Sensitivity and Reliability of a Specific Test of Stroke Performance in Table Tennis

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Purpose: To develop a simple, reliable, and sensitive test to measure stroke performance (ball speed and accuracy) in table tennis. *Methods*: Fifty-two players were divided into 3 groups in accordance with their level: expert (EG), advanced (AG), and inexperienced (IG). The test consisted of 45 forehand shots where players were asked to reach 3 targets. The test was performed 2 times (separated by 8 min) during the first session (n = 52) to assess intrasession reliability. A second session (n = 28), at least 3 d later, was performed to test intersession reliability. Both speed and accuracy of the ball were measured to evaluate the absolute sensitivity and reliability of the specific test. *Results*: This study showed good reliability of the specific test for both ball speed and accuracy of EG and AG (ICC range .42–.96, CV range 2.0–9.0%). However, the reliability is low for IG. Ball speed and accuracy were greater in EG than in the other groups, and both variables were correlated with the level of the players. *Conclusion*: Results suggest that the specific test appears to be a simple and sensitive procedure to assess stroke performance in table tennis and that this test could be a relevant tool for coaches in table tennis.

Keywords: speed, accuracy, exercise performance

Performance in racket sports is multifactorial and involves technical, tactical, psychological, and physiological skills.[1] Thus, a lot of specific field tests have been proposed to evaluate these skills.[2–8] In table tennis, numerous studies have been conducted to assess aerobic[9,10] and anaerobic capacities[11,12] during an ecological exercise. However, while technical aspects are usually decisive for winning the rally,[7] to the best of our knowledge, no gold-standard test exists in table tennis to evaluate some technical parameters during a simple and ecological table tennis task.

In racket sports, ball speed and accuracy (ie, the capacity to hit a desired area) are the 2 relevant technical parameters to describe stroke performance.[13,14] Moreover, both parameters are crucial in table tennis since the distance between players and the reaction time are short.[15] Sakurai and Ohtsuki[16] showed that the accuracy, defined by the probability of hitting a vertical target placed on a wall 4 m from the player during a forehand-smash stroke in badminton was higher for the highly skilled players than for the inexperienced players, but the speed of the shuttlecock was not measured. Few studies have evaluated simultaneously both accuracy and ball speed.[2,14,17] The approach used by Vergauwen et al[2] in tennis seems relevant, because it tried to emphasize the interrelation between velocity and precision of the ball during forehand and backhand strokes during neutral tennis situations, that is, ball close to the area around the middle of the baseline. They reported that both velocity and precision (ie, evaluated as the distance to the sideline) of the ball were higher for international players than national players. We note that these authors calculated a velocity/precision index and demonstrated that this index is relevant to evaluate the quality of the stroke. The use of these tests has given valuable information depending on several variables such as level of expertise or fatigue. For instance, Vergauwen et al[2] showed that this test was sensitive to

detect the alterations of velocity and precision of the ball when fatigue occurred during a neutral situation in tennis.

Therefore, the main aim of this study was to develop a field test that might be able to evaluate both the ability to produce high ball speed and the accuracy of table tennis players. We proposed to assess the sensitivity of the measurements to the level of expertise of the athletes[2] and the reliability, meaning that the results of the test are consistent when subjects perform a test repeatedly.[18] The proposed test might be a relevant tool to discriminate player level. In addition, it should enable evaluation of the improvement in players' stroke quality after a training period.

Methods

Participants

Fifty-two male subjects (mean ± SD age 26.1 ± 8.7 y, height 178.3 ± 5.8 cm, mass 72.9 ± 9.5 kg) volunteered to participate in this study. They were divided into 3 groups determined by their single rankings by the French Federation of Table Tennis (FFTT) set in September 2014. Table 1 presents the individual characteristics of each group (age, height, body mass, table tennis experience, training volume, ranking). In the expert group (EG), all players were well trained (5.9 ± 4.5 times/week) and participated in national and/or international competitions. In the advanced group (AG), players were less trained (2.3 ± 1.3 times/week) and participated in a regional championship. The inexperienced group (IG) was composed of sport-science students without experience in table tennis and not ranked by the FFTT. All participants gave their written consent after they were informed about the procedures and the nature of the protocol, which was approved by the local ethics committee.

\<<<<<<<<<<<<<<**TABLE 1**>>>>>>>>>\

Design

Fifty-two subjects performed a session of a specific table tennis test (duration ≈ 23 min). This session started with a 10-minute

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standardized warm-up consisting of repeating a range of simple forehand rallies. Once familiarized with the procedure (ie, ball sent by the robot and target localization), each subject had to perform the test twice to assess intrasession reliability, with an 8-minute resting period in between. Twenty-eight of the 52 subjects initially recruited participated in a second session to assess intersession reliability (n = 11, 9, and 8 for IG, AG, and EG, respectively). There was a minimum of 3 days between the 2 sessions.

Specific Table Tennis Test

The test consisted of 45 forehand top-spin shots, which is a classic stroke of the modern offensive game.[19] They were asked to hit, alternately but in the same order, 3 targets placed on the table (Figure 1). The 3 targets were in strategic locations. Two rectangular targets (80 cm length, 20 cm width) were positioned on the sides (right and left) of the table, 20 cm from the edge of the table. The third target was a semicircle 25 cm in diameter positioned at the center of the table and close to its edge. The players were instructed to hit the ball for winning the point as they would during an official game. Fifteen trials were evaluated for each target. The ball was sent by a robot (Robo-Pong 2040, Donic, Völkingen, Germany) to ensure the same kinematic characteristics (ie, speed, placement, bounce height). For each trial, the robot sent the ball to the center of the table, placing it 100 to 120 cm away from the net (Figure 1). The ball was delivered by the robot at 35 km/h every 3 seconds with a slice effect.

\<<<<<<<<<<<<<<**FIGURE 1**>>>>>>>>>\

The performance assessment (ie, the score of accuracy and the methodology to calculate the performance index, describe further on) was explained to the subjects before starting the test. During the test, subjects were strongly encouraged and informed on their outcome to maintain vigilance and concentration throughout the procedure.

Data Processing

Ball Speed.

For each stroke, the speed of the ball hit by the players was measured with a radar device (Stalker ATS ii, Stalker Radar, Plano, TX, USA) at a frequency of 50 Hz and an accuracy of ± 0.041 m/s. The radar was located 1 m behind the table, between the axis of the robot and the player, at a height of 113 cm. All data were recorded on a personal laptop (Stalker ATS 5.0 software, Plano, TX, USA). The ball speed for each of the 45 strokes was measured. The mean speed was then calculated by averaging the 45 speed values.

Accuracy.

Accuracy was directly assessed (ie, in real time) by 2 experienced examiners who had played table tennis for at least 10 years and were therefore accustomed with ball trajectories. The following procedure was used: When the ball reached the target, 2 points were granted (ie, accuracy); 1 point when the ball reached the table but did not touch the target (ie, consistency); and 0 point when a fault was committed. This procedure gave a score between 0 and 90 for each series. The distribution (ie, percentage of faults, consistency, and accuracy) was also calculated.[14,20]

Performance Index.

To take into account the speed–accuracy conflict,[21] a performance index (PI) was calculated to link the 2 measured parameters with the following formula: PI = average speed of the series × accuracy/100.

Statistical Analysis

Statistical tests were performed with Statistica V6 software (Statsoft, Tulsa, OK, USA). Normality testing (Kolmogorov-Smirnov) was passed for all groups. Values are presented as mean ± SD. Speed, accuracy, and PI were compared across the 3 populations (IG, AG, EG) by using a 1-way analysis of variance (ANOVA) (3 between-subjects factors: EG vs AG vs IG) for the first series of the first day. Post hoc analyses were performed when appropriate using an honestly significant difference Tukey test for multiple comparisons. Partial eta-square ($_p\eta^2$) values are reported as measures of effect size, with moderate and large effects considered for $_p\eta^2 \geq 0.07$ and $_p\eta^2 \geq 0.14$, respectively.[22] Finally, correlation analyses (Bravais-Pearson) were performed to determine whether speed, accuracy, and/or PI were correlated to skill level (ie, FFTT ranking). The level of significance was set at $P < .05$. For each group and for EG and AG jointly, standard errors of measurement (SEM), intraclass correlation coefficients (ICC), and coefficients of variation (CV) were calculated for both intraday and interday.[18] Since we used a set time between sessions, the $ICC_{3,1}$ was chosen from Shrout and Fleiss.[23] Interday reliability was assessed by using the first series of day 1 versus the first series of day 2.

Results

Ball Speed

Our results showed a significant effect of expertise ($_p\eta^2 = 0.67$, $P < .001$), indicating that ball speed was higher for EG than for AG and IG (+23% and +44%, respectively, $P < .001$) and for AG than for IG ($P < .01$, +17%) (Figure 2[A]). In addition to this, a significant correlation was observed between ball speed and player ranking ($r = .83$, $P < .001$, n = 34, IG excluded).

\<<<<<<<<<<<<<<**FIGURE 2**>>>>>>>>>\

Accuracy

A significant main effect was observed for accuracy ($_p\eta^2 = 0.84$, $P < .001$), showing that the score of accuracy (on 90 points) was higher for EG than for AG and IG (+22% and +104%, respectively, $P < .001$) and for AG than for IG ($P < .001$, +66%) (Figure 2[B]). A significant correlation was also found between accuracy and ranking ($r = .76$, $P < .001$, n = 34, IG excluded). More specifically, Figure 3 gives the distribution of responses depending on the level of the players. Thus, EG made fewer errors (ie, fault) (−57%, $P < .001$) than IG, while no significant difference was observed between EG and AG ($P = .07$). EG also reached the targets significantly more often than AG and IG ($P < .001$). AG made fewer errors (−43%, $P < .001$) than IG and also reached the targets significantly more often than IG ($P < .001$). No significant difference was observed between AG and IG for consistency ($P = .07$).

\<<<<<<<<<<<<<<**FIGURE 3**>>>>>>>>>\

Performance Index

The ANOVA revealed significant differences between the 3 groups ($_p\eta^2 = 0.89$, $P < .001$) for the PI (Figure 2[C]). It was higher for EG than for AG and IG (+54% and +174%, respectively, $P < .001$) and for AG than for IG ($P < .001$, +77%). PI was highly correlated with player ranking ($r = .92$, $P < .001$, n = 34, IG excluded).

Intrasession and Intersession Reliability and Interexperimenter Reliability

The mean values, SDs, ICCs, SEMs, and CVs are shown in Table 2 for intrasession and intersession reliability for each group. The measured scores were strongly different depending on the group

considered. Low CVs were found for EG among all parameters (2.0–6.8%), with a moderate to high ICC, except for accuracy and PI for intersession (.42 and .07, respectively). The CVs for AG group were acceptable for all variables (2.9–11.0%), and moderate to high ICCs were also observed (.45–.91). Except for ball speed, CVs were low for IG for intrasession and intersession (17.8–24.4%), and ICCs were regularly low.

\<<<<<<<<<<<<<**TABLE 1**>>>>>>>>\

Discussion

The main outcomes of this study are that the proposed test is sensitive enough to discriminate groups with different levels, gives a PI that is highly correlated to the ranking of the players, and provides a reliable tool to assess the quality of strokes from a table tennis player.

Stroke Characteristics and Sensitivity of the Specific Test

Our results highlighted that expert players hit the ball faster than advanced players and inexperienced players. The mean speed of the ball ranged from 37.8 (± 6.3 km/h) for IG to 54.7 (± 4.7 km/h) for EG. A significant correlation was found between ball speed and player ranking ($r = .83$, $P < .001$, n = 34), showing that this parameter remains clearly related to success at a high level of expertise. Thus, the observed difference in ball speed is associated with a reduction of the time required by the ball to cross the table (± 42 milliseconds between EG and AG). The time to react for the opponent is decreased, inducing favorable conditions to win the rally. Such a difference was also measured in tennis by Vergauwen et al,[2] who showed that international players produced significantly higher ball speed (5% faster) than semiprofessional players during a neutral tennis situation.

In addition, we showed that expert players made fewer faults and were more accurate than advanced and inexperienced players, as previously mentioned in racket sports.[2,16,24] Sakurai and Ohtsuki[16] also highlighted clear differences for accuracy between skilled and unskilled badminton players for smashes performed toward a target on the wall. Concerning tennis, Vergauwen et al[2] found that international players made 25% to 38% fewer errors than national players, depending on the situation met (defensive vs neutral situation). Also in tennis, Lyons et al[24] observed that expert players made 45% fewer errors and reached the target 50% more often than nonexpert players. Therefore, our study is in line with previous ones (24% fewer errors and 34% targets more often reached when EG was compared with AG). This result shows that technical aspects, that is, speed and/or accuracy of the ball,[13,14] assessed by our test may partly explain the difference between national and regional players. However, we cannot exclude that physiological and psychological aspects may also be critical to perform in table tennis at a high level.

When the 2 preceding parameters (ball speed and accuracy) were analyzed simultaneously (ie, using PI), our results clearly showed significant differences among all groups. On the other hand, when EG was examined separately, a significant correlation was also found between PI and ranking ($r = .72$, $P < .001$). This result demonstrates the high sensitivity of both the specific test and the associated index (PI), which are able to discriminate the level of the players either between or within group when expertise is proved. Vergauwen et al[2] have already shown in tennis that the velocity–precision index reveals significant differences between national and international players in both neutral and defensive situations. Due to our visual methodology, it was not possible to measure the distance to the sideline[2] or to position several areas[14] to a better accuracy

approach. However, the PI measured appears to be a good predictor of performance in table tennis.

Reliability of the Specific Test

Our results demonstrate that the proposed specific test provides a reliable tool for table tennis players. Indeed, all variables showed low SEMs (1.3–4.9) and CVs (2.0–6.8%) for EG, reflecting a small within-subject variation when participants performed the test in a short period (ie, intrasession reliability) or several days later (ie, intersession reliability). For EG, ICC values varied widely and generally were low, lower than .7,[27] for the intersession reliability of PI. However, several authors have emphasized that the ICC is largely dependent on the heterogeneity of the sample and that a low between-subjects variability tends to decrease this parameter.[17,25,26] In the current study, experienced players who performed the test twice to assess the intersession reliability (n = 8) constituted a more homogeneous group in terms of technical ability, expertise level, and ranking than the overall EG group (n = 20). Moreover, PI showed a very small intersession variability (SDs of 2.7 and 3.3), which may explain the low ICC found for intersession. Moreover, given the fact that both SEM and CV were good—lower than 10%[27] (1.3–4.9 and 2.0–6.8% for SEM and CV, respectively)—one may conclude that our protocol was consistent for this group.

For AG, CVs, even if they were slightly higher than those observed for EG, can be considered acceptable.[27] The poor ICC observed for accuracy and PI may be attributed to a relatively homogeneous group, as already explained, and lower technical skills, which may lead to players' lower ability to successfully modify their pattern of movement when they miss the targets.[28] Thus, several studies have previously demonstrated that the better the racket player, the better his or her capacity to be accurate in either nonfatigued[2,16,24] or fatigued[24,28] conditions.

Finally, except for ball speed during both intrasession and intersession testing for IG, a high CV (17.8–24.4%) was observed for all variables (Table 2). These results demonstrate that for inexperienced players, there was no consistency from one test to another (within or between days). We suggest that this poor reliability was due to the lack of technical skills when these players were confronted with a ball with a sliced effect. This situation induced them to find other solutions during the test, resulting in a large variability of the results. Therefore, greater reliability was linked to a more experienced player. This is consistent with previous studies that assessed reliability during a specific activity of technical[2,29] or physiological[3,5] performance variables. Therefore, only table tennis players have sufficient technical skills to perform this specific test protocol.

Several methodological limitations may be addressed on the use of the test. First, the 45 consecutive aggressive strokes performed during the test session may have induced fatigue, which could alter the results. However, we only compared the first 10 and the last 10 strokes from each series. Because no significant effect was found, we presume that there was no deleterious effect of fatigue. Second, a significant improvement was observed for IG for both accuracy and PI between the first and second tests for both intrasession and intersession (Table 2). We cannot exclude that the familiarization was not sufficient for this inexperienced group, thus resulting in better performance during the second test and altering the reliability of the data for this group.

Practical Applications

Our specific test appears to be a simple and reliable procedure that could be easily used by coaches with trained to well-trained table

tennis players. Indeed, the sensitivity of the specific test was demonstrated by comparing the results between 3 typical different groups. Therefore, the proposed test could be used to compare stroke quality between players. Moreover, the good reliability of the test highlights its relevance to evaluate improvement in stroke quality during a training period.

Conclusion

The specific table tennis test developed herein appears to be a sensitive and reliable tool to quickly assess the stroke-performance level of a table tennis player with minimal expertise.

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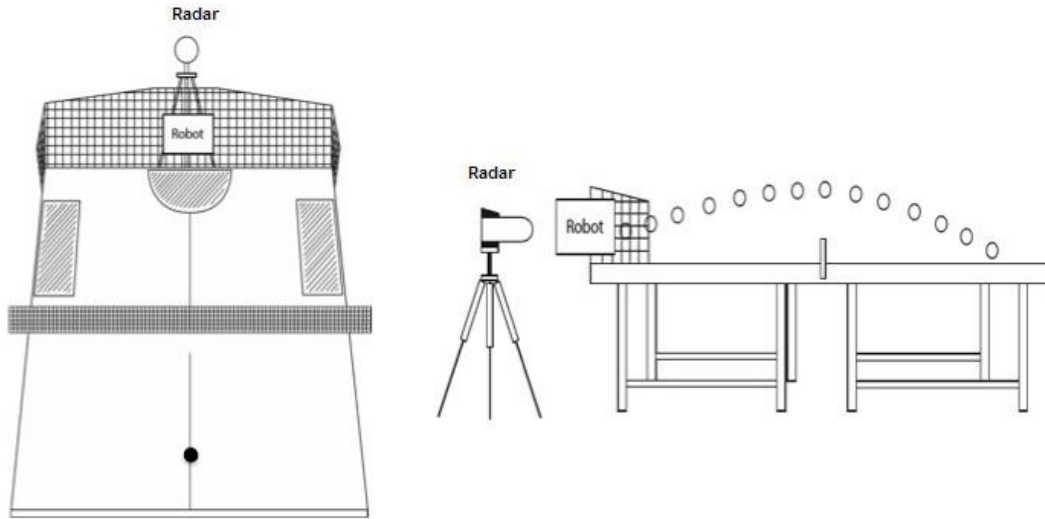
Figure 1 — Top view (left) and side view (right) of the device used during the specific test. On the left, shaded areas correspond to the 3 targets that the players had to reach and the black circle corresponds to the rebound of the ball on the table.
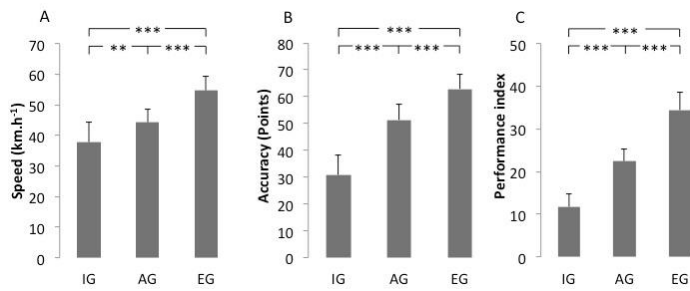
Figure 2 — (A) Ball speed, (B) accuracy, and (C) performance index for the inexperienced (IG), advanced (AG), and expert (EG) groups, mean ± SD. Significant difference between groups, **$P < .01$, ***$P < .001$).
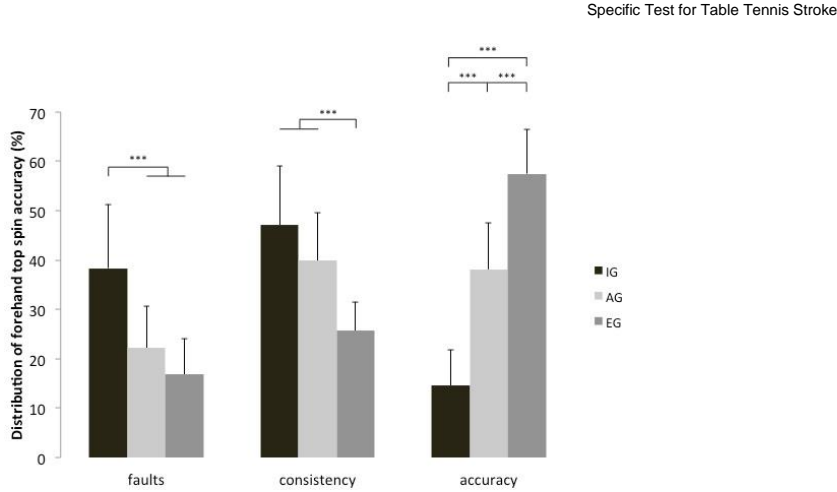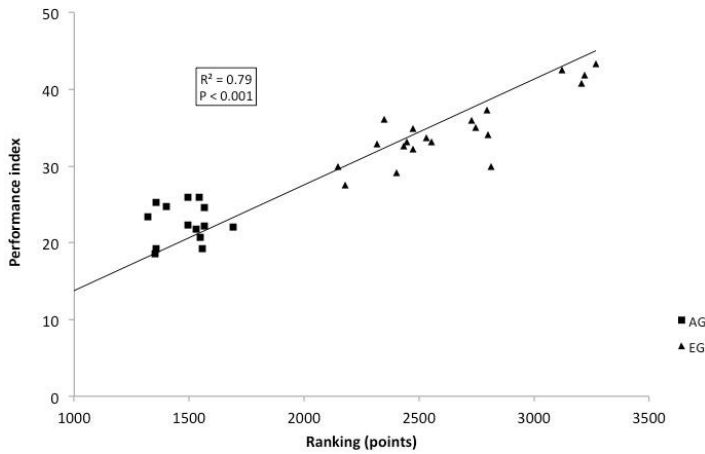
Figure 3 — Distribution of forehand top-spin responses for the inexperienced (IG), advanced (AG), and expert (EG) groups, mean ± SD. ***Significant difference between groups, $P < .001$.

Figure 4 — Performance index was linearly related to the ranking of the players. Only players from the expert group (EG) and advanced group (AG) are included (n = 34).

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Table 1 Anthropometric Values and Table Tennis Experience for the Inexperienced (IG), Advanced (AG), and Expert (EG) Groups, Mean ± SD

	IG	AG	EG
n	18	14	20
Age (y)	19.5 ± 0.9	30.7 ± 11.3	28.4 ± 6.7
Height (cm)	176.9 ± 5.9	178.3 ± 6.2	178.9 ± 6.2
Body mass (kg)	69.0 ± 6.4	74.0 ± 12.3	74.5 ± 9.7
Table tennis experience (y)	—	13.4 ± 8.6	19.8 ± 6.8
Training volume (h/wk)	—	4.1 ± 2.3	10.4 ± 7.9
Ranking (French Federation of Table Tennis points)	500	1478.4 ± 107.5	2650.1 ± 343.2

Table 2　Intrarater and Interrater Reliability for Ball Speed, Accuracy, and Performance Index (PI) for the Expert (EG), Advanced (AG) and Inexperienced (IG) Groups

| | | Intrasession Reliability | | | | | Intersession Reliability | | | | | |
| | | Mean (SD) | | | | | | Mean (SD) | | | | |
Dependent variable	n	T1	T2	ICC	Mean CV (SD)	SEM	n	T1	T3	ICC	Mean CV (SD)	SEM
Expert group	20						8					
Ball speed (km/h)		54.7 (4.6)	54.7 (5.1)	.96	2.0 (1.5)	1.3		55.3 (3.7)	53.7 (3.5)	.85	3.7 (1.5)	1.89
Accuracy (/90)		62.9 (5.3)	64.3 (8.3)	.66	6.3 (3.7)	4.6		59.1 (3.0)	60.4 (7.8)	.42	6.8 (4.3)	4.9
PI		34.4 (4.1)	35.2 (5.5)	.79	6.6 (3.9)	2.6		32.8 (2.7)	32.2 (3.3)	.07	6.8 (5.8)	3.0
Advanced group	14						9					
Ball speed (km/h)		44.0 (4.9)	44.4 (4.1)	.89	2.9 (3.0)	1.9		42.8 (6.8)	42.7 (7.4)	.91	5.7 (3.5)	3.0
Accuracy (/90)		51.1 (5.7)	51.3 (8.7)	.45	9.0 (8.2)	5.9		49.0 (6.1)	53.7 (6.8)	.84	7.1 (5.7)	3.4
PI		22.4 (2.8)	22.6 (3.1)	.55	7.5 (7.0)	2.2		20.8 (3.9)	22.7 (3.6)	.75	11.0 (5.9)	2.3
Inexperienced group	18						11					
Ball speed (km/h)		38.3 (5.9)	37.4 (7.4)	.89	6.8 (5.4)	3.1		40.1 (5.5)	37.1 (7.0)	.72	9.3 (6.6)	3.9
Accuracy (/90)		30.8 (7.2)	36.9 (7.2)	.54	17.8 (13.3)	5.5		29.4 (8.1)	39.0 (7.9)	.49	24.4 (15.4)	6.2
PI		11.7 (3.0)	13.6 (3.1)	.47	19.7 (12.7)	2.4		11.7 (3.5)	14.3 (3.4)	.63	20.4 (13.2)	2.3

Abbreviations: T1, first series of the first session; T2, second series of the first session; T3, first series of the second session; ICC, intraclass correlation coefficient; CV, coefficient of variation; SEM, standard error of measurement.