A STUDY TO INVESTIGATE THE RELIABILITY AND CONSISTENCY OF THE SPORTS TUTOR TENNIS CUBE™ VELOCITY, TRAJECTORY AND LANDING POINTS

Michelle Norris, Sarah Breen, Ross Anderson and Ian Kenny

Biomechanics Research Unit, University of Limerick, Limerick, Ireland

The purpose of this study was to investigate the reliability and consistency of the Sports Tutor Tennis Cube™ ball launcher. Five identical (mass, diameter) competition standard tennis balls were each launched twenty-five times and flight was assessed using 3D infra red motion analysis. 3D resultant velocity was found to be 18.9 ± 0.89 m/s, landing points had a coefficient of variation in the lateral direction of 8.28% and 18.4% in the vertical direction Trajectory was also projected to estimate ball carry showing ball flight range (horizontal spread) of 14.9 ± 3.71 m. Results showed that whilst the commercially popular tennis ball launcher was stroke specific, it exhibited a level of variability This could be seen to bring variance to tennis players' practice that they once thought did not occur with the use of tennis ball machines.

KEY WORDS: Ball machine, Speed, Tennis ball

INTRODUCTION: The purpose of this study was to investigate the variability of outcome of commonly used projectile launchers. Machines such as tennis ball launchers and baseball pitchers are used from recreational to professional levels yet no previously published studies exist as far as the authors are aware on their accuracy and consistency, however numerous studies have used these machines and reported these data. For example in tennis, the CV for ball projection speeds typically ranges from 2-10 percent (Knudson, 1991; Bower & Cross, 2005; Cooke & Davey, 2005) and angles of projection with 7 percent variation (Knudson, 1991). While some are designed to vary projection to simulate a tennis rally many professional players and coaches encourage the use of tennis ball launchers (TBL) in practice as they "can be programmed to serve the exact ball required in terms of length, trajectory, angle and spin for both tennis and table tennis" (Launder, 2001 p.122). However, it is unclear if recently manufactured TBL's have improved upon the consistency of ball projection variables and so for this study a popular commonly used TBL, the Sports Tutor Tennis Cube™ was investigated.

METHODS: For the relatively slow tennis ball launch velocity selected (15-25 ms^{-1}) three-dimensional high speed motion analysis was deemed our laboratory's most accurate method of assessing ball flight. Thus pilot trials were conducted using two tennis balls wrapped with 3M™ reflective tape to examine the robustness of the tape wrapping. Trials showed that taping remained intact on ball one up to trial thirty-four and ball two up to trial twenty-five. It was therefore decided that to perform one hundred trials five balls would be needed, twenty trials each. Equipment & Materials: The Sports Tutor Tennis Cube™ launcher was used. Five new premium competition-standard tennis balls (Wilson Trainer™) were each labelled A-E and wrapped with five pieces of retro-reflective tape (5 cm diameter, 21 cm length) so that they were fully covered. Wrapping followed standard retro-reflective marker covering protocol indicated by leading motion analysis system manufacturers (Motion Lab Systems 2011). For the current study the TBL was placed 3.58 m back from a target wall, at a height of 0.79 m and surrounded by a semi circle arrangement of 6 Eagle digital cameras (Motion Analysis Corporation Ltd., Santa Rosa, California) operating at 400-Hz. The TBL was set to Speed 10 and the trajectory was at its lowest, nearly horizontal trajectory 1. These settings remained constant throughout the experiment. Protocols: Data collection was triggered via manual start. The five tennis balls were then fired twenty times each at the wall and 3D data was collected for each trial. The tennis balls were tracked from TBL projection to wall impact and rebound. Data were filtered using Cortex at 6-Hz. Data Analysis: Variables examined were horizontal velocity, projected trajectory and landing points. Descriptive statistics (mean, standard deviation, range and quartiles) were calculated. Variability analysis was performed by applying a coefficient of variation test to all data. The coefficient of variation was calculated as the standard deviation divided by the mean and expressed as a percentage. 95% confidence ellipse was also calculated for the landing points (mean ±SD) (Ennos, 2007). Projected trajectory was calculated using initial velocity, angle of release and height of release taken 3 frames after TBL ball projection to allow clearance from the machine.

RESULTS: The TBL's maximum speed as indicated by the manufacturer was to be 22.4 m/s (50 mph). However infra-red motion analysis recorded a maximum initial resultant velocity of 20.9 m/s. The initial velocity was used because it was observed that after the initial output, velocity decreased over the flight path and ball aerodynamics was not the aim of the current study. Initial velocity was 18.9 ± 0.89 m/s. The range of the data were 5.4 m/s indicating that the data are spread over a large interval. As there were some outliers present in the results these can affect the variability magnitude and so the interquartile range was derived and found to be 1.97 m/s. Landing points (wall target) were also analysed. Results showed (Figure 1) that 95% of landing points landed between 500 and 1000mm in the lateral and 500 and 800 mm in the vertical. Results also showed that the coefficient of variation in the lateral direction was 8.28% and the coefficient of variation in the vertical direction was 18.4%.

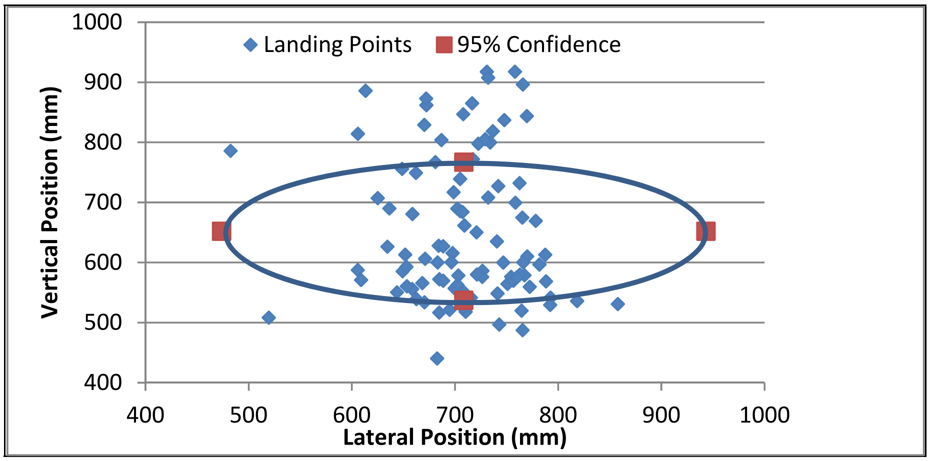

Figure 1. 95% Confidence ellipse of all ball landing points as captured by high speed infrared 3-D motion analysis illustrated in the lateral plane.

Ensemble graphs of each ball trajectory show differences in trajectory within and between the five balls projected (Figure 2). Angle of release over the 96 trials was 8.98 ± 3.98 º.

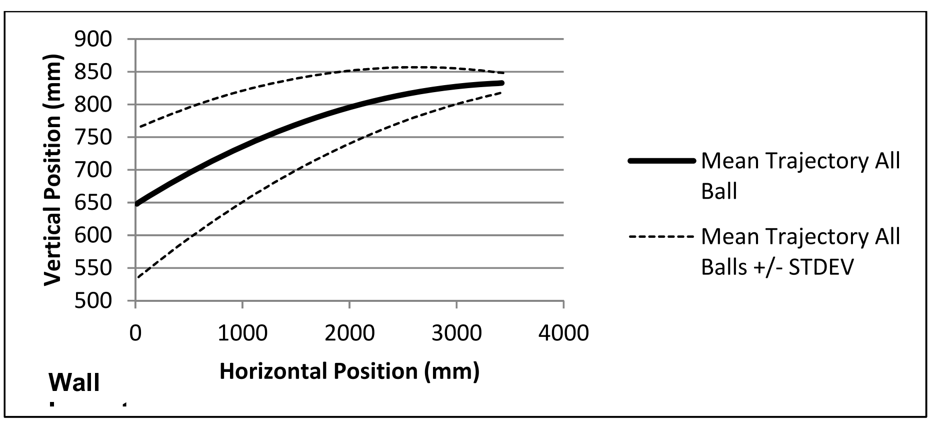

Figure 2. Mean trajectory for all balls with normalised data illustrated in the horizontal plane.

The projected trajectory was also calculated. Results showed a range of 14.9 ± 3.71 metres in the horizontal direction and 1.43 ± 0.62 metres in the lateral direction (Figure 3).

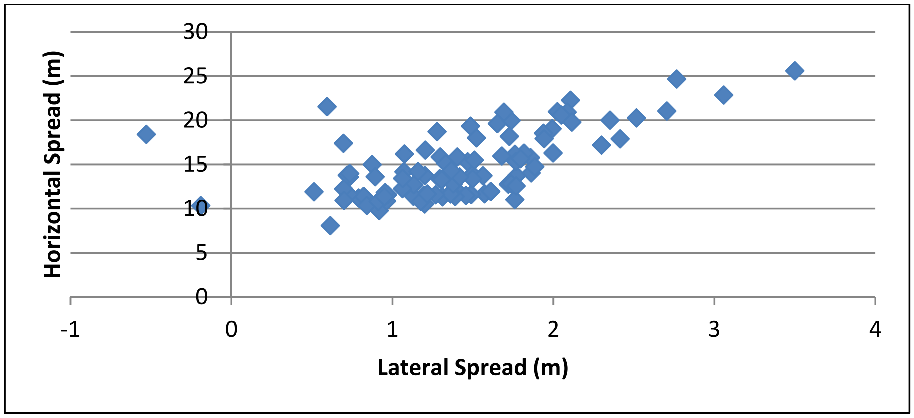

Figure 3. Lateral and horizontal spread of projected ball trajectories over the 96 trials.

DISCUSSION: The current study set out to assess the reliability and consistency of the Sports Tutor Tennis Cube™ to ascertain whether this TBL is as accurate as players and coaches expect it should be in repeating shot conditions (Launder, 2001). The results of the present study showed variation in the TBL performance. In the present study it was found that the maximum initial projection velocity was almost 1.5 m/s below what the manufacturer claimed. As advertised the TBL's maximum velocity is 22.4m/s (50mph). It also found similar results of projectile velocity variance as those found by Bower (2005) and Cooke and Davey (2005) perhaps indicating that advances in technology have not decreased velocity variability. However, this could also be due to the reflective tape on the balls reducing grip (therefore decreasing ball speed) when in contact with the TBL's rotating wheels. Another factor looked at was trajectory. It is known that the factors affecting a trajectory of a projectile are angle of release, height of release and velocity of release. It is already seen that the velocity altered over the range of shots. The angle of release also varied by ± 3.98º. Variation in angle of release could have been due to the way in which the ball was compressed between the two spinning wheels of the TBL. The counter rotating wheels of the TBL can be tilted to adjust angle or release. Although for this present study the trajectory on the TBL was constant the balls fall from the ball bin due to gravity and so their positioning when they connect with the wheels are random. It is also possible this change in trajectory was related to the Magnus effect. Although the present study did not examine ball spin a study by Nathan (2007) looked at the effect that spin has on a baseballs trajectory when projected from a baseball pitching machine and found that when a baseball was projected at various rates top spin it led to the balls having different trajectories. This variation of velocity, release angle and perhaps Magnus effect influence all combined to result in spread of landing points. Landing points displayed quite a large spread, 500-1000 mm in the lateral and 500-800 mm in the vertical .This spread would have been large in the lateral direction when put into a play context as this spread reached up to 1000 mm. This would have meant a change in the players' positioning and stance in order to return the ball. These results are dissimilar to those found by Davey, Thorpe and Williams (2002) and Cooke and Davey (2005) who found the placement feeds of the tennis ball machine used in their study's to be accurate over multiple trials. The last important analysis of the TBL which was conducted was to project the tennis ball trajectories so as to put them into real life context on a court. In tennis when learning from a young age static, deliberate practice is first utilised. Deliberate practice is based on the idea that development of a sport is related to the hours put in and the type of training done (Ericsson, Krampe & Tesch-Romer, 1993). Static practice is performing a specific set of actions. In tennis these are often performed against a tennis ball machine as they are seen to be far more consistent then a human opponent. However this present study shows that there is a degree of inconsistency leading to a more dynamic practice. Looking at the range of the balls trajectory in the horizontal direction, there is a large variation, 14.9 (±3.71 m). This margin of variability allows room for different return shots to be practiced as the ball falls short or carry further than expected. In the lateral direction the variation is not as wide, 1.43 (±0.62 m). This means less variation would be seen in terms of backhand shots and shots played near the sides of the body.

CONCLUSION: Results show that the Sports Tutor Tennis Cube™ does present inconsistency. Although using the same initial setting, not every shot produced the same trajectories and velocities. When applied to the field people who practice with this TBL will respond to the machine with a varying repertoire of shots although perhaps trying to undergo static training. Further research should be done on a range of pitching machines to investigate their accuracy and consistency using both balls with and without tape.

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