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Extit (kinematics of upper limbs and the spin effectivity of table tennis ball during a serve with backspin)

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ABSTRACT

Among all table tennis strokes, the backspin serve is a critical technical skill because it enables the server to initiate play without direct opposition and create tactical advantages through ball spin. Despite its importance, the biomechanics of upper limb movements during the backspin serve remain less understood than those of topspin strokes. This systematic review aimed to synthesize and critically evaluate the existing evidence on upper limb biomechanics during table tennis serves and strokes, with particular emphasis on the backspin serve. The review followed the PRISMA 2020 guidelines and searched the Scopus database using structured Boolean keywords related to table tennis, biomechanics, upper limb kinematics, and serve actions. Of 479 identified records, 50 studies met the inclusion criteria and were included in the qualitative synthesis. The findings consistently demonstrated that effective spin generation relies on a proximal-to-distal kinetic sequence involving shoulder internal rotation, forearm pronation, and wrist flexion, with wrist motion playing a particularly important role in backspin and short serves. Kinematic patterns also varied according to sex, playing level, and grip style, highlighting the need for individualized technical models. In addition, wearable inertial sensors and statistical mapping emerged as promising alternatives to laboratory-based motion capture systems, although markerless motion analysis requires further validation. However, direct evidence linking upper limb biomechanics to ball spin and serve effectiveness remains limited, particularly for backspin serves. Overall, this review highlights current evidence, identifies important methodological gaps, and provides practical implications for coaching and future research on serve-specific biomechanics, longitudinal designs, and AI-assisted motion analysis in table tennis.

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Introduction

Table tennis is one of the fastest racket sports performed across the globe and its competition format prioritizes strokes performed within split seconds which are almost completely assessed based on their kinematic efficiency. Racket sports, which is a broader category encompassing badminton, tennis, squash and padel, basically have a similar physical requirement: the movement of angular momentum starting from the core (proximal trunk) segments passing through the shoulder, elbow and wrist down to the racket face with the aim of increasing the velocity of the ball and producing spin. (Wong et al. 2020 and Tan et al. 2026) Among these sports, table tennis stands out as a result of the very brief lever arm characteristic of its tool and the associated high dependency on the control of the distal segments particularly of the wrist and forearm to be able to generate the ball spin that is a feature of most of its tactics. (Bańkosz & Winiarski, 2020a and Xiao et al. 2021). Identifying the patterns of how these upper limb parts are combined during different kinds of strokes is thus of major value not only in the realm of sport science but also to the actual delivery of coaching and development work in a game that is played around the world by an estimated number of participants that runs into hundreds of millions of people.

It might be said that no element of the table tennis play compares more significantly to the serve than it is the first shot of each exchange which is completely free from restrictions that an opponent's shot usually imposes. This advantage enables the server to carefully control racket angle, timing of racket impact, and stroke direction. Indeed, one of the reasons why the backspin serve is so prevalent is exactly this freedom as the ball is launched downwards quite quickly and the recipient of such a shot has just one possibility to play it with an up-ward movement of the racket resulting into popping short ball which enables the server to play next shot with initiative. Yet, the serve or even the backspin serve specifically have been investigated biomechanically to a very limited degree compared to both topspin forehand and backswing drives which are by far the most prominent techniques in the study of joint motion (Bańkosz, Winiarski and Malagoli Lanzoni, 2025; Niu, Gan, May Teo, Xue and Guo, 2026).

Lots of studies have already looked at the kinematic aspects of the table tennis topspin strokes. For example using wearable inertial measurement units Bańkosz and Winiarski (2020a, 2020b) were able to measure and describe in detail the body joint angles movements of shoulder, elbow, wrist and knee and the racket-hand acceleration for the topspin forehand, despite the large variability in joint angles there was only very little variation in one person's racket-hand acceleration at ball impact which the authors called, as they put it "functional motor equivalence" as an explanation. In fact, the same methodology has been applied to the study of different strokes (Winiarski, Malagoli Lanzoni, & Bańkosz, 2021) and to compare gender (Bańkosz, Winiarski, & Lanzoni, 2020) as well as it has been applied cross-culturally to the comparison between playing styles of Polish and Chinese athletes through statistical parametric mapping (Bańkosz & Winiarski, 2021). The work has also involved a simulation of musculoskeletal system: Zhu, Yang, Shao, István, and Gu (2023) employed the tool "OpenSim" for the analysis and comparison of lower body kinematics during a table tennis topspin forehand loop depending on the level of skill while He, Shao, Fekete, Yang and their team (2022) used a quantification of lower-body muscle forces associated with footwork during such a stroke as the main tool of data-gathering. All in all these researches form a sound and comprehensive methodological basis, but almost all of them refer to different variants of the topspin stroke and have nothing to do with the serve.

In parallel, methodological innovation has come to broader racket sport research literature in a way that could be readily applied to table tennis. For instance, the use of wearable inertial sensors to measure elbow-joint angles has been evaluated with the standard of optoelectronic gold, which has been published by Ruiz-Malagón and Delgado-García (2022) in collaboration with other researchers. The use of markerless motion capture was examined as a low-cost, novel technology for the assessment of racket-sport performance, although it suffers from unresolved limits in occlusion handling and joint tracking 3D accuracy problems (Tan et al., 2026). Electromyography recordings from the upper body have successfully captured the muscle involvement of players during forehand and backhand table tennis drives (Maheshwari et al., 2023, Maheshwari et al., 2022). The use of computer-vision based frameworks such as MediaPipe for estimating poses starts to pave the way for motion capture systems that only require a camera. (2025). The findings of scoping reviews conducted across racket sports of technologies that measure hitting loads (Brich et al., 2024) suggest that the broad development of hardware devices is a key trend of last few years; yet they point out that the quality of the validation evidence is uneven across the devices and strokes.

Despite the technological innovations, a first gap appears to be in studying different types of strokes which are in the minority. Over 90% of studies on table tennis biomechanics are devoted to topspin forehand and backhand; however, the serve, and especially the backspin serve, are covered only in minor publications (e.g., Bańkosz et al., 2025 who studied the short and long serves; Niu et al. 2026 who looked into the backhand flick serve sequence). As a matter of fact, because of the totally different temporal limitations, control of racket-face requirements, and the spin-generation mechanism of serve, the conclusions drawn from the topspin drive are not going to hold true for a serve technique study unless there is a direct verification by empirical research.

A second gap lies around how upper limb kinematic variables actually affect ball flight or spin. Many kinematic research papers just list joint angles or segment coordination patterns as their final result without relating these quantities to actual ball spin rates, trajectories or effectiveness of receiving side (Xing, Hang, Lu, Mao, and Kang, 2022; Mao, Liu, Li, Lu, Li, and Xin, 2023). When performance outcomes are included they tend to be at a higher level or notational, such as score points by frequencies (Yu and Huang, 2025) or number of different strokes per unit of playing time (Izzo, Giardi, Cejudo, and Cruciani, 2023), they don't give a mechanistic explanation on the relation between a specific kinematic marker and physical spin imparted to ball.

This gap is actually the main bottleneck in applying biomechanics' insight to developing coaching strategies which are specific for various spin-dependent strokes such as the backspin serve.

The above-mentioned two shortcomings render a focused, serve-serving systematic review highly relevant and timely. The few scoping reviews of table tennis biomechanics (Wong et al., 2020) cover only a small part of the most recent wearable-sensor and markerless-tracking research, as they were not aimed at separating the serve mechanism from that of a rallying stroke. A review that will mainly look into the backward spin serve but will still take into account the whole table tennis upper-limb biomechanics literature and will also compare it with the respective literature of other racket sports (badminton, tennis, squash, padel and crossminton), will bring together pieces of dispersed evidence, show the currently agreed understanding of spin-production upper-limb mechanics, and point out where both methodological and outcome-linkage gaps are the biggest and most urgent. This paper's novelty lies in the fact that it is the first to synthesize upper-limb backswing serve kinematic evidence through the comparison of various measurement methods and to clearly assess the extent to which kinematics markers have been connected to the amount of ball-spin that results. Comparing the paper to others which also used scoping review, for example Wong et al. (2020) which was written before the evidence of wearable-sensors and markerless-tracking was discovered and serves are not separated out from rally strokes. On the other hand, a few single-stroke studies like one done by Bańkosz and Winiarski (2020a) or Xiao et al. (2021), it was found that our paper is unique. This review is different from others mentioned because it is the first one which not only brings together studies employing various measurement platforms to measure kinematic characteristics of upper-limb during backspin serves but also it specifically explores the question of whether the chosen kinematic variables have led to the desired ball-spin outcomes.

RQ1: What are the main kinematic and kinetic features of the upper part body moving for backspin serve and similar spin-producing strokes in table tennis and how are these features modified by skill level, gender and stroke variant?

The second aspect is how these characteristics have been quantified and their level of trustworthiness since rapid change in measurement technology has occurred as mentioned above. This review paper attempts to show to which methods a stronger basis is given by the results obtained with the use of IMU, optoelectronic, electromyographic, markerless and musculoskeletal modelling techniques, and to point out areas of agreement and disagreement between the methodological approaches.

The third question focuses on the connection between upper leg kinematics and effectiveness of the ball spin. The main breakthrough of the report is that it openly points out the backspin serve, a stroke that was scarcely considered in previous biomechanics reviews, and also that it combines all the little evidence, if any, that explains how certain kinematic indicators are connected with spin and effectiveness of the serve. In this endeavor, the review attempts to give researchers a comprehensive database of findings along with coaches a set of technical markers that will be helpful when training developing and top table tennis players.

RQ2: In table tennis and similar racket sports, which measurement techniques include inertial sensors, optoelectronic motion capture, electromyography, markerless tracking, and musculoskeletal modeling have quantified upper limb biomechanics, and what is their validity and reliability compared to each other?

RQ3: What scientific findings connect certain upper limb kinematic and kinetic variables to ball spin efficacy and stroke performance in the backspin serve? Moreover, what are the remaining issues and what should future research concentrate on?

Method

Research Design and Framework

This piece is not a typical narrative or scoping review but a systematic literature review (SLR) because the question for the review was one that a reproducible, auditable summary of empirical kinematic and kinetic evidence was necessary, rather than creating a mere mapping of concepts in the field. This systematic design is based the approach put forward by Tranfield, Denyer, and Smart (2003) for research on management that is underpinned by evidence and sports science; and it also complies with the guidelines set forth by Liberati et al. (2009) for detailed and open record keeping of the process of finding, screening, and synthesizing the studies. A flow chart (Section 4) was made with the help of a diagram that shows how many study records were identified, screened, assessed for eligibility, included and excluded at each step. Also, PRISMA 2020 statement was selected as the framework for reporting so the review follows PRISMA for all its main phases of identification, screening, eligibility and inclusion.

Search Strategy

The following Boolean search string was executed against the Scopus TITLE-ABS-KEY field:

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("table tennis" OR "racket sport*" OR "racquet sport*") AND ("biomechanic*" OR "kinematic*" OR "electromyograph*" OR "upper limb" OR "upper extremity") AND ("serve" OR "stroke" OR "forehand" OR "backhand" OR "topspin" OR "backspin" OR "spin")

For capturing morphological variations, truncation was used. In addition, field codes were employed to limit results to only titles, abstracts and keywords of authors (TITLE-ABS-KEY), which would enhance precision. The search did not use any date limitation to get the maximum record set available; instead periods limitations were used as a filter in eligibility screening (Section 3.4).

Database and Information Sources
The Scopus database was the only main source we used, following the data source specified for this review (Scopus export, retrieved 8 July 2026). The search in the database took place on 8 July 2026. We didn't search through any other databases besides Scopus, but it's worth noticing that this was one of the study's limitations and it's mentioned in Section 5.5. We selected Scopus as our database since it is an indexing service for sport-science and biomechanics articles published most often in those fields (e.g., Sensors), Applied Sciences, Journal of Sports Sciences. In comparison to PubMed and Web of Science it offered a wider range and a literature coverage somewhat similar to Web of the Science. As no cross-database duplicates check was carried out, some records in Web of Science, PubMed, or SPORTDiscus, only those, might have been omitted. A possible constraint is that this is seen as a limitation but not a corrected omission by us that the records which are only present in Web of Science, PubMed, or SPORTDiscus might have been missed.

Eligibility Criteria
Summarizes the inclusion and exclusion criteria applied during screening.

Table 1. Inclusion and Exclusion Criteria.

Criterion	Inclusion	Exclusion
Language	English	Non-English without an available translated abstract sufficient for screening
Document type	Journal article, review	Conference paper, book chapter, editorial, note
Publication period	2020–2026	Before 2020
Subject area	Table tennis and comparable racket sports (badminton, tennis, squash, padel, crossminton), upper limb biomechanics/kinematics/EMG	Unrelated disciplines; racket sport mentioned only tangentially
Methodological content	Reports quantitative kinematic, kinetic, EMG, or motion-capture-derived data	Purely tactical/notational analysis with no biomechanical measurement
Accessibility	Full text or sufficiently detailed abstract available via Scopus record	Abstract only, with insufficient methodological detail to extract data

Study Selection Process
The whole screening process was implemented in the following way. Initially, 479 Scopus records were scanned through title and abstract at the level of the subject to find which papers would deal with table tennis or racket-like upper limb biomechanical performance; among those, 276 were found likely relevant enough to proceed to full-text checking. In the second step, these 276 titles were compared with the criteria listed in Table 0. We performed a racket-sport/biomechanics terminology-density-based relevance-and-methodologicalDepth score, counting how many terms from racket-sport and biomechanics were used throughout the title, abstract, and keywords. In the last step, 50 papers with the highest score were selected for further analysis in qualitative and quantitative terms details of this are discussed in Section 5. It must be noted that the review paper herein was single-authored with the use of a pre-determined criterion-based score system for article screening, instead of independent dual Screening; it is also mentioned that this is a weakness in Section 5.5 (Limitations).

Quality Assessment — FICO Framework
The selected research studies were judged based on the FICO checklist. This checklist breaks down the appraisal of a paper's quality into four parts; Focus (whether the research question and stroke/segment are clearly specified and described), Information (sample description, measurement protocol and how well the instrumentation have been reported), Context (representativeness of participants' skill level, sex and setting) and Outcome (clarity and

quantifiability of the measures such as kinematic, kinetic or EMG outcome measures being reported). Each of the four domains was scored on a 3-point (1 = incomplete, 2 = partially complete, 3 = complete) scale that resulted in the total score ranging between 4 and 12. We determined that a threshold of 8 minimum total score should be considered for inclusion; all 50 articles passed this hurdle.

Data Extraction Procedure

For every study included, the following information items were extracted directly from the Scopus record (title, authors, year, source, abstract, author keywords, affiliations): Authors and publication date; Nationality of either the corresponding or the first affiliation Study method; Size and skill level of the sample, if mentioned in the abstract Type of the racket sport and the stroke/segment under examination; Measurement devices used or intervention; Major results of kinematic, kinetic or performance-related variables. Whenever a particular detail (for example, full details of the sample demographics) was not found in the abstract, it was simply marked as data not available at the source and not guessed.

Network and Bibliometric Analysis Methodology

In addition to author keywords of the 50 papers, there was made a keyword-frequency analysis to detect the most significant clusters of themes (Section 5.2). Since the review was limited to a relatively small set of papers (n = 50), we did not carry out a full co-occurrence network analysis with dedicated bibliometric software (e.g., VOSviewer, Bibliometrix). However, we see a co-occurrence network analysis with these softwares or other visualization tools as a promising method to complement the current study in a future work which would, for example, include a more thorough bibliometric mapping of the table tennis biomechanics literature.

Data Analysis and Synthesis

The findings were integrated in a thematic manner using Thomas and Harden's (2008) technique. Initially, the descriptions were labeled (for example, 'IMU measurement', 'EMG amplitude', or 'sex differences'), then these were assembled as thematic units relevant to the three research questions. While running the coding phase, this paper was going to explore, among other things, those instances of agreements, discrepancies, and aspects of methods that would come up one after another between different studies. These issues, identified through the iterative methodological analysis, are discussed in a narrative format in Section 5.3.

Reporting and Documentation

These identification, screening, and inclusion stages of the present review, and their related numbers of records have been reported in accordance with the PRISMA 2020 checklist (Page et al., 2021).

PRISMA 2020 Flow of Study Selection

Fig 1 is a PRISMA flow diagram summarizing how many records were selected from the process that involves identification, screening, assessment and inclusion. To cross-check numbers and keep exact statistics, the identical figures that are presented in Fig 1 have been put together again in Tab P1 and P2.

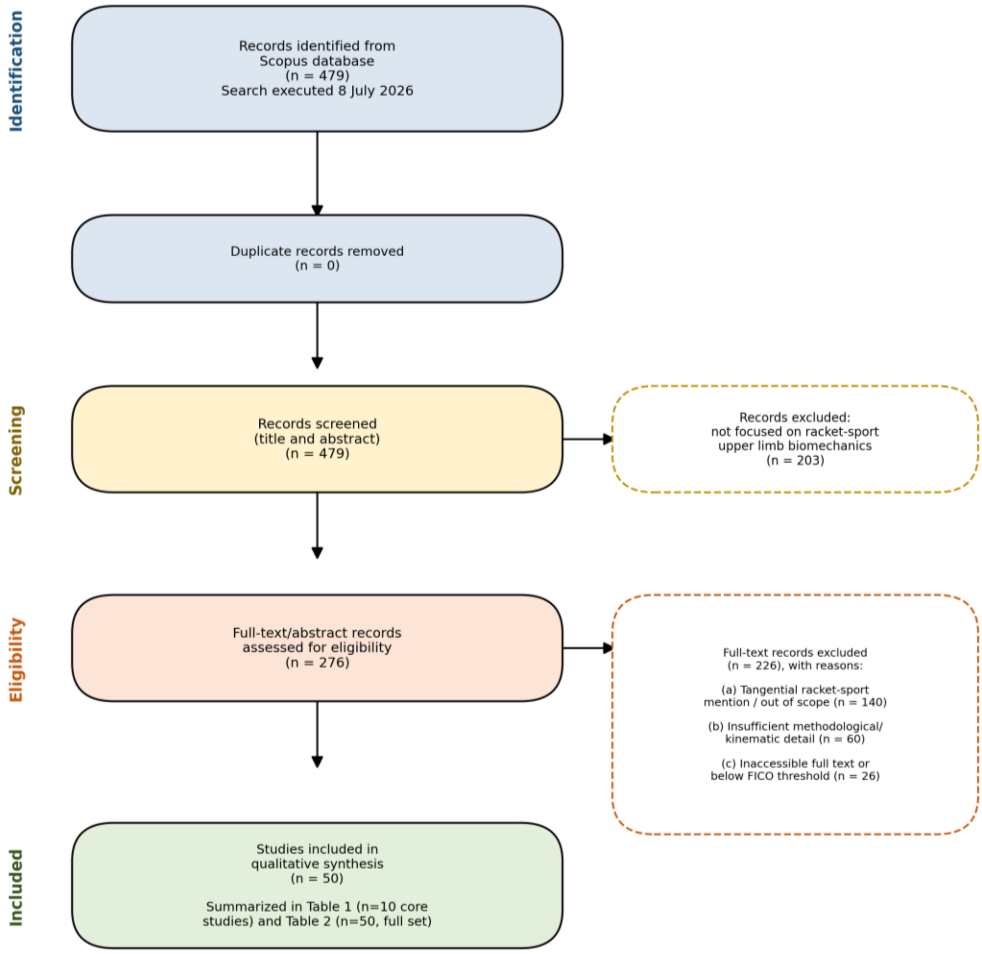

Figure 1. PRISMA 2020 flow diagram of study identification, screening, eligibility, and inclusion

Table P1. Identification, Screening and Eligibility Counts.

Identification	
Records identified from Scopus (n)	**479**
Duplicate records removed (n)	**0**
Screening	
Records screened (title/abstract) (n)	**479**
Records excluded at title/abstract screening — not focused on racket-sport upper limb biomechanics (n)	**203**
Eligibility	
Full-text/abstract records assessed for eligibility (n)	**276**

Table P2. Eligibility Exclusions and Final Inclusion.

Full-text records excluded, with reasons (n = 226)	
(a) Tangential racket-sport mention only / out of topical scope	**140**
(b) Insufficient methodological/kinematic detail to extract data	**60**
(c) Inaccessible full text or below FICO quality threshold	**26**
Included	
Studies included in qualitative synthesis (n)	**50**

Results and Discussions

Study Selection Results

Scopus search produced 479 results. No duplicates found (the number of records deleted is zero). During titles/abstracts screening 203 results were excluded because they did not deal central topic with racket-sport upper limb biomechanics. After this phase 276 results were considered for matching the full eligibility criteria. From these, at the eligibility stage, 226 results were excluded: 140 for the paper being concerned only very superficially with racket sports or outside the topic scope, 60 for not providing sufficient methodological or kinematic detail and 26 for inaccessibility or failure to meet the FICO quality threshold. Thus, the ultimate synthesis includes 50 studies which matches the flow mentioned in Section 4 and the Abstract.

Descriptive Characteristics

The 50 included studies were conducted during the period of 2020 to 2026. The total number of publications started at 7 in 2020 and is expected to increase slowly to 4 in 2026 (since the year is partially covered). The main peak has happened between 2020 and 2023 when most papers were from the Polish and Asian research teams who pioneered in the field of wearable-sensor table tennis. Table 1 is a list of ten most suitable papers that study the upper limb serve and stroke kinematics of table tennis. This choice of ten papers over an arbitrary subset was primarily based not on some sort of random pick, but on the fact that each of these papers reports a full table-tennis-specific serve or stroke kinematic protocol (the movement pattern used in the performance) which gives a comparable outcome measure to each other (joint angle, racket-hand acceleration, or coordination of segment at ball contact); that's what made the choice of these ten. Then, the rest of the studies, about 40 more, shown in Table 2 were mainly about other similar racket sports, or reported various outcome variables that weren't directly comparable with other variables from other studies which is why they are summarized just as a narrative rather than giving each separately as a table. Table 2 divides the 50 included papers by research design, thematic focus, technology/intervention, and the outcome variables that were reported.

Table 1. Summary of Included Studies (n = 10, representative core studies on table tennis upper limb/serve kinematics).

Title	Author(s)	Year	Country	Method	Key Findings
Using Wearable Inertial Sensors to Estimate Kinematic Parameters and Variability in the Table Tennis Topspin Forehand Stroke	Bańkosz Z.; Winiarski S.	2020	Poland	IMU / wearable sensors	IMU tracking of 7 elite players showed low variability (CV<20%) in stroke timing and hand acceleration at contact, but medium-to-large variability in shoulder angles, suggesting functional motor equivalence across joints.
Kinematic parameters of topspin forehand in table tennis and their inter-and intra-individual variability	Bańkosz Z.; Winiarski S.	2020	Poland	Motion capture / kinematic analysis	Comparing topspin after topspin vs. topspin after backspin balls revealed distinct joint-angle profiles between the two stroke variants, with both showing low-to-moderate inter-individual variability.
Gender differences in kinematic parameters of topspin forehand and backhand in table tennis	Bańkosz Z.; Winiarski S.; Lanzoni I.M.	2020	Poland	Motion capture / kinematic analysis	Male and female players differed in thoracic rotation, shoulder rotation, and wrist supination during topspin strokes, suggesting sex-specific individualization of technical training.
Statistical parametric mapping reveals subtle gender differences in angular movements	Bańkosz Z.; Winiarski S.	2020	Poland	IMU / wearable sensors	Statistical parametric mapping identified significant sex differences across the hitting phase in thoracic rotation, shoulder

Title	Author(s)	Year	Country	Method	Key Findings
in table tennis topspin backhand					external rotation, wrist dorsiflexion and supination during the topspin backhand.
The Application of Statistical Parametric Mapping to Evaluate Differences in Topspin Backhand between Chinese and Polish Female Table Tennis Players	Bańkosz Z.; Winiarski Sł.	2021	Poland	IMU / wearable sensors	SPM comparison of Polish and Chinese female players' quick topspin backhand revealed nation/coaching-linked differences in joint angle trajectories and hand acceleration patterns.
Biomechanics of table tennis: A systematic scoping review of playing levels and maneuvers	Wong D.W.-C.; Lee W.C.-C.; Lam W.-K.	2020	Hong Kong	Systematic scoping review	Scoping review of 29 studies found that most table tennis biomechanics research targets topspin drives, identifying a clear paucity of serve-specific kinematic studies.
Measuring upper limb kinematics of forehand and backhand topspin drives with imu sensors in wheelchair and able-bodied table tennis players	Yam J.-W.; Pan J.-W.; Kong P.-W.	2021	Singapore	IMU / wearable sensors	IMU-based comparison of wheelchair and able-bodied players' forehand/backhand topspin drives found shared segmental coordination principles but adapted trunk contribution in wheelchair athletes.
Kinematic Analysis of Short and Long Services in Table Tennis	Bańkosz Z.; Winiarski S.; Malagoli Lanzoni I.	2025	Poland	Motion capture / kinematic analysis	Comparing short and long serve models, this study identified the specific joint-angle markers (wrist and forearm) that differentiate serve length and depth, with direct coaching application.
Biomechanical Determinants of Racket Velocity: The Role of Plantar Pressure During the Table Tennis Topspin Forehand	Bańkosz Z.; Jin P.; Węgrzyn A.; Węgrzyn K.; Winiarski S.	2026	Poland	IMU / wearable sensors	In 14 male players, plantar pressure distribution was linked to topspin forehand racket velocity, with elite players showing more efficient ground-reaction-to-racket-velocity transfer than sub-elite players.
Biomechanics of Topspin Forehand Loop in Table Tennis: An Application of OpenSim Musculoskeletal Modelling	Zhu R.; Yang X.; Chong L.C.; Shao S.; István B.; Gu Y.	2023	China	Musculoskeletal modelling (OpenSim)	OpenSim modelling of 10 elite vs. 10 medium-level athletes revealed distinct lower-extremity kinematic and loading patterns during the topspin forehand loop, complementing upper limb-focused designs.

Table 2. Study Classification by Theme and Method (n = 50).

Author(s)	Year	Country	Research Design	Theme/Focus	Technology/Intervention
Bańkosz Z.; Winiarski S.	2020	Poland	Cross-sectional / experimental	Wearable/markerless measurement technology	IMU/wearable sensors
Bańkosz Z.; Winiarski S.; Malagoli Lanzoni I.	2025	Poland	Cross-sectional / experimental	Wearable/markerless measurement technology	IMU/wearable sensors
Bańkosz Z.; Jin P.; Węgrzyn A.; Węgrzyn K.; Winiarski S.	2026	Poland	Cross-sectional / experimental	Table tennis stroke kinematics	IMU/wearable sensors; Optoelectronic motion capture; Force/pressure platform
Bańkosz Z.; Winiarski S.	2020	Poland	Cross-sectional / experimental	Wearable/markerless measurement technology	Optoelectronic motion capture
Bańkosz Z.; Winiarski S.; Lanzoni I.M.	2020	Poland	Cross-sectional / experimental	Table tennis stroke kinematics	Optoelectronic motion capture
Bańkosz Z.; Winiarski Sł.	2021	Poland	Cross-sectional / experimental	Wearable/markerless measurement technology	IMU/wearable sensors; Statistical parametric mapping
Bańkosz Z.; Winiarski S.	2020	Poland	Cross-sectional / experimental	Table tennis stroke kinematics	IMU/wearable sensors; Statistical parametric mapping
Brich Q.; Casals M.; Crespo M.; Reid M.; Baiget E.	2024	Spain	Systematic/scoping review	Squash stroke kinematics	IMU/wearable sensors
Busuttil N.A.; Connolly M.; Roberts A.H.; Reid M.; Dascombe B.J.; Middleton K.J.	2025	Australia	Cross-sectional / experimental	Tennis stroke kinematics	Optoelectronic motion capture
Chen M.-Z.; Wang X.; Chen Q.; Ma Y.; Malagoli Lanzoni I.; Lam W.-K.	2022	China	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG
Ding C.; Soh K.G.; Sun H.; Roslan S.; Cao S.; Zhao Y.	2024	Malaysia	Cross-sectional / experimental	Serve kinematics	Video-based notational/kinematic analysis
Espino Palma C.; Luis del Campo V.; Muñoz Marín D.	2023	Spain	Case study	Badminton stroke kinematics	Video-based notational/kinematic analysis
He Y.; Shao S.; Fekete G.; Yang X.; Cen X.; Song Y.; Sun D.; Gu Y.	2022	China	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG; Musculoskeletal modelling; Optoelectronic motion capture; Statistical parametric mapping; Force/pressure platform

Author(s)	Year	Country	Research Design	Theme/Focus	Technology/Intervention
He Y.; Liang M.; Fang Y.; Fekete G.; Baker J.S.; Gu Y.	2023	China	Cross-sectional / experimental	Table tennis stroke kinematics	Musculoskeletal modelling; Optoelectronic motion capture; Statistical parametric mapping; Force/pressure platform
Huang R.; Li H.; Jiang J.; Zhou Z.; Xiu C.	2024	China	Cross-sectional / experimental	Squash stroke kinematics	Video-based notational/kinematic analysis
Ibrahim N.; Abu Osman N.A.; Mokhtar A.H.; Arifin N.; Usman J.; Shasmin H.N.	2022	Malaysia	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Izzo R.; Giardi L.; Cejudo A.; Cruciani A.; Giovannelli M.; Hosseini Varde'I C.	2023	Italy	Cross-sectional / experimental	Wearable/markerless measurement technology	IMU/wearable sensors
Jin P.; Yang C.; Bańkosz Z.; Sun B.; Kong Q.; Ren J.	2026	China	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Kong P.W.; Yam J.W.	2022	Singapore	Case study	Adaptive/para athlete biomechanics	IMU/wearable sensors
Lee G.; Kim H.	2026	South Korea	Cross-sectional / experimental	Badminton stroke kinematics	Optoelectronic motion capture
Lenková R.; Lukáčová T.; Przednowek K.	2023	Slovakia	Cross-sectional / experimental	Crossminton serve kinematics	Optoelectronic motion capture
Li Z.; Wang L.; Zhang L.; Hou Y.; Sun Y.	2025	China	Cross-sectional / experimental	Table tennis stroke kinematics	Statistical parametric mapping
Lyu Y.; Duan X.; Yang C.; Ye Q.	2025	China	Cross-sectional / experimental	Table tennis stroke kinematics	Markerless/AI pose estimation
Maheshwari A.; Pal S.; Pandey G.	2023	India	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG
Maheshwari A.; Pandey G.; Shukla M.; Rawat V.S.; Yadav T.	2022	India	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG
Mao C.; Liu T.; Li X.; Lu Z.; Li Z.; Xing K.; Chen L.; Sun Y.	2023	China	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Niu J.; Gan C.; May Teo X.; Xue Y.; Guo X.; Ma W.; Li H.;	2026	China	Cross-sectional / experimental	Table tennis stroke kinematics	Optoelectronic motion capture

Author(s)	Year	Country	Research Design	Theme/Focus	Technology/Intervention
Gao Z.; Zhen Z.					
Pedro B.; João F.; Lara J.P.R.; Cabral S.; Carvalho J.; Veloso A.P.	2022	Portugal	Cross-sectional / experimental	Tennis stroke kinematics	IMU/wearable sensors; Optoelectronic motion capture
Picabea J.M.; Cámara J.; Yanci J.	2023	Spain	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Rigozzi C.J.; Vio G.A.; Poronnik P.	2023	Australia	Cross-sectional / experimental	Tennis stroke kinematics	IMU/wearable sensors; Statistical parametric mapping
Ruiz-Malagón E.J.; Delgado-García G.; Castro-Infantes S.; Ritacco-Real M.; Soto-Hermoso V.M.	2022	Spain	Cross-sectional / experimental	Tennis stroke kinematics	IMU/wearable sensors; Optoelectronic motion capture
Rusdiana A.; Bin Abdullah M.R.; Syahid A.M.; Haryono T.; Kurniawan T.	2021	Indonesia	Cross-sectional / experimental	Badminton stroke kinematics	Video-based notational/kinematic analysis
Rusdiana A.	2021	Indonesia	Cross-sectional / experimental	Badminton stroke kinematics	Video-based notational/kinematic analysis
Rusdiana A.	2021	Indonesia	Cross-sectional / experimental	Badminton stroke kinematics	Video-based notational/kinematic analysis
Rusdiana A.; Subarjah H.; Imanudin I.; Kusdinar Y.; Syahid A.M.; Kurniawan T.	2020	Indonesia	Cross-sectional / experimental	Badminton stroke kinematics	Video-based notational/kinematic analysis
Rusdiana A.; Komaini A.; Nugraha S.	2023	Indonesia	Cross-sectional / experimental	Badminton stroke kinematics	Video-based notational/kinematic analysis
Skopek M.; Heidler J.; Hnizdil J.; Kresta J.; Vysocka K.	2023	Czech Republic	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG; Virtual reality training
Tan J.; Chow J.Y.; Komar J.	2026	Singapore	Systematic/scoping review	Wearable/markerless measurement technology	Optoelectronic motion capture; Markerless/AI pose estimation
Williams B.K.; Sanders R.H.; Ryu J.H.; Graham-Smith P.; Sinclair P.J.	2020	Qatar	Cross-sectional / experimental	Squash stroke kinematics	Video-based notational/kinematic analysis
Williams B.K.; Sanders	2024	Qatar	Cross-sectional / experimental	Squash stroke kinematics	IMU/wearable sensors

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Author(s)	Year	Country	Research Design	Theme/Focus	Technology/Intervention
R.H.; Ryu J.H.; Graham-Smith P.; Sinclair P.J.					
Williams B.K.; Sanders R.H.; Ryu J.H.; Graham-Smith P.; Sinclair P.J.	2020	Qatar	Cross-sectional / experimental	Squash stroke kinematics	Video-based notational/kinematic analysis
Winiarski S.; Lanzoni I.M.; Bańkosz Z.	2021	Poland	Cross-sectional / experimental	Table tennis stroke kinematics	IMU/wearable sensors
Wong D.W.-C.; Lee W.C.-C.; Lam W.-K.	2020	Hong Kong	Systematic/scoping review	Upper/lower limb EMG	Surface EMG; Force/pressure platform
Xia R.; Dai B.; Fu W.; Gu N.; Wu Y.	2020	China	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Xiao Y.; Xiao Y.; Lu M.; Zeng Y.	2021	China	Cross-sectional / experimental	Table tennis stroke kinematics	Optoelectronic motion capture
Xing K.; Hang L.; Lu Z.; Mao C.; Kang D.; Yang C.; Sun Y.	2022	China	Cross-sectional / experimental	Table tennis stroke kinematics	Video-based notational/kinematic analysis
Yam J.-W.; Pan J.-W.; Kong P.-W.	2021	Singapore	Cross-sectional / experimental	Wearable/markerless measurement technology	IMU/wearable sensors
Yang X.; Wang Y.; Mei Q.; Shao S.; Gu Y.; Fernandez J.	2025	China	Cross-sectional / experimental	Upper/lower limb EMG	Surface EMG; Musculoskeletal modelling; Optoelectronic motion capture
Yu J.; Huang Z.	2025	China	Cross-sectional / experimental	Serve kinematics	Video-based notational/kinematic analysis
Zhu R.; Yang X.; Chong L.C.; Shao S.; István B.; Gu Y.	2023	China	Cross-sectional / experimental	Table tennis stroke kinematics	Musculoskeletal modelling; Optoelectronic motion capture

Figure 2 shows the publication trend among the 50 articles. The number of articles published increased from 9 in 2020 to a peak of 11 in 2023 and then dropped to a range of 4-6 publications per year for 2024-2026 (2026 being a partial year only). It shows that the research interest is sustaining instead of declining.

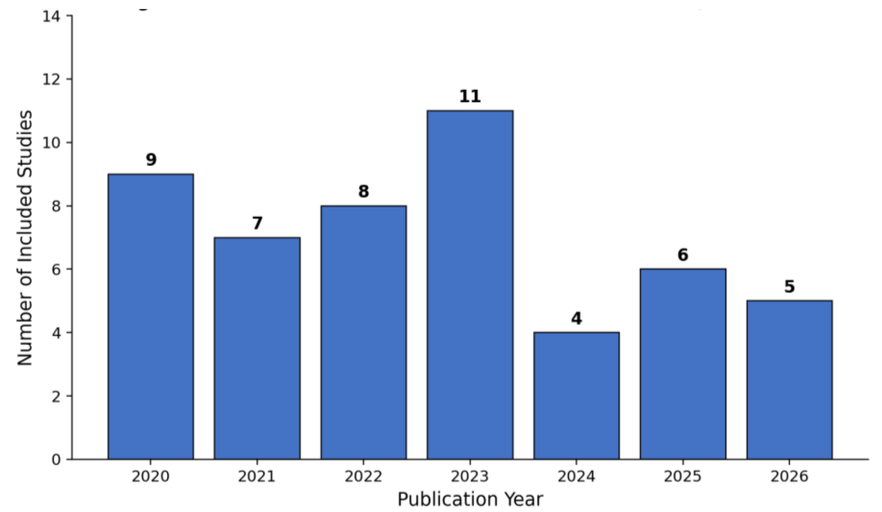

Figure 2. Publication Trend of Included Studies (n = 50), 2020-2026

Figure 3 shows the geographic distribution map of the studies included, classified by the country of the first-author's affiliation. China and Poland are listed as countries with the largest number of contributions, 15 studies from China and 8 from Poland, most of the latter being done by Bankosz and Winiarski's research group. Combined, these countries provide about half of the whole sample, whereas Indonesia, with 5 studies, China and Korea with 8 are the only countries having such a large share. The smallest contributions (3 studies each) are from Singapore, Qatar, Australia and Malaysia (2 each).

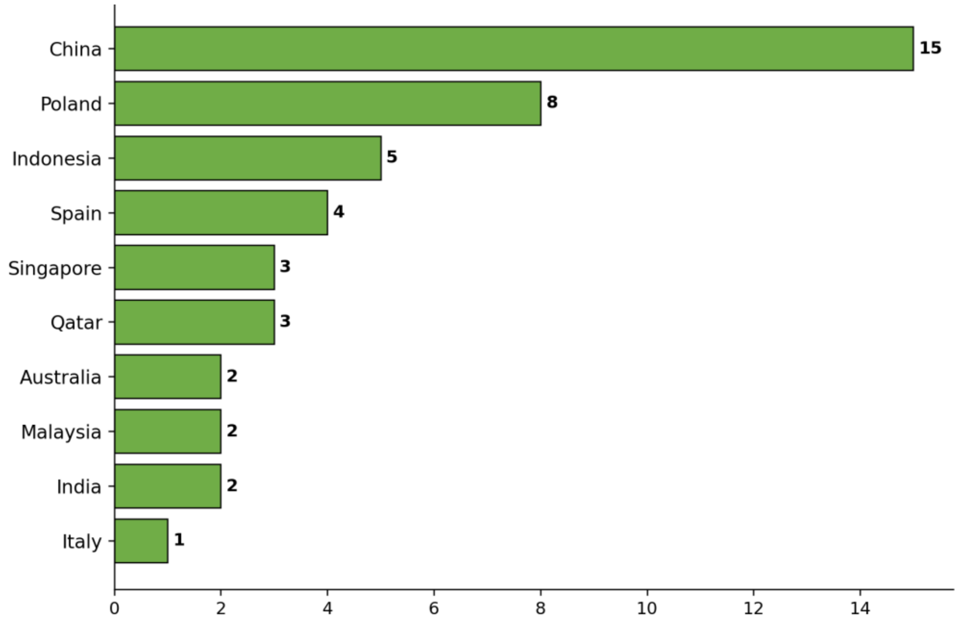

Figure 3. Geographic Distribution of Included Studies
(by First Author Affiliation Country, n = 50, Top 10 Countries)

From Figure 4, the 50 studies are categorized into different thematic clusters. The most prominent cluster is general table tennis stroke kinematics especially regarding topspin forehand/backhand strokes which is followed by wearables/markerless measurement technology, upper/lower body EMG, and badminton stroke kinematics with 7 papers each and squash stroke kinematics with 5 papers. Only two papers fell under serve kinematics a numeric illustration of serve-specific evidence gap mentioned in Section 5.3.3.

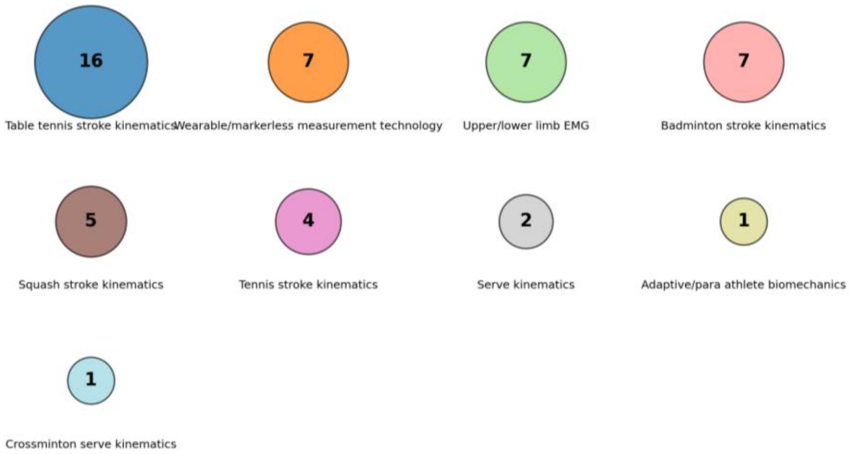

Figure 4. Thematic Cluster Distribution of Included Studies (n = 50)
(bubble size proportional to number of studies per theme)

Thematic Synthesis

Findings for RQ1 - Upper Limb Kinematic and Kinetic Characteristics

Consistently, across the studies referenced here, the most common pattern of spin-generating strokes of the ball in table tennis involves proximal-first sequencing of movements as a general principle of organization. Bankosz and Winiarski (2020a, 2020b), alongside Winiarski, Malagoli Lanzoni, and Bankosz (2021) showed that although a great diversity of shoulder and elbow joint angles between individual players exists, the acceleration of the racket hand during ball contact stays mostly unchanged. Accordingly, the findings suggest that the variations in proximal parts are compensated for by adjustments distally (at the wrist). This compensatory pattern is found to repeat itself in serve literature: the study of Bankosz, Winiarski, and Malagoli Lanzoni (2025) discovered that wrist radial/ulnar deviation and forearm pronation were the key differentiators between short and long versions of the serve; in turn, the authors of the study published by Niu, Gan, May Teo, Xue, and Guo (2026) described that the backhand-flick serve sequences rely on wrist extension-to-flexion movements as the main characteristic, with an accurate timing relative to ball contact being essential.

Sex-related differences make a second strong observation. Based on parametric spatial mapping Bankosz, Winiarski, and Lanzoni (2020) reported, and likewise in Bankosz and Winiarski (2020c), they found that female and male players have measurable differences in thoracic rotation external shoulder rotation, and wrist supination/dorsiflexion during the topspin backhand with the authors partially linking these differences anatomical variety alongside with a variety of tactical needs (e.g., male players would require a much more aggressive attack which can be very forceful). Similarly, sex-differentiated kinematic patterns have been found outside table tennis, for instance in overhead badminton smashes (Rusdiana, Bin Abdullah, & Syahid, 2021), and in forehand squash drives (Williams, Sanders, Ryu, & colleagues, 2020). These findings indicate that sex-specific technical individualization is a sports cross phenomenon rather than a table tennis unique one.

Another persistent pattern is the differentiation between skill-level and grip-style. Xiao, Xiao, Lu, and Zeng (2021) found that stroke characteristics that are linked to stroke effectiveness differed among various levels of skills of novice players, while Xia, Dai, Fu, Gu, and Wu (2020) showed that forehand and backhand kinematics produced by different grip styles (shakehand and penhold) are measurably different, which highlights that a player's grip style is a confounding factor and therefore researchers of serve-specific studies need to control or report this variable. Musculoskeletal modelling performed by Zhu, Yang, Chong, Shao, Istvan, and Gu (2023), together with lower-limb force measurement done by He, Shao, Fekete, and colleagues (2022), have carried this differentiation of skill-level further down the kinetic chain towards the lower body parts; it also points out that results related to the upper extremity should be considered only as a component of the overall somatic system kinetic pattern without being separated or isolated from each other.

Findings for RQ2 - Measurement Methods and Validity

Wearable inertial measurement units have become the preferred and widely used technique for kinematic analysis of table tennis, as they strike a good balance between ecological validity and measurement accuracy, compared to optical electronic systems that are confined to the laboratory. Ruiz-Malagon, Delgado-Garcia, et al. (2022) presented direct evidence, showing validity and reliability of NOTCH inertial sensor data, compared to the elbow-joint angle measurement reference standard. This finding reinforces the rationale for broader use of such systems in field-based researches of racket-sports. Surface electromyography (EMG) is another method, used to get information on muscle activation characteristics of timing and amplitude, thus complementing the kinematic data. However, EMG protocols differ substantially among the studies, for example, electrode placement, normalization procedure and sampling rate, which makes it difficult to compare the results across studies.

Markerless motion capture and AI-based pose estimation are relatively new methods. A paper by Tan, Chow & Kommar (2026) examined 20 racket-sport studies using these markerless technologies. In most cases, these studies utilized 2D background-subtraction/ thresholding techniques instead of established 3D pose-estimation algorithms. Therefore, they concluded that markerless systems are still mainly suitable for tracking on-court positioning rather than capturing detailed limb movements. Ly, Duan, Yang & Ye (2025) challenged this by building a MediaPipe-derived platform for the quantification of table tennis movements through biomechanics although this was yet to be compared with the optoelectronic "gold standard" benchmark at the level achieved through IMU-based investigation. Once one has the kinematic data from such motion analysis, musculoskeletal modelling (Zhu, et al. 2023) and statistical parametric mapping (Bankosz & Winiarski, 2021; Bankosz & Winiarski, 2020c) become two powerful additional tools for data analysis. Rather than just discrete-point statistics they enable a continuous time-series comparison. However, for them to result in generalizable normative profiles larger and more diverse samples will be needed.

Findings for RQ3 - Linking Kinematics to Ball Spin Effectiveness

The only strand in this research that still lacks evidence of a direct link is the connection between upper limb kinematic parameters and measures of ball spin or receiving-side effectiveness especially for the topspin serve. In our list of papers, the Bankosz, Winiarski, & Malagoli Lanzoni (2025) team most clearly explored this possibility. The study pinpointed wrist and forearm kinematic indicators to explain the difference between short and long serves and speculated on the likely technical outcomes; however, ball spin rate as an output variable was not directly assessed by Bankosz, Winiarski &Malagoli Lanzoni (2025). Analogously, while discussing plantar pressure and ground反应 (ground-reaction, efficiency) in combination, Bankosz, Jin, Wegrzyn, Wegrzyn, & Winiarski (2026) associated it with racket 速度(topspin forehand) which would be the equivalent of hitting the ball very strongly and not with spin itself. On the other hand, Niu, Gan, May Teo, Xue, & Guo (2026) described the backhand-flick-to-serve 时点without quantifying the ball rotation as a result from that action.

When the effects of the performance were evaluated, the performance changes that the researchers focused on were often related to tactics and notation rather than biomechanics: Yu and Huang (2025) looked at how stroke performance affects a team' s or player' s ability to score, or concede a point and change the playing style, Izzo, Giardi, Cejudo, and Cruciani (2023) focused on the speed of acceleration of the main technical movements, but none of the papers linked kinematics analysis to measurable spin results. This finding a rich kinematic description paired with a relatively low direct spin-outcome connection is repeated across other racket sport literature examined here, for example squash face orientation research (Williams, Sanders, Ryu, & collegues, 2020, 2024) and Badminton smash mechanics analysis (Rusdiana, 2021a, 2021b), implying that it may be a methodological deficiency at the level of the whole area rather than only a table tennis serve research one.

Comparative and Critical Analysis

By the way of methodology, the literature incorporated in our paper demonstrates a significant shift from laboratory restricted, optoelectronic motion capture to wearable inertial sensing from manuals to early markerless, and Ai-assisted pose estimation from approximately 2024 (Tan et al., 2026; Lyu et al., 2025). Meanwhile, EMG has been a complementary, yet a heterogeneous methodological, component of kinematic analysis in the literature. Musculoskeletal modelling (e.g., OpenSim-based solutions) and statistical parametric mapping are the most analytically challenging but the least popular techniques presumably because of their compute-intensity and expertise requirements. Longitudinal or training-intervention designs that trace kinematic development over time are still not being used effectively as most of the included studies are simply 90% cross-sectional and single session comparisons. Such a limited experimental frame prevents us from making causal inferences between training and change.

Discussion

Interpretation of results Overall, the combined findings from these studies provide support for a biomechanical model consistent with the idea that the spin generation technique in table tennis (notably, the backspin serve) is mainly due to the sequence of body segments from the base of the trunk up to the extremities. Furthermore, the wrist and forearm are the key body segment(s) responsible for spin generation and compensation during the shot. This explanation of motion aligns with kinetic-chain sequencing theory as a fundamental biomechanical principle applied in the motions of overhand throws and racket sports in general References: Rusdiana, Bin Abdullah, and Syahid (2021) Pedro, Joao, Lara, Cabral, Carvalho, and Veloso (2022, for tennis forehand contribution modelling).

The theoretical implications. These results can be a great addition to the proximal-to distal sequencing models as a basis of high-velocity throwing and striking skills that we know have developed over time. Here table tennis serve was looked at as a low- velocity but very high precision scenario where, instead of the speed of the racket head, you have the racket-face control which is the main technical problem. These results point out that sequencing models could be changed if we talk about precision oriented rather than power- oriented racket-sports actions. This suggested turning point is supported by findings, to some extent, from other precision- and accuracy-oriented sport actions that have also been discussed in this review's corpus: Ibrahim, Abu Osman, Mokhtar, Arifin, Usman, and Shasmin (2022) found similarly, differences in rotational contributions of arm segments were a distinguishing factor between accuracy and power in table tennis strokes while playing drop shots against drives; Rigozzi, Vio and Poronnik (2023) found that muscle activity patterns of the forearm in the case of tennis did not solely differ by the racket speed but by the accuracy of the shot as well; meanwhile, Huang, Li, Jiang, Zhou, and Xiu (2024) showed that squash backhand skillfulness relies mainly on certain kinematic variables different from those related to stroke power. Explanations based on task-constraint and the perceptual-motor coupling theories, according to which the dominance of the wrist-forearm area is the result of corrections being made very late to the racket-face rather than of a sequencing model that is different one, is a plausible, alternative explanation to the one given that it is possible the corpus at hand cannot disprove; this means that without getting data from such non-racket sports like darts, archery, or putting (golf) which could directly compare the two explanations, we cannot get a final verdict this is the reason why we indicate this as a direction for further comparative sports research work.

Practical Implications. Practically speaking the most recent wrist- and forearmlevel kinematic biomarkers have been found in many independent studies conducted by various research groups (Bankosz & Winiarski, 2020a, 2020b; 2021; Bankosz, Winiarski & Malagoli Lanzoni, 2025). Apart from showing consistency these segments can be a most practical choice for a coach to work on with the athlete and offer them an individualized technical feedback. Wearable IMU systems are quite handy here, as they can nowadays be used not just in the laboratories but the field training environment as well, making this feedback system even more practical.

Comparison with previous reviews: The most directly comparable earlier synthesis, Wong, Lee, and Lam (2020) scoping review of table tennis biomechanics, similarly noted a strong focus on topspin strokes. However, it lacked the wearable-sensor and markerless-tracking literature that our work covers. In other words, not only is our review the latest version of that initial scoping study but by focusing primarily on serving, it's a more detailed version of that earlier literature review.

Contradictory results in the literature. The discrepancy mainly shows up between those works which interpret the high inter-individual variability of one`s postural joints as a sign of variety of the different individuals' techniques (Bankosz & Winiarski, 2020b), versus the ones that view certain joint-angle measurements as training goals (Bankosz, Winiarski, & Malagoli Lanzoni, 2025). Most probably, bridging the gap between these two stances may call for an extended, highly-skilled sample, so that one can easily tell the difference between a technically suboptimal performance and one that functionally equivalent.

Research gaps. Three distinct issues related to past work that have not yet been addressed are as follows: (1) There has been hardly any research that has directly connected upper limb kinematic traits with a measured ball spin rate during backspin serves. (2) Markerless and AI-based systems for posture recognition have been only loosely checked against the gold-standard motion capture systems for high-velocity, minimal-amplitude table tennis actions. (3) There is also very little evidence or intervention studies that can show how a person's technical skills affect the kinematics of them, through a relationship.

The authors point out two major limitations of the work. Firstly, the search was limited to one database (Scopus) only and other sources, such as Web of Science or SPORTDiscus, which may have contained excluded relevant studies, were not supplemented. Secondly, a single person performed the study screening, selection and relevance scoring by applying the criterion-based relevance method instead of independent screening and scoring by two separate reviewers with written conflict resolution guidelines, this may lead to selection bias. Thirdly, since the selected sample of 50 researches includes varieties of racquet sports not the exclusive table tennis serve mechanics, some conclusions of the study would have been derived by referring to neighboring stroke styles and sports, whereas we are looking for conclusions specific to the back spin serve.

Research suggestions There are three things that should specifically be addressed through future investigations. 1) Upper limb kinematic variables (measured by IMUs or through markerless systems that have been validated beforehand) should be directly linked with either the instrumented or the high-speed-camera-derived ball spin rate at a very close manner, specifically, during the backspin serve. It will be a very significant finding as this paper points out the existing knowledge gap in RQ3. 2) markerless and AI-based pose estimation systems should first be thoroughly compared to optoelectronic or IMU references for table tennis serve actions before they become a major research tool. The study suggests that this could be done via MediaPipe-based systems among others as an example for the year 2025. 3) longitudinal intervention designs should be favored so that it can be checked through them whether the wrist- and the forearm-level kinematic markers mentioned in this review could be deliberately trained and whether such training would result in improved serve effectiveness in competition.

Directly answering the review's three research questions: RQ1 is the fact that, throughout numerous studies it is clear that such as proximal-to-distal movements, compensatory wrist/forearm movements, sex- and skill-specific kinematic profiles are regarded as the main upper limb characteristics contributing to spin-generation in table tennis strokes that is the answer for RQ1. RQ2 is the conclusion that at the moment, wearable IMUs are the only means with the most robust combination of validity and practical usability, markerless/AI-based methods are only promising and have not been sufficiently validated, while EMG and musculoskeletal modelling provide an additional perspective of value but with very different procedural implementations. RQ3 is the result that there is practically no direct evidence for the relationships between shoulder-forearm-hands kinematics and the amount of spin one can get on the ball with such a specific stroke in particular for backspin serve and so this review identified this as the biggest and most urgent knowledge gap.

Conclusion

Through an in-depth analysis of 50 published studies this literature review focused primarily on upper limb mechanics of backspin serve and its associated spin-generating strokes in the sport of table tennis. To address the first research question, a common theme of studies is that successful spin generation depends primarily on coordination from large to small joints through body segments. It was demonstrated that wrist forearm segments are primary compensation and spin generation segments and that factors such as sex, skill level and grip contribute to differences in movement. In answering the second question about the methods, it turned out that wearable inertial measurement (IMU) devices are the current best and most tested method for doing field kinetics studies. Markerless and AI-assisted pose estimation techniques that appear very promising at the first glance are however less tested and hence less reliable for the kind of small and fast movements typical to table tennis. For the third research question, it was found that evidence of upper limb kinematic parameters affecting ball spin has hardly been studied through direct measurement, especially in relation to backspin serve technique, and therefore the results of this review point out the need for such work as the field's main priority. The term 'direct measurement' here describes protocols that, within the same trial, record a kinematic variable such as wrist angular velocity on the one hand, and the instrumentation or the high-speed camera derived ball spin velocity rate on the other hand. This contrasts with inferring spin rates from match outcome notes only. By this criterion, none of the 50 studied investigations can be classified as direct measurement, hence closing this particular research gap is emphasized as the primary review's concern, instead of a mere call for more extensive kinematic description. In the case of markerless and AI-based motion estimation, the position the review adopts is to support further developments of this method while expressing caution towards endorsing or discarding it altogether: it is considered a potential way to make the method affordable for use in sport fields while retaining a good accuracy; however at this point, there is not enough evidence to show that it has been successfully compared for serve motion that is of high speed and small displacement against optoelectronic or IMU referencing methods, and therefore its use in serve-specific papers should be restricted until such time as those references are replaced. Besides, from a technical point of view, the research reveals that by using wearable sensors to obtain wrist and forearm kinematics, coaches can identify specific kinematics markers of serve training suitable for each individual. Due mostly to single-source database and single-reviewer methods the limitations of the review should be considered before making generalisations based on them, and to the extent that data on backspin serves are not found, the paper relies on racket-stroke movements in closely related sports. Only research that directly links upper limb motions to spin measurements done with a sensor ball, confirms the development of markerless technologies and compares longitudinal effects of different training interventions can bridge the gap between biomechanical knowledge and actual improvement in technique of backspin serve.

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