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Research article

Accuracy and Reliability of a New Tennis Ball Machine

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Abstract
The aim was to evaluate the reliability of a newly-developed ball machine named 'Hightof', on the field and to assess its accuracy. The experiment was conducted in the collaboration of the 'Hawk-Eye' technology. The accuracy and reliability of this ball machine were assessed during an incremental test, with 1 min of exercise and 30 sec of recovery, where the frequency of the balls increased from 10 to 30 balls·min^{-1}. The initial frequency was 10 and increased by 2 until 22, then by 1 until 30 balls·min^{-1}. The reference points for the impact were 8.39m from the net and 2.70m from lateral line for the right side and 2.83m for the left side. The precision of the machine was similar on the right and left sides (0.63 ± 0.39 vs 0.63 ± 0.34 m). The distances to the reference point were 0.52 ± 0.42, 0.26 ± 0.19, 0.52 ± 0.37, 0.28 ± 0.19 m for the Y-right, X-right, Y-left and X-left impacts. The precision was constant and did not increase with the intensity. (e.g ball frequency). The ball velocity was 86.3 ± 1.5 and 86.5 ± 1.3 km·h^{-1} for the right and the left side, respectively. The coefficient of variation for the velocity ranged between 1 and 2% in all stages (ball velocity ranging from 10 to 30 balls·min^{-1}). Conclusion: both the accuracy and the reliability of this new ball machine appear satisfying enough for field testing and training.

Key words: Technology, tennis, testing, training, ball-machine.

Introduction

The interest and limits of using a ball machine for technical training, physical conditioning or testing in tennis have been previously shown (Baiget et al., 2014; Fargeas-Gluck and Leger, 2012). However the stroke timing of players may be affected by being opposite to a ball machine (Carboch et al., 2014), but it remains interesting to standardize specifically the protocols for physical components development. We emit some limits when the balls are sent by coaches trying to follow a defined rhythm and a ball quality. The reliability may be disturbed by the focus and the attention on technical execution. Therefore we prefer the use of ball machine to allow the fulfillment of physical fitness development on the tennis court. For example, despite the non-specific situation (e.g. no opponent which can create instability in the game), Smekal et al. (2000) or Baiget et al. (2014) used a ball machine (The Playmate TH – Metaltec and the Pop Lob Airmatic 104, respectively) during their specific tennis field tests. However, the use of a mobile ball machine, which could throw balls with different spin, velocities, and rebound zones, would offer new possibilities in training drills and for testing. More specifically, it would improve the assessment of the energetic and technical capacities of the players during an incremental field test. However, the accuracy and the reliability of such a ball machine have never been published.

The use of a reliable and accurate ball machine can be beneficial in different situations: technical and physical training and testing at any level and age, from the beginner to the elite player; using different types of ball and different exercises.

Therefore, the aim of this study is to evaluate the reliability of a newly-developed ball machine ('Hightof') on court and to assess accuracy of the balls released from this ball machine using the Hawk-Eye technology.

Methods

Description of the 'Hightof' ball machine

The 'Hightof' ball machine weights 60 kg, for a height of 99 cm, a width of 62 cm and a depth of 70 cm (Figure 1). It holds 300 balls and ejects balls according to the electronic command printed on the screen. The balls are thrown thanks to the technology used with 2 rollers; one roller ejects the ball in a direction pre-defined, the second one makes turn the ball.

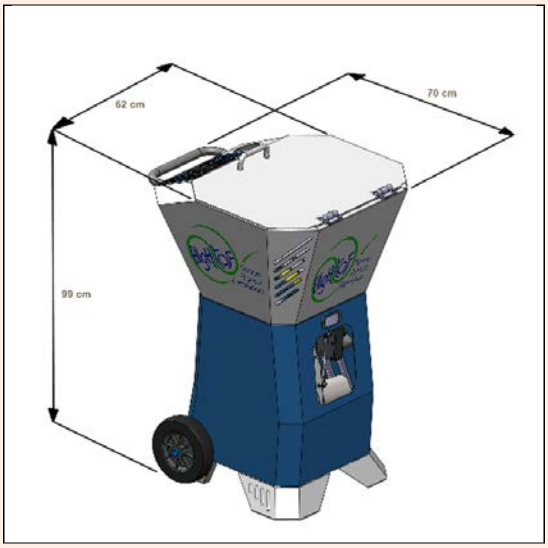

Figure 1. Dimensions of the 'Hightof' ball machine.

Ball throws are executed by a total of 3 motors to combine parameters of distance, velocity, and time. The

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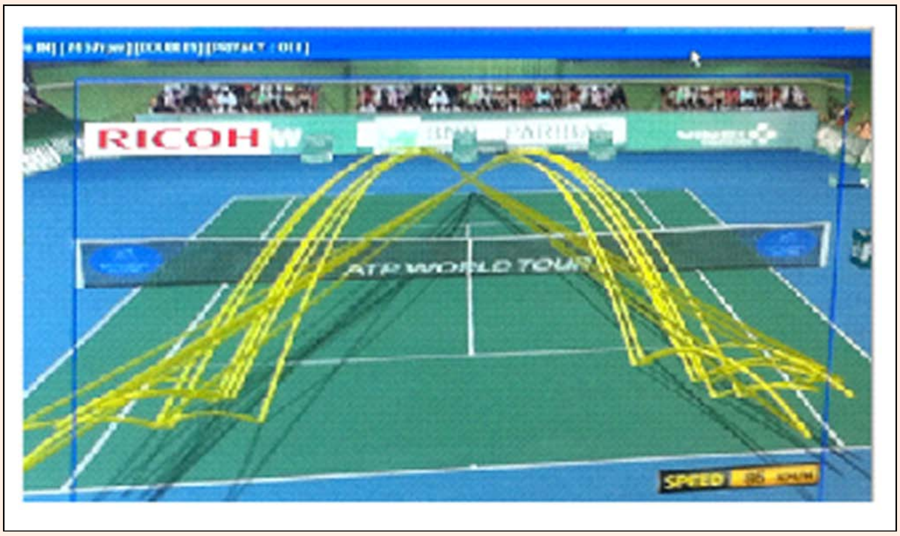

Figure 2. **Ball speed measured by 'Hawk-Eye' Technology (i.e stage 26 balls·min^{-1}).**

target zone is controlled by 2 motors. One gives the X axis and the other one the Y axis. Another motor governs the time between ball throws and sequences. With the Hightof' machine, there is only one ball velocity corresponding to 86 km.h^{-1}. We can only modify the spin. All the settings can be prepared in situ, or before either on a computer or a smartphone. The 'Hightof' machine works with all operating systems.

The device allows setting and recording a predefined program (number and frequency of balls, duration of rallies; ball velocity; zones of impact). Of interest is the possibility for the device to record return ball velocities from the player (with integrated radar).

Experimental design

The experiment was conducted in the collaboration of the 'Hawk-Eye' technology that was installed for the ATP tournament Paris Bercy Master 1000 (Figure 2). This technology was validated on 14 October 2005, when the ITF announced that 'Hawk-Eye' had met the standards set by the committee comprising representatives of the ITF, ATP and WTA Tour for use in reviewing decisions made by on-court officials. The accuracy and reliability of the ball impact location and the reliability of the ball velocity from the machine were assessed. Even the machine can produce 3 different topspin, we only consider the topspin intermediate, which is currently used during testing and training.

Incremental test

The accuracy and reliability of the 'Hightof' machine were assessed during an incremental test, with 1 min of exercise and 30 sec of recovery, where the frequency of the balls increased from 10 to 30 balls.min^{-1}. The initial frequency was 10 balls·min^{-1} and increased by 2 balls·min^{-1} until 22 balls.min^{-1}, then by 1 balls·min^{-1} until 30 balls·min^{-1}. The type of ball ejected by the 'Hightof' ball machine was determined with top spin. The trajectories of balls were programmed from the screen of command of the ball machine. We alternated balls to the right and to the left on a zone situated between the line of service court and the ledger line of court.

The accuracy of the device was evaluated by the distance calculated by trigonometry between impact and the reference point on right and left sides (Figure 3).

Statistical analysis

Mean and standard deviation (SD) and coefficient of variation (CV) were calculated for all the ball impacts and ball speeds. CV was calculated as the ratio of the standard deviation by the mean.

For all variables (i.e. ball velocity and Y and X distances to the reference points), we compared means by paired t-test. We calculated mean (standard deviation), we assessed the strength of the relationships between Hawkeye and Hightof data using intraclass correlation coefficients (ICC). Finally we calculated mean bias [95% lower limit; 95% upper limit] using the Bland-Altman method.

Results

The reference points for the impact were at 8.39 m from the net and 2.70 from lateral line for the right side vs 8.74 m and 2.83 for the left side. The accuracy of the balls released from the 'Hightof' machine (evaluated by the distance calculated by trigonometry between impact and the reference point) was similar on right and left sides (0.63 ± 0.39 vs 0.63 ± 0.34 m). The accuracy was constant and did not increase with the intensity (e.g. ball frequency) (Figure 4).

The ball velocity (from the machine) was 86.3 ± 1.5 and 86.5 ± 1.3 km·h^{-1} for the right and the left side, respectively (Figure 5). The velocity remained stable during the test. The coefficient of variation for the velocity ranged between 1 and 2% in all stages (ball velocity ranging from 10 to 30 balls·min^{-1}).

The distances to the reference point were 0.52 ± 0.42, 0.26 ± 0.19, 0.52 ± 0.37, 0.28 ± 0.19 m for the Y-right, X-right, Y-left and X-left impacts. The means for ball speed (right and left sides) and impact location (X

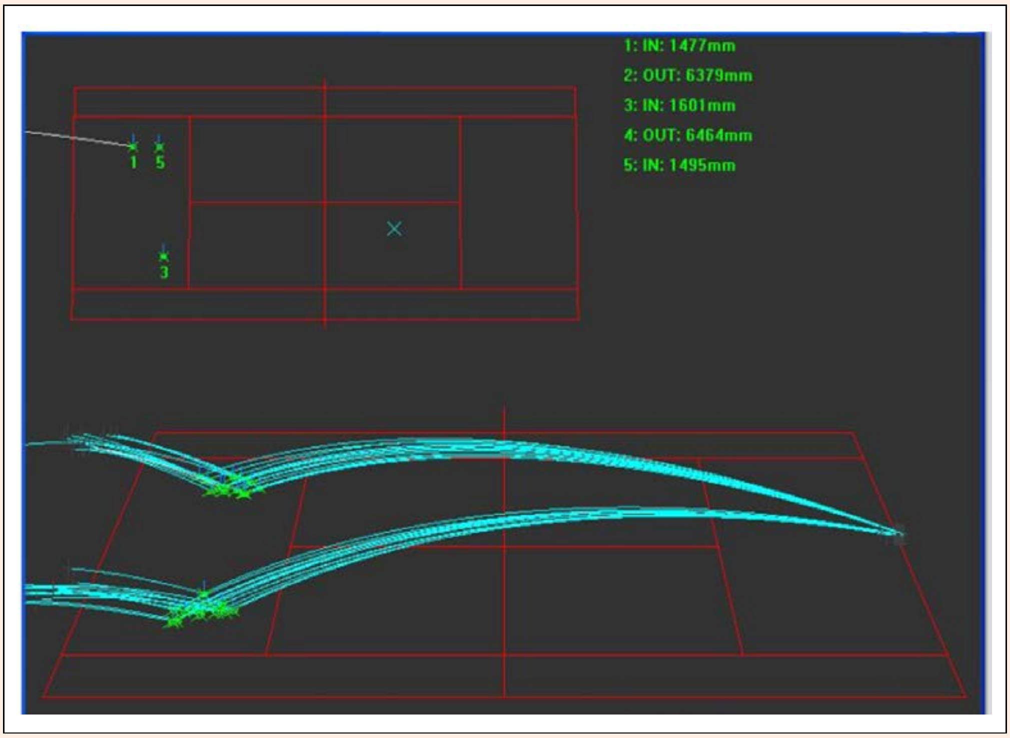

Figure 3. **Ball impact measured by 'Hawk-Eye' during the experiment (i.e stage 26 balls·min^{-1}).**

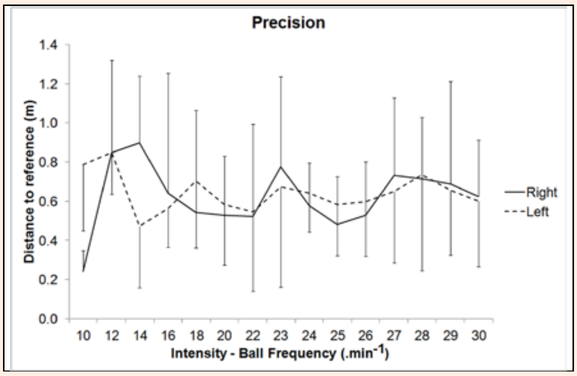

Figure 4. **Accuracy of the 'Hightof' ball machine: distance of impact to the reference point on right and left side of the court at ball frequencies increasing from 10 to 30 balls·min^{-1}.**

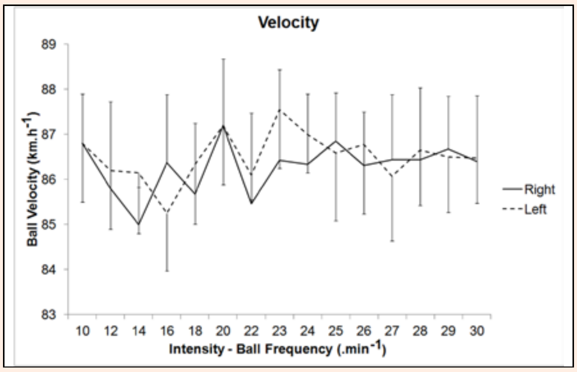

Figure 5. **Velocity of the ball from the 'Hightof' ball machine on right and left side of the court at ball frequencies increasing from 10 to 30 balls·min^{-1}.**

and Y axes on right and left sides) were not statistically different with p values from paired t-test ranging between 0.59 and 0.97.

The mean bias and 95% limits of agreement using the Bland-Altman method are -0.06 [-3.04; 2.92] km·h^{-1} for the ball velocity on right side; 0.04 [-2.59; 2.50] km·h^{-1} on left side; 0.00 [-0.82; 0.81], 0.00 [-0.38; 0.37], 0.00 [-0.72; 0.72] and 0.01 [-0.37; 0.39] m for the Y-right, X-right, Y-left and X-left impacts.

Discussion

The accuracy and the reliability of the 'Hightof' ball machine were assessed by using the 'Hawk-Eye' Technology. Both the accuracy and the reliability of the new ball machine appear satisfying enough for field testing. The ball velocity was relevant for an analysis of the quality of ball during technical drills, as practiced by professional tennis players (86 km·h^{-1} for topspin balls) (Fernandez-Fernandez et al., 2010). Moreover, the high reliability of the speed would allow accurate displacements of the players from left to right during tests and avoid to surprise the player during a sequence (Figure 5). The accuracy of the balls released from the ball machine supported by the low standard deviation at the different ball frequencies (Figure 4) would allow a good practice of the drills and to anticipate the run distance by the athletes.

The use of a reliable and accurate ball machine can be beneficial in different situations: technical and physical training, and testing at any level and age, from the beginner to the elite player, using different types of ball and different exercises. The 'Hightof' has already been used in few studies to assess new design of aerobic training with or without ball hitting (Pialoux et al., 2015) and to highlight the interest to implement motor imagery during such task-specific training (Guillot et al., 2015). It underlines first the interest to use ball machine for standardizing and optimizing the training time, and secondly the usefulness of this new technology in the way of specific fitness testing, and training. However, the practical relevance of the study remains limited as only a fixed ball velocity was tested for reliability. For players with different characteristics (e.g. age, beginners versus professionals, etc.), the selection of different ball speeds should be possible. Therefore, further studies investigating the reliability of different ball velocities as well as various ball rotations (i.e. spin) are required.

We cannot compare the present results with the existing literature since the accuracy and the reliability of any ball machine have never been published. The relevance of shuttle running tests has been questioned in tennis, leading to the development of so-called “sport specific” protocols. Therefore, recent field tests have been used in tennis to determine the endurance capacity (Girard et al., 2006; Smekal et al., 2000) or technical performance (i.e., stroke precision, accuracy) (Fernandez-Fernandez et al., 2010; Smekal et al., 2000) of athletes with acceptable accuracy under standardized conditions. However, for further improving the specificity of these tests, two points are important: 1) the use of the tennis court dimensions and 2) the combination of specific footwork and hitting actions. None of the previous tests proposed replicates the characteristics of the tennis actions. During the Navten test (Fargeas-Gluck and Leger, 2012), the coach throws the balls to hit the target zone at a frequency that increases at each 1-min stage. The rhythm in conducted by a CD player. During the specific incremental field test of Girard et al. (2006) and the Hit and Turn Tennis Test (Ferrauti et al., 2011), players were instructed to mime a powerful stroke without ball. In our opinion, any specific field test requires “real strokes” and therefore using a ball machine. Then the reliability of this test would be highly dependent of the validity and the reliability of the ball thrown. In addition, the ball machine has to be portable, capable of operating under a wide range of environmental conditions, and able to operate accurately, simply and quickly. Since the ‘Hightof’ ball machine appears as accurate and reliable, it should lead to more efficient and specific evaluation design and associated physical training programs.

Conclusion

The present study aimed to evaluate the reliability of a newly-developed ball machine named 'Hightof', on the field and to assess its accuracy. Both the accuracy and the reliability of this new ball machine appear satisfying enough for field testing and training.

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Key points

- The reliability and accuracy of a new ball machine named 'Hightof' were assessed.
- The impact point was reproducible and similar on the right and left sides (±0.63 m).
- The precision was constant and did not increase with the intensity (e.g ball frequency).
- The coefficient of variation of the ball velocity ranged between 1 and 2% in all stages (ball velocity ranging from 10 to 30 balls·min^{-1}).

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