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The longitudinal development of endurance, sprint, agility, strength and jumping performance within college volleyball players

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Abstract

Objectives: The aim of this study was to evaluate the annual development of biomotor characteristics in college volleyball players.

Methods: A total of 16 college male volleyball players (age: 21.75 (4.45) years, body mass: 78.60 (12.20) kg, and body height: 187.0 (18.9) cm) from Turkish National Volleyball Leagues were tested. All college volleyball players take part in the two year (8 month each year) volleyball-specific training and competitions. The 30m sprint, ilinois agility, countermovement and squat jump, 20m beep test and maximal muscular strength tests of all participants were measured.

Findings: Significant progress (p<0.05) was monitored in summation 30m sprint, ilinois agility, countermovement and squat jump, 20m beep test and maximal muscular strength tests. Findings for the one-way repeated measures ANOVA revealed a considerable main effect among tests on 30m sprint, ilinois agility, countermovement and squat jump, 20m beep test and maximal muscular strength tests performance.

Conclusion: The findings of this study indicate that, within a college population of male volleyball players, enhancing endurance, sprint, jumping and strength characteristics in regular exercises are moderately associated with improves in aerobic endurance, sprint, jumping and strength ability.

Keywords: Endurance, strength, sprint, countermovement, squat

Introduction

The role of the strength and conditioning coach within the long-term development of youth athletes is to advance the physical characteristics required for sports performance. This long-term development process usually involves the implementation of performance tests to

objectively determine and monitor performance adaptations (Anderson et al., 2008). Practitioners should use comparative data for monitoring and evaluating the development of youth athletes to assist in identifying player's strengths and weaknesses, talent identification and selection, evaluating training interventions and prescribing training programmes (Pyne et al., 2014). This comparative data can be drawn from two distinct types of data collection; cross-sectional and longitudinal. Currently, research and practical application of the measurement and evaluation of physical performance predominantly utilize cross-sectional analyses within annual-age cohorts (Till et al., 2013; Vaeyens et al., 2008) and as such little is known about the developmental pathways of athletes (Matthys et al., 2013), which requires longitudinal observations. Prospective longitudinal studies require the collection of data from the same individuals for two or more distinct periods (Falk et al., 2004) but studies of this type are limited due to the difficulties of collecting such data (e.g., financial costs, player availability, methodological issues). However, longitudinal data collection on the same individuals can inform coaches of the expected changes within and between athletes having implications for long-term player development (Anderson et al., 2008; Falk et al., 2004; Till et al., 2015).

Volleyball appears to be characterized by frequent short bouts of high-intensity exercise, followed by periods of low-intensity exercise and brief rest periods (Polglaze and Dawson, 1992; Viitasalo, 1991). The high-intensity bouts of exercise with relatively short recovery periods, coupled with the total duration of the match (~90 minutes), would suggest that volleyball players require well-developed creatine phosphate and glycolytic metabolic pathways, as well as reasonably well-developed aerobic capabilities (Smith et al., 1992; Spence et al., 1980; Viitasalo et al., 1987). Based on testing results and observation of match conditions, considerable demands are also placed on the neuromuscular system during the various sprints, jumps, and multidirectional court movements that occur repeatedly during competition (Dyba, 1982). As a result, it could be logically assumed that volleyball players require well-developed speed and muscle power along with the ability to perform these repeated maximal efforts with limited recovery for the duration of the match. Physiological assessment of volleyball players has typically involved estimates of speed (5- to 10-m sprint), muscle power (vertical jump and spike jump), and maximal aerobic power (multistage fitness test; Smith et al., 1992; Gabbett et al., 2007). The specificity of the multistage fitness test, however (whereby athletes are required to shuttle back and forth along a 20-m distance), in relation to volleyball is questionable. Although aerobic metabolism is likely of some

relevance in volleyball to replenish energy stores used in characteristically anaerobic efforts (Viitasalo et al., 1987; Gabbett et al., 2007), a staged aerobic-power test appears very dissimilar to competition performance demands. In addition, it has been shown that measures of maximal aerobic power such as the 20-m multistage shuttle run do not discriminate between successful and less successful volleyball players at the high-performance and elite level (Gabbett et al., 2007; Dyba, 1982). This suggests that physiological factors other than, or in addition to, maximal aerobic power contribute to success in volleyball at higher levels of playing proficiency.

Jumping ability is critical to success in volleyball, allowing for a competitive advantage in attack (gaining a great height to hit over the block/superior angle of attack) and also in defence obtaining a higher blocking position (Sheppard et al., 2007a; Sheppard et al., 2007b; Sheppard and Borgeud, 2008). To increase vertical jump, loaded jumps are often used to train lower body strength and power (Newton et al., 1999; Newton et al., 2006). This has been shown to be very useful in increasing the force and power of the leg extensors, and as a result, this increase appears to contribute in part to an improvement in vertical jump height (Newton et al., 1999; Newton et al., 2006; McBride et al., 2002) Successful team sport performance depends on well developed physical qualities and superior anticipation and decision-making skills (Sheppard et al., 2007a). Given that athletes are required to perform physical skills, such as sprints and changes of direction in response to cognitive stimuli, agility has recently been defined as a rapid, whole body movement with change of velocity or direction in response to a stimulus (Newton et al., 2006).

Training periodization consists in establishing and guiding the athlete physical preparation process, in an attempt to achieve the best specific fitness in a target competition. Along with this, the physical fitness is understood as a biological adaptation process due to the training stimulus, manifested after a long-term preparation to the competition. Periodization is the process to unify the physical, technical, tactical and psychological variables that characterizes the athlete training to compete (Aquino et al., 2016).

An understanding of the longitudinal development biomotor characteristics (endurance, sprint, jumping and strength) would allow a greater appreciation for player development on an annual and long-term basis (i.e., 2 years). Therefore, the aim of this study was to evaluate the annual development of biomotor characteristics in college volleyball players. It was hypothesized that annual improvements in biomotor characteristics would occur with greater percentage improvements evident at the college volleyball players. In

addition, it was hypothesized that large increases in biomotor characteristics would occur over a long-term (i.e., 2 year) period with large evident.

Methods

Experimental design

The current study was a repeated-measures design, which monitored the changes in endurance, sprint, jumping and strength capacity in national competing volleyball players from August until April (during two years). The competitive season runs from October until April. To examine whether endurance, sprint, jumping and strength ability did change over time during the preparatory and competition period, tests were performed before and after a 2-week control period in August and April. The August testing was used as the pre-season measurement. The same tests were performed at the end (April) of the competition season.

Participants

A total of 16 college male volleyball players (at the same team) from Turkish National Volleyball Leagues were tested. In order to be included in the study a) players had to play in the Turkish National Volleyball Leagues (1st and 2nd), b) not having any medical disability which might affect the result of the study (this question asked all players), c) not having chronic injuries and diseases, d) not having lower extremity injuries within two years. Excluding criteria were: a) having any chronic injuries during the seasons, b) missing deliberately at most five training days c) consumption any ergogenic aids. Following these procedures, twelve players met the criteria for further analysis. Before conducting the experiment, all participants were informed on the risks of the study and gave informed consent. The study was approved by the Ethics Committee of the Inonu University and met the conditions of the Helsinki Declaration. All college volleyball players take part in the two year (8 month each year) volleyball-specific training and competitions.

Collection of data

Anthropometric measurements and field test protocols were applied to volunteers participating in the study. Participants were told to rest 24 hours before the measurements, away from any heavy physical strain. They were informed a day in advance, that they should not consume stimulants such as tea, coffee, and fizzy drinks. All the measurements and test protocols applied in the study were applied in the Inonu University School of Physical Education and Sports (SPES) physiology laboratory and sports hall. Somatotype

measurements were made on all participants in a resting state in the morning after 8 hours of fasting. The participants' motor tests (Monday: sprint performance, Wednesday: shuttle run test, and Friday: squat and bench press strength test) were measured between 09.00 and 11.00. As per the normal testing protocol for players, the volleyball players completed their typical practice warm-up before each testing session. This warm-up included 10 minutes of general activity (walk, jog, light stretching), followed by 5 minutes of dynamic activity increasing in speed and intensity (skips, leg swings, arm swings), 10 minutes of 2-person volleyball skill rally (i.e., "pepper drill"), followed by 3 to 5 minutes of rest before starting the session. Players were familiarized with the testing protocol by way of 2 to 5 submaximal practice attempts.

Anthropometric measurements

The anthropometric measurements of the participants were made at Inonu University SPES physiology laboratory. In the study, all the anthropometric measurements of the subjects were made in accordance with the measurement techniques and standards recommended by the "International Society for the Advancement of Kinanthropometry" (ISAK). In the study, each participant's height was measured with a stadiometer with a sensitivity level of 0.01 meter (m) and their body weight (BW) was measured with an electronic scale (SECA, Germany) with a sensitivity level of 0.1 kilogram (kg). These measurements were used to calculate Body mass index (BMI) as the quotient of body mass (kg) to stature squared (m²). The participants' skinfold thicknesses (SFT) value were determined with a skinfold caliper (Holtain, UK) applying a pressure of 10 gr to 1 mm² with a ± 2 mm error and were obtained from seven areas (triceps, suprailiac, subscapula, calf, thigh, pectoral, abdominal). In the SFT measurements, the thickness of subcutaneous fat layer between the thumb and index finger was slightly raised up just enough to separate from muscle tissue. The caliper was placed about 1 cm away from the fingers. The other measurement was taken after waiting for a certain period of time against the possibility of lower values showing up in measurements made one right after another. The display was read within 2-3 seconds (sec) and recorded in favour millimetres (mm). For skin fold thickness (SFT) measurements, the value was recorded when the difference between two measurements was <5% and <1% for the other measurements. If the differences were outside these limits, a third measurement was taken and the average of the three values was recorded

Field tests

In the study, the field tests of the participants were conducted at the Inonu University SPES Sports Hall. The tests were held between 09.00 and 11.00. Volunteers participating in the study were subjected to a general warm-up protocol before all tests to minimize the risk of disability and to achieve optimal performance.

30m sprint test

A "30m sprint test" was performed to determine the participants' alactic anaerobic power and sprint times (Nilsson, and Cardinale, 2015). The measurement was made such that the distance between the starting and ending lines on a flat ground would be 30m. Passive resting was practiced for 3 min between measurements for the restoration of adenosine triphosphate-phosphocreatine (ATP-PCr) deposits and for achieving maximal performance. Running scores were recorded in seconds using electronic timing gates placed on the start and finish lines (Smart Speed; Fusion Sport, Australia). The test was repeated three times for each participant for the reliability of the test and the best performance score was recorded (Hopkins, 2000).

Illinois agility test

The Illinois Agility Test (IAT) was used to measure agility. IAT was in a test course that was 10 meters long and 5 meters wide. The test launched with the player standing with one foot in front of the other at the starting line, and at order the player sprinted through the course. Whilst turning after the first 10-meter sprint, and again prior to the last 10-meter sprint to the finish line, the player contacted the ground with one hand to ensure that the line was crossed. Passive resting intervals of 3 min were applied between the repetitions. The time display started to work with an accuracy of 0.001 sec when the feet of the participant lost contact with the ground while the participant was on the jumping ground platform (Smart Jump; Fusion Sport, Australia). The time stopped with the participant landing on the platform again and thus the duration of staying in the air was determined. One practice trial with light jogging was allowed before the two test trials.

Counter movement jump and squat jump

Players in barefoot condition started from an upright standing position. Players were required to perform a countermovement jump (CMJ) vertically with arm swing. In accordance with the test protocol, they jumped to the highest distance they can reach with their legs stretched and without pulling the knees up. The hands were kept on the hips throughout the squat jump (SJ), knees were flexed until the thigh was in parallel to the floor, and the athletes

were instructed to execute a maximal vertical jump without plantar flexion of the ankle joint. Both test were repeated three times for each participant for the reliability of the test and the best value was recorded. Passive resting intervals of 3 min were applied between the repetitions. The intra-class correlation coefficient (ICC) for test-retest reliability and technical error of measurement for the 30m run test, IAT, CMJ, and SJ were between 0.87 and 0.93.

20m multistage run (beep) test

Maximal oxygen uptake was estimated using the multistage fitness test. Participants were required to shuttle run 20m, keeping to a series of beeps. Testing at the speed of a slow jogging (8.5 km / h) and subjects that begins first the sound signal start s to run course. Second until the voice signal has to reach the line. When you hear the second sound again to return to the starting line and the running speed of rotating every minute 0.5 km/h increasing signals continues. When the participants heard the sound signal, at the second signal have to reach at the other side of the line. The speed, the slow at first, increases gradually in every 10 seconds. When the participant misses the first signal sound and hears the second signal, it has to continue with the test or misses the signal sounds two times again, the test ends. The Determination of VO₂ max: In order to appreciate a sportsman with test, it is occurred a level form. With every 20-meters line, it is made a sign on the form. At the end of the test the sign, which the sportsmen received is counted and from the valuation from, the maximum VO2max value of the participant is fixed approximately in ml/kg/min category (Leger and Lampart, 1982; Fox et al., 1999).

Maximal muscular strength

1RM half squat and bench press strength was recorded as the maximal weight subjects were able to raise as described by Marques et al. (2008). In the present study, a free weight squat exercise was performed, allowing players to bend their knees to reach half-squat position (90-degree angle in the knee joint between femur and tibia) with the barbell held over the shoulders (back squat). The bar position for the free weight bench press exercise began in the up position at full elbow extension, moved to chest level for a momentary pause, and finished back at the starting position. No bouncing of the bar off the chest was allowed. Hand and foot positions were determined for each subject during familiarization and were held constant during all testing. Repetitions performed incorrectly were not included in the count. Prior to the test, players performed 2 warm-up sets each of 8 repetitions at; 65 to 75% of there perceived maximal loads. To determine the maximal strength, loads of 5-kg increments for back half squat and 2-kg increments for bench press were subsequently added until players

failed to finish 6 repetitions with proper technique. There were 3-minute rests between sets. Maximal strength (1RM) of back half squat and bench press were determined by 6RM using the formula (i.e., 6RM = 85% of 1RM) as suggested by the USA National Strength and Conditioning Association (Baechle et al., 2000). Maximal muscular strength was determined for no more than 4 sets for all players.

Training procedures

The 1st volleyball-training season lasted 39 weeks, including 13 weeks of pre-season training, 20 weeks of in-season training and 6 weeks post-season training. The 2nd volleyball-training season lasted 41 weeks to be completed, including 14 weeks of pre-season training, 22 weeks of in-season training and 5 weeks post-season training. Volleyball training procedures included both seasons volleyball training activities (technical and tactical training, games and matches) and conditioning (agility, coordination, plyometric, stretching, flexibility, endurance and strength development) during the pre-season, in a season and as well as post-season. The average duration of practice sessions was 90-120 min. All specific volleyball training procedures indicated in table 1.

Type of activity	Exercise	Set x repetition	1-RM%	Days
Resistance training	Barbell bench press Machine long pull Dumbbell shoulder press Standing barbell curl Machine leg extension Machine leg curl Barbell half squat	2x 10-12 (20 weeks, Aug, Sep, Oct, Nov, Dec) 3x10-12 (19 weeks, Jan, Feb, Mar, Apr, May)	60 70	Tuesday, Thursday
	Exercise	Section	Duration (minute)	
Specific volleyball training	Stretching and flexibility	Warming up and cool down,	15	Before every training day
	Sprint and agility	Before technical training	10	Tuesday, Thursday
	Plyometric	Before technical training	12	Wednesday
	Technical training	Main training	20	Wednesday, Friday
	Tactical preparation	After technical training	15	Wednesday, Friday
	Games	After technical and	20	Friday

Table 1. Overview of two seasons volleyball specific training outline.

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	tactical training		
Match Days	Competitions		Saturday, Sunday
Regeneration Day	Jogging, Pilates, sauna or massage	55	Monday
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Statistical analyses

The statistical analysis was initially performed by the "Shapiro Wilks" normality test and by the homoscedasticity test. All the variables presented normal distribution and homoscedasticity. The effect of the four warm up protocols were analysed by an "ANOVA for Repeated Measures" (1stPre-test x 1stPost-test x 2ndPre-test x 2ndPost-test), with sphericity checked using "Mauchly's Test". When the assumption of sphericity was not met, the significance of F ratios was adjusted according to the "Greenhouse-Geisser" procedure. Pairwise tests were run to further investigate the effect of each condition. Effect sizes were calculated and classified to determine the magnitude of changes among experimental conditions as proposed by "Cohen's d". An effect size was classified as 0.2 was deemed small, 0.5 medium, and 0.8 large (Cohen, 1988). The findings are presented as mean \pm SD (standard deviation) and an alpha level of p<0.05 was considered statistically significant for all analyses. All data analysis was conducted using SPSS statistics computing program version 22.0 (IBM for OSX).

Results

In terms of the physical characteristics of the participants (Table 2), no significant changes were observed for body mass, BMI, and BF throughout 1st and 2nd volleyball season.

Danamatana	1 st Pre-test	1 st Post-test	2 nd Pre-test	2 nd Post-test
rarameters		X ±SD		
Age (years)	21.8±4.1	22.1±4.3	22.3±4.5	22.9±5.2
Height (cm)	187.7±16.9	187.9±16.1	187.8±16.4	187.9±16.6
Body mass (kg)	77.0±9.2	77.7±11.9	78.5±10.4	78.1±10.6
$BMI (kg/m^2)$	21.87±3.2	22.1±3.0	22.2±3.1	22.1±3.3
BF (%)	12.1±3.8	11.76±4.1	13.0±4.4	12.6±3.6
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Fable 2. Maiı	ı physical	features	of the	players
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(BMI: Body mass index; BF: Body fat; X: Mean; Sd: Standard Deviation)

The pre- and post-test values of 30-meter, IAT, CMJ and SJ found that statistical significance difference, in favour of post-tests (p=0.00, Table 3).

Table 3. Longitudinal	development of endurance	, sprint, strength	and jumping
performance of college male v	olleyball players		

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Parameters	1 st Pre-test	1 st Post-test	2 nd Pre-test	2 nd Post-test
30m sprint (sec)	4.13±0.16	3.96±0.13 ^a	4.03±0.23 ^b	3.90±0.11°
IAT (sec)	20.7±1.54	19.9±1.44 ^a	19.9±1.71 ^b	19.5±1.37 ^c
CMJ (cm)	44.2±3.27	48.3±3.39 ^a	45.9±3.34 ^b	53.3±2.90°
SJ (cm)	36.0±3.14	40.1±3.09 ^a	37.8±3.01 ^b	43.5±3.08°

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20m Multistage Run Test (m)	1960±120	2200±110 ^a	1980±110 ^b	2300±90 ^e
VO _{2max} (ml/kg/min)	57.6±9.3	60.6 ± 8.8^{a}	58.2±9.1 ^b	62.2±10.5 ^c
Bench Press (1-RM)	64.9±4.20	81.7±4.73 ^a	72.8±3.88 ^b	92.5±4.73°
Bench Percentile (1-RM/kg)	0.83 ± 0.025	1.04±0.038 ^a	$0.93 {\pm} 0.029^{b}$	$1.18 \pm 0.050^{\circ}$
Squat (1-RM)	80.4±4.96	100.0±5.21 ^a	88.8±4.72 ^b	114.1±5.57 ^c
Squat Percentile (1-RM/kg)	1.03 ± 0.10	1.29±0.14 ^a	1.14±0.11 ^b	1.47 ± 0.16^{c}

(IAT: Illinois Agility Test; CMJ: Countermovement Jump; SJ: Squat Jump; VO_{2max}: Maximal Oxygen Consumption; 1-RM: One Maximum Repetition; ^a: Differences between 1stpre- and 1stpost-test, ^b: differences between 1stpost- and 2ndpre-test; ^c: differences between 2ndpre- and 2ndpre-test)

30m and IAT sprint performance

Results for the one-way repeated measures ANOVA disclosed a substantial main effect among tests on 30 m sprint ($F_{(1,15)}$ =96.997; p=0.00) and IAT ($F_{(1,15)}$ =207.041; p=000) sprint performance. Pairwise comparison indicated that a significantly the best 30 m sprint performance was indicated after 2ndpost-test (M=3.90±0.11, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=4.13±0.16, p=.000; M=3.96±0.13, p=.000 and M=4.03±0.23, p=.000; respectively). And also, a significantly the best IAT sprint performance was found after 2ndpost-test (M=19.54±1.37, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=20.74±1.54, p=.000; M=19.92±1.44, p=.000 and M=19.98±1.71, p=.000; respectively).

CMJ and SJ performance

Findings for the one-way repeated measures ANOVA revealed a considerable main effect among tests on CMJ ($F_{(1,15)} = 682.508$; p=0.00) and SJ ($F_{(1,15)} = 502.119$; p=000) performance. Pairwise comparison showed that a significantly the best CMJ performance was found after 2ndpost-test (M=53.33±2.90, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=44.25±3.27, p=.000; M=48.33±3.39, p=.000 and M=45.91±3.34, p=.000; respectively). Also, the best SJ performance was determined after 2ndpost-test (M=43.50±3.08, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=36.08±3.14, p=.000; M=40.16±3.09, p=.000 and M=37.83±3.01, p=.000; respectively).

20m multistage run test and Vo_{2max} performance

Findings for the one-way repeated measures ANOVA elicited a remarkable main effect among tests on 20m multistage run test ($F_{(1,15)} = 215.284$; p=0.00) and VO_{2max} ($F_{(1,15)} = 116.742$; p=000) performance. Pairwise comparison disclosed that a significantly the best 20m multistage run test performance was ascertained after 2ndpost-test (M=2300±90, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=1960±120, p=.000; M=2200±110, p=.000 and M=1980±110, p=.000; respectively). In addition, the best VO_{2max} performance was found after 2ndpost-test (M=62.2±10.5, p=.000) as compared with the 1stpre-, 1stpost and

 2^{nd} pre-test (M=57.6±9.3, p=.000; M=60.6±8.8, p=.000 and M=58.2±9.1, p=.000; respectively).

Bench press and squat performance

Results for the one-way repeated measures ANOVA disclosed an important main effect among tests on bench press ($F_{(1,15)} = 488.760$; p=0.00) and bench percentile ($F_{(1,15)} = 625.300$; p=000) values. Pairwise comparison disclosed that a significantly the best bench press performance was found after 2ndpost-test (M=92.58±4.73, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=64.91±4.20, p=.000; M=81.75±4.73, p=.000 and M=72.83±3.88, p=.000; respectively). Similarly, the best bench percentile performance was calculated after 2ndpost-test (M=1.18±0.050, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=1.18±0.050, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=1.04±0.038, p=.000 and M=0.93±0.029, p=.000; respectively).

Findings for the one-way repeated measures ANOVA revealed a substantial main effect among tests on squat ($F_{(1,15)}$ =475.522; p=0.00) and squat percentile ($F_{(1,15)}$ =338.116; p=000) values. Pairwise comparison revealed that a significantly the best squat performance was found after 2ndpost-test (M=114.16±5.57, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=80.41±4.96, p=.000; M=100.08±5.21, p=.000 and M=88.83±4.72, p=.000; respectively). Likely, the best squat percentile performance was calculated after 2ndpost-test (M=1.47±0.16, p=.000) as compared with the 1stpre-, 1stpost and 2ndpre-test (M=1.03±0.10, p=.000; M=1.29±0.14, p=.000 and M=1.14±0.11, p=.000; respectively).

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), limited studies have examined this in volleyball (Sheppard et al., 2012). The results of this investigation are novel in that they examine the changes in endurance, sprint, jumping and strength, as they relate to the 2year development of volleyball players. The main results of this study is that endurance, sprint, jumping and strength performance improved at the end of the both volleyball season, as was indicated by significant enhances in endurance, sprint, jumping and strength both first and second volleyball season. The findings of this study indicate that, within a college population of male volleyball players, enhancing endurance, sprint, jumping and strength

characteristics in regular exercises are moderately associated with improves in aerobic endurance, sprint, jumping and strength ability. Since the latest change in play rules, volleyball has developed in popularity, but at the same time the physical demands of modern volleyball have also increased requiring highly developed qualities of muscular fitness such as strength, power, agility and speed (Dervisevic and Hadzic, 2012). Prior study has reported that, in athletes participating in sports that require a high number of jumps for successful performance, strength and power assessments correlate strongly with VJ performance (Ashley and Weiss, 1994; Peterson et al., 2006). Gabbett et al. (2014) reported that training related changes have been evident in athletes following a range of training modalities (e.g., strength, small sided games, sport specific training). As we hypothesized, the majority of aerobic endurance, sprint, jumping and strength ability enhanced over a long-term (i.e., 2 year) period with the greatest boosts occurring between the college volleyball players. The novel results of this study are demonstrated that endurance, sprint, jumping and strength performance improved at the end of the both volleyball season. Such findings provide evidence of the annual changes that may occur in endurance, sprint, jumping and strength performance within college volleyball players. In addition, these findings suggest that strength characteristics will demonstrate the largest gains.

The CMJ and SJ tests are widely accepted as the most important performance indicators in volleyball (Sheppard et al., 2007; Sheppard et al., 2009). During the course of this study, the players increased their CMJ and SJ to 20.58 and 20.83%. These are remarkable enhancements in this population and further support the justification of the CMJ and SJ 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. Additionally, in the Hoff and Helgerud study (2004), the findings of the players' squat improved from 116 to 176 kg and their vertical jumping height increased from 57.2 to 60.2 cm. End of this research, the college volleyball players improved their bench press and half squat strength performance to 42.52 and 41.91%, respectively.

The current study is the first to use resistance training together with specific volleyball training for volleyball players. The resistance training together with specific volleyball training significantly increased aerobic endurance as evidenced by the improvement in 20m Multistage Run Test and VO_{2max}. The volleyball players increased their 20m Multistage Run Test from 1960 to 2300 (m) and VO_{2max} from 57.6 to 62.2 (ml/kg/min). Therefore, resistance training together with specific volleyball training may be considered to be an alternative for

concurrent training. Chtara et al. (2005) reported that concurrent muscular strength training and aerobic interval training, which improved aerobic capacity in physically active individuals. Consequently, the results of this study clearly demonstrate that activated muscles could increase their oxidative capability as a training response to the aerobic interval training without affecting neural adaptation, thus improving aerobic endurance (Wong et al., 2010). On the other hand, Milic, Grgantov & Katic (2013) argued that longitudinal dimensionality of the skeleton (muscle tissue, fat tissue, ossification of bone tissue, arm length), or height and growth may be most important characteristic in volleyball. It has also been known that development in biomotor ability which are affecting volleyball performance such as muscular endurance, power, strength, agility are influenced by physical (circumference, diameter and length of the body part, skinfold values, somatotype and endocrine function etc) and psychosocial factors (structure of the family, environment etc) should be evaluated and kept under control throughout pre-pubertal or pubertal stage of the player. Although, Cabral et al (2011) reported that somatotype or vertical jump height does not permit to distinguish elite volleyball players from non-elite volleyball players. We suggested that these physical and psychosocial factors should be determined in a cross-sectional or longitudinal manner in further studies.

Conclusion

Volleyball players must improve their sprint, agility, strength, VO_{2max} , CMJ and SJ. There are likely many factors that can contribute to achieving these aims, but in general, this is best accomplished through increasing improving strength and speed strength, and developing anaerobic energy pathways. With these methods in mind, strength and conditioning coaches can evaluate the physical development, 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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