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Long-term training adaptations in elite male volleyball players

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Abstract

Several investigations have demonstrated differences in anthropometry, jump performance, and strength variables between developmental and elite level volleyball players. However, within the elite level of play, the magnitude of change that can occur with training is unclear. The purpose of this investigation was to examine the anthropometric, vertical jump, and strength quality changes over two years in a group of national team volleyball players. Fourteen national team volleyball players (23.0 ±4.1 yrs, 1.98 ±0.07 m, 91.7 ±7.9 kg) began and completed this study. Participants had all played international matches (representing Australia) prior to the examination time period, and continued to do so during the international season. Anthropometry (stature, mass, and ∑7 skin-folds), vertical jump measures (counter-movement vertical jump, CMVJ; depth-jump from 0.35 m, DJ; spike-jump SPJ, all including arm-swing), lower body power (jump squat at body-mass, JSBW and jump squat +50% body-weight, JS50) measures were tested prior to and at the conclusion of the investigation period. Significant ($p<0.05$) improvements were observed in ∑ 7 skin-folds, DJ, SPJ, and JS50 performance, with large magnitude changes ($d>0.70$) in the ∑ 7 skin-folds reduction, SPJ, and leg extensor power. This study has demonstrated that elite male volleyball players can improve leanness and power which contribute to improvements in vertical jump.

Keywords: jump, spike jump, elite, volleyball, training

INTRODUCTION

Volleyball is an intermittent and explosive sport, involving brief but frequent movements such as jumping and diving (3, 8). Jumping activities can include both horizontal approach movements (spike jumps, SPJ), as well as movements without a horizontal approach (jump setting, jousts, blocking). Considering the importance of these jumping activities to the performance outcome in volleyball, and the frequency that they occur in a typical match (7), both counter-movement vertical jump ability (CMVJ) and spike jump ability (SPJ) are considered important qualities contributing to game performance by elite volleyball players, and they are the primary targets that training programs aim to enhance (4, 6, 12).

Recent studies have examined the difference between junior and senior elite volleyball players (7), highlighting the importance of vertical jump improvement for developing athletes to progress successfully from lower to higher levels. Cross-sectional examinations of junior and senior groups provides strong evidence for the need to improve both CMVJ and SPJ, as well as presenting useful performance data for setting standards and benchmarks for athletes aspiring to play at the international level (6, 7, 8, 11). Despite the acknowledged significance, little is known as to the trainability of CMVJ and SPJ and other potentially related qualities within senior elite populations of volleyball players. Of great interest to the sport scientist and strength and conditioning coach working with elite volleyball athletes, is the magnitude of trainability of these qualities, and which specific variables require development to underpin these improvements in vertical jump ability. As studies with elite populations of athletes is rare, the magnitude of improvement possible with elite athletes is poorly understood, nor is the inter-play of these trainable aspects. The purpose of this investigation was to examine potential changes in anthropometry, vertical jump ability, and fundamental neuromuscular capacities over a 2 year time period in elite male volleyball players to gain insight into the trainability of these qualities within an elite population.

METHODS

Experimental Approach to the Problem

To assess the changes that occurred in jump performance, speed-strength, and anthropometric variables, a longitudinal analysis was performed over a 2 year time period with a cohort of elite national team volleyball players.

Subjects

Fourteen national team volleyball players (23.0 ±4.1 yrs, 1.98 ±0.07 m, 91.7 ±7.9 kg) began and completed this study. Participants had all played international matches (representing Australia) prior to the examination time period, and continued to do so during the international season. During professional seasons, match play volume varied depending on club, with training time typically involving 4-7 court and 2 strength sessions per week. During international seasons, participants typically engaged in 7-9 court and 2-4 strength sessions per week, with match involvement varying by player from 15-40 per season.

Strength training sessions varied throughout the 2 year time period, based on individual and to a large extent their professional club commitments. However, the main components of the sessions typically involved 1-2 Olympic lifts and/or variations (e.g. Snatch, power clean) (3-10 sets total), 1-3 maximal strength training exercises (Squat, Front Squat, Pull-up)(1-6 repetitions, 4-10 sets total), 2-4 supplementary exercises (uni-lateral leg strength, rows, etc.), followed by any prescribed medical exercise. Total sets for workouts ranged greatly depending on the athlete and the time of year, from 8-22 main ‘working’ sets.

All participants received a clear explanation of the study, including the risks and benefits of participation and if following this explanation their decision was to not be included in the analysis it did not adversely affect any current or future team selection. All included participants provided

written informed consent for testing and data analysis. Approval for this investigation was granted from the Institutional Human Ethics Committee.

Procedures

Participants performed a maximum effort counter-movement vertical jump (CMVJ), depth jump from a 0.35 m box (DJ), as well as a spike jump (with approach) (SPJ) using a vaned jump and reach apparatus which allowed for recording of the maximum height reached to the nearest centimetre (Yardstick, Swift Systems, Lismore, Australia). In the CMVJ no horizontal approach was allowed, whilst in the SPJ an approach ranging from 3-4 steps was used, based on the athlete's preference. For the DJ, participants stepped off a 0.35 m box, and immediately upon landing, attempted to jump as high as possible. The population-specific intra-class correlation coefficients (ICC) (%TE in parenthesis) of the height of the CMVJ, DJ, SPJ was 0.98 (2.5%), 0.97 (3.0%), and 0.97 (3.2%) respectively.

Kinetic and kinematic assessments of jump-squat performance 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, Adelaide, Australia) was connected to a 400 g wooden pole (bodyweight jumps, BWJS) or weightlifting bar and weightlifting lifting plates (bodyweight plus 50% of body-weight as additional mass, JS50) 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, Adelaide, Australia) that allowed direct measurement of force-time characteristics (force plate) and displacement-time and velocity-time (position transducer) variables.

Prior to 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 calibrated using a known distance of 1 m. The ICC and %TE of the displacement, force, and power measures used in the

assessment methodology, with this population group, was 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 subjects were assessed for height, mass, standing reach, and the sum of 7 skin-folds. The sum of 7 skin-folds was determined following measurement of the triceps, subscapula, biceps, supraspinale, abdominal, quadriceps, and calf skin-fold using a Harpenden skinfold calliper (British Indicator, UK). A composite ratio of body-mass divided by the sum of 7 skin-folds was then determined to reflect the amount of mass that is made up of lean tissue, termed the Lean Mass Ratio (LMR). All tests were conducted by a single researcher certified by the International Society for the Advancement of Kinanthropometry (ISAK). The ICC 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 skin-fold assessment was 0.99 (2.2%).

All testing was conducted under the same conditions, at the same time of day, for each testing type. Although having elite athletes completely recovered for the purpose of testing is unrealistic, to minimize fatigue testing took place after a complete rest day, and was spread over 2 days. Anthropometry was completed in the morning of Day 1 to attempt to control for hydration status, with the vertical jump testing occurring in the afternoon. Speed-strength assessment was completed the following day, in the afternoon.

Statistical Analyses

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 changes in the anthropometric and vertical jump variables over the 24 month period, with alpha set at $p<0.05$. 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; and 0.70-1.00 large.

RESULTS

Anthropometric changes across the 2 year investigation period are presented in Table 1. A large magnitude reduction in skin-folds (d=0.70, $p<0.001$) contributed to a moderate increase in the LMR (d=0.65, $p<0.001$).

Jump height for CMVJ, DJ, and SPJ (d=0.52, 0.51, and 0.70 respectively, $p<0.001$) increased significantly over the 2 year period (Figure 1). Loaded jump squat height (JS50) also increased significantly (Figure 2) with large magnitude increases (d=0.70, $p<0.001$). With the exclusion of a moderate (d=0.51, $p=0.043$) increase in peak power in the BWJS, no other changes were observed in the measured kinetic and kinematic descriptors of the jump squat tests.

DISCUSSION

Of great interest to the strength and conditioning coach working with elite programs, is the specific variables that can be developed to advance performance. This information is invaluable in decision-making and priority setting for optimizing the success of elite athletes. The results of this investigation are novel in that they examine the changes in CMVJ and SPJ, as they relate to changes in anthropometry and speed-strength over 2 years in elite volleyball players. We have demonstrated that large changes in vertical jump ability and speed-strength and improvements in lean mass can be realized, even in such a highly trained population. This investigation provides the strength coach and sport scientist with the basis of a rationale to prioritize: 1. Reducing fat mass; 2. increasing stretch load tolerance (through depth jumping and other jumping methods) and 3. increasing loaded jump performance, in elite national team players.

Total skin-fold thickness was reduced by a large magnitude (d=0.70, $p<0.001$) over the course of this investigation, supporting a moderate and significant (d=0.65, $p<0.001$) LMR increase from 1.7 to 1.9 (Table 1). In a comparison of athletes transitioning from junior to senior elite

competition over a similar time period to this study, LMR was observed to increase from 1.5 to 1.8 (10). Considered together, these results emphasize the importance of increasing lean mass in junior elite players to accommodate the large increases in strength observed (10), but also that further reductions in fat-mass and increases in LMR should be expected for elite volleyball players. It stands to reason that in a sport where jumping ability is of primary importance (4, 5, 6, 7, 9), training should be aimed at increased strength and maximal power whilst maintaining very low fat mass.

During the course of this investigation, the participants improved their CMVJ and SPJ by 0.045 m and 0.090 m respectively, which are considered moderate-large, and practical, change magnitudes (d=0.52 & d=0.70, $p<0.001$). These improvements suggest that not only are increases in jumping ability required for developing volleyball players (10, 11), but also that further improvements can and should be made within elite populations.

Our present results support previous findings that demonstrate the importance of depth jump ability in volleyball players, and the likely relationship between developing depth jump ability and improving both CMVJ and SPJ (4, 6, 9). In the current investigation, DJ scores improved by 0.041 m (d=0.51, $p<0.001$). Considering these results, as well as others that demonstrate strong association between improving depth jumping ability and increasing CMVJ and SPJ (1, 4, 6, 9), strength and conditioning coaches should consider improving stretch load tolerance in depth jumping and related activities, as an important training priority in elite volleyball players.

The large increases in loaded jump squat height (d=0.70, $p=0.001$) demonstrate the importance of fast force production in elite volleyball players. This quality is highly trainable in developing volleyball players (10), and the results of the present study supports the trainability of this quality even in elite players. Furthermore, the results of this study highlight the potential association between increased power output under load and improved vertical jump ability in volleyball players. As recently highlighted by Cormie et al (2), increased force, impulse and

power output during jumping is in part a result of more effective utilization of the eccentric phase. Although not assessed in the current study, improvement in DJ performance indirectly lends support to this suggestion.

Examinations of training-induced changes are rare in elite populations of athletes. The results of this study suggest that even in elite populations, several impactful gains can be made in anthropometry, stretch-shorten cycle function, and speed-strength, which may underpin vertical jump improvement in elite volleyball players.

PRACTICAL APPLICATIONS

Large changes in vertical jump ability, lower body power, and improvements in lean mass can be realized in already well trained volleyball players. These results provide the strength coach and sport scientist with the basis of a rationale to prioritize: 1. Reducing fat mass; 2. increasing stretch load tolerance (through depth jumping and other jumping methods) and 3. increasing loaded jump performance, in elite national team players.

Volleyball players should be expected to increase their CMVJ and SPJ, even at the most elite level. This may be in part accomplished through reducing fat mass, improving force and power output during jumping, and development of high levels of stretch load tolerance in SSC activity. Strength and conditioning coaches should prioritize training for each individual volleyball player based on a testing profile, in order to highlight areas of relative weakness, and in turn, to best exploit trainable qualities in elite players.

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FIGURE LEGENDS

Figure 1: Mean (±SD) of two year changes in counter-movement vertical jump (CMVJ), depth-jump, and spike jump of elite male volleyball players (n: 14).
All changes statistically significant ($p<0.01$)

Figure 2: Mean (±SD) of two year changes in unloaded (JSBW) and loaded jump squat (body-weight + 50% body-weight, JS50) performance of elite male volleyball players (n: 14).
* Indicates change is statistically significant ($p<0.001$)

Table 1: Changes (mean ±SD) in anthropometric variables over 2 years in elite male volleyball players (n=14)

	Pre-Test	**Post-Test**	**ES (*d*)**	**Magnitude**	**Alpha (*p*)**
Height (cm)	198.1 ±7.0	187.8 ±7.1	0.04	No change	0.415
Mass (kg)	91.7 ±7.9	92.7 ±6.9	0.14	No change	0.225
Skinfolds (mm)	56.7 ±9.0	50.8 ±8.5	0.7	Large	<0.001
LMR	1.7 ±0.3	1.9 ±0.3	0.65	Moderate	<0.001

Alpha <0.05 considered significant

Table 2: Changes (mean ±SD) in speed-strength variables over 2 years in elite male volleyball players (n=14)

	Pre-Test	**Post-Test**	**ES (*d*)**	**Magnitude**	**Alpha (*p*)**
Unloaded Jump Squat					
Peak Power (W)	6978 ±1256	7440 ±890	0.51	Moderate	0.043
Relative Peak Power (W/kg)	76.2 ±12.3	80.4 ±9.1	0.47	No change	0.069
Force (N)	2140 ±243	2228 ±209	0.42	No change	0.104
Jump Height (m)	0.502 ± 0.065	0.512 ± 0.066	0.15	No change	0.365
Loaded Jump Squat (+50% BM)					
Peak Power (W)	5793 ±771	5957 ±742	0.22	No change	0.287
Relative Peak Power (W/kg)	63.2 ±6.3	64.4 ±7.7	0.16	No change	0.393
Force (N)	2579 ±283	2640 ±232	0.26	No change	0.246
Jump Height (m)	0.340 ±0.038	0.376 ±0.052	0.7	Large	<0.001

Alpha <0.05 considered significant