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Physiological and Anthropometric Characteristics of Australian Junior National, State, and Novice Volleyball Players

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Abstract. Gabbett, T., and B. Georgieff. Physiological and anthropometric characteristics of junior national, state, and novice volleyball players. *J. Strength Cond. Res. 21(3):902–908. 2007.*—The purpose of this study was to investigate the physiological and anthropometric characteristics of junior volleyball players competing at the elite, semi-elite, and novice levels and to establish performance standards for these athletes. One hundred and fifty-three junior national (N = 14 males; N = 20 females), state (N = 16 males; N = 42 females), and novice (N = 27 males; N = 34 females) volleyball players participated in this study. Subjects underwent measurements of standard anthropometry (body mass, height, standing reach height, and sum of 7 skinfolds), lower-body muscular power (vertical jump and spike jump), upper-body muscular power (overhead medicine ball throw), speed (5-m and 10-m sprint), agility (T-test), and estimated maximal aerobic power (multistage fitness test) during the competitive phase of the season, after obtaining a degree of match fitness. Significant differences ($p < 0.05$) were detected among junior national, state, and novice volleyball players for height, standing reach height, skinfold thickness, lower-body muscular power, agility, and estimated maximal aerobic power, with the physiological and anthropometric characteristics of players typically improving with increases in playing level. Male players were taller, heavier, leaner, and had greater standing reach height, speed, agility, muscular power, and estimated maximal aerobic power than female players. These findings provide normative data and performance standards for junior volleyball players competing at the elite, semi-elite, and novice levels. Given the improvements in lower-body muscular power, agility, and estimated maximal aerobic power with increased playing level, and given the importance of these qualities to competitive performances, conditioning coaches should train these qualities to improve the playing performances of junior volleyball players.

Key Words. Talent Search, fitness, performance standards

Introduction

Volleyball is an intermittent sport that requires players to compete in frequent short bouts of high-intensity exercise, followed by periods of low-intensity activity (2, 11, 19). The high-intensity bouts of exercise, coupled with the total duration of the match (~90 minutes), require players to have well-developed aerobic and anaerobic alactic energy systems (7, 19). Considerable demands are also placed on the neuromuscular system during the various sprints, jumps (blocking and spiking), and high-intensity court movement that occur repeatedly during competition (7). As a result, volleyball players require well-developed speed, agility, upper-body and lower-body muscular power, and maximal aerobic power ($\dot{V}O_2max$).

Several studies have documented the physiological and anthropometric characteristics of senior volleyball players (1, 8, 10, 16), with the fitness of players increasing as the playing level is increased (15, 18). Smith et al. (15) compared physical, physiological, and performance characteristics of national-level and college-level volleyball players and found significantly higher block and spike jumps, 20-m speed, and $\dot{V}O_2max$ in the national-level players, indicating that physiological capacities play an important role in the preparation and selection of elite volleyball players (15). In addition, Thissen-Milder and Mayhew (18) demonstrated that selected physiological and anthropometric characteristics could successfully discriminate among freshman, junior varsity, and varsity volleyball teams and among starting and nonstarting players. Collectively, these findings indicate a relation between physical fitness and the playing level attained.

While several studies have documented the physiological capacities of senior volleyball players, investigations of the physiological capacities of junior volleyball players are limited (5, 6). Gabbett et al. (6) reported that the physiological capacities of junior novice volleyball players failed to change in response to skill-based training, despite significant improvements in spiking, setting, and passing accuracy and in spiking and passing technique. These findings indicate that improvements in playing ability may occur without concomitant improvements in the physiological and anthropometric characteristics of players and that factors other than physical fitness may determine success in junior volleyball players. However, while the physiological capacities of junior novice volleyball players have been documented, no study has characterized the physiological capacities of junior elite volleyball players and developed performance standards for these athletes. In addition, no study has compared the physiological capacities of junior elite, semi-elite, and novice volleyball players. It is likely that as a result of increases in playing intensity with increased playing level that the physiological and anthropometric characteristics of national volleyball players would be superior to those of state and novice volleyball players. Furthermore, the development of physical performance standards for junior volleyball players would allow coaches to identify player weaknesses and to develop specific training programs to enhance the playing performance of these athletes. With this in mind, the purposes of this study were to investigate the physiological and anthropometric characteristics of male and female junior volleyball players competing at national, state, and novice levels and to establish performance standards for these athletes.

Methods

Experimental Approach to the Problem

The present study investigated the physiological and anthropometric characteristics of talent-identified junior volleyball players using a cross-sectional research design.

Subjects were participating at national, state, or novice levels in junior volleyball. All subjects performed measurements of standard anthropometry, lower-body muscular power, upper-body muscular power, speed, agility, and maximal aerobic power during the competitive phase of the season, after obtaining a degree of match fitness. It was hypothesized that there would be a progressive improvement in the physiological and anthropometric characteristics of junior volleyball players as the playing level increased.

Subjects

One hundred and fifty-three junior volleyball players ($N = 57$ males; $N = 96$ females; mean $\pm$ *SE*; age: 15.6 ± 0.1 years) participated in this study. All players were scholarship holders within the Queensland Academy of Sport Talent Search volleyball program and were competing at national ($N = 14$ males; $N = 20$ females), state ($N = 16$ males; $N = 42$ females), or novice ($N = 27$ males; $N = 34$ females) level in beach or indoor volleyball. The Queensland Academy of Sport Talent Search volleyball program identifies young athletes deemed to have the necessary physiological and anthropometric characteristics (e.g., height, standing reach height, muscular power, speed, agility, and maximal aerobic power) for volleyball success (13) and places those athletes in a high-performance coaching environment, where they are provided with specialized volleyball coaching. National-level players competed against other international teams and at the time of the study were members of teams that finished eighth (males) and ninth (females) in World junior volleyball championships. State players were members of teams that competed in a national tournament (Australian Junior Volleyball Championships) against other states from within Australia. At the time of the study, the Queensland team had finished in third place or better in the Australian Junior Volleyball Championships. Novice players competed in a city-based domestic competition. Subjects had participated in a wide range of sports (e.g., swimming, track and field, martial arts, mountain biking, tennis, netball, basketball, hockey, touch football, and rugby union) prior to volleyball. The mean ($\pm$ *SE*) sporting experience of all subjects was 7 ± 2 years. The mean ($\pm$ *SE*) sporting experience of national, state, and novice players was 8 ± 1 years, 8 ± 2 years, and 3 ± 1 years, respectively. All subjects had completed the same training program for 12 weeks prior to commencing this study. Training sessions were designed to develop passing, setting, serving, spiking, and blocking skills as well as game tactics and positioning skills. While no player performed individual strength training programs, all players participated in agility, speed, and on-court decision-making training as part of their program. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written parental or guardian consent was obtained before players were permitted to participate. The Institutional Review Board for Human Investigation approved all experimental procedures.

Fitness Testing Battery

Standard anthropometry (height, standing reach height, body mass, and sum of 7 skinfolds) (12), upper-body muscular power (overhead medicine ball throw) (13), lower-body muscular power (vertical jump and spike jump) (13), speed (5-m and 10-m sprint) (13), agility (T-test) (9), and maximal aerobic power (multistage fitness test) (14) were the fitness tests selected. Players were instructed to refrain from strenuous exercise for at least 48 hours prior to the fitness testing session and to consume their normal pretraining diet prior to the testing session. The testing session began with anthropometric measurements. Players then underwent measurements of upper-body muscular power (overhead medicine ball throw), lower-body muscular power (vertical jump and spike jump), speed (5-m and 10-m sprint), and agility (T-test) measurements. Subjects performed 2 trials for the speed, agility, and muscular power tests, with a recovery of approximately 3 minutes between trials. Players were encouraged to perform low-intensity activities and stretches between trials. Upon completion of the respective tests, the field-testing session concluded with players performing the multistage fitness test (estimated maximal aerobic power).

Anthropometry

Excess body mass and body fat have been shown to negatively influence performance (e.g., power:body mass ratio, thermoregulation, and aerobic capacity) (12). As an estimate of adiposity, skinfold thickness was measured at 7 sites using a Harpenden skinfold caliper (British Indicators Ltd., West Sussex, UK). Biceps, triceps, subscapular, supraspinale, abdomen, thigh, and calf on the right side comprised the 7 sites selected. The exact positioning of each skinfold measurement was determined in accordance with procedures described by Norton et al. (12). Height was measured using a stadiometer, and body mass was measured using calibrated digital scales (A & D Company Limited, Tokyo, Japan). Standing reach height was measured using a Yardstick vertical jump device (Swift Performance Equipment, New South Wales, Australia). Players were requested to stand with their feet flat on the ground, extend their arm and hand, and mark the standing reach height. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for height, standing reach height, body mass, and sum of 7 skinfolds measurements were 0.99, 0.94, 0.99, and 0.99 and 0.2%, 0.6%, 0.8%, and 3.0%, respectively.

Upper-Body Muscular Power

The ability to generate high levels of upper-body muscular power during spiking and serving is an important attribute of volleyball players. Upper-body muscular power was estimated using an overhead medicine ball throw (13). Players stood one step behind a line marked on the ground facing the throwing direction, with a 3-kg medicine ball held in both hands behind the head. Players were instructed to plant the front foot with the toe behind the line and to throw the medicine ball overhead as far forward as possible. Each throw was measured from inside the line, to the nearest mark made by the fall of the medicine ball. Throwing distance was measured to the nearest 1 cm, with the greatest value obtained from 2 trials used as the overhead throw score. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the overhead medicine ball throw test were 0.96 and 5.4%, respectively.

Lower-Body Muscular Power

Volleyball players require high levels of lower-body muscular power to perform the spiking, blocking, and jumping tasks that are frequently executed during a match. Lower-body muscular power was estimated by means of the vertical jump test and the spike jump test (13) using a Yardstick vertical jump device (Swift Performance Equipment). Players were requested to stand with feet flat on the ground, extend their arm and hand, and mark the standing reach height. After assuming a crouch position, each subject was instructed to spring upward and touch the Yardstick device at the highest possible point. Vertical jump height was calculated as the distance from the highest point reached during standing and the highest point reached during the vertical jump. Vertical jump height was measured to the nearest 1 cm, with the highest value obtained from 2 trials used as the vertical jump score. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the vertical jump test were 0.96 and 2.9%, respectively.

The spike jump used similar procedures to the vertical jump. Players were requested to stand with feet flat on the ground, extend their arm and hand, and mark the standing reach height. Players were then instructed to take a run-up or spike approach and leap as high as possible off of both legs, displacing as many vanes on the Yardstick as possible. Spike jump height was calculated as the distance from the highest point reached during standing and the highest point reached during the spike jump. Spike jump height was measured to the nearest 1 cm, with the highest value obtained from 2 trials used as the spike jump score. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the spike jump test were 0.99 and 2.2%, respectively.

Speed

Volleyball players require the ability to move quickly in order to position themselves to receive a pass or block a shot from an opponent. The running speed of players was evaluated with a 5-m and 10-m sprint effort (13) using dual-beam electronic timing gates (Swift Performance Equipment). The timing gates were positioned 5 m and 10 m from a predetermined starting point. Players were instructed to run as quickly as possible along the 10-m distance from a standing start. Speed was measured to the nearest 0.01 second, with the fastest value obtained from 2 trials used as the speed score. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the 5-m and 10-m sprint tests were 0.80 and 0.89 and 3.6% and 1.7%, respectively.

Agility

Volleyball players require the ability to rapidly accelerate, decelerate, and change direction. The agility of subjects was evaluated using a T-test (9) using dual-beam electronic timing gates. Four cones were placed 5 m apart in the shape of an inverted 'T.' Players were instructed to run as quickly as possible along the agility run. Agility times were measured to the nearest 0.01 second, with the fastest value obtained from 2 trials used as the agility score. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the T-test were 0.85 and 2.9%, respectively.

Maximal Aerobic Power

Depending on the level of competition, volleyball matches may last up to 90 minutes in duration (7, 19). Players also require high levels of aerobic fitness to aid recovery after high-intensity bouts of activity. Maximal aerobic power was estimated using the multistage fitness test (14). Players were required to run back and forth (i.e., shuttle run) along a 20-m track, keeping in time with a series of signals on a compact disk. The frequency of the audible signals (and, hence, running speed) was progressively increased, until subjects reached volitional exhaustion. Maximal aerobic power ($\dot{V}O_2max$) was estimated using regression equations described by Ramsbottom et al. (14). When compared to treadmill-determined $\dot{V}O_2max$, it has been demonstrated that the multistage fitness test provides a valid estimate of maximal aerobic power (17). In addition, in a previous study (5) we completed duplicate multistage fitness tests, performed 1 week apart, to determine test-retest reliability. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the multi-stage fitness test were 0.90 and 3.1%, respectively.

Statistical Analyses

Differences in the anthropometric characteristics, upper-body and lower-body muscular power, speed, agility, and estimated $\dot{V}O_2max$ of players were compared using a 2-way (playing level and gender) analysis of variance. When required, comparisons of group means were performed using a Tukey honestly significantly different post-hoc test. Based on an alpha level of 0.05 and a sample size of 26 (average number of athletes in each group), the beta level (power) was $\geq$0.80 for detecting effect sizes of 0.2 among gender and playing levels. The Pearson product moment correlation coefficient was used to determine the relationship between physiological and anthropometric characteristics and playing level. Stepwise multiple linear regression analysis was performed to determine which of the physiological and anthropometric variables could predict selection in the 3 teams. The level of significance was set at $p \leq 0.05$, and all data are reported as means $\pm$ *SE*.

Results

Anthropometric Characteristics

There were no significant differences ($p > 0.05$) between playing levels for body mass. However, national players had a greater height and standing reach height than state and novice players. In addition, national and state players had significantly lower skinfold thickness than novice players (Table 1). Male players were significantly ($p < 0.05$) taller, heavier, leaner, and had a greater standing reach height than female players.

Physiological Characteristics

The lower-body muscular power, upper-body muscular power, 5-m and 10-m speed, agility, and estimated $\dot{V}O_2max$ of junior national, state, and novice volleyball players are shown in Table 2. The vertical jump height results of national and state players were significantly greater than those of novice players. Spike jump height, agility, and estimated $\dot{V}O_2max$ were greater in national and state players than in novice players. No significant differences were detected among playing levels for upper-body muscular power or 5-m or 10-m speed. Male players had significantly greater ($p < 0.05$) speed, agility, upper-body muscular power, lower-body muscular power, and estimated $\dot{V}O_2max$ than female players. Individual physiological and anthropometric data from the highest ranked junior national male and female players are shown in Table 3.

Relationship Between Physiological and Anthropometric Characteristics and Playing Level

The correlations between playing level and the physiological and anthropometric variables are shown in Table 4.

Table 1. Body mass, height, standing reach height, and sum of 7 skinfolds for junior national, state, and novice volleyball players (data are reported as mean ± *SE*).

	National		State		Novice	
	Male	Female	Male	Female	Male	Female
Height (cm)	195.2 ± 2.4*†‡§	179.2 ± 1.0	190.0 ± 1.2§	179.5 ± 0.6	187.3 ± 0.5§	177.0 ± 0.6
Body mass (kg)	80.2 ± 1.9§	68.4 ± 1.3	81.8 ± 1.7§	67.2 ± 1.3	80.9 ± 2.5§	66.8 ± 1.2
Sum of 7 skinfolds (mm)	57.8 ± 3.0‡	69.7 ± 1.1†‡	50.5 ± 1.0‡§	85.1 ± 2.4‡	88.4 ± 6.2§	114.0 ± 3.1
Standing reach height (cm)	256.4 ± 3.4*§	236.1 ± 1.3	250.0 ± 1.3§	235.8 ± 1.0	248.2 ± 0.5§	233.6 ± 1.2

* Significant playing level × gender interaction ($p < 0.05$).
† Significantly different ($p < 0.05$) from state players.
‡ Significantly different ($p < 0.05$) from novice players.
§ Significantly different ($p < 0.05$) from female players. National ($N = 14$ males, $N = 20$ females); state ($N = 16$ males, $N = 42$ females); novice ($N = 27$ males, $N = 34$ females).

Table 2. Lower-body muscular power, upper-body muscular power, speed, agility, and estimated maximal aerobic power for junior national, state, and novice volleyball players (data are reported as mean ± *SE*).

	National		State		Novice	
	Male	Female	Male	Female	Male	Female
Vertical jump (cm)	54.6 ± 2.2*‡§	45.7 ± 1.6‡	63.3 ± 3.2‡§	41.5 ± 0.9‡	48.5 ± 1.0§	35.9 ± 1.4
Spike jump (cm)	65.8 ± 3.7*‡§	51.2 ± 1.8‡	71.9 ± 2.9‡§	45.3 ± 1.0‡	53.6 ± 1.1§	38.7 ± 1.5
Overhead medicine ball throw (m)	8.8 ± 0.3§	6.1 ± 0.1	8.3 ± 0.3§	6.1 ± 0.2	8.1 ± 0.2§	5.6 ± 0.2
5-m sprint (s)	1.04 ± 0.02	1.04 ± 0.02†	1.01 ± 0.02§	1.11 ± 0.01	1.03 ± 0.01§	1.15 ± 0.02
10-m sprint (s)	1.80 ± 0.02§	1.90 ± 0.01	1.76 ± 0.03§	1.95 ± 0.02	1.81 ± 0.02§	2.03 ± 0.03
Agility (s)	9.90 ± 0.17‡§	10.33 ± 0.13	9.76 ± 0.15‡§	10.55 ± 0.14	10.47 ± 0.18§	11.23 ± 0.16
Estimated $\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	50.6 ± 1.4*‡§	41.2 ± 0.9‡	49.8 ± 1.1‡§	39.3 ± 0.7	41.2 ± 1.2§	37.0 ± 0.8

* Significant playing level × gender interaction ($p < 0.05$).
† Significantly different ($p < 0.05$) from state players.
‡ Significantly different ($p < 0.05$) from novice players.
§ Significantly different ($p < 0.05$) from female players. National ($N = 14$ males, $N = 20$ females); state ($N = 16$ males, $N = 42$ females); novice ($N = 27$ males, $N = 34$ females).

TABLE 3. Individual physiological and anthropometric data from the highest ranked junior national male and female volleyball players.

	National	
	Male	Female
Height (cm)	205.0	185.8
Body mass (kg)	91.6	58.1
Sum of 7 skinfolds (mm)	67.6	66.3
Standing reach height (cm)	271.0	244.0
Vertical jump (cm)	68.0	64.0
Spike jump (cm)	90.0	73.0
Overhead medicine ball throw (m)	10.0	5.9
5-m sprint (s)	0.96	0.97
10-m sprint (s)	1.67	1.75
Agility (s)	8.66	9.06
Estimated $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	57.6	48.4

Height was positively associated ($p < 0.05$) and skinfold thickness negatively associated ($p < 0.05$) with playing level for both male and female players. While standing reach height was positively associated ($p < 0.05$) with playing level in male players, the relationship between standing reach height and playing level for female players was not significant ($p > 0.05$).

Significant associations ($p < 0.05$) were detected between playing level and vertical jump height, spike jump height, and estimated $\dot{V}O_2$max for both male and female players. In addition, greater agility times (i.e., slower agility) were negatively associated ($p < 0.05$) with playing level for both male and female players. While greater 5-m and 10-m sprint times (i.e., slower 5-m and 10-m speed) were negatively associated ($p < 0.05$) with playing level in female players, the relationship between speed and playing level for male players was not significant ($p > 0.05$).

Stepwise Multiple Linear Regression Analysis

Table 5 shows the stepwise linear regression analysis that was performed to determine which of the physiological and anthropometric variables could predict selection in the 3 playing levels. Agility, 10-m sprint, spike jump, and estimated $\dot{V}O_2$max were the variables that contributed significantly ($p < 0.05$) to the predictive model.

DISCUSSION

The present study is the first to investigate the physiological and anthropometric characteristics of junior national, state, and novice volleyball players. The results of this study demonstrate that significant differences exist among junior volleyball players of different playing abilities for height, standing reach height, skinfold thickness, lower-body muscular power, agility, and estimated maximal aerobic power, with the physiological and anthropometric characteristics of players generally improving with increases in playing level. These findings provide normative data and performance standards for male and female junior volleyball players competing at the elite, semi-elite, and novice levels.

Previous studies have reported a strong relationship between physical fitness and the playing level attained, with the fitness of volleyball players typically increasing as the playing level is increased (15, 18). Smith et al. (15) compared physical, physiological, and performance characteristics of national-level and college-level volleyball players and found significantly higher block and spike jumps, 20-m speed, and $\dot{V}O_2$max in the national-level players, indicating that physiological capacities play an important role in the preparation and selection of elite senior volleyball players (15). In addition, Thissen-Milder and Mayhew (18) demonstrated that selected physiological and anthropometric characteristics could successfully discriminate among freshman, junior varsity, and varsity volleyball teams and starting and nonstarting players. The present findings confirm and extend those of others (15, 18) by demonstrating that successful junior volleyball performance is determined, at least in part, by the physical qualities of athletes.

The present study found greater height and standing reach height and lower skinfold thickness in junior national volleyball players compared to junior state and novice volleyball players. The lower body fat component of elite junior players may decrease the physiological demands on players required to support this weight during a match and may increase their ability to dissipate heat during intense physical activity. Certainly the lower body fat component of elite junior players would contribute to the superior vertical jump, spike jump, and agility in these players, thereby enhancing their ability to perform volleyball-specific tasks. Equally, the finding of a higher standing reach height in the national volleyball players emphasizes the importance of this physical quality for the spiking and blocking tasks that occur during a match.

The speed and vertical jump of the elite junior volleyball players in the present study were comparable to those reported for elite senior volleyball players (1, 15).

TABLE 4. Relationship between physiological and anthropometric characteristics and playing level in male and female junior volleyball players.

	Playing level		
	All players	Male	Female
Height (cm)	0.196*	0.508†	0.235*
Body mass (kg)	−0.007	−0.014	0.077
Sum of 7 skinfolds (mm)	−0.524†	−0.480*	−0.701†
Standing reach height (cm)	0.152	0.398†	0.155
Vertical jump (cm)	0.294†	0.327*	0.472†
Spike jump (cm)	0.341†	0.465†	0.510†
Overhead medicine ball throw (m)	0.156	0.159	0.247
5-m sprint (s)	−0.166	−0.17	−0.292*
10-m sprint (s)	−0.193*	−0.057	−0.364†
Agility (s)	−0.322†	−0.322*	−0.377†
Estimated $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	0.350†	0.553†	0.358†

* Significant correlation ($p < 0.05$) between variables.
† Significant correlation ($p < 0.01$) between variables. Data are Pearson product moment correlation coefficients, *r*.

TABLE 5. Multiple linear regression analysis to predict playing level.

	r^2
Model 1	
Playing level = (Estimated $\dot{V}O_2$max × 0.333) + 0.214*	0.111
Model 2	
Playing level = (Estimated $\dot{V}O_2$max × 0.268) + (Agility × −0.190) + 1.066*	0.143
Model 3	
Playing level = (Estimated $\dot{V}O_2$max × 0.370) + (Agility × −0.301) + (10-m sprint × 0.255) + 0.126*	0.177
Model 4	
Playing level = (Estimated $\dot{V}O_2$max × 0.248) + (Agility × −0.262) + (10-m sprint × 0.373) + (Spike jump × 0.288) − 1.755*	0.205

* Contributed significantly ($p < 0.05$) to the predictive model.

However, the $\dot{V}O_2$max results were similar to those of some (16), but not all (1, 15), studies of elite volleyball players. The in-season $\dot{V}O_2$max of 45.6 ml·kg^{-1}·min^{-1} in the elite junior volleyball players of the present study compared favourably to an average $\dot{V}O_2$max of 44.2 ml·kg^{-1}·min^{-1} reported previously in elite senior volleyball players (16). However, the $\dot{V}O_2$max of the elite junior players in this study was considerably lower than previously reported (1, 15) for Canadian (56.7 ml·kg^{-1}·min^{-1}) and United States (48.8 ml·kg^{-1}·min^{-1}) senior national-level volleyball players. The finding of lower $\dot{V}O_2$max in junior players in comparison to senior players is consistent with findings of studies of other intermittent sports that have found a progressive improvement in physiological capacities as the playing level increased (4). The lower $\dot{V}O_2$max in junior players may be explained by differences in training and playing intensities (3), genetic endowment (15), or maturational factors. Alternatively, the low $\dot{V}O_2$max, despite similar speed and agility between elite junior and senior players, may reflect differences in coaching philosophies between the present and previous conditioning programs or an increased emphasis on speed and agility (and decreased aerobic fitness emphasis) in modern volleyball competition.

The finding of greater agility, lower-body muscular power, and aerobic fitness in junior national volleyball players in comparison to junior novice volleyball players is in agreement with previous studies that found greater block and spike jumps, 20-m speed, and $\dot{V}O_2$max in national-level volleyball players than in college-level volleyball players (15). The finding of greater agility, vertical jump, and aerobic fitness in junior elite volleyball players may reflect the higher training and competition intensity at the elite level. Indeed, recent evidence has shown that the intensity of junior novice volleyball training sessions is low, with the majority (57.4%) of training time spent in low-intensity (40–70% maximum heart rate) activities (6). In contrast, junior elite volleyball players spend considerably less time in low-intensity activities (19.3%) and considerably more time (28.3% vs. 7.8%) in high-intensity (>85% maximum heart rate) activities (unpublished observations). The low training intensity in novice volleyball players appears insufficient to induce significant cardiovascular, metabolic, or muscular adaptations to rival the physical fitness of elite-level competitors.

The present study found a significant relationship between playing level and height, standing reach height, and skinfold thickness, with elite players generally being taller and leaner than their less-skilled counterparts. In addition, lower-body muscular power (as estimated from the vertical jump and spike jump) was positively associated with playing level in both male and female players. However, standing reach height was not significantly related to playing level in female players, whereas significant relationships were detected between high running speed and playing level in female (but not male) players. These findings indicate that the demands of junior volleyball, or the factors that contribute to success and that discriminate among playing levels in junior volleyball, differ between male and female players. Alternatively, the finding of a significant relationship between speed (but not standing reach height) and playing level may indicate that the ability to quickly manoeuver around the court is more important than standing reach height in female players.

Estimated $\dot{V}O_2$max and spike jump, coupled with 10-m speed and agility, were the physiological variables that contributed significantly to the multiple linear regression equation to predict playing level. These findings indicate that a high level of aerobic fitness and muscular power, coupled with fast speed and agility, contributes to successful performance in junior volleyball players. However, while the relationships between playing level and these variables were significant, because of the nature of volleyball, it is extremely rare that players will exhibit any of these physical qualities in isolation. For example, players may be required to dive forward to intercept a serve and then be required to regain their feet and sprint laterally to receive a pass from another player. While aerobic metabolism is likely to contribute to the replenishment of energy stores following these anaerobic efforts, the common variance between playing level and estimated $\dot{V}O_2$max was only 12.3%, indicating that the ability to repeatedly perform the various sprints, dives, jumps, and multidirectional court movements that occur during competition is dependent on factors in addition to, or other than, a high $\dot{V}O_2$max. These findings indicate that any conditioning program or physiological assessment of junior volleyball players should also incorporate the repeated-effort demands of competition.

While the results of the present study clearly demonstrate differences in physical fitness among playing levels for junior volleyball players, these findings provide no information on responsiveness to training. In addition, while the ability to perform skills successfully is constrained by physiological limitations (17), no information was obtained on the skill levels of players and their ability to play the game. Clearly, the development of a standardized skill testing battery for volleyball players is warranted. A standardized skill assessment that tests the core skills of volleyball (i.e., spiking, setting, serving, and passing) and allows the identification of specific strengths and weaknesses and individualization of coaching programs would provide a useful tool to complement the physical fitness tests commonly used to monitor the development of these athletes.

Although only a select number of field tests were performed, the results of this study clearly demonstrate significant differences among playing levels for height, standing reach height, skinfold thickness, lower-body muscular power, agility, and maximal aerobic power in junior volleyball players. However, the measurement of additional physiological qualities, such as strength and repeated-effort ability, may have provided a more comprehensive description of the physiological characteristics of junior elite, sub-elite, and novice volleyball players. While further field tests might have provided additional information on the physiological qualities of junior volleyball players, the time and personnel available and the coaching philosophies employed in the respective squads limited the number of tests included in the field testing battery. Clearly, further studies are required to completely determine the physiological, strength, and anthropometric qualities of junior volleyball players. Additional studies assessing the relationship between the skill and fitness of volleyball players are also warranted.

In conclusion, the present study investigated the physiological and anthropometric characteristics of male and female junior volleyball players competing at the national, state, and novice levels and established performance standards for these athletes. The results of this study demonstrated significant differences in the physiological and anthropometric characteristics of junior volleyball players competing at different playing levels. These findings provide normative data and performance standards for male and female junior volleyball players competing at the elite, semi-elite, and novice levels.

Practical Applications

The present study investigated junior national, state, and novice volleyball players. The 5-m and 10-m speed, agility, vertical jump, spike jump, and aerobic fitness of the junior elite players in the present study were slightly lower than those reported for senior elite players (15, 18). In addition, the physiological characteristics of the junior novice players are consistent with those previously reported for junior novice volleyball players (6). These findings indicate that the present cohort was reasonably representative of junior elite, semi-elite, and novice volleyball players. Therefore, the results reported in this study provide normative data for male and female junior volleyball players competing at different playing levels. These results may be used as a tool for talent identification in volleyball (4). In addition, the differences in physical characteristics between male and female competitors demonstrate the need to consider gender specificity when using physiological and anthropometric data to identify potentially talented volleyball players.

Conditioning coaches may use the results of this study to design training programs to enhance player performance and to develop realistic performance standards for elite, semi-elite, and novice volleyball players. Given the progressive improvements in lower-body muscular power, agility, and estimated maximal aerobic power with increased playing level and the importance of these qualities to competitive performances, conditioning coaches should train these qualities to improve the physiological and anthropometric characteristics and playing performances of junior volleyball players. Strength and power programs designed to enhance hip, knee, and ankle extensor strength (for spiking skills) and hip abductor and adductor strength (for stabilizing the pelvis and accelerating and controlling the leg during sprinting and rapid changes in direction) should be implemented to enhance physical performance and the long-term development of junior volleyball players. Game-specific aerobic training would also facilitate recovery after high-intensity bouts of activity and assist junior players to compete and concentrate for the duration of a match. Finally, given that 10-m speed, agility, muscular power, and aerobic power are physical qualities that are rarely expressed in isolation, and given that all of these physical qualities contributed to predicting playing level, conditioning programs incorporating the repeated-effort demands of competition (i.e., the various sprints, dives, jumps, and multidirectional court movements) may enhance the playing performance of junior volleyball players.

References

1. Fleck, S.J., S. Case, J. Puhl, and P. Van Handle. Physical and physiological characteristics of elite women volleyball players. *Can. J. Appl. Sport Sci.* 10:122–126. 1985.
2. Franks, B.D., and G.C. Moore. Effects of calisthenics and volleyball on the AAHPER fitness test and volleyball skill. *Res. Q.* 40:288–292. 1969.
3. Gabbett, T.J. Physiological and anthropometric characteristics of amateur rugby league players. *Br. J. Sports Med.* 34:303–307. 2000.
4. Gabbett, T.J. Physiological characteristics of junior and senior rugby league players. *Br. J. Sports Med.* 36:334–339. 2002.
5. Gabbett, T.J. Changes in physiological and anthropometric characteristics of rugby league players during a competitive season. *J. Strength Cond. Res.* 19:400–408. 2005.
6. Gabbett, T., B. Georgieff, S. Anderson, B. Cotton, D. Savovic, and L. Nicholson. Changes in skill and physical fitness following training in talent-identified volleyball players. *J. Strength Cond. Res.* 20:29–35. 2006.
7. Häkkinen, K. Changes in physical fitness profile in female volleyball players during the competitive season. *J. Sport Med. Phys. Fitness* 33: 223–232. 1993.
8. Hascelik, Z., O. Basgoze, K. Turker, S. Narman, and R. Ozker. The effects of physical training on physical fitness tests and auditory and visual reaction times of volleyball players. *J. Sport Med. Phys. Fitness* 29:234–239. 1989.
9. Hoffman, J.R., C.M. Maresh, L.E. Armstrong, and W.J. Kraemer. Effects of off-season and in-season resistance training programs on a collegiate male basketball team. *J. Hum. Muscle Perform.* 1:48–55. 1991.
10. Hosler, W.W., J.R. Morrow, and A.S. Jackson. Strength, anthropometric, and speed characteristics of college women volleyball players. *Res. Q.* 49:385–388. 1978.
11. Kunstlinger, U., H.G. Ludwig, and J. Stegemann. Metabolic changes during volleyball matches. *Int. J. Sports Med.* 8:315–322. 1987.
12. Norton, K., M. Marfell-Jones, N. Whittingham, D. Kerr, L. Carter, K. Saddington, and C. Gore. Anthropometric assessment protocols. In: *Physiological Tests for Elite Athletes.* C.J. Gore, ed. Champaign, IL: Human Kinetics, 2000. pp. 66–85.
13. Osborne, M. Protocols for the physiological assessment of beach volleyball players. In: *Queensland Academy of Sport Laboratory Manual.* Unpublished laboratory manual, Brisbane, 2002. pp. 1–21.
14. Ramsbottom, R., J. Brewer, and C. Williams. A progressive shuttle run test to estimate maximal oxygen uptake. *Br. J. Sports Med.* 22:141–144. 1988.
15. Smith, D.J., D. Roberts, and B. Watson. Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *J. Sports Sci.* 10:131–138. 1992.
16. Spence, D.W., J.G. Disch, H.L. Fred, and A.E. Coleman. Descriptive profiles of highly skilled women volleyball players. *Med. Sci. Sports Exerc.* 12:299–302. 1980.
17. Starkes, J.L., and K.A. Ericsson. *Expert Performance in Sports. Advances in Research on Sport Expertise.* Champaign, IL: Human Kinetics, 2003.
18. Thissen-Milder, M., and J.L. Mayhew. Selection and classification of high school volleyball players from performance tests. *J. Sport Med. Phys. Fitness* 31:380–384. 1991.
19. Viitasalo, J., H. Rusko, O. Pajala, P. Rahkila, M. Ahila, and H. Montonen. Endurance requirements in volleyball. *Can. J. Appl. Sports Sci.* 12:194–201. 1987.

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