International Journal of Physical Education and Sports Sciences

Vol. V, No.I, April-2013,
ISSN 2231-3745

REVIEW ARTICLE

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International Journal of Physical Education and Sports Sciences
Vol. V, Issue I, April-2013, ISSN 2231-3745

Effects of Same-Day Strength Training On Serve Performance in Female Collegiate Tennis Players

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INTRODUCTION:-

Tennis has become a highly competitive sport requiring a tremendous amount of power and accuracy in order to be successful. One of the most important strokes each player must learn is the tennis serve. The serve is the start of each point and is the only aspect in which a player has total control over its outcome (2). However, it is the most difficult stroke to learn because of the complex and coordinated movements involving the trunk and upper and lower extremities (2). The coordination of body parts has been termed the kinetic chain (8, 15), and allows generation, summation, transfer, and regulation of forces from the legs to the hand (12). It is well known that in order to increase serve performance, muscle strength of the entire kinetic chain must be increased without affecting serve accuracy. Proper strength training has, therefore, become a vital aspect of tennis training. Due to the multiple competition seasons that occur in tennis, it is inevitable that players may be scheduled to strength train on the same day as a match. Many athletes and coaches choose to forgo such strength training sessions on the premise that strength training the same day as competition will decrease performance (17).

Previous research evaluating the effects of same-day strength training on sport performance (10, 13, 17) have shown that same-day strength training among female athletes did not have any effect on various aspects of performance. Results from previous studies suggest that strength training is not as detrimental to performance as once thought, warranting further research in other sports. Therefore, the purpose of this study was to evaluate the effects of same-day strength training on velocity and accuracy of the tennis serve, compared to serve performance without an earlier strength training stimulus.

METHODS SUBJECTS

Ten members of the 2004-2005 women's intercollegiate Division I tennis team at Brigham Young University were invited to participate in this study. Subjects followed a specified strength training program throughout the duration of this study. The strength training program was designed by the coaches and strength training staff. None of the participants had been involved in a periodized strength training program that consisted of lifting two or more times a week within the last 3 months. All participants had been involved in a regular strength training program in the last year which consisted of lifting two or more times a week for at least six weeks. All participants completed and signed an informed consent form prior to participation in the study. This study was approved by the Institutional Review Board (IRB) at Brigham Young University. Experimental Design A 2x2x2 repeated measures design guided this study. Serve performance of each participant was measured four times for each of the two variables over the course of this study. Testing occurred twice each week in conjunction with the strength training program, termed the lift-day (LD), and twice without the strength training stimulus, termed the non lift day (NLD). This occurred at the second week and sixth week of the strength training program. Strength training sessions started the second week of September on Monday, Tuesday, Thursday, and Friday, with lifting taking place at 6:45 a.m. the day of testing. Testing was performed four times each week at 11:30 a.m., approximately a half hour prior to the start of practice. This allowed an average of four hours rest from the end of the strength training session to the start of serve testing. There was at least a 24 hour span between each of the serve testing days.

Upper and lower body strength training sessions were each performed twice a week for a total of four strength training sessions per week. Serve performance was tested on the same day that the lower body and core was strength trained. The decision was made to serve test the same day as the lower body strength training was performed because 54% of the total force generated during serve performance comes from the leg/hip/trunk link, with only 21% of total force coming from the shoulder (12). Strength Training Program

The strength training program was designed as a split-body routine. Each strength training session included a warm-up followed by a variety of either upper or lower body lifts using two to six sets of three to ten repetitions with each exercise. Training intensity varied between 60% and 90% of a one repetition maximum (1 RM), depending on the number of sets and reps that were performed. Lifts performed on the lower-body strength training day included squats, hang cleans, lunges, stiff leg deadlifts, and calf rises.

SERVE PERFORMANCE

Both velocity and accuracy were measured during all serve testing sessions and each participant completed 20 NCAA Division I match rule serves per session Subjects were given a second attempt if the first serve was fault, and if both serves were fault, zero points were awarded for that serve. If a serve hit the net and landed in the service court, also known as a let, subjects were given a re-serve which did not count against the two attempts given for each one serve.

Ball velocity (mph) was measured using a Sports Radar gun (Sports Radar Company; Homosassa, FL). The radar gun was placed inside the serve court, set back 8 inches from the net, and 18 inches from the midline stripe, in the opposite serve court so that it was in line with the individual. This allowed for velocity to be recorded as the ball came off the racquet, even if the net was hit, or a let occurred.

Accuracy was measured by the ability to serve into a marked area of the deuce court. There were three arcs drawn on the court, the first measuring 18 inches from the midline corner and each subsequent line 18 inches from the previous one (Figure 1). The highest value of 1.75 points was rewarded for serving within the arced area closest to the corner, 1.5 points for serving within the second arc, 1.25 points for serving within the third arc, one point for any other part of the serve court, and zero points were awarded for a double fault serve. Velocity (mph) of each serve was multiplied by the accuracy point value to create an overall serve performance score for each serve. Overall serve performance scores for all 20 scores were averaged to create one score for each day.

STATISTICAL ANALYSIS

A 2X2X2 repeated measures ANOVA was used to compare the serve testing scores between 1) lift day (LD) verses non-lift day (NLD), 2) following two and six weeks of training, and 3) the first day verses the second day of testing each week. Because initial results between the two weeks of testing showed no significant difference in any of the variables (velocity, accuracy, and velocity x accuracy), the data were pooled so only serve performance scores on LD and NLD were compared. A one- way repeated measures ANOVA was then computed to compare velocity, accuracy, and velocity x accuracy between the NLD and LD (alpha = 0.05). The pooled data allowed for an increase in power in the statistical analysis.

RESULTS

Of the ten tennis team members who were invited to participate in this study, five completed the study. All five players which discontinued participation in the study did so due to non-research related injuries or issues. A summary of the serve performance scores (velocity, accuracy, and velocity x accuracy) on the LD and NLD are shown in Table 1. The repeated measures ANOVA revealed no significant difference between serve performance variables between the LD and NLD following two and six weeks of training. The average serve velocity on the NLD and the LD was 80.08 ± 2.3 mph and 79.00 ± 2.9 mph, respectively. The difference between serve velocity on the NLD and LD (1.22 ± 0.6 mph) was not significant ($p = 0.15$).

The overall serve accuracy on the NLD and the LD was 0.95 ± 1.01 and 0.98 ± 0.89, respectively. The difference between the serve accuracy on the NLD and LD (0.06 ± 0.12) was not significant ($p = 0.48$). The overall serve performance score (velocity x accuracy) on the NLD and LD was 77.56 ± 8.54 and 78.05 ± 7.39, respectively. The individual combined difference between the overall serve performance scores on the NLD and LD (3.67 ± 1.15) was not significant ($p = 0.84$).

DISCUSSION

The results of this study suggest that same-day lower body strength training followed by adequate recovery does not have a detrimental effect on serve performance following two or six weeks of strength training. These findings agree with those of Woolstenhulme et al. (17) who reported that strength training had no effect on either anaerobic power or shooting accuracy when both were performed on the same day by female collegiate basketball players.

The underlying reason for why coaches and players often forego strength training on the same day as a performance is the potential for muscle fatigue and soreness to alter performance. Bloomer and Ives (4) reported that in order for a muscle fiber to be trained, it must first be recruited and then fatigued. Furthermore, Rooney et al. (16) stated that skeletal muscle fatigue contributes to strength training induced gains in strength. Fatigue as defined by Kent-Braun (11) and Allman (1) is the reduction in the maximum force generating capacity of a muscle. Evidence of muscle fatigue, such as alterations to excitation-contraction coupling has been shown to still be present one day post isometric resistance training, and also muscle damage was present 3-5 days post training (3). It has also been shown that proprioception altered by fatigue could lead to disruption in efferent neuromuscular responses (14) causing a decrease in control over the speed of

movement, and decrease the accuracy of position sense (9) affecting serve performance. We speculate that the strength training program used in this study did not have an effect on serve performance because it did not induce fatigue or soreness of significant magnitude or duration. It is unlikely that an athlete would engage in strength training to the extent of intentionally causing lasting fatigue and soreness that would influence performance. The intent of the strength training program used in this study was not necessarily to induce fatigue or soreness but to represent an in season strength training session that an athlete would typically perform. There are several reasons why the strength training program used in this study did not induce muscle fatigue or soreness of the magnitude or duration necessary to affect performance. The strength training program used in this study was a split body routine and serve performance was measured only following the lower body lifting session. It was shown by Kibler (12) that 51% of the kinetic energy and 54% of total force generated during the tennis serve originated from the leg/hip/trunk link, with only 13% of total energy and 21% of total force coming from the shoulder. Therefore, it was assumed that serve performance would be most affected following a lower body strength training session. The fact that service performance was not affected by same- day strength training suggests that fatigue was not severe enough to alter performance. We also believe that the split-body strength training was not a factor because the results of this study agreed with results of previous studies done at Brigham Young University which used a full-body strength training routine while researching the effects of same day strength training on performance among female collegiate soccer and basketball players (13, 17).

Carpenter et al. (6) suggested that the alterations in shoulder proprioception that could lead to changes affecting serve performance may be reduced with proper training. Therefore, serve performance of athletes with greater strength training experience is less likely to be affected by changes in shoulder proprioception related to strength training. Same-day strength training may not have affected serve performance of athletes in this study because they had been involved in strength training prior to the beginning of the study. Therefore, the participants were accustomed to strength training and were already somewhat conditioned despite the two month lag in the strength training program. Bompa (5) suggested that recovery following activity is largely associated with fitness level. The higher the fitness level, the faster the recovery of skeletal muscles following a fatiguing bout of exercise. This infers that the four-hour rest period between strength training and serve performance in this study was sufficient enough to provide the participants of this study time to recover. Woolstenhulme (17) and Murakami (13) made similar conclusions. Woolstenhulme (17) reported that six hours was enough recovery time between strength training and anaerobic power testing, and eight hours was enough recovery time before speed spot shooting among female basketball players. Clarkson et al. (7) demonstrated that exercise induced injury to the anatomy of the muscle depends on an individuals training level, with a more trained individual experiencing less damage. The subjects in this study were members of a Division I intercollegiate tennis team, who had been engaged in a routine strength training program for at least two weeks prior to assessing serve performance and had been involved in similar strength program in the year prior to testing. Serve performance was tested following the second week of strength training in this study to avoid the effects of delayed onset muscle soreness often experienced at the commencement of a strength training program. The findings of this study also support the suggestions made by Carpenter et al. (6) and Bompa (5) that the higher the training level, the less likely that the expected effects of fatigue that are seen in untrained populations would occur. Our findings may also support those of Behm et al. (3) who reported trained individuals had less of a chance of losing velocity if muscle damage occurs.

Most strength training programs are periodized so that less strain is put on the muscle during in-season competition times, and more strain during the off season. Because tennis has multiple competition seasons, athletes or coaches may decrease the lifting load to prevent unwanted muscle soreness that is thought to affect performance. This raises the question of whether or not the lifting load would be sufficient to elicit the desired fatigue (i.e., training) response. Because testing was not done immediately following the strength training stimulus, it is unknown if the stimulus received was enough to cause muscle fatigue that would alter serve performance, or if the subjects had enough recovery time. Due to the fact the lifting program was a split body routine, even if the stimulus was enough to elicit change, results may have not been as significant if compared to a same-day total-body strength training routine evaluated in a similar manner, despite the fact that over half the total energy and force come from the lower half of the body (12).

The sample size for this study was small leading to a question of power, but results of a power analysis showed that with an alpha of 0.05, power was 0.54. However, the mean difference between the LD and the NLD was only one-tenth of the standard deviation between subjects, suggesting a low effect size. We also computed an effect size analysis that assumed a stronger power of 0.8 and found that the mean detectible difference that would be statistically significant was 1.019. This was over two times the amount of the mean difference found in our study

(0.49), suggesting that even if we had more subjects, and greater power in this study, the results would still be in favor for strength training on the same day as serve performance. In addition, the accuracy and overall scores were slightly better in the LD group, suggesting that there would still be no detrimental effect of weight training seen, even if more subjects had been included.

There was a slight trend toward decreased velocity on the LD when evaluated alone, however this decrease was not statistically significant. This information might be useful for future research, in that training might affect speed, but not accuracy, and when taken performance into account on same-day strength training days, subjects may decrease speed and increase accuracy as a compensation.

One aspect that is crucial to sport performance is how the athlete feels and the psychological ramifications that may accompany same-day strength training and performance testing. This study did not evaluate the psychological effects of strength training and performance on the same day, we therefore cannot rule out the possible psychological impact of same-day strength training on competitive performance. Even though there was no significant difference between the LD and the NLD, an athlete or coach who has the mindset that same-day strength training affects performance, may not be able to accept such results. Future studies can begin to evaluate any psychological changes that might result from a similar same-day strength training study, and they can also begin to look at the effects that same-day strength training has on performance within four hours of strength training, since this study and other studies (13, 17) showed that fatigue was not an issue after then. PRACTICAL

APPLICATIONS

The results of this study suggest that when routine strength-training sessions and tennis matches fall on the same day, athletes do not need to forego their regularly scheduled strength-training session if adequate recovery time is permitted. Serve performance was not effected by same day lower body strength training followed with adequate recovery.

Table 1

Comparison of serve performance scores on lift and non-lift days

Non Lift Day	Lift Day	p Value
Velocity	80.082 ± 2.3	79.000 ± 2.9
Accuracy	0.953 ± 1.01	0.975 ± 0.89
Combined†	77.562 ± 8.54	78.049 ± 7.39

All values are mean ± standard deviation for all 5 subjects and both weeks of serve testing. †Combined value represents velocity x accuracy.

NET

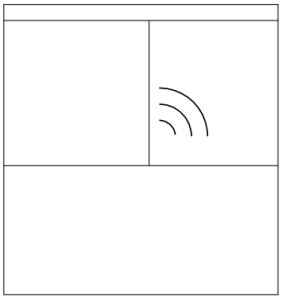

Figure 1 Court setup with accuracy lines.

Tennis is an age-old sport that has over the years become a highly competitive sport that requires a tremendous amount of power and accuracy. One of the most important strokes is the tennis serve. The serve is the start of each point and is the only aspect in which a player has total control over its outcome (Bahoamonde, 2000). However, it is the most difficult stroke to learn, because of the complex movements involving the trunk, upper and lower extremities, all working in coordination with each other (Bahoamonde, 2000). This coordination of body parts is termed the kinetic chain (Cohen and Mont, 1994; Roetert, Ellenbecker, Chu, and Bugg, 1997), and allows generation, summation, transfer, and regulation of forces from the legs to the hand (Kibler, 1995). It is well known that in order to increase power, muscle strength of the entire kinetic chain must also be increased. Strength training has, therefore, become a vital aspect of tennis training. Because of the long tennis season, strength training is often performed during the competitive season. Due to the multiple competition seasons, it is inevitable that some of the scheduled strength training sessions fall on the same day as a match. Due to the popular opinion that strength training the same day as competition will decrease performance, many athletes and coaches choose to forgo such strength training sessions (Kerbs, 2000; Woolstenhulme, 2000). Little research has been completed evaluating the effects of same-day strength training on sport performance (Kauranen, Pertti, and Vanharanta, 1999; Kerbs, 2000; Murakami, 2002; Woolstenhulme, 2000). However, it is still unclear whether strength training the day of competition is beneficial, detrimental, or has no effect at all (Kerbs, 2000; Woolstenhulme, 2000). No research has been done on evaluating the effects of strength training on the tennis serve, and no research was found reviewing same-day strength training effects on elite tennis players in moderately or highly strength trained conditions.

OPERATIONAL DEFINITIONS

Kinetic chain - the link of legs, hips, trunk, and upper limbs that generates force for certain motions, such as the tennis serve.

Elite tennis player - an individual who has played competitive tennis and is a member of a Division I NCAA collegiate tennis team

Moderately trained state - An individual who is currently involved in a highly regular total body strength program, strength training at least twice a week for no more than two weeks, but prior to the two weeks has had no regular total body strength training program, strength training less that once every week for the prior two months. However, in the prior year the individual has at some time been involved in a regular strength training program.

Highly trained state - An individual who is involved in a highly regular, total body strength training program, strength training two or more times a week for at least six weeks.

Service accuracy - The ability to serve into a specified area marked on the tennis court.

A 2 x 2 factorial with repeated measures on two factors guided this study. Weight training (same-day strength training, non-strength training day) and state of strength training (moderate, high) are the independent variables. Serving velocity and accuracy will be recorded and analyzed as the dependant variables two-weeks and at least six weeks into the strength training program.

Subjects will be female volunteers from Brigham Young University women's intercollegiate tennis team. Subjects will meet requirements of being members of the NCAA Division I women's tennis team at Brigham Young University. Testing will begin only after Institutional Review Board (IRB) approval from the university has been obtained. Each subject will also read and sign an informed consent form regarding the procedures of the study prior to participation. Subjects will also fill out a questionnaire regarding the amount of strength training that was done two months prior to their return to school before the beginning of the study, and the fall strength training program to ensure they fulfill requirements of the moderately trained state.

STRENGTH TRAINING PROGRAM

The women's tennis strength training program is adjusted throughout the year by the concept of periodization. Peridiozation is a training concept that divides the year into major periods called macrocycles, into monthly or weekly periods called mesocycles, and into daily periods called microcycles. Through the cycles, the load, intensity, and volume of the workout are varied so that overtraining is avoided, and peak strength is maintained throughout the competition season. Service testing will take place after two weeks into the fall in-season strength training program and at least six weeks into the fall program. Individual one-repetition maximal lifts will be performed during the first week of the fall in-season program and will be used as the basis to develop a program specific to each individual. Each strength training session includes a warm-up followed by a variety of lifts using two to six sets of three to ten repetitions with each exercise. Training intensity will be at a level that varies around 80% of a one repetition maximum (1 RM), depending on the number of sets and reps that will be performed. The recovery time will vary from two to four minutes between sets. Strength training will take place at least twice a week on Monday thru Thursday depending on practice schedule. Practice will take place Monday thru Friday afternoons, and sometimes Saturday mornings. Participants will be instructed in proper technique and form prior to starting the strength training program. Procedures

The study will require two days of strength training and service testing termed as the lifting day (LD), and two non-lifting days (NLD) where only service testing will be measured. Each of the four testing days will be separated by at least 24 hours. This will take place twice, once two weeks into the fall strength training program, termed baseline for this study, and at six weeks into the fall strength training program. There will be at least a four hour delay on the LD from the finish of the strength training session to the beginning of testing generally before muscle soreness or DOMS develops. Subjects will be randomly assigned so that the order testing on LD and NLD can be randomized, and to also allow enough time to complete testing before practice.

Subjects will be instructed to arrive at the outdoor courts dressed in suitable tennis clothes and shoes. Subjects will be allowed to complete a standardized warm-up that is equivalent to the warm-up performed before a match. On each of the testing days, subjects will be allowed to take up to five maximal efforts serves in order to understand the requirements and to familiarize themselves with the testing procedures and accuracy lines (Figures 2 and 3). Following the warm-up and familiarization serves, subjects will be instructed to serve 20 maximal velocity serves into the service court on the opposite side. Each serve will follow NCAA Division I match rules regarding serves. This means that subjects will be given a second attempt if the first serve is a fault, and if both serves are fault, zero points will be awarded for that serve. If a serve hits the net and lands in the service court, also known as a let, subjects will be given a re-serve which does not count against the two attempts given for each one serve. Accuracy will be measured by three arced lines with the first line 18 inches from the top corner and each subsequent line another 18

inches from the previous . This will help grade accuracy according to where highly desirable serves are commonly placed. Each area will be assigned a point value to help quantify accuracy (Figure 3). One and 3/4ths points will be awarded for the highest accuracy and zero points will be awarded if it lands outside of the service court, also known as a fault. The side of the serve court will be adjusted for left and right serve dominant players.

Ball velocity will be measure by using a radar gun (Sports Radar Company; Homosassa, FL). The radar gun works by utilizing a low power microwave transceiver that senses speed of an object using the Doppler principle. The Doppler principle works by sending out a constant x-band signal from the transmitter portion of the radar gun and then the receiver portion picks up this signal as it bounces off of objects in front of the antenna. If the object is moving, the received frequency will be slightly different than the original. The frequency difference is proportional to the speed of the object, which the radar gun converts this to Miles or Kilometers per hour.

The radar gun will be placed inside the serve court, 18 inches from the midline stripe that divides the two serve courts and eight inches back from the net. It will be aimed through the net so that it records ball speed as it comes off the racquet and approaches the net. This will allow for velocity to be recorded even if the net is hit, or a let occurs. It will also ensure safety of the radar equipment.

All 20 serves will be averaged for velocity and accuracy. This will help to evaluate whether there are any decreases to performance on strength training days versus non-strength training days.

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