IS BALL-RACKET CONTACT CONCOMITANT WITH THE MAXIMAL RACKET SPEED IN YOUNG TRAINED TABLE TENNIS PLAYERS?

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Previous table tennis studies have broadly assumed the racket to reach its maximal speed at ball-racket impact but only few identified this instant experimentally. Hence, there remains a lack of information regarding the validity of this hypothesis and therefore a need to develop a strategy to identify ball-racket contact that can be implemented into future experimentations. A 3D motion capture system was used to measure racket movements of seven young talents (12.6 ± 0.8 years old) -a category that had not been tested yet- during topspin forehand and backhand drives. Ball-racket impacts were identified with a synchronized microphone. Maximal racket speed and sound peak occurrences were compared, and racket parameters (speed, orientation) were calculated at both events. Differences emerged when examining participants individually for forehand drives and over the whole cohort for backhand drives, with consequences on both racket orientation and speed between the two events. As it was shown that ball-racket contact is not always concomitant with the maximal racket speed, futures studies should add supplementary equipment such as a synchronized microphone to identify the exact impact time.

KEYWORDS: impact, kinematics, table tennis, timing.

INTRODUCTION: Beyond their impact on the playing strategy, the efficiency of table tennis shots directly depends on ball-racket contact. Therefore, in a coaching perspective, improving the shots' performance would require the investigation of the biomechanics of both the player and the shots during the whole attack phase, which means until ball-racket contact. In line with this, one key component is the moment of impact between the ball and the racket.
Until now, most of the studies assumed the ball-racket contact to be concomitant with the maximum racket speed during the stroke (Ferrandez et al., 2020). Only few articles have focused on into proving this coincidence, using various techniques, and they determined the ball-racket impact to be close to (Iino & Kojima, 2009; Zhang et al., 2017) or to match (Sheppard & Li, 2007) the moment when the racket speed was maximal. To identify the impact, some authors added thin strips of reflective material to the ball and observed ball trajectory with a motion capture system (Sheppard & Li, 2007); others used a high-speed camera to track balls covered with ink marks (Iino & Kojima, 2009, 2011) or a combination of two high-speed cameras with different orientations (Iino & Kojima, 2016); and more recently, others measured the exact contact time by fixing an acoustic sensor (Bańkosz & Winiarski, 2017) or a piezoelectric sensor (Bańkosz & Winiarski, 2020) directly on the surface of the racket. However, most of these studies focused on forehand strokes in adult highly trained table tennis players and it is still unsure that this remains valid for backhand strokes and for young players. Hence, the aim of this study was to test the hypothesis of concomitance between ball-racket impact time and maximal racket linear speed on young talented players and on various types of shot, including top spin forehand and backhand drives.

METHODS: Seven young talents (12.6 ± 0.8 years old) and enrolled in an intensive table tennis training centre (around 20h of practice per week, all ranked in the top 6% of all the French licensed players, all categories mixed) participated to the experiment. They were asked to

perform topspin forehand and backhand drives at maximal intensity using their own racket. The balls were thrown and returned by a second player, but only one player was recorded at a time and from 5 to 15 acquisitions (including from 2 to 14 strokes each) were measured for each player.
The experiments took place in a biomechanical laboratory using a 15-cameras optoelectronic motion capture system (Vicon® System, ©Oxford Metrics Inc., UK) running at a 200 Hz frequency, with a synchronized unidirectional microphone (2000 Hz) placed aside to the table on the tested participant's side. Because the analogue signal was sampled at a very low frequency for audio acquisition, the sound of four forehand drive acquisitions of the first participant was additionally acquired by a remote omnidirectional microphone at 44.1 kHz to verify the ability of the under-sampled signal to allow for ball-racket impact time identification.
At each time frame, the centre of the racket head was registered in the motion capture coordinates system based on the three racket markers' raw data, and the racket centre linear velocity was calculated using the Savitzky-Golay algorithm (with a 7-points-window and third degree polynomials) (Savitzky & Golay, 1964) and the resulting speed (i.e. norm of the velocity vector) was retained to identify the instant of maximal racket speed. Regarding the signal from the unidirectional microphone, the upper envelope was extracted, and the ball-racket impact sounds were identified by applying a threshold (fixed manually at 1.3*99th percentile of the unidirectional microphone sound signal) onto this resulting signal and looking at the closest audio peak from the maximal racket speed occurrence. For the trials where the additional microphone (set at 44.1 kHz) was available, the synchronization between the two audio signals was performed based on peak occurrences on the whole signals.
To evaluate the delay between the two events (audio peaks and maximal racket speed) the relative and absolute time differences were calculated. To examine the effect of this delay on racket parameters, the racket velocities, and orientations (angle between the normal vector of the racket plane and the vertical) were computed.

RESULTS:

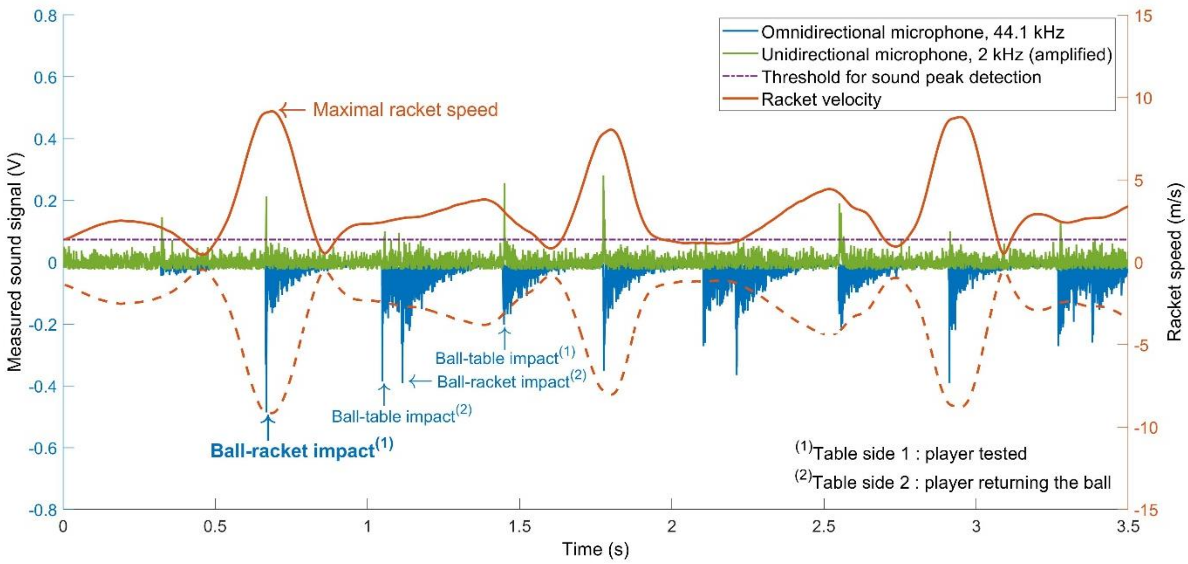

Figure 1: Upper envelopes of the measured sound signal of both microphones (2 kHz and 44.1 kHz) and racket speed over the duration of one typical acquisition of three strokes. Each local speed maximum bell represents one stroke. The signal of the 44.1 kHz microphone is plotted symmetrically to the time axis for reading purpose.

<u>Identification of ball-racket contact time:</u> regarding the viability of using a microphone for ball-racket contact identification, Figure 1 shows that simultaneous sound peaks occurred close to the maximal racket speed on both microphones. However, even if the unidirectional

microphone showed visible peaks at the impact moments (despite its low frequency of acquisition of 2 kHz), some peak could be not retained with respect to the chosen threshold, resulting in a loss of stokes that could have been analysed. However, in this study, the number of acquisitions that were recorded were 5 to 15 (including from 2 to 14 strokes each) depending on the participant and the type of shot.

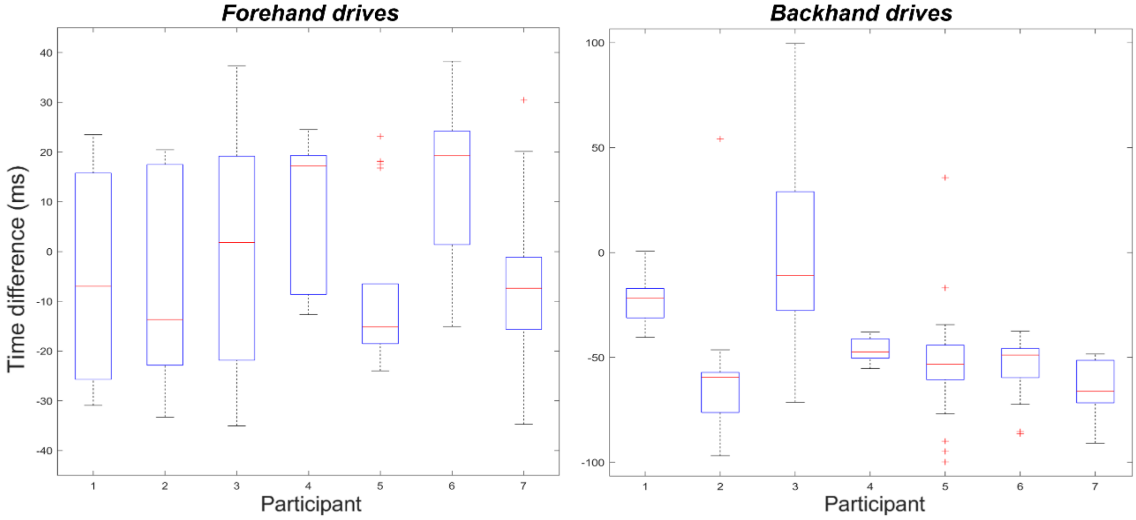

Figure 2: Boxplots of time differences between the impact audio peak and the maximal racket speed occurrences of each participant. All strokes from all acquisitions of each participant were included in the boxplot (min. 10 strokes per participant). The centre line represents the median of each sample, the edges correspond to the 25th and 75th percentiles, the whiskers extend to the extreme data points that are not outliers (identified by "+" on the plots).

Differences in timing: regarding the delay between ball-contact and maximal racket speed, over all the participants, the relative time difference was 0 ms for forehand drives whereas it reached -45 ms for backhand drives (a negative value represents a maximal speed occurring after the ball-racket impact). When looking at participants individually (Figure 2), there is an important inter-subject variability with a mean relative time difference ranging between -10 to 15 ms for forehand drives and from -65 to 2 ms for backhand drives. An intra-subject variability was also observed (Figure 2) highlighted by standard deviations reaching 20 ms and 50 ms for forehand and backhand drives, respectively. Regarding the absolute time difference, the delays for the whole cohort were 20 ± 10 ms and 50 ± 20 ms for forehand and backhand drives, respectively.
Finally, these timing difference resulted in racket speed difference ranging from 3 to 11 % and from 3.5 to 35% for forehand and backhand drives, respectively, depending on the participant. This also result in average racket orientation differences of 13 ± 10° and 31 ± 17° for forehand and backhand drives, respectively.

DISCUSSION:

Identification of ball-racket contact time: this study shows the ability of the microphone-based method for automatically identifying the instants of ball-racket contact, even with a unidirectional low-sampled (2 kHz) microphone. However, as the loss was about 10 % of the measured strokes, a higher sampling rate, and maybe an omnidirectional microphone rather than unidirectional one, would noticeably improve the detection rate. Besides, a recent study (Russell, 2018) determined the sound from the ball-racket impact to emit in a range of 8.5-12 kHz, which opens the perspective of studying table tennis shot biomechanics in close-to-real game situations, for instance during matches performed in laboratory. If it is not possible to increase the sampling rate, a manual inspection of the 2 kHz signal would still result in a lower stroke loss than that was observed in this study (Figure 1).

Differences in timing: regarding the average timing difference, the concomitance hypothesis appears still valid for young players during top spin forehand drives. However high inter- and intra-subject variability challenged this conclusion, drawn on averaged results, because positive and negative time differences balance each other out. Looking at the absolute time differences, the divergence becomes more difficult to ignore. Regarding the backhand drives, the hypothesis of concomitance was immediately invalidated: most of the impact occurrences happened in average 45 ms after the occurrence of the maximal speed. For racket kinematics, these timing differences involved differences in maximal racket speed exceeding 10% and a 30° difference in racket orientation for backhand drives, which reduces the accuracy of the shot analysis. Consequently, future studies should determine the moment of ball-racket impact rather than using the maximal racket centre linear speed.

CONCLUSION: The aim of this study was to test the hypothesis of a concomitance between ball-racket contact and maximal racket speed in young talented table tennis players during top spin forehand and backhand drives. For this purpose, a method was proposed to easily identify the moment of ball-racket contact without influencing the player's equipment (racket and ball). Using this method, the hypothesis was rejected at the participant level for forehands and even at the whole cohort level for backhands. Future studies should therefore include a technology to identify ball-racket contact in their experimental set-up. Regarding the method used in the present study, the improvements recommended are to increase the sampling rate, or to manually inspect the signal rather than using a fully automatic identification.
Finally, as the concomitance between ball-racket contact and maximal racket speed has a direct influence on the player energic efficiency, this study also opens new perspectives in improving the player’s performance.

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