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RELEVANCE OF PERCEIVED EXERTION AND ACCURACY OF SECOND SERVE IN COLLEGIATE MENS TENNIS PLAYERS

Kuroda Y[1], Takizawa K[2], and Mizuno M[1]

[1]*Hokkaido University, Sapporo Hokkaido, Japan*

[2]*Institute of Physical Development Research, Japan*

ABSTRACT

This study aimed to evaluate the relationship between serve accuracy, strength and agility performances, and the rating of perceived exertion (RPE) during on-court tennis-specific tennis test in collegiate level tennis players. Eight Japanese collegiate male tennis players, who participated in the All Japan Tennis Championship for university students, were the participants in this study (age: 23.0 ± 2.6 years, height: 174.6 ± 4.8 cm, weight: 64.5 ± 7.7 kg). All participants completed a single training session which included 50-min of tennis drills and a 30-min simulated match and were measured serve accuracy, RPE, grip strength (as an index of strength performance), and the time required to perform the spider run (as an index of agility performance). Each of the measures were taken PRE, INT, and POST training session, excluding serve accuracy as measured PRE-and POST. Neither maximum grip strength (51.3 ± 4.7 vs. 51.3 ± 6.0 kg, mean ± SD) nor spider run time (15.89 ± 0.82 vs. 15.77 ± 0.76 sec) was affected by the tennis training. The mean number of successful serves tended to decrease after the training (6.9 ± 1.6 balls, $p = 0.09$). Post-training serve accuracy was inversely correlated with the post-training RPE ($r_s = -0.81$) ($p = 0.01$). This study demonstrated that strength and agility performances were consistent during the 80-minute training period. It was found that serve accuracy is associated with perceived exertion but not strength and agility performances in collegiate level tennis players.

Keywords: muscle fatigue, serve performance, exercise intensity, strength, agility

INTRODUCTION

In modern tennis, competitive players need to maintain their serve quality. Kovacs (2007) reported that tennis has evolved into a fast-paced, explosive sport based on physical ability in which 210 km/h serves are common. Johnson et al. (2006) reported that serves (first and second) accounted for 45%, 60%, and 56% of all strokes played during service games in the French Open, Wimbledon, and the US Open, respectively. Furthermore, Ma et al. (2013) reported that the numbers of aces, valid first serves, and second service points won in 9,144 men’s singles Grand Slam tournament matches played between 1991 and 2008 were associated with match outcomes.

To win matches, tennis players need speed, agility, and power throughout their body (Kovacs, 2006). In modern tennis, Grand Slam matches involve many forehand strokes played with the dominant hand. In fact, players often play rallies in which they mostly hit forehand groundstrokes. During forehand-dominated play, tennis players have to re-position their body quickly so that they can return the ball with their dominant forehand stroke instead of a backhand one. Therefore, tennis players require fast reaction times and explosive "first step" speed and agility (Kovacs, 2006). They also need upper limb strength to enable them to return balls travelling at high speed (Kovacs, 2006). Increasing evidence suggests that motor skills such as power, strength, agility, speed, and explosiveness, as well as mental strength and highly developed neuromuscular coordination are correlated with tournament performance (Fernandez-Fernandez et al. 2009). Therefore, tennis players need to train hard to be able to achieve consistency.

If a player is not in a good physical condition, he might not be able to sustain essential characteristics such as technique, coordination, and concentration in long matches, as fatigue can impair virtually all tennis-specific skills (Fernandez-Fernandez et al. 2009). While serving is one of the most important tennis-specific skill, little research has been conducted on serve performance and how it is affected by physical conditions such as fatigue. Many previous studies examining tennis match intensity have employed the heart rate (HR) and the rating of perceived exertion (RPE) scales. Mean HR values should not be used as the sole measurement of exercise intensity, as this would not accurately represent the intermittent nature of tennis match play (Fernandez-Fernandez et al., 2009). On the other hand, the RPE can be used as an indicator of a player's exercise intensity during training. In a study in which the 15-point RPE scale was employed during tennis match play, mean values ranging from 11 ("light") to 14 ("somewhat hard") were obtained, and the peak value was 17 ("very hard"), which confirmed that periodic increases in exercise intensity occur during tennis matches (Fernandez-Fernandez et al., 2009). Previous studies on tennis performance have suggested that as the game progresses, performance falls due to increasing fatigue (Davey et al., 2002; Gomes et al., 2011; Lyons et al., 2013). Studies that examined the relationship between the RPE and tennis-specific performance found that groundstroke accuracy declined significantly among both expert and non-expert tennis players experiencing high-intensity fatigue (RPE=18) (Lyons et al.,2013). For example, groundstroke accuracy decreased by 69% when volitional fatigue developed in the Loughborough intermittent tennis test (Davey et al., 2002). Furthermore, Gomes et al. (2011) reported that the RPE increased during tennis games, and the number of rallies decreased accordingly. We need to think about how exercise intensity and fatigue influence serve accuracy. However, to our knowledge, no previous study has examined this topic. In modern tennis, the ball speed is very fast, forcing players to play shots with their dominant hand. We suspect that the load placed on the dominant arm has increased in recent years. Therefore, we hypothesized that the upper limbs would be more susceptible to fatigue than the lower limbs during the 80-minute stress test period and that fatigue would decrease grip strength by the end of the stress test period. A previous study suggested that the RPE rose as the number of rallies or match time increased (Fernandez-Fernandez et al., 2009). In addition, another study reported that high-intensity exercise, such as that experienced during tennis matches, leads to worse shot performance (Lyon et al., 2013). We hypothesized that serve accuracy decrease from the pre-stress test to post-stress test time points, and a negative correlation was detected between post-stress test serve accuracy and post-stress test RPE.

This study aimed to evaluate the relationship between serve accuracy, strength and agility performances, and the RPE during on-court training in collegiate level tennis players.

METHODS

Subjects

Eight Japanese collegiate male tennis players, who participated in the All Japan Tennis Championship for university students, were the participants in this study (age: 23.0 ± 2.6 years, height: 174.6 ± 4.8 cm, weight: 64.5 ± 7.7 kg). The subjects were right-handed. They were instructed to eat normal meals and fast for about 1.5 h before the start of the experiment. Moreover, they were instructed to avoid alcohol for a day before the experiment, and to avoid caffeine and smoking on the day of the experiment. The study protocol was approved by the ethics board of the Hokkaido University Faculty of Education Ethics Committee.

Procedures

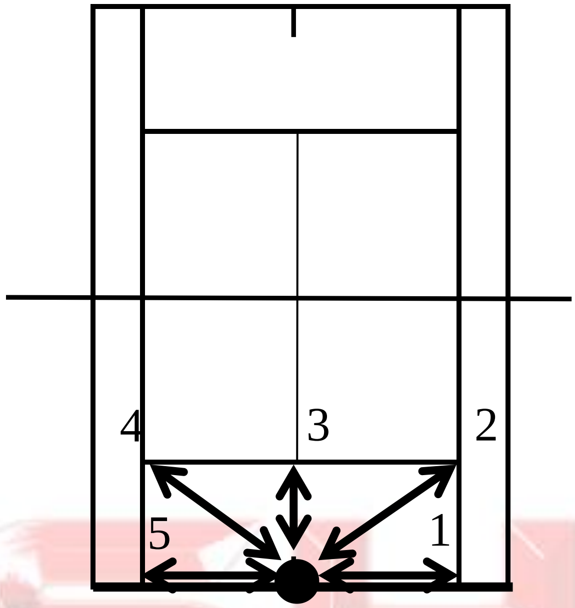
Prior to the training session, subjects were instructed to replicate their typical pre-match warmup routine. All subjects underwent the same on-court training program, which was divided into 4 sections: stroke practice for 20 minutes (direction: straight for 10 minutes and cross-court for 10 minutes); volley and stroke practice, which was performed in turns lasting 5 minutes each (direction: straight for 10 minutes and cross-court for 10 minutes, total: 20 minutes); serve practice for 10 minutes; and a simulated match (singles) for 30 minutes (total training time: 80 minutes). This acute load test and flow have been performed to give the tennis-specific stress on the subject. This physical load test was a form closer to the game of tennis for incorporating all the type of stroke and intermittent exercise similar to tennis matches. Two subjects performed the tennis-specific stress test at one time. During the stress test, they were allowed to drink water as necessary. The measurements were taken before stress test (PRE), after 40 minutes of stress test (INTER), and after 80 minutes of stress test (POST).

Index of strength and agility performances

The maximum voluntary contraction force of the dominant hand was assessed using a grip dynamometer (Takei Scientific Instruments, Niigata, Japan) as an index of strength performance. At each time point, subjects completed three attempts separated by 10-sec rest intervals.

The spider run is a tennis-specific sprint test developed by the Japan Tennis Association (2005) (Figure 1). In the present study, the time taken to perform the spider run was used as an index of agility performance. In this exercise, the subjects were instructed to stand on the center mark of a tennis court. They were then asked to run from the center mark to point 1 (Figure 1) and back again, before immediately repeating the task for points 2-5 (in numerical order). At each of the numbered points, the subjects had to touch a tennis ball. The time taken to run to each point and return to the center mark was recorded. At each time point, subjects completed three attempts separated by 10-sec rest intervals. The subjects were ordered to exert the maximal effort during these tasks. These performance tests were measured PRE, INTER and POST. These measurements were evaluated as strength and agility performances. The Mean ± SD for each time point assessed for each test.

Figure 1. Spider run. The subjects were instructed to perform the spider run as shown in the figure. They were asked to run from the central point(●) to point 1 and back again, before immediately repeating the task for points 2-5 (in numerical order). At each of the numbered points, the subjects had to bend down and touch a tennis ball.



Subjective assessments of training intensity and fatigue

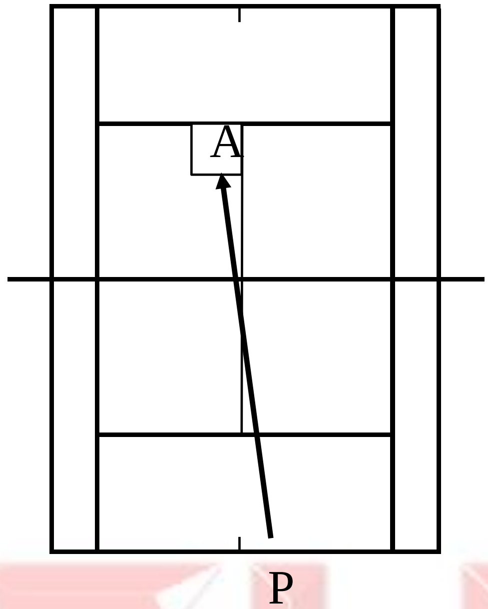
Exercise intensity was obtained using the 15-category Borg scale (Borg, 1982). The subjects were instructed how to use the scale prior to the training session. At the POST time points, they were asked, "how hard do you feel the exercise was?" before serve accuracy test.

Subjective fatigue of the upper and lower limbs by exercise were obtained using 10 cm visual analogue scales (VAS) on which 0 cm indicated "comfortable with no fatigue" and 10 cm represented "too exhausted to do anything." The subjects completed these scales at the PRE, INTER and POST time point.

Serve accuracy test

Serve accuracy was determined as the number of successful serves out of 20; i.e., serves that landed in a hitting area located in the back right of the service box (1.07 m × 1.07 m, the height of singles sticks) (Figure 2). The players were allowed to practice to test area for 1 minute before the test. The players hit their second serves within 20 seconds. The service test was performed at the PRE and POST time points, and the success of each serve was judged by two referees who were tournament level tennis players.

Figure 2. Serve accuracy. The subjects served 20 times from point P to the left side of the service box, aiming at target A. Serve accuracy was determined as the number of serves that successfully hit target A out of 20 serves. The players hit their second serves at match pace.



Statistical analysis

The subjective data regarding exercise intensity and upper and lower limb muscle fatigue were analyzed using the Friedman test. When a significant difference was detected, the Scheffe test was performed.

Comparisons between related parameters were performed using the Wilcoxon matched-pairs signed-rank test, and the interdependence of observations was evaluated using Spearman's rank correlation coefficient. All variables are expressed as mean ± standard deviation values, and p-values of less than 0.05 were considered significant.

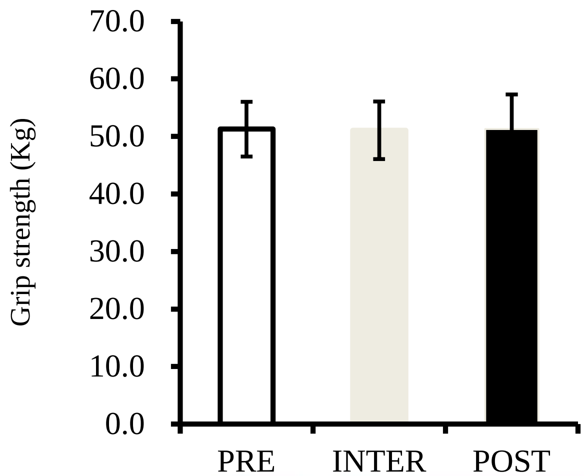
RESULTS

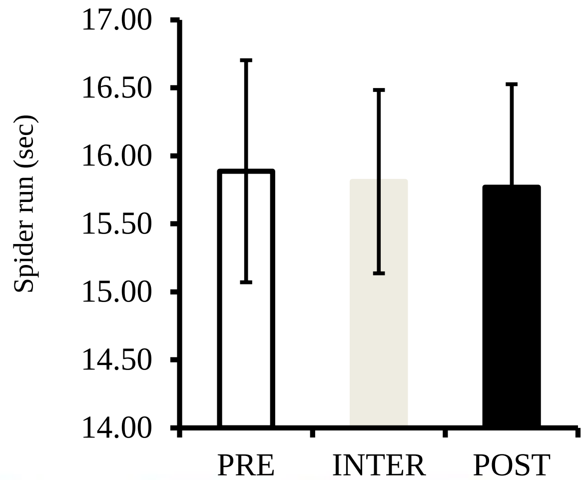
Indexes of strength and agility performances

A comparison between the mean grip strength values (as an index of upper limb muscle fatigue) obtained at each time point is shown in Figure 3a. Mean grip strength did not differ among the three time points (PRE: 51.3 ± 4.7, INTER: 51.1 ± 5.0, and POST: 51.3 ± 6.0 kg; mean ± SD). Their mean of coefficients of variation was 1.8% (range: 0.0 - 3.3%). The intraclass correlation coefficient was 0.988.

A comparison between the mean spider run times (as an index of lower limb muscle fatigue) obtained at each time point is shown in Figure 3b. The mean spider run time did not vary among the three time points (PRE: 15.89 ± 0.82, INTER: 15.81 ± 0.67, and POST: 15.77 ± 0.76 sec; mean ± SD). Their mean of coefficients of variation was 0.7% (range: 0.4 - 0.9%). The intraclass correlation coefficient was 0.887.

Figure 3a. Comparison between mean grip strength (as an index of upper limb muscle fatigue) at the PRE, INTER, and POST time points. No significant differences were detected between the time points. *Figure 3b.* Comparison between the mean spider run times (as an index of lower limb muscle fatigue) recorded at the PRE, INTER, and POST time points. No significant differences were detected between the time points.





Subjective perceived exercise intensity and upper and lower limb fatigue

The RPE recorded during the 80-minute stress test period varied between individuals. The mean RPE recorded 14.6± 2.8. The mean upper limb VAS at PRE, INTER and POST were 2.3 ± 1.3cm, 5.6 ± 1.4cm, 7.0 ± 1.1cm, respectively. In comparison with measurement at PRE, those observed at the INTER ($\chi^2(2) = 14.250$, p = 0.0466, r = .80) and POST time points ($\chi^2(2) = 14.250$, p = 0.0003, r = 1.33) were significantly higher. The mean lower limb VAS at PRE, INTER and POST were 3.3 ± 1.7cm, 6.0 ± 1.2cm, 7.5 ± 0.8cm, respectively. The VAS score for lower limb was significantly higher only at the POST time point, comparing PRE ($\chi^2(2) = 14.250$, p = 0.0004, r = 1.33).

Relevance of serve accuracy and measurement parameters

The mean serve accuracy at the PRE and POST time points is shown in Figure 4. The subjects served 20 times at each time point. The mean number of successful serves was 8.4 ± 2.4 balls before stress test period and 6.9 ± 1.6 balls after it. Thus, serve performance tended to decrease by about 1.5 balls between the PRE and POST time points (Z (7) = 1.687, p = 0.0935, r = .60).

The correlations between serve accuracy and the other examined parameters were also assessed. As shown in Figure 5, post-test's serve accuracy was found to be strongly negatively correlated with the post-test RPE (r_s = -0.81, p = 0.0129). Strength and agility performance and VAS score at upper and lower limb at post-stress test were not found relationships with the post-test serve accuracy.

Figure 4. Comparison between mean serve accuracy at the PRE and POST time points. Serve accuracy tended to decrease from the PRE to POST time points. (†: p =0.09).

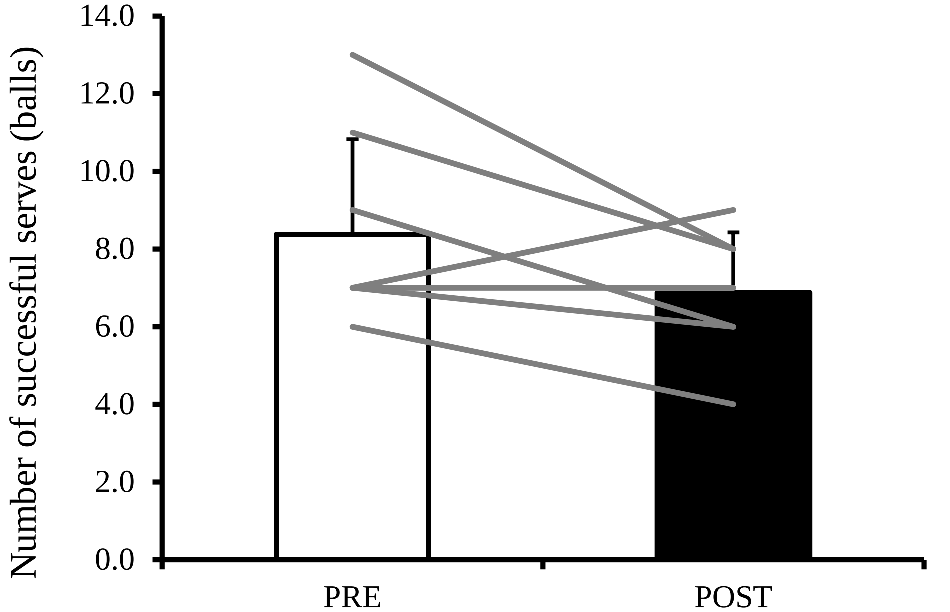
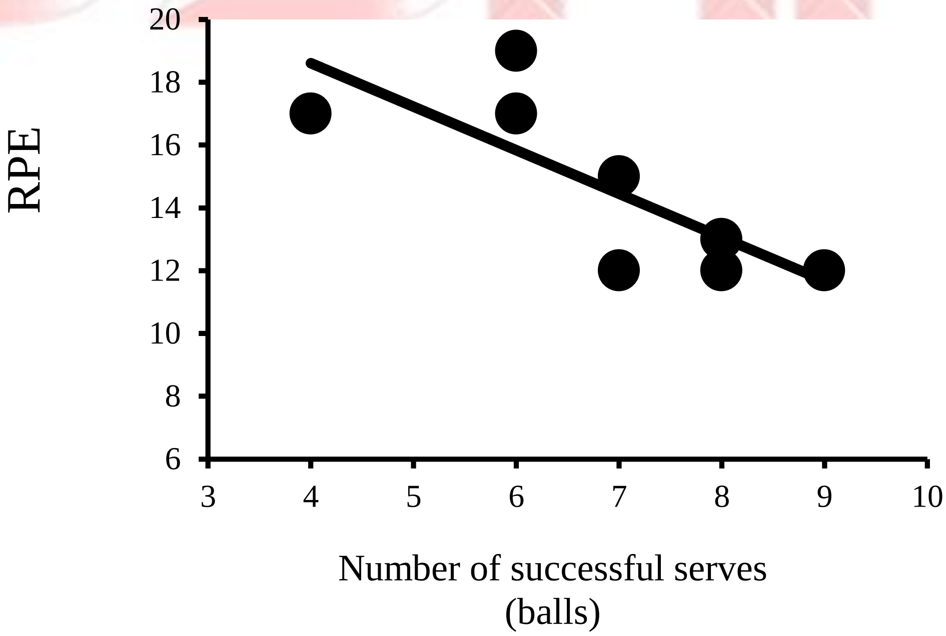


Figure 5. An inverse correlation was detected between post-training serve accuracy and post-training RPE (r_s=-0.81) (p =0.01).



DISCUSSION

This study aimed to evaluate the relationship between serve accuracy, strength and agility performance, and the RPE during on-court test in collegiate level tennis players. This study was found that strength and agility performances were consistent throughout the 80-minute tennis-specific stress test period, and subjective fatigue of the upper and lower limbs increased with progressing stress test. Post-test serve accuracy was found to be inversely associated with post-test RPE in this study.

Previous studies have reported that grasping actions, such as those involved in grip strength measurements, reflect the performance of the upper limb muscles. In the present study, mean grip strength did not differ among the three time points. The forearm muscles clearly make a significant contribution to grasping motions during exercise, e.g., holding a tennis racket. In addition, while playing tennis, the forearm is the first part of the body that feels the impact of the ball on the racket (Hennig, 2007; Wei et al., 2006). Eygendaal et al. (2007) suggested that the load placed on the arms during tennis matches has risen in recent years due to increases in ball velocity and the explosive physical activity of the players. Contrary to our hypothesis, no changes in grip strength were detected at any time point. We thought that reduction in grip strength was suppressed because it is less physical stress due to the improved performance of the racket.

The mean spider run time did not differ among the three time points. Girard et al. (2006) reported that the peak power levels exhibited by tennis players during lower limb performance were maintained despite increases in the RPE. Although the exercise type and time was different, the present study too, like the previous study, showed that lower limb performance was consistent. This study also found that agility performance (the spider run time) remains constant throughout the 80-minute stress period, which matched the result of the previous study.

Compared with fatigue before the stress test period, subjective upper limb fatigue was significantly higher at the INTER and POST time points, whereas subjective lower limb fatigue was significantly higher only at the POST time point. Subjective fatigue in upper limb increased with progressing the stress test. The fact that the subjects' upper limbs became fatigued at an early stage suggests that tennis players will often suffer chronic disorders affecting the upper limb, comparing lower limb.

Serve accuracy tended to decrease from PRE to POST time points. In addition, post-stress test serve accuracy was found to be correlated with the post-stress test RPE. However, serve accuracy was not associated with performance test（i.e., grip strength and spider run time）and subjective fatigue in upper and lower limb. The subjects maintained their physical performance（i.e., grip strength and spider run time）throughout the study period, despite the fact that their RPE increased and their serve accuracy decreased. These findings suggest that serve accuracy was relevant to the perceived intensity of the exercise.

Serves are an important tool for taking control of tennis games. This study suggests that the serve accuracy that experience physical or psychological tightness will fall during tennis matches, regardless of lower or upper limb physical performance. Tennis requires precise control and players who cannot maintain the quality of their serves will find it difficult to win games. This study also suggests that the serve accuracy of collegiate level tennis players will decline as with increasing RPE, and their chance of winning points will fall. Kovacs (2006) showed that fatigue decreases athletic performance. But no changes in lower or upper limb physical performance occurred during the 80-minute stress test period in this study. However, subjective upper and lower limb fatigue both increased during the same period. This study may be suggested that the subjects were able to maintain their upper and lower limb performance in response to our requests that they expend maximal effort during the relevant tasks, although they felt that their upper and lower limbs muscles were fatigued. We think that the subjective fatigue by stress tests did not affect the subjects' physical performance and the perceived exertion was increased to maintain physical performance. This suggestion may be thought that the subjects experienced volitional fatigue. A previous study suggested that the RPE rose as the number of rallies or match time increased (Fernandez-Fernandez et al., 2009). In addition, another study reported that high-intensity exercise, such as that experienced during tennis matches, leads to worse shot performance (Lyon et al., 2013). In this study, serve accuracy tended to decrease from the PRE to POST time points, and a negative correlation was detected between post-stress test serve accuracy and post-stress test RPE. This study was suggested that the perceived exertion on exercise relevance serve performance, especially the ability to target specific regions of the tennis court.

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