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Research article

Ball Machine Usage in Tennis: Movement Initiation and Swing Timing While Returning Balls from a Ball Machine and from a Real Server

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Abstract
Practicing with the use of a ball machine could handicap a player compared to playing against an actual opponent. Recent studies have shown some differences in swing timing and movement coordination, when a player faces a ball projection machine as opposed to a human opponent. We focused on the time of movement initiation and on stroke timing during returning tennis serves (simulated by a ball machine or by a real server). Receivers' movements were measured on a tennis court. In spite of using a serving ball speed from 90 kph to 135 kph, results showed significant differences in movement initiation and backswing duration between serves received from a ball machine and serves received from a real server. Players had shorter movement initiation when they faced a ball machine. Backswing duration was longer for the group using a ball machine. That demonstrates different movement timing of tennis returns when players face a ball machine. Use of ball machines in tennis practice should be limited as it may disrupt stroke timing.

Key words: Tennis, ball machine, server, return stroke, movement initiation.

Introduction

Returning a tennis serve is one of the most important actions in tennis. Even on the slowest court surface (clay courts), serves and returns are the strokes that influence match results the most in modern tennis games (Gillet et al., 2009). Tennis serves may reach a velocity higher than 200 kph and give a player on a short time to react. However, tennis players also use slower spin serves or second serves with decreased velocity (120 kph). Serve velocity decreases at the moment when a player makes a contact with the ball by 60-70% compared to its initial velocity (Coe, 2000). That means that the time of ball delivery is somewhere between 0.5-1.2 s, depending on serve quality (first and second serve), initial velocity and court surface (Dunlop, 2000). Kleinöder (2001) indicates that average ball delivery time of serves on a clay court is 913 ms for the first serve and 1158 ms for the second serve; however, ball delivery time on a carpet floor (faster surface) is 720 ms for the first serve and 868 ms for the second serve.

The task for a tennis player who is trying to hit the incoming ball from an opponent includes: anticipation and timing, prediction of a ball flight trajectory in space, and the moment of racquet contact (Schmidt, 1991). Crucial factors for a successful tennis return are timing and movement preparation, optimization of the initial position and reacting on velocity and direction of the moving ball during the serve (Vaverka et al., 2003). One of the stages of constructing information coupling is to attract attention to key information sources (Jacobs and Michaels, 2002). Removal of critical information sources at specific developmental stages could impede learning, resulting in unintended changes to coordination of actions, and therefore, while practice task constrains might contain some specific variables, which are available to support learner's actions during practice tasks (e.g. batting against a bowling machine – which is often used in cricket), learners should also be provided with opportunities to pick up specific variables available to support performance in competitive context (Pinder et al., 2009).

Shim et al. (2005a) argue that it is possible to anticipate the type of stroke, but not the direction of the outgoing ball. Other researches (Abernethy and Zawi, 2007; Shim et al., 2006) compared groups of novice players and expert players in a given sport. They show the different cues focusing between the groups and demonstrate higher fruitfulness of anticipation among experts. Singer et al. (1996) says that expert tennis players have a shorter reaction time and a higher accuracy of ball outcome anticipation compared to novice players. Goulet et al. (1989) say that expert tennis players focus their vision more on the opponents' racquet-arm area whereas novice players focus on the ball. Shim et al. (2006) say that a relative racquet and forearm motion provides important information for perception of differences in coordination patterns among different stroke types. This information is not available while using the ball machine. Pinder et al. (2009) suggested that the use of a ball machine changes not only available informational variables until ball release, but also the nature of delivery after ball release.

In other tennis research, Day (1980) showed that skilled tennis players were able to make predictions based on pre-contact cues. Hence most in-situ research was concerned with visual anticipation of ball direction. Williams (1999) says that a player can rely on pre-contact cues more reliably compared to on-line visual information from early parts of a ball flight. Despite the apparent importance of anticipatory cues from server's action, players regularly practice using ball machines (in which anticipatory cues are largely absent). However, information about a ball trajectory is very important to tennis players – it is also called perceptive anticipation (Crespo and Miley, 2002; Poulton, 1957). Renshaw et al. (2007) showed differences in movement initiation of backswing in cricket. Batters who used a bowling machine began the backswing 0.02 s after the ball release. However, the time against a real bowler increased to 0.10 s after the ball

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release. Similar differences were found in the initiation of downswing – downswing was initiated 0.32 s after the ball release from the bowling machine and 0,41 s after the ball release from the bowler. Pinder et al. (2011) proposed methods of how to optimize developmental programmes in fast ball games and situations, in which a ball machine can be used. It is not clear, how important prior vision of server's action actually is for timing of receiver's movements.

The aim of this study is to examine whether different constraints of returning against a ball machine compared to a real server in tennis affect timing of the return stroke. We hypothesize that movement initiation will be shorter in a group of players using a ball machine. Backswing duration is expected to be longer in a group using a ball machine, but their forward swing is expected to be shorter.

Methods

Subjects

Two representative groups of 7 right-handed males participated in the study. The group (1) with a mean age of 23.3 years (SD = 2.28) faced balls coming from a ball machine. The group (2) with a mean age of 25.3 years (SD = 4.19) and faced a real tennis player. The participants were assigned into the groups randomly.

All participants were national tournament players ranked in top 200 of the Czech national ranking system in a men's category. None of them had corrected vision. The research was approved by the ethic committee of the Faculty of Physical Education and Sport at Charles University in Prague.

Apparatus

The research proceeded in an indoor tennis court (fast surface). The ball machine imitated a tennis serve. It was placed on a base line of a tennis court, 1 m to the right from a centre service mark (same as the server's position). The muzzle of the ball machine was placed at a height of 2.8 m. The ball machine was calibrated to serve balls in only one direction with a minimum spin. There was a dark green curtain in the background of the ball machine. The action was recorded by a video camera (Sony HDR-HC3 HDV 1080i) with a frequency of 50 fps for evaluation. The video camera was placed 6 m behind the baseline and 6 m to the right of the right sideline so that we could see the server's and the receiver's action (see Figure 1).

For the group no. 2 the ball machine was replaced with an experienced tennis player (age=31), who was serving. For all participants we used the same server. The server was regularly playing national championships, other important national competitions and in addition worked as a tennis coach. He also used to play professional tennis tournaments. The server made a contact with the balls at a height of 2.8 m. That was confirmed in a pilot study (mean = 2.81 m; SD = 0.03). The server was serving a flat serve with a minimum spin. The ball trajectory was similar to the one from the ball machine. The server was able to serve balls consistently. There was a dark green curtain in the background of server.

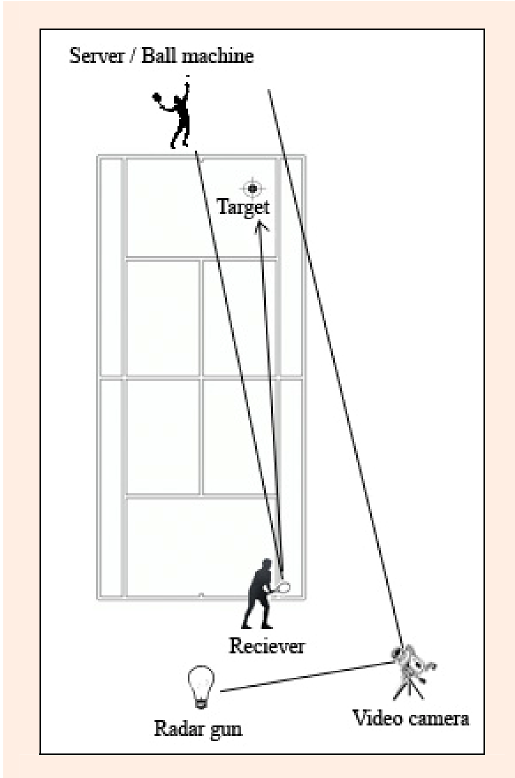

Figure 1. Experimental setup.

Task and procedures

Each participant was allowed to warm up. Subjects were told that they would be videotaped. They were hitting the balls only with a forehand stroke. The balls were sent in a way, so that the subjects did not have to leave the starting position to reach the ball, they just had to use their common stroke position. They were instructed to hit the ball with a full swing (not to set their racquet nor block the ball without any swing). They were also told to hit the ball down the line. There was a target on the opposite side of the court, which they tried to aim at. The initial position was the same for every player. This position was marked on the tennis court 0.5 m behind the base line and 0.7 m to the left from the right side line. We told all subjects to start every trial from this position.

There were two conditions during the trials based on the type of the server. The ball speed was between 95–135 kph. The ball travelled to returners in approximately 960–1240 ms. The speed was checked by a radar. If the ball hit the net or was served wide, the trial was repeated till the ball landed in the correct field.

Each subject received 3 practice trials. Approximately 0.5-1.5 second before the ball machine sent a ball, a signal "action" was called (only in a case of the ball machine). Consequently 20 trials proceeded and there was a short 2 minute break after 10 trials.

Data analysis

The research was evaluated from a two-dimensional analysis of video recordings. There were 3 different dependant outcome variables in the study. Movement initiation time was measured at the beginning of a racquet backswing. Specifically, this was the time between the ball appearance from the ball machine (or when server struck the ball) and the initial movement of a player's forearm till the start of a forehand backswing. For the second dependent variable we measured the backswing duration, i.e. the time elapsed between initial backward movement of a player's forearm to start the backswing and the initial forward movement to start the forward swing. The third dependant variable was the duration of a forward swing, i.e. the time between the initial forward movement of a player's forearm to start a forward swing and a racquet-ball contact. For data analysis we used descriptive statistics and non-parametric Mann-Whitney U two-samples test for the difference in medians (Nachar, 2008). The significance level was set at 0.05.

Results

Each group received 140 balls (20 balls per person) – group number one returned from a ball machine; group number two from a real server. No balls were missed in neither of the groups.

Receiver's movement initiation

The mean of the initial movement time was 0.05 s longer for the real server compared to the ball machine. Players responded earlier when they were facing the ball machine (see Table 1). The average ball speed was 113 kph and the average ball delivery time was 1.1 s. However, the fastest ball speed (around 130 kph) equalled to a delivery time of about 0.96 s; the slowest ball speed (around 95 kph) equalled to a delivery time of about 1.24 s. Median value of the initial movement time in a ball machine group was 0.38 s while in a real server group 0.41 s. The receiver responded later, when he was facing a real server in comparison to a ball machine ($z = 2.132$, $p < 0.05$). The time left for a players' swing was only 0.66 – 0.68 s.

Backswing duration

Mean scores for all conditions are displayed in Table 1. The median in a ball machine condition was 0.59 s; and in a real server condition 0.49 s. The backswing duration was significantly shorter when players received balls from real server ($z = -2,016$, $p < 0.05$).

Forward swing duration

The mean of forward swing duration was almost the same for both conditions (see Table 1). The forward swing towards the ball took 0.16-0.17 s. The distribution of players acting from a ball release is displayed in Figure 2. When the server struck a ball or when a ball was released from a ball machine, the time started at the value of 0.00 s. Generally, receiving players had longer initial movement time and shorter swing duration when they were facing a real server. The forward swing duration was equal for both conditions, but the backswing duration altered.

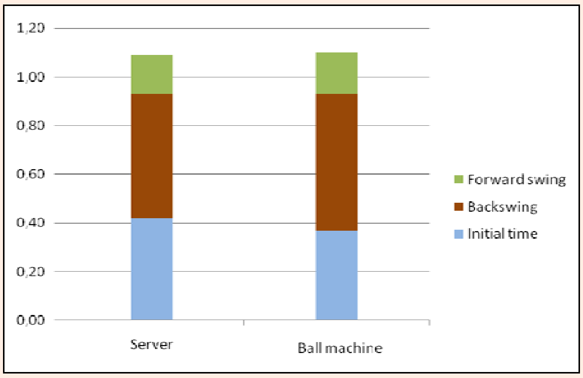

Figure 2. Time distribution of movement initiation and swing during the real server and ball machine conditions.

Discussion

We tried to examine whether there are stroke timing differences in returns in players returning against a ball machine compared to players returning against a real server. There were some limitations in this study. First, we could not use the repeated measures design because we had two different groups. We were supposed to use the same subjects for 2 different conditions. With the current design the study had been poor to attribute the results. Second, video collection frequency was low (50 fps) and only forehand returns were used. Therefore, participants did not have to decide, whether they play a forehand or a backhand return. In spite of these limitations, we obtained interesting results.

We observed different times of movement initiation. As expected, the ball machine group had a shorter initiation time comparing to the real server group. The ball machine group had to rely only on information associated with a ball flight. The server group was able to pick up additional information from server's movement patterns. As the ball machine group did not see any pre-contact cues, they tried to initiate their move as soon as possible. Vaverka et al. (2003) reported that initial movement at a professional tennis level is about 0.3 s, when top players face first and second serves (speed up to 200 kph). Also Renshaw et al. (2007) showed differences in movement initiation, because when cricket batters faced a ball machine, they initiated their moves earlier comparing to a real bowler. It also seems that players are using visual information from the speed of the racquet

Table 1. Detailed scores of movement initiation; backswing duration; forward swing duration; and ball speed.

	Initiation move		Backswing		Forward swing		Ball speed	
	Server (s)	Ball machine (s)	Server (s)	Ball machine (s)	Server (s)	Ball machine (s)	Server (kph)	Ball machine (kph)
Mean	.42	.37	.51	.56	.16	.17	112.5	113.8
SD	.04	.02	.05	.04	.02	.02	11.6	11.4
Min.	.34	.34	.48	.50	.14	.14	91.0	96.4
Max.	.48	.42	.62	.60	.20	.20	134.5	130.3
Range	.14	.08	.14	.10	.06	.06	43.5	33.9

prior its contact with a ball and from other server's moves (also see Shim et al., 2005b; or Shim et al., 2006), as they could afford later movement initiation compared to the case of a ball machine. Pinder et al. (2009) found that initial movement of cricket batters began later when they were facing a bowling machine as players needed to assimilate ball flight information. Vaverka et al. (2003) reported that top tennis players have during movement initiation 0.5 s for back and forward swing.

The backswing duration was longer in the ball machine group as we hypothesized. The ratio of initial movement and backswing duration was (40%: 60%) in the ball machine condition and (45%: 55%) in the real server condition. Renshaw et al. (2007) show the ratio of backswing to downswing within a stroke - the duration of backswing was shorter than of downswing (47%: 53%) in the bowling machine condition, whereas backswing was proportionally longer than downswing (54%: 46%) in the bowler condition.

The forward swing duration was the same for both conditions in our study, which does not support our hypothesis. This is different to findings of Renshaw et al. (2007), where the forward swing duration was longer for players in the ball machine group compared to the group with a real bowler. However Gibson and Adams (1989) say that the downswing against the bowler occurred earlier.

In general, we can see some differences in movement time distribution in the group using a ball machine and a real player in various sports (i.e. cricket and tennis).

Altering the informational constraints of practice caused major changes to the information-movement couplings of developing cricketers (Pinder et al., 2009). The use of a bowling machine resulted in batters converging on nonspecifying variables, delaying the development and attunement to specifying variables (Araújo et al., 2007). Renshaw et al. (2007) argue that practising batting against bowlers will afford attunement to information from bowlers actions and will support the acquisition of appropriate information-couplings for batting in competitive performance; however, batting against bowling machines will result in attunement to early ball flight information, leading to information-movement couplings which may be consistent, but lacks the adaptability needed against bowlers.

Timing of tennis receiver's movements (backswing) is altered with a ball machine. Player is acting differently while using a ball machine compared to a real server. This shows that the stroke timing was different. Pinder et al. (2009) say that using ball machines affects movement timing and coordination of skilled cricket batters and other athletes. We can support this finding as there were differences in movement initiation and backswing duration when players faced a ball machine. Bartlett (2003) suggested that batting against a ball machine is different compared to batting against bowlers. Ball projection machines may be used in various sport games such as tennis, baseball and cricket. We have demonstrated some differences in movement timing against a ball machine. Although there are some cricket studies examining the same topic, more research in tennis is needed to support our findings; also in addition, this type of research should be done also in other sports (e.g. baseball, softball) where the use of a ball machine during practice is often common.

Conclusion

Players have shorter initial movement time when they face a ball machine. That shows that they have more time during the backswing phase resulting in a different swing and movement timing. There is no difference in the forward swing duration between the server and the ball machine conditions. Playing against a ball machine affects stroke timing so that using a ball machine in practice sessions should be limited to minimum. Pre-contact cues are very important for stroke timing.

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Key points

- Players have shorter initial move time when they are facing the ball machine.
- Using the ball machine results in different swing timing and movement coordination.
- The use of the ball machine should be limited.

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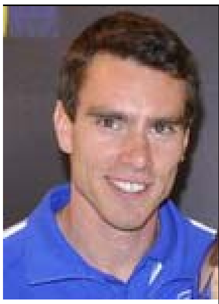

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