.15$, $p < 0.001$) and loaded jump squats ($d = 1.04$, $p = 0.001$) demonstrate the importance of applying force quickly and generating high power outputs for volleyball players. Improvements in jump-squat height for both the unloaded and loaded jump squats were both approximately 8%, with a similar magnitude of effect ($d = 1.21$, $p = 0.002$ and $d = 1.35$, $p < 0.001$, respectively), providing strong support for the validity of these test results, and supporting the utility of speed-strength training in volleyball players, likely best developed through Olympic style lifting and jump-squat methods (2,3,5).

Practical Applications

To progress from junior representation to senior national team, volleyball players must increase their CMVJ and SPJ. There are likely many factors that can contribute to achieving these aims, but in general, this is best accomplished through increasing lean mass and reducing fat mass, improving strength and speed-strength, and developing SSC function. With these methods in mind, strength and conditioning coaches can evaluate the relative strength and weaknesses of each volleyball player across these priority areas and in turn improve areas of weakness so that greater performance improvements can be made.

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