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AUTHOR

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Systematic Review

A Systematic Review of Spatial Differences of the Ball Impact within the Serve Type at Professional and Junior Tennis Players

Jan Vacek [1], Michal Vagner [1,2,*], Daniel John Cleather [1,3] and Petr Stastny [1]

[1] Department of Sports Games, Faculty of Physical Education and Sport, Charles University in Prague, 162 52 Prague, Czech Republic
[2] Department of Military, Faculty of Physical Education and Sport, Charles University in Prague, 162 52 Prague, Czech Republic
[3] Faculty of Sport, Health and Applied Science, St. Mary's University, Waldegrave Road, Twickenham TW1 4SX, UK
* Correspondence: vagner@ftvs.cuni.cz; Tel.: +420-702-003-325

Abstract: Since the flat serve (FS) minimizes the ball spin and kick serve (KS) combined topspin and sidespin, this systematic review aimed to explore the ball impact location (BI) within the FS and KS at the professional men, junior men, and women tennis players. The PRISMA guideline was used, and the original articles were searched in Scopus, Web of Science, and PubMed. The means and standard deviations computed from the distance of BI from the origin within the FS and KS on the x, y, and z axes (global coordinate system) were normalized by the participants' height and weighted by the number of participants in one-way ANOVA. Ten articles with a pooled sample of 133 males and 51 females aged 11–25 were included. The professional men had more stable BI on the x-axis within the FS by 56% ($p < 0.001$), within the KS by 58% ($p < 0.001$), and on the y-axis within the KS by 90% ($p < 0.001$) than junior men. The professional and junior men had the BI more leftwards from the origin on the x-axis within the KS by 188% ($p < 0.001$) and 88% ($p < 0.001$), respectively than within the FS.

Keywords: kinematics; ball toss; flat serve; kick serve

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1. Introduction

Tennis serve and return are the two most essential strokes in tennis, and their level improves with professional ranking [1,2]. Tennis serves are usually classified into three technique categories based on the angle of the racket face and velocity vector relative to the ball at impact. (i) flat technique that maximizes ball speed and minimizes ball spin, (ii) slice technique that emphasizes sidespin, (iii) twist technique that emphasizes combined topspin and sidespin [3,4] also known as kick serve [5,6]. Since it has been shown that these tennis serves have different technique execution, researchers have examined the kinematics of the body segments, tennis racket, and the tennis ball toss [4,7].

Concerning the tennis racket, the forward component of racket velocity is prominent for the flat technique of the serve, the lateral velocity of the racket is larger than the forward velocity in a slicing technique of the serve, and the vertical velocity of the racket is larger than forward and lateral velocity in the twist technique of the serve [8]. The contribution of the body segment for these velocities was examined for the flat serve and it found that the ulnar flexion at the wrist joint produced 30.6% of the final velocity [9,10]. Although there is a relationship between serve type technique and racket velocity related to the racket position (racket face angel) at the moment of the impact [3,8] and differences in BI height [11], there is no clear classified whether there is a typical position of the ball at the moment of impact with the strings/racket within the ball toss in relation to different technique types of services across gender and performance level of the tennis players.

Ball toss kinematics are characterized by the position of the ball relative to the player and the court at three main events/points during the serve delivery: release, peak vertical height, and impact with the strings/racket. To represent the ball's position at the moment of impact (one frame prior to a racket-ball contact), the term ball impact (BI) is used [12–15]. The BI location is calculated in the global coordinate system relative to the origin on the x-axis (mediolateral), y-axis (anterior-posterior), and z-axis (vertical). The origin is usually defined, in the case of considering the BI location within the serve, in the global coordinative system at the point of the first metatarsal joint of the front foot [14–16]. In this context, not only the BI location from the origin is found but also its variability or stability. The analysis of the variability of the three points (on the x, y, and z axes) of the BI location is conducted axis by axis, that is, in a one-dimensional way. The stability is measured using the standard deviation and the coefficient of variation [17].

Regarding the BI location, although the players should not use visible differences in the BI location relative to the target and the type of serve, in order to hide their intentions from the perspective of the opponent [18], studies found differences position of the BI location from the origin on the x, y, and z axes among different technique serve types related to the target zone [14,16,19].

Concerning the professional men's tennis players, the differences in the BI location within the serve were found for the first serve related to the target zone (center and wide service from the deuce side) on the x-axis, where the BI location within the twist serve was more leftwards from the origin than slice serve [17] and on the y-axis, where the BI location within the flat serve was more forwards from the origin than the twist serve [14]. The junior men's tennis players had the BI location within the twist and flat serve closer to the origin on the y-axis and more leftwards from the origin on the x-axis than the junior women tennis players [20]. Professional women's tennis players had the BI location within the second service closer to the origin on the x-axis than professional men's tennis players [3]. Less experienced women performed the BI location within the flat serve closer to the origin on the y-axis than their more experienced counterparts [15]. The BI location within the first and second serve can be related to the experience level of participants and gender.

Therefore, this systematic review compared the distance BI spatial location from the origin and stability (cluster around the mean) of the BI (on the x, y, and z axes in the global coordinate system) among serve types of professional and junior men and women tennis players. We hypothesize that professional men's tennis players have more stable BI (cluster around the mean of the ball impact location on the x, y, and z axes) than junior men's tennis players within the FS and KS.

2. Materials and Methods

This article is a systematic review. The PRISMA methodology [21,22] was used to select the articles included in this review (Figure 1). This review protocol was prospectively registered online with PROSPERO (registration number: CRD42022315098).

2.1. Search Strategy

The search was performed on 13 January 2022 using the Web of Science, PubMed, and Scopus search engines within the title, abstract, and keywords. The search strategy combined terms related to the ball toss and serve (tennis, ball toss, serve, and kinematic). Table S1 shows the full Boolean syntax used in Web of Science, PubMed, and Scopus. Additional records were added based on the scanned reference list of selected articles. The chosen studies from the database search were sent to an excel file where one author removed duplicates.

2.2. Study Selection

One author screened the titles and abstracts to remove the articles unrelated to tennis. Two authors independently screened the titles and abstracts for exclusion of the articles which did not examine the ball toss and serve. The full text was reviewed for articles that met the eligibility criteria, and then articles suitable for systematic review were selected. In case of disagreement between the two reviewers, a third reviewer decided to include or not the article. Finally, the reference lists were analyzed to include potentially relevant articles.

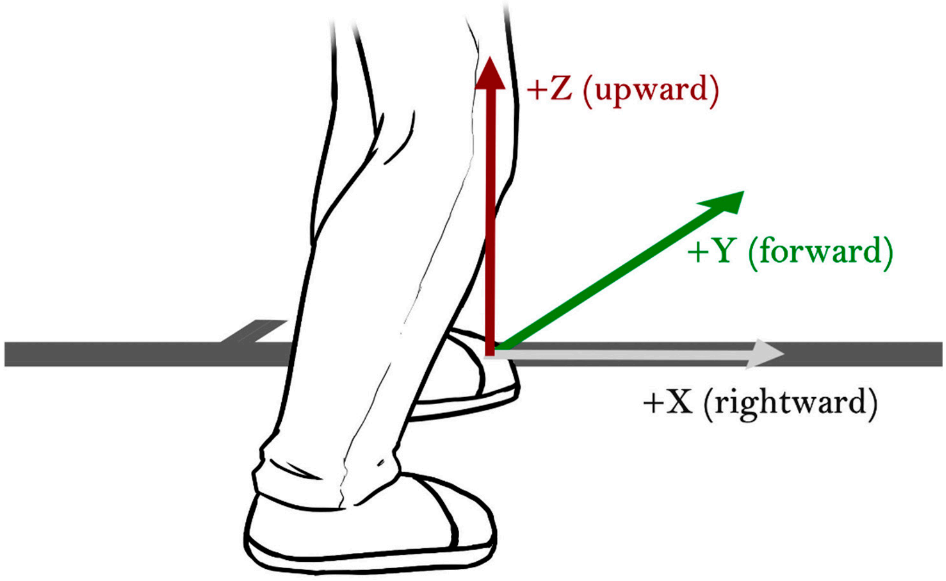

Figure 1. Orientation and origin of the global coordinate system.

2.3. Eligibility Criteria

The following inclusion criteria were applied during the title and abstract screening: (i) at least one outcome of BI location (x, y, or z axes in a global coordinate system) was reported related to service; (ii) the data of the BI location was obtained by a hi-speed camera system; (iii) manuscript was published in English.

2.4. Assessment of Methodological Quality and Risk of Bias

All articles included in this systematic review were evaluated concerning methodological quality. Two evaluators performed the evaluation. A scale was compiled to assess each article based on the evaluation tool STROBE [23]. The checklist consists of 11 items which were scored 2 points for "yes", 1 point for "unclear", and 0 points for "no" or "not applied." The questions are as follows:

(1) Was an informative and balanced summary of what was carried out and what was found provided in the abstract? (2) Was the scientific background of the study reported? (3) Were the specific objectives stated, including any pre-specified hypotheses? (4) Were the eligibility criteria, sources, and methods of selecting participants stated? (5) Was the condition measured in a standard, reliable way for all participants in the study? (6) Was the execution of the measurement of kinematics described in sufficient detail to permit its replication? (7) Was the data collection described? (8) Were all relevant results described? (9) Were any efforts to address potential sources of bias described? (10) Were key results summarised with reference to study objectives? (11) Were all outcomes and conclusions clearly defined?

The maximum possible number of points was 22. Studies were classified as excellent, good, fair, and poor methodological quality if they scored 20–22 points, 17–19 points, 14–16 points, and $\leq$14 points, respectively.

2.5. Terminology

The terminology for different labeling tennis serves among studies has been unified using the following rules. Only data for serves performed from the deuce side were used. Flat serve (serve with maximal ball speed and minimal intended spin) was marked FS. Kick serve (serve with a combined twist and sidespin) was marked KS. Other serve types were not examined due to the lack of comparable data. The ball's position at the moment of contact with the strings/racket was defined as the "ball impact" (BI) location. The position of the BI location was determined in the global coordinate system with the origin of the player's front foot metatarsophalangeal joint (Figure 1). The distance of the ball impact location from the origin was analyzed in the planes where (x-axis) represented mediolateral direction, (y-axis) represented anteroposterior direction, and (z-axis) represented vertical direction [13].

3. Data Treatment and Analysis

Data of the BI location from the chosen articles were divided into categories by experience, gender, and service types using the following rules: (i) Data of the participants younger than 16 were put into the junior group, whereas data of the participants older than 16 were put into the professional group [24]. (ii) Participants and their data were put into groups (M) and (W) according to their gender. (iii) Participants and their data were put into two groups according to the type of service (FS and KS). Since the anthropometric parameters of the participants could bias the comparison ball impact location among participants [25], the means and standard deviations were normalized by the participants' height (Supplementary Materials, Table S2).

The statistical analysis of the results was conducted using Statistica 14 (Tibco Software Inc., Palo Alto, CA, USA), R version 4.1.0 (R Core Team, 2021), and Microsoft Excel (Microsoft Corporation, Redmond, Washington, DC, USA). The mean and standard deviation (the distance BI location from the origin on the x, y, and z axes) within FS and KS were normalized by the participants' height and weighted by the number of participants. The aggregate forest plots presented the normalized mean and 95% confidence interval of the BI location of the individual chosen studies and the normalized weighted mean and 95% confidence interval of the BI location computed from the studies included in individual groups (Professional men, Junior men, Professional women, and Junior women). The one-way ANOVA with Tukey's post hoc test was used to analyze differences among groups within the FS and KS; a significance level was 5%. A partial eta square (η^2) and Cohen's d were used to estimate the effect sizes. Levene's test performed the assumption of data equality of variance. The normalized weighted mean BI location was used to compare ball position among individual groups (serve type FS and KS x professional and junior tennis players) separately for the x, y, and z axes. The BI location's stability analysis was computed separately for the x, y, and z axes comparing the normalized weighted standard deviation among the individual groups within the FS and KS.

3.1. Results

The search in the systematic literature resulted in 386 records and six additional articles from referent lists. After removing 62 duplicates, 324 articles were screened at the title and abstract levels. There were 250 articles rejected since they did not meet the subject of research. For full text, 74 studies were accessed; however, 64 were excluded since they did not contain the BI location at least on one of the coordinate axes. The search process according to PRISMA is shown in Figure 2. The records of the remaining ten articles, with a pooled sample of 133 males and 51 females aged 11–25, were included for systematic review (Tables 1 and 2). However, there were not enough data for women and therefore it was not possible to relevantly compare differences in the stability and position of the BI within the FS and KS.

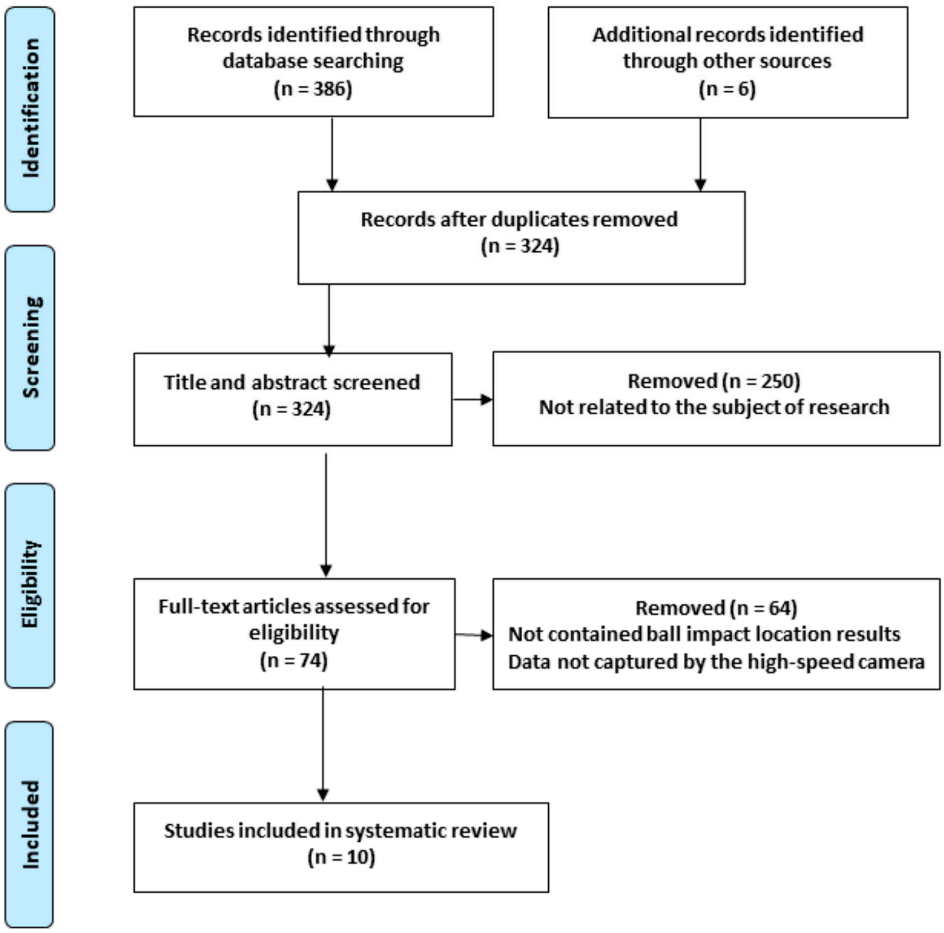

Figure 2. The flow chart of the systematic approach to the retrieval articles relevant to the ball impact location within the tennis serve.

Table 1. Characteristics of the chosen studies for systematic review.

Articles	Participants	Capture System	Serve Types	Aim of the Study	Main Findings
Reid a 2011 [14]	6 professional men, 18–24 y, 183 ± 6 cm	22 cameras 250 Hz VICON MX	Flat serve	The study aimed to determine whether players serve different court parts from the same toss.	The positions of the front foot, ball zenith, and ball impact were significantly different in the FS, while kinematics across all KS were consistent. The front foot position was closer to the center mark in the T FS, and players impacted the ball further left in the wide FS compared to the T FS.
Carboch 2018 [19]	15 professional men, 25.3 ± 4.6 y, 185.4 ± 5.6 cm, 81.7 ± 8.1 kg	1400 Hz Basler piA640	Flat serve Kick serve	This study aimed to assess the two-dimensional kinematics of the ball toss during different serve types.	The TP and RC of the kick serve occurred further to the right (18–21 and 30–35 cm, respectively) compared to other serve types from both serving sides. Compared to the second serves wide, the second serve to the T had a TP and RC 11 and 18 cm further to the right, but only from the deuce court.

Table 1. *Cont.*

Articles	Participants	Capture System	Serve Types	Aim of the Study	Main Findings
Carboch 2015 [26]	10 professional men, 25.3 ± 3.6 y, 184.9 ± 6.28 cm, 81.6 ± 9.81 kg	1400 Hz Basler piA640	Kick serve Slice serve	This study aimed to examine whether serving players use the same ball toss for kick serve (KS) and slice serve (SS) in two different directions of serves, from the receiver's view.	They found differences in the ball toss execution between KS and SS. The vertical toss peak of KS was horizontal to the right compared to SS, and the point of racquetball contact of KS was even more to the right by approximately 30 cm from the receiver's view. Serving players should use the same toss for each type of serve to hide their intention.
Mendes 2013 [17]	12 professional men, 25.2 ± 3.9 y, 1.77 ± 0.06 cm, 72.3 ± 4.2 kg	2 cameras 210 Hz Casio Exilim Pro EX-F1	Flat serve	The study was made to analyze the variability and stability of the serve toss in tennis on the x (side-to-side), y (back-to-front), and z (vertical) axes, under the influence of crosswind (induced aerodynamic flow) produced by an industrial ventilator.	The vertical dimension of the tennis serve is assumed as a constant feature, which is guaranteed in the remaining varying dimensions (y and x-axis) of the ball toss. Thus, the variability should be seen as part of the solution and not as something to be avoided by players and coaches.
Reid 2010 [27]	5 junior men 13.4 ± 0.5 y, 164.9 ± 8.5 cm	22 cameras 250 Hz VICON MX	Flat serve	The study investigated the immediate effects of the decomposition on kinematics, offering insight into their efficacy in developing the serve.	Vertical displacement of the ball at its zenith increased significantly during BT compared with the FS and temporal associations between racket and ball motion during the FS (r = 0.861) were affected during task decomposition.
Connolly 2021 [20]	14 junior men 13.6 ± 1.7 y, 169.8 ± 12.7 cm, 56.8 ± 13.1 kg 10 junior women, 12.3 ± 1.3 y, 160.5 ± 13.1 cm, 51.6 ± 8.1 kg	12 cameras, 250 Hz VICON MX	Flat serve Kick serve	This study aimed to compare the flat and kick serve kinematics of asymptomatic elite adolescent male and female tennis players with and without lumbar spine abnormalities.	Pelvis and ball toss kinematics vary with gender and serve type but not necessarily abnormality in the elite adolescent serve. There is evidence to suggest that the order and timing of key serve events might help to identify those at risk of lumbar spine abnormalities
Fett 2021 [28]	14 junior men 14.6 ± 1.8 y, 176 ± 15.9 cm, 61.4 ± 16.3 kg	8 cameras 300 Hz Vicon Vantage V5	Flat serve	This study aimed to compare the body and ball kinematics of flat serves from both service sides.	The results underline biomechanical differences regarding the starting position (feet and upper torso) and the movement and ball kinematics that could be relevant for skill acquisition, injury prevention, and performance enhancement.
Giblin 2017 [29]	8 professional men 17.3 ± 1.2 y, 177.8 ± 9.7 cm, 69.7 ± 15.6 kg	10 cameras 500 Hz Vicon MX	Flat serve	This study aimed to contrast the effect of the removal of visual feedback on the ball and racket kinematics in the serve.	These results highlight that the serve is not entirely pre-programmable and that visual feedback is critical to the spatiotemporal regulation of the serve.

Table 1. *Cont.*

Articles	Participants	Capture System	Serve Types	Aim of the Study	Main Findings
Campbell 2013 [30]	7 junior men 15.6 ± 1.2 y, 178 ± 4.5 cm, 69.4 ± 7.9 kg	250 Hz Vicon	Flat serve Kick serve	This study aimed to quantify and compare lumbar region kinetics in a kick and flat serves performed by elite adolescent male players with and without a history of low back pain (LBP).	There was no significant difference in racquet velocity or ball position at impact between pain groups or serve types. The lumbar region undergoes substantial loading during both the kick and the flat tennis serves, including lateral flexion forces approximately eight times those experienced during running.
Whiteside 2013 [31]	12 and 11 junior women, 10.5 ± 0.5 y, 14.6 ± 0.7y, 143.5 ± 5.9 y cm, 166.9 ± 4.7 cm 36.5 ± 3.7 kg, 56.7 ± 3.8 kg 8 professional women, 21.3 ± 3.8 y, 169.2 ± 4.8 cm, 61.9 ± 4.2 kg	22-camera 500 Hz VICON MX	Flat serve	This study aimed to quantify the flat serve kinematics in elite prepubescent, pubescent, and postpubescent female tennis players.	Racket velocity was significantly lower in the prepubescent group than in the two older groups. In generating racket velocity, the role of the serving arm appears to become more pronounced after the onset of puberty, whereas leg drive and "shoulder-over-shoulder" rotation mature even later in development. These factors are proposed to relate to strength deficits and junior players' intentions to reduce the complexity of the skill.

Table 2. The mean and standard deviation of the distance ball impact location from the origin within the tennis serve.

Ball Toss Impact (cm)	**Men**			**Women**		
	***x*-Axis**	***y*-Axis**	***z*-Axis**	***x*-Axis**	***y*-Axis**	***z*-Axis**
FS professional						
Number of mean results	4	3	4	1	1	1
Number of participants	41	26	41	8	8	8
Participants' height (cm)	180	177.5	180	169	169	169
Ball impact (Mean ± SD, cm)	15.73 ± 15.15	56.2 ± 15.83	271.75 ± 9.87	14 ± 16	61 ± 5	254 ± 7
FS junior						
Number of mean results	4	4	4	3	3	3
Number of participants	40	40	40	33	33	33
Participants' height (cm)	172	172	172	157	157	157
Ball impact (Mean ± SD, cm)	25.4 ± 18.13	59.05 ± 14.78	252.25 ± 16.4	7.17 ± 18.5	51.27 ± 9.93	236 ± 9.4
KS professional						
Number of mean results	3	1	3	1	1	1
Number of participants	31	6	31	10	10	10
Participants' height (cm)	184	183	184	161	161	161
Ball impact (Mean ± SD, cm)	46.78 ± 16.61	51.44 ± 22.72	276.15 ± 11.48	25.1 ± 22	23.9 ± 13.7	246.9 ± 12.5
KS junior						
Number of mean results	2	2	2	0	0	0
Number of participants	21	21	21	-	-	-
Participants' height (cm)	174	174	174	-	-	-
Ball impact (Mean ± SD, cm)	39.3 ± 29.85	35.1 ± 16.95	258.05 ± 17	-	-	-

The graphical presentations of the pooled data from the individual studies are presented in two forest plots, one for FS and one for KS, each with three subgraphs for the *x*, *y*, and *z* axes (Figure 3). Comparing the normalized weighted mean (Supplementary Materials, Table S2) of the BI location among the individual groups within FS; on the *x*-axis: the most leftwards BI location from the origin was performed by junior men; on the y-axis: professional women performed the BI location the most forwards from the origin; on the z-axis: junior men performed the BI location the lowest from the origin. For KS on the x-axis: the least leftwards BI location from the origin was performed by the junior women; on the y-axis: the junior women performed the least forward BI location from the origin, and on the z-axis: the lowest BI location from the origin was performed by junior men.

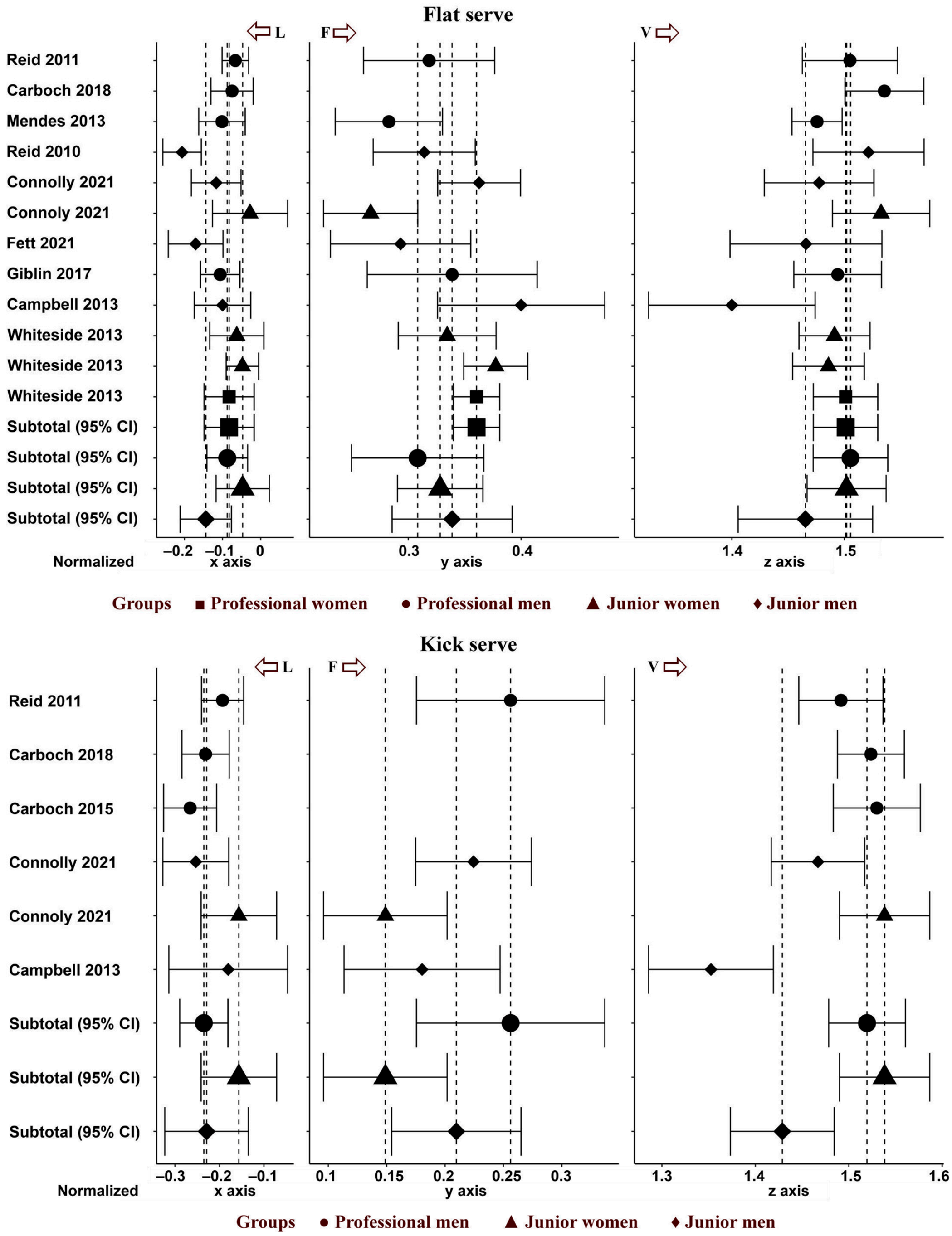

Figure 3. The forest plots present the ball impact location. There are presented the normalized mean and 95% confidence interval of the ball impact location in chosen studies. The subtotal presented a normalized weighted mean and their 95% CIs of the groups divided according to the serve type (upper part = Flat serve and lower part = Kick serve). Note: ← L (leftwards from the origin on the x–axis); F → (forwards from the origin on the y–axis; V → (upwards from the origin on the z–axis. References: [14,17,19,20,26–31].

3.2. Assessment of Methodological Quality

The assessment of methodological quality, which consisted of the STROBE tool, resulted in an average score of 91% ± 5% ranging from 82% to 100%, where three studies showed moderate and seven low risks of bias (Supplementary Materials—Table S3). The researchers' level of agreement about the methodological quality of the observed articles was 95%. The disagreements were discussed and solved to reach the final agreement of 100% between researchers. The highest limitations of the studies were lack of effort to find the potential source of bias (Item 9), unclear description of objectives and pre-specified hypothesis (Item 3), and missing eligibility criteria for selecting the participants (Item 4).

3.3. Subgroup Analysis

The assumption of data normality and equality of variance was not violated. There were differences in the normalized weighted mean of the BI location on the *x*-axis among professional and junior, and serve types of the men tennis players, $F_{3,123} = 17.3$, $p = 0.0001$, $\mu^2 = 0.3$; Figure 4A, where post hoc testing revealed that BI location of the $KS_{\text{junior men}}$ was more leftwards from the origin than $FS_{\text{junior men}}$ and $FS_{\text{professional men}}$ ($p < 0.001$, $d = 0.9$; $p < 0.001$, $d = 1.23$, respectively), $KS_{\text{professional men}}$ was more leftwards from the origin than $FS_{\text{professional men}}$ and $FS_{\text{junior men}}$ ($p < 0.001$, $d = 1.88$; $p < 0.001$, $d = 1.31$, respectively), and $FS_{\text{junior men}}$ was more leftwards from the origin than $FS_{\text{professional men}}$ ($p < 0.05$, $d = 0.4$). There were differences in the normalized weighted standard deviation of the BI location on the *x*-axis among experience and serve types of the male tennis players, $F_{3,123} = 79.74$, $p = 0.0001$, $\mu^2 = 0.66$, Figure 4B, where post hoc testing revealed that BI location of the $KS_{\text{junior men}}$ was less closely clustered around the mean than $FS_{\text{professional men,}}$ $FS_{\text{junior men,}}$ and $KS_{\text{professional men}}$ groups ($p < 0.001$, $d = 3.9$; $p < 0.001$, $d = 3.42$; $p < 0.001$, $d = 3.19$, respectively).

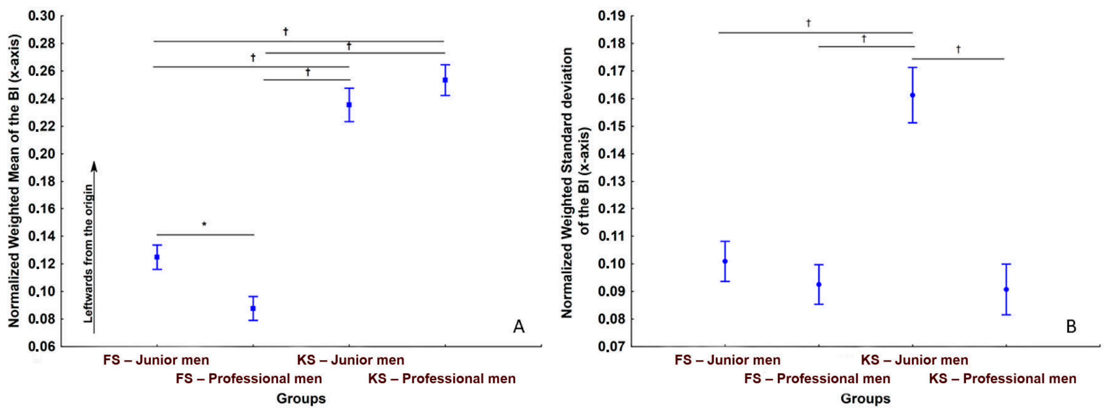

Figure 4. Differences in the ball impact location on the *x*-axis (professional and junior men). Note: FS—flat serve; KS—kick serve; * Significant differences, $p < 0.05$.; † Significant differences, $p < 0.01$; Vertical bars denote 95% CIs. Note: (**A**) normalized weighted mean of the ball impact, (**B**) normalized weighted standard deviation of the ball impact.

There were differences in the normalized weighted mean of the BI location on the *y*-axis among professional and junior, and serve types of the men tennis players, $F_{3,93} = 5.503$, $p = 0.002$, $\mu^2 = 0.15$; Figure 5A, where post hoc testing revealed that BI location of the $KS_{\text{ junior men}}$ was less forwards from the origin than $KS_{\text{professional men,}}$ $FS_{\text{professional men,}}$ and $FS_{\text{ junior men}}$ ($p < 0.01$, $d = 0.53$; $p < 0.01$, $d = 0.99$ and $p < 0.01$, $d = 1.03$, respectively). There were differences in the normalized weighted standard deviation of the BI location on the *y*-axis among professional and junior, and serve types of the men tennis players, $F_{3,93} = 31.153$, $p = 0.001$, $\mu^2 = 0.5$, Figure 5B, where post hoc testing revealed that BI location of the $FS_{\text{junior men}}$ was more clustered closely around the mean than $FS_{\text{professional men}}$, $KS_{\text{ junior men}}$, and $KS_{\text{professional men}}$ ($p < 0.01$, $d = 1.22$; $p < 0.001$, $d = 1.28$; and $p < 0.0001$, $d = 8.4$, respectively), $FS_{\text{adult men}}$ was more clustered closely around the mean than $KS_{\text{professional men}}$

($p < 0.001$, $d = 3.52$), and $KS_{junior\ men}$ was more clustered closely around the mean than $KS_{professional\ men}$ ($p < 0.001$, $d = 1.48$).

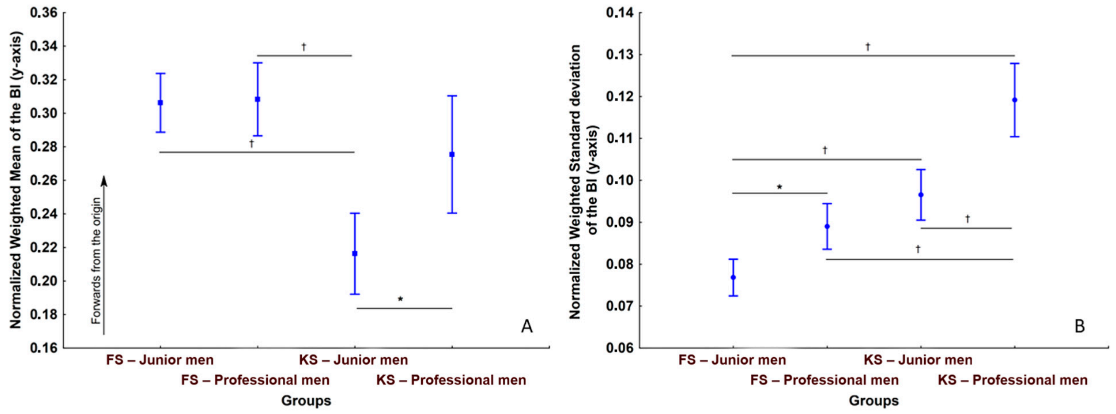

Figure 5. Differences in the ball impact location on the *y*-axis (professional and junior men). Note: FS—flat serve; KS—kick serve; * Significant differences between professional and junior men and the serve type, $p < 0.05$.; † Significant differences between professional and junior men and the serve type, $p < 0.01$ Vertical bars denote 95% CIs. Note: (**A**) normalized weighted mean of the ball impact, (**B**) normalized weighted standard deviation of the ball impact.

There were differences in the normalized weighted mean of the BI location on the *z*-axis among experience and serve types of the male tennis players, $F_{3,123} = 63.180$, $p = 0.0001$, $\mu^2 = 0.61$; Figure 6A, where post hoc testing revealed that BI location of the $FS_{less\text{-}experienced}$ was less high from the origin than $FS_{professional\ men}$, $KS_{junior\ men}$, and $KS_{profesional\ men}$ ($p < 0.001$, $d = 2.85$; $p < 0.001$, $d = 1.92$; and $p < 0.001$, $d = 2.68$, respectively). There were differences in the normalized weighted standard deviation of the BI location on the *z*-axis among experience and serve types of the male tennis players, $F_{3,123} = 59.645$, $p = 0.001$, $\mu^2 = 0.59$, Figure 6B, where post hoc testing revealed that BI location of the $FS_{high\text{-}experienced}$ was more clustered closely around the mean than $FS_{junior\ men}$, $KS_{professional\ men}$, and $KS_{junior\ men}$ ($p < 0.001$, $d = 3.27$; $p < 0.05$, $d = 0.72$; and $p < 0.001$, $d = 2.66$, respectively), and $KS_{professional\ men}$ was more clustered closely around the mean than $FS_{junior\ men}$ and $KS_{junior\ men}$ ($p < 0.001$, $d = 1.5$; $p < 0.001$, $d = 1.64$, respectively). There was not enough data to compare differences in the BI location between gender.

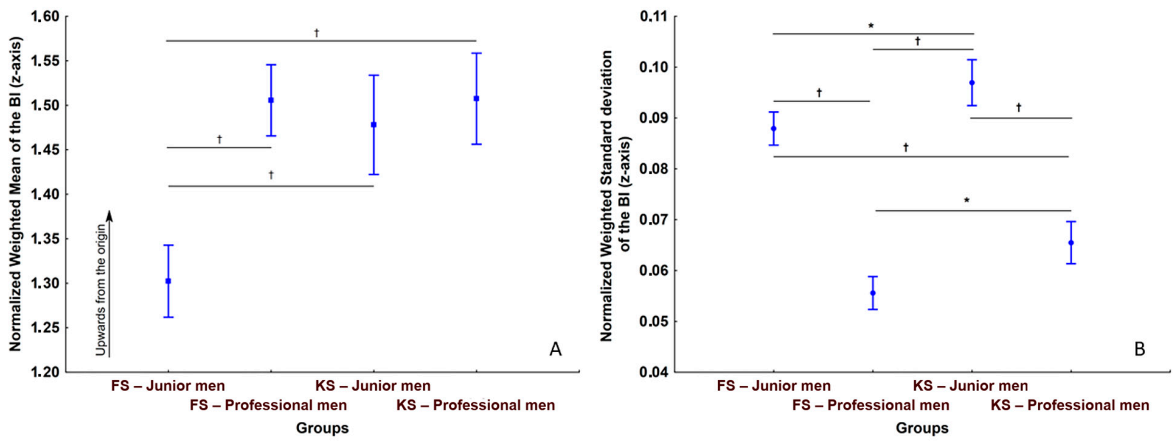

Figure 6. Differences in the ball impact location on the *z*-axis (professional and junior men). Note: FS—flat serve; KS—kick serve; * Significant differences between professional and junior men and the serve type, $p < 0.05$.; † Significant differences between professional and junior men and the serve type, $p < 0.01$ Vertical bars denote 95% CIs. Note: (**A**) normalized weighted mean of the ball impact, (**B**) normalized weighted standard deviation of the ball impact.

4. Discussion

The main finding confirmed our hypothesis that the professional men had a more stable BI location on the z-axis by 56% in FS and 58% in KS than junior men (Figure 6B), which concurs with previous studies [14,17,27]. In addition, the professional men had a more stable BI location on the x-axis by 90% in KS than junior men (Figure 4B). On the other hand, the junior men had more stable BI locations on the y-axis by 17% in FS and 27% in KS than professional men (Figure 5B). Our findings may be most related to the FS and KS performed from the deuce side and targeting the T (the perpendicular center mark on the court or the middle serve line) and body zone of an opponent.

Practically, professional men hit the ball more at the same height within FS and KS than junior tennis players. The average ball hitting height within the FS was 272 cm and KS was 276 cm at professional men and 252 cm and 276 cm, respectively at junior men. This was also related to the higher personal height of professional men than junior men, however, the standard deviation from the average ball-hitting height was 7 cm greater in junior men within FS and 5 cm greater within KS than in professional men. Additionally, the largest differences were found in the mediolateral plane for KS, where junior men had a 13 cm greater standard deviation than professional men. Since better stability of the ball impact locations within the serve has a positive influence on the serve coordination [30], the junior men should focus primarily on a stable ball toss in the vertical and mediolateral planes.

4.1. What Is Known: Summary of the Chosen Studies

- Professional men had the BI location within FS more forwards on the y-axis and less leftwards from the origin on the x-axis than KS [14,19].
- Junior men had the BI location within FS more forwards on the y-axis and less leftwards the origin on the x-axis than KS [20,30], and both serves (FS and KS) more forwards on the y-axis and less leftwards from the origin on the x-axis than junior women [20].
- Junior women had the BI location within FS less forwards from the origin on the y-axis than professional women [31,32], and both serves (FS and KS) had higher from the origin on the z-axis than junior men [20].

4.2. The Main Findings on the x-Axis

In line with previous studies [14,15,26], we found that professional men players have not had more stable BI location on the x-axis within the FS than junior men players. On the other hand, the professional men had a more stable BI location on the x-axis than junior men within KS by 90% (Figure 4B). However, this finding for junior men could be influenced by their tendency to combine the slice serve and the twist serve [31] and a heightened need to impart spin to the ball within the second serve [20]. The identified higher variability in the junior men within KS is consistent with the claim that it is more important for players to learn how to perceive and respond to the varying BI location [32]. The junior men should nevertheless focus on improving the BI location stability within KS.

Concerning the position, junior men performed the BI more leftwards from the origin by 43% than professional men within the FS. On the other hand, the professional men had more leftwards the BI location from the origin than junior men within the KS (by 8%, not significantly different).

Different position of the BI on the x-axis was found to be related to serve types. The professional and junior men had the BI location more leftwards from the origin within the KS by 188% and 88% than FS (Figure 4A), as reported in previous findings [14,20]. It is probably related to the racket's kinematics since the racket's lateral and vertical components are higher for KS than FS, and the more leftwards position of the racket together with more leftwards BI location from the origin on the x-axis allows more peak velocity of the racket. Moreover, there have been proven differences between ball impact performed from the position of the deuce court (right from center) and the position of the ad court (left from center) on the mediolateral axis at the junior players [28], whereas in our study we compared only ball impact from the deuce position.

4.3. The Main Findings on the y-Axis

The studies investigating the BI location on the *y*-axis reported that the junior players performed the BI location more forward within FS than KS [33]. We found that the professional men players had a less stable BI location on the *y*-axis than junior men within FS (by 17%) and KS (by 27%) (Figure 5B). This more stability in the junior men is probably related to the lower ability to vary the serve for tactical purposes (choosing between safety and speed) than professional men. It is in line with the study [17], which reported that professional players tend to present more variability on the *y*-axis than on the *z*-axis within the serve. Concerning the BI location, we found no difference between professional and junior men players within the FS. On the other hand, the professional men performed the BI location by 29% more forwards from the origin than junior men within the KS (Figure 5A). The more forward BI location allows hitting faster serve but is riskier, and therefore it is used by more experienced players.

4.4. The Main Findings on the z-Axis

As mentioned above, the professional men had more stability in the BI location than junior men within FS (56%) and KS (58%) (Figure 6B). Concerning the position of the BI, the junior men performed the BI less upwards from the origin on the *z*-axis by 15% than professional men (Figure 6A). However, the disparity of the BI location in the vertical position of the professional and junior men may relate to more leftward BI from the origin on the *x*-axis to impart more spin [13] and different knee flexion during the preparation phase within the FS in junior players [34].

Concerning the women, although the women group could not be included to compare due to the lack of studies that we selected for this review that professional women had a similar normalized vertical position of the BI on the *z*-axis as junior women; performed the BI location more leftwards on the *x*-axis and a more forwards on the *y*-axis than junior women within FS (Figure 3).

4.5. Limitations of the Study

The main study limitation was an impossible comparison of differences between men and women due to the lack of women's data and eligibility criteria of English articles from only three databases. Another limitation is dividing the category of players' experience only into professional and junior, instead of more common competition differentiation to beginner, intermediate, advanced, and elite players. This was conducted due to the reported categories in the original studies in the original studies. Other limitations are in limiting tennis movement analyses [35] such as volley [36], forehand, backhand, and muscle activation comparison [37].

5. Conclusions

The main finding of the systematic review was that professional men had a more stable height (upward, *z*-axis) and mediolateral position (leftward/rightward, *x*-axis) of the ball impact within the ball toss for both FS and KS than junior men. On the other hand, professional men had less stability anterior-posterior position (forward/backward, *y*-axis) of the ball impact within the ball toss for both FS and KS than junior men. Therefore, we recommend that junior men focus more on the same height of the ball impact but, on the contrary, do not be afraid to vary the anterior-posterior plane of the ball impact, where they can use higher racket speeds when hitting the ball more forward or more control when hitting the ball more backward. For further conducted research, it would be appropriate to focus more on the differences in hitting the ball during the ball toss in the anterior-posterior plane (forward/backward on the *y*-axis) and find out if there is a clear connection with the placement of the ball on the court (T body or wide location).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13063586/s1, Table S1: The search terms used in the review to identify ball impact location title; Table S2: The normalized data of the ball impact extracted from the chosen articles; Table S3: Assessment of methodological quality. References [3,14,15,17,19,20,26–32] are cited in Supplementary Materials.

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