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PLAYERS WITH TALENT-IDENTIFIED VOLLEYBALL SKILLS AND PHYSICAL FITNESS AFTER TRAINING

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Abstract

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(1):29–35. 2006.—This study investigated the effect of a skill-based training program on measurements of skill and physical fitness in talent-identified volleyball players. Twenty-six talented junior volleyball players (mean ± SE age, 15.5 ± 0.2 years) participated in an 8-week skill-based training program that included 3 skill-based court sessions per week. Skills sessions were designed to develop passing, setting, serving, spiking, and blocking technique and accuracy as well as game tactics and positioning skills. Coaches used a combination of technical and instructional coaching, coupled with skill-based games to facilitate learning. Subjects performed measurements of skill (passing, setting, serving, and spiking technique and accuracy), standard anthropometry (height, standing-reachheight, body mass, and sum of 7 skinfolds), lower-body muscular power (vertical jump, spike jump), upper-body muscular power (overhead medicine-ball throw), speed (5- and 10-m sprint), agility (T-test), and maximal aerobic power (multistage fitness test) before and after training. Training induced significant ($p < 0.05$) improvements in spiking, setting, and passing accuracy and spiking and passing technique. Compared with pretraining, there were significant ($p < 0.05$) improvements in 5- and 10-m speed and agility. There were no significant differencesbetween pretraining and posttraining for body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, and maximal aerobic power. These findings demonstrate that skillbased volleyball training improves spiking, setting, and passing accuracy and spiking and passing technique, but has little effect on the physiological and anthropometric characteristics of players.

Key Words: Accuracy, Technique, Physiological Characteristics, Anthropometric Characteristics, Talent Search

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 (13,23). The high-intensity bouts of exercise, coupled with the totalduration of the match (~ 90 minutes), requires players to have well-developed aerobic and anaerobic alactic (ATPCP) energy systems (9, 23). Considerable demands are also placed on the neuromuscular system during the various sprints, jumps (blocking and spiking), and high-intensity court movement that occurs repeatedly during competition (9). As a result, volleyball players require well-developed speed, agility, upper-body and lower-body muscular power, and maximal aerobic power (VO_2max). Several studies have documented the physiological and anthropometric characteristics of volleyball players (4,10,12, 19), with the fitness of players increasing as the playing level is increased (18,20). Smith et al. (18) 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 VO_2max in the national-level players, suggesting that physiological capacities play an important role in the preparation and selection of elite volleyball players (18). Changes in the physiological and anthropometric characteristics of volleyball players in response to training and over the course of a season have also been documented (3,5,8,10). However, studies of the effect of volleyball and physical conditioning training on the physiologicaland anthropometric characteristics of players are equivocal, with reports of increased (3,5,10), decreased (9), or unchanged fitness (8) in response to training. Improvements in VO_2max (3,10), speed (5), strength (10), and visual reaction time (10) have been reported following 5–10 weeks of volleyball and physical conditioning training. However, recent evidence has demonstrated unchanged speed, agility, lower-body muscular power, and VO_2max over a season in talent-identified junior volleyball players (8). Skill-based coaching is increasingly being used as a means of improving performance of athletes from skillbased sports (1). Although volleyball players rely on welldeveloped physiological capacities, volleyball is also a game that requires high levels of tactical and technical skill (9). However, no study has quantified changes in technical skill and accuracy in response to a skill-based training program in volleyball players. In addition, it is unclear whether skill-based training sessions offer an adequate training stimulus to improve the physiological capacities of volleyball players. With this in mind, the purpose of this study was to quantify changes in skill and physical fitness following an 8-week training program consisting entirely of skill-based training activities in talent-identified volleyball players.

METHODS

Experimental Approach to the Problem

The present study tracked the skill and physiological and anthropometric changes of talent-identified volleyball players over an 8-week skill-based training period. Skills sessions were designed to develop passing, setting, serving, spiking, and blocking technique and accuracy as well as game tactics and positioning skills. Coaches used a combination of technical and instructional coaching, coupled with skill-based games to facilitate learning. Subjects performed measurements of skill (passing, setting, serving, and spiking technique and accuracy), standard anthropometry (height, standing-reach height, body mass, and sum of 7 skin folds), lower-body muscular power (vertical jump, spike jump), upper-body muscular power (overhead medicine-ball throw), speed (5- and 10-m sprint), agility (T-test), and maximal aerobic power (multistage fitness test) before and after an 8-weekskill-based training program, which included 3 skill-based court sessions per week. It was hypothesized that volleyball training consisting entirely of skill-based sessions would improve spiking, passing, serving, and setting technique and accuracy, without significantly changing the physiological and anthropometric characteristics of players.

Subjects

Twenty-six junior volleyball players (mean ± SE age, 15.5 ± 0.2 years) participated in this study. All players were scholarship holders within the Queensland Academy of Sport, Talent Search volleyball program. 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 (15) and places those athletes in a high-performance coaching environment, where they are provided with specialized volleyballcoaching. All subjectshadbeen participating in volleyball for 3 months prior to the commencement of the study. While subjects had limited volleyball experience, they 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 being selected into the Talent Search volleyball program. Eighteen subjects (69.2%) had participated in 1 sport, while 4 subjects (15.4%) had participated in 2 or more sports. The mean ± SE sporting experience of all subjects was 5 ± 1 year (range: 0–11 year). 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.

Skill Testing Battery

Players were familiarized with all testing procedures prior to beginning the study. Players underwent accuracy and technique assessments of spiking, passing, setting, and serving skills. Following a standardized warm-up, players performed 6 trials of each skill. Two 37-mm digital cameras (Sony, DCR-TRV 950), positioned approximately 5 m from the player, were used to film each skill. In the case of spiking and setting skills, players were filmed from the side and behind, while serving and passing skills were filmed from the side and front of the player. The players' accuracy was determined on their ability to hit specific targets. The players' technique was subjectively evaluated from video footage by 2 expert coaches using standardized technical criteria (Table 1). Coaches used a 1–7 Likert scale to assess a player's technique.

Spiking

A target 2 m long and 1 m wide was placed on a wall, 7 m from the player. The target was divided into five 20cm segments. Players were instructed to hit (spike) the

TABLE 1. Criteria used by coaches to assess technical skill of volleyball players.

Skill	Criteria
Spiking	Identify height, speed, and location of set Angle approach to maximize hitting zone Build speed and increase momentum of approach Contact ball high in front of hitting shoulder Fast arm swing, which follows through past the contact point
Setting	Feet, hips, and shoulders facing target Hips forward and an upright body position Ball set from forehead and above Follow through to target (arms and legs)
Serving	A disciplined and consistent routine prior to each serve Controlled toss in front of the hitting shoulder Solid contact in the center of the ball (without spinning) Low trajectory
Passing	Feet slightly wider than shoulder width Knees and back slightly bent Arms away from the body Elbows locked and shoulders rotated forward Arms tilted toward the target

ball toward the target. If players were able to hit the middle 20-cm segment, they were awarded 5 points. Three points were awarded for successfully hitting the two 20cm segments on either side of the middle segment, while 1 point was awarded for hitting the 2 outer 20-cm segments of the target. A score of 2 and 4 points were awarded if players successfully hit the target between the 1 point and 3-point segments, and 3 point and 5-point segments, respectively. The aggregate from 6 trials was recorded as the player's accuracy score. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for spiking accuracy and technique were 0.85 and 0.90 and 0.9% and 5.1%, respectively.

Passing

The passing ability of the players was evaluated by determining their ability to return a pass to a target positioned at the net, 2 m from the right-hand sideline. The target dimensions were 1.6 m long and 2.3 m wide. This target was chosen, as it was at the approximate position the setter would stand during a match. A coach, positioned in the service position, approximately 1 m above the ground and 10 m from the receiving player, threw an overhead pass to the receiving player. Players were required to pass (dig) the ball to another player standing with arms extended above their head, in the target area. Players who successfully passed the ball to the player in the target area were awarded 2 points. A second target area was created for passes that did not make the main target area, but would be likely to reach another player in a match situation. The second targetextendedfromthe right-hand sideline and was 3 m long and 4.1 m wide. Players who successfully passed the ball within the second target area were awarded 1point. Finally, apassthat did not reach either of the target areas was awarded 0 points. The aggregate from 6 trials was recorded as the player's accuracy score. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for passing accuracy and technique were 0.94 and 0.90 and 0.2% and 5.1%, respectively.

Setting

The setting ability of players was evaluated by determining their ability to set to a target positioned next to the net at net height 5.5 m from the setting player. This target was chosen as it was the approximate position a receiving player would stand when preparing to spike the ball during a match. A coach, positioned approximately 5 m from the setting player, threw an overhead pass to the setting player. Players were required to set the ball to a target 80 cm in diameter. Playerswhosuccessfullysetthe ball through the target were awarded 3 points. Balls that hit the outside edge of the target but did not go through the target were awarded 2 points. Players who set the ball within 2.3 m of the net (and therefore 1.5 m of the target) were awarded 1 point. Balls that did not reach the target areas were awarded 0 points. The aggregate from 6 trials was recorded as the player's accuracy score. The intraclass correlation coefficients for test-retestreliability and typicalerror of measurementforsettingaccuracyand technique were 0.88 and 0.98 and 0.39% and 6.6%, respectively.

Serving

Serving accuracy was determined as the ability of players to serve in the court from a service position. Given that the players had limited exposure to volleyball prior to beginning the study, it was considered unreasonable for players to possess the coordination to hit specific service targets (other than an entire court) (i.e., 9 m width). The aggregate from 6 trials was recorded as the player's accuracy score. The intraclass correlation coefficients for test-retest reliability and typical error of measurement for serving accuracy and technique were 0.94 and 0.6% and 0.85 and 6.9%, respectively.

Fitness Testing Battery

Standard anthropometry (height, standing-reach height, body mass, and sum of 7 skinfolds) (14), upper-body muscular power (overhead medicine-ball throw) (15), lowerbody muscular power (vertical jump and spike jump) (15), speed (5- and 10-m sprint) (15), agility (T-test) (11), and maximal aerobic power (multistage fitness test) (16) 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 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 (5and 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 betweentrials. 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 to body mass ratio, thermoregulation, and aerobic capacity) (15). As an estimate of adiposity, skinfold thickness was measuredat 7 sites using a Harpenden skinfold caliper. Biceps, triceps, subscapular, supraspinale, abdomen, thigh, and calf on the right side were the 7 sites selected. The exact positioning of each skinfold measurement was in accordance with procedures described by Norton et al. (14). Height was measured using a stadiometer, and body mass was measured using calibrated digital scales (A & DCompany 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 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 (15). Players stood 1 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 toebehind the line and 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 muscularpower 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 (15) 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. Nospecific instructions were given regarding the depth or speed of the countermovement. 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 proceduresto thevertical 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 both legs, displacing as many vanes on the Yardstick as possible. Spike-jump height was calculatedasthe 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 intra class 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 a5- and 10-msprint effort (15) using dual beam electronic timing gates (Swift Performance Equipment). The timing gates were positioned 5 and 10 m from a predetermined starting point. Players were instructed to run as quickly as possible along the 10-mdistancefrom 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- 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 (11) using dual-beam electronic timing gates (Swift Performance Equipment). 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, volleyballmatches may last up to 90 minutes (9, 23). Players also require high levels of aerobic fitness to aid recovery after highintensity bouts of activity. Maximal aerobic power was estimated using the multistage fitness test (16). 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 (VO_2max) was estimated usingregression equations described by Ramsbottom et al. (16). When compared with treadmill-determined VO_2max, it has been demonstrated that the multistage fitness test provides a valid estimate of maximal aerobic power (16). In addition, in a previous study (7), 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 multistage fitness test were 0.90 and 3.1%, respectively.

Training Sessions

Each player participated in an 8-week skill-based training program, which included 3 organized court-training sessions per week. Skills sessions were designed to develop passing, setting, serving, spiking, and blocking technique and accuracy as well as game tactics and positioning skills. Coaches used a combination of technical and instructional coaching, coupled with skill-based games to facilitate learning. Training sessions typically included a low-intensity warm-up (e.g., jogging and stretching), with a progression fromlow-intensity to high intensity activities throughout the session. Low-intensity activities included serving, passing, and setting in small groups. High-intensity activities included blocking and spiking technique and peppering (i.e., digging a ball that has been spiked by an opponent) drills. Training sessions typically concluded with high-intensity small-sided (e.g., 3 vs. 3 or 5 vs. 5) games. The duration of training sessions was recorded, with sessions typically lasting between 120 and 180 minutes. None of the players were performing any additional resistance or aerobic training outside of the 3 skill-based sessions. Training heart rates were recorded using recordable Polar S610i heart-rate monitors. Once the raw data were collected, it was downloaded using Polar Precision Performance software.

Statistical Analyses

Changes in the anthropometric characteristics, upperbody and lower-body muscular power, speed, agility, VO_2max, and skill levels of players over the training period were compared using paired t-tests. The level of significance was set at $p \leq 0.05$ and all data are reported as means ± SE.

RESULTS

The average heart rate over the 8-week training period was 138 ± 2 beats·min21, with the majority of training time (57.4 ± 3.6%) spent in very low-intensity (40–70% maximum heart rate) activities (Figure 1). The percentage of time spent in low-intensity (70–75% maximum heart rate), moderate-intensity (75–85% maximum heart rate), and high-intensity (> 85% maximum heart rate) activities was 13.6 ± 1.0%, 20.6 ± 2.2%, and 7.8 ± 1.6%, respectively.

Skill

Accuracy. The changes in spiking, serving, setting, and passing accuracy are shown in Table 2. Training induced significant ($p < 0.05$) improvements in spiking (+76%), setting (+335%), and passing (+40%) accuracy. While there was a trend for serving accuracy to improve with training (+15%), there were no significant differences ($p > 0.05$) between pretraining and posttraining. Technique. The changes in spiking, serving, setting, and passing technique are shown in Table 3. Training induced significant ($p < 0.05$) improvements in spiking (+24%) and passing (+29%) technique. While there was a trend for serving (+17%) and setting (+14%) technique to improve with training, there were no significant differences ($p > 0.05$) between pretraining and posttraining.

Physiological and Anthropometric Characteristics

Anthropometric Characteristics. The changes in height, standing-reach height, body mass, and skinfold thickness

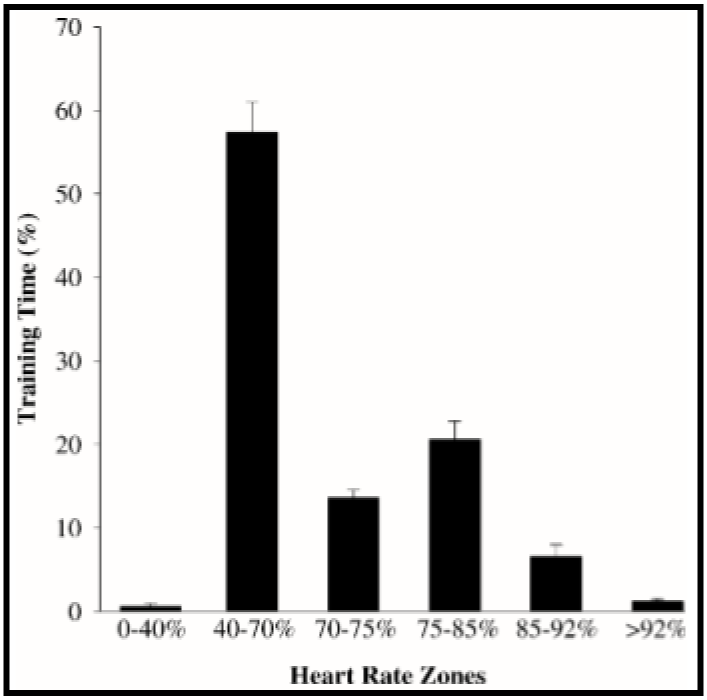

FIGURE 1. Percentage of total training time spent in different heart-rate training zones during skill-based training in talentidentified volleyball players.

TABLE 2. Spiking, setting, serving, and passing accuracy of talent-identified volleyball players before and after 8 weeks of training. *

	Pretraining	Posttraining
Spiking accuracy	5.9 ± 0.9	10.4 ± 0.9
Serving accuracy	3.3 ± 0.4	3.8 ± 0.3
Setting accuracy	2.0 ± 0.5	8.7 ± 0.7
Passing accuracy	9.4 ± 0.8	13.2 ± 0.6

* Data are reported as means ±SE.
† Significantly different ($p < 0.05$) for pretraining.

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TABLE 3. Spiking, setting, serving, and passing technique of talent-identified volleyball players before and after 8 weeks of training. *

	Pretraining	Posttraining
Spiking accuracy	2.9 ± 0.3	3.6 ± 0.2†
Serving accuracy	3.0 ± 0.2	3.5 ± 0.2
Setting accuracy	2.9 ± 0.2	3.3 ± 0.2
Passing accuracy	2.8 ± 0.2	3.6 ± 0.2†

* Data are reported as means ± SE.
† Significantly different ($p < 0.05$) from pretraining.

are shown in Table 4. There were no significant differences ($p > 0.05$) between pretraining and posttrainingfor height, standing-reach height, body mass, and sum of 7 skinfolds.
Physiological Characteristics. Compared with pretraining, there was a significant ($p < 0.05$) improvement in 5- and 10-m speed and agility. There were no significant differences ($p > 0.05$) between pretraining and posttraining for lower-body muscular power (vertical-jump height and spike-jump height), upper-body muscular power (overhead medicine-ball throw), and VO_2max (Table 5).

TABLE 4. Body mass, height, standing-reach height, and sum of 7 skinfolds of talent identified volleyball players before and after 8 weeks of training. *

	Pretraining	Posttraining
Body mass (kg)	72.3 ± 2.5	72.3 ± 2.3
Height (cm)	182.2 ± 1.5	182.6 ± 1.2
Standing-reach height (cm)	241.7 ± 2.0	240.7 ± 2.1
Sum of skinfolds (mm)	88.7 ± 5.7	86.8 ± 5.7

* Data are reported as means ± SE.

TABLE 5. Upper- and lower-body muscular power, speed, agility, and maximal aerobic power of talent-identified volleyball players before and after 8 weeks of training. *

	Pretraining	Posttraining
Vertical jump (cm)	45.7 ± 2.3	45.7 ± 2.4
Spike jump (cm)	50.0 ± 2.5	51.2 ± 2.9
Overhead medicine-ball throw (m)	6.7 ± 0.3	6.8 ± 0.3
5-m sprint (s)	1.12 ± 0.02	1.06 ± 0.01†
10-m sprint (s)	1.95 ± 0.03	1.87 ± 0.02†
Agility (s)	11.12 ± 0.16	10.54 ± 0.18†
VO_2max ($ml \cdot kg^{1} \cdot min^{1}$)	40.8 ± 1.1	43.2 ± 1.1

* Data are reported as means 6 SE.
† Significantly different ($p < 0.05$) from pretraining.

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DISCUSSION

The present study investigated the effect of a skill-based training program on measurements of skill and physical fitness in talent-identified volleyball players. Traininginduced significant improvements in spiking, setting, and passing accuracy and spiking and passing technique. Significant improvements in speed and agility were also observed. However, there were no significantdifferencesbetween pretraining and posttraining for body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, and VO_2max. These findings demonstrate that skill-based volleyball training improves spiking, setting, and passing accuracy and spiking and passing technique, but has little effect on the physiological and anthropometric characteristics of players. Skill-based training programs should be supplemented with an appropriate amount of energy system training to enhance the physiological and anthropometric characteristics of talented junior volleyball players.

In the present study, technique improved by 21%, while accuracy improved by 117%. The technical skill improvement following training in the present study was similar to that achieved following training in other skillbased sports (1, 22). However, the large improvement in accuracy most likely reflected the poor accuracy in the volleyball players prior to training. While measures of skill improved following short-term training, it is unclear if these skill improvements would have been maintained following a longer period of training or if similarimprovements would have been made by highly skilled volleyball players. The present results are therefore limited to talent-identified junior volleyball players and may not be applicable to highly skilled, elite volleyball players. In addition, all skill tests were conducted in a controlled environment. Therefore, it is unclear if the improvements in skill would have transferred to a competitive environment, where skill is dependent on the player's cognitive knowledge of the game-specific situation, their ability to process visual and other game-specific information, and their ability to execute the skill under the pressure of competition (22). While skill in the isolated tasks of spiking, setting, serving, and passing improved following training, a player's ability to execute skills successfully after making a decision (e.g., during competition) is of greater importance (21). Future studies investigating the effect of skill-based training on skill acquisition could use a game-specific performance test to assess the decisionmaking ability of players under conditions simulatingthe pressure and fatigue of competitive matches. In addition, studies investigating the changes in skill and physiological characteristics of talented volleyball players over the course of a season are required to determine the longterm effect of skill-based training on the skill and fitness of these players.

The present study found significant improvements in the accuracy of spiking, setting, and passing skillsfollowing 8 weeks of skill-based volleyball training. However, the posttraining serving accuracy was not significantly different from that recorded prior to training. It is well documented that movement speed and target widthinfluence accuracy, with slower movements and wider targets producing greater accuracy (17). Given the wider target area involved in the serving task (i.e., 9 m) and the large muscular strength and power component of hitting the ball over the net, it is likely that movement speed was considerably increased in this task. Therefore, the finding of unchanged serving accuracy following training may be expected. In addition, it is likely thattheservingtaskhad greater complexity than the other skills because more body segments were involved in the task. The greater task complexity would have resulted in a number of muscle forces combining to produce the resultant force at the shoulder joint, but also increasing the likelihood of errors in target accuracy (17).

The present study found improvements in agility and speed and unchanged body mass, skinfold thickness, upper and lower-body muscular power, and VO_2max in talent-identified volleyball playersfollowing8weeksofskillbased training. The improved speed and agility in response to training may reflect the highly repetitive nature of selected explosive volleyball skills (e.g., blocking, spiking). However, it is unclear why these skills failed to improve vertical-jump and spike-jump ability. It has previously been shown that agility is a function of sprinting speed and technique and muscular strength, power, and reactive strength (24). In addition, high levels of agility are also dependent on perceptual and decision-making factors (e.g., visual processing, anticipation, pattern recognition, and situation knowledge) (24). Given that muscular power was unchanged over the training period, it is possible that the improved agility occurred as a result of improved running speed and improved perception and decision making.

The present study found no change in VO_2max following 8 weeks of skill-based training. The finding of similar pretraining and posttraining VO_2max may be attributed to the low average heart rate (138 beats·min 21) achieved by subjects during training. Indeed, subjects spent 57.4% of training time in low-intensity activities below 70% maximum heart rate. The finding of a low VO_2max following training may be expected given that only 20.6% of total training time was spent in activities deemed to be appropriate for the development and maintenance of aer
obic fitness (2). Therefore, it is likely that the intensity of the skill-based training stimulus employed by the volleyball players of this study was inadequate to induce significant central and/or peripheral adaptations for improvements in VO_2max (6).

The subjects of the present study were selected into the Queensland Academy of Sport, Talent Search volleyball program based on physiological and anthropometric characteristics (e.g., height, standing-reach height, muscular power, speed, agility, and maximal aerobic power) that have previously been shown to be beneficial to volleyball success (15). To minimize the possible effects of learning on skill measurements, all subjects underwent a familiarization period prior to the commencement of the study. Furthermore, improvements in technique and accuracy were considerably greater than the typical error of measurement, suggesting that skill improvements were not due to random measurement error. These findings provide important information on skill and fitness adaptations in response to skill-based training in talentidentified junior volleyball players. However, further research is required to determine if conditioning training alone can improve measures of fitness and skill, and if measurable improvements in skill can be achieved following a similar training period in highly skilled, elite volleyball players.

In conclusion, the present study investigated the effect of a skill-based training program on measurements of skill and physical fitness in talent-identified volleyball players. Training induced significant improvements in spiking, setting, and passing accuracy and spiking and passing technique. Significant improvements in speed and agility were also observed. However, there were no significant differences between pretraining and posttraining for body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, and VO_2max. These findings demonstrate that skill-based volleyball training improves spiking, setting, and passing accuracy and spiking and passing technique, but has little effect on the physiological and anthropometric characteristics of players.

PRACTICAL APPLICATIONS

Skill-based coaching is increasingly being used as a means of improving performance of athletes from skillbased sports. The results of this study demonstrate that skill-based volleyball training improves spiking, setting, and passing accuracy, spiking and passing technique, and speed and agility. However, skill-based training has little effect on body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, or VO_2max. From a practical viewpoint, these findings demonstrate that skill-based training programs should be supplemented with an appropriate amount of energy system training to enhance the physiological and anthropometric characteristics of talented junior volleyballplayers.Inaddition, given the importance of lower-body and upper body muscular power to volleyball performance and the failure of skill-based training to improve these qualities, training age-appropriate strength and power programs should be implemented in these athletes. Strength and power programs designed to enhance shoulder extensor strength (for spiking and serving skills); hip, knee, and ankle extensor strength (for blocking and spiking skills); and hip abductor and adductor strength (for stabilizing the pelvis, and accelerating and controlling the legduring rapid changes in direction) should be implemented to enhance physical performance and the long-term development of talent-identified volleyball players.

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