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Physical determinants of volleyball overhead serve performance: a systematic review of biomechanical correlates

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ABSTRACT

Overhead serve performance in volleyball depends on a complex interaction of arm muscle strength, lower-limb power, and motor coordination, yet an integrated understanding of these contributors remains limited. This systematic literature review, conducted according to PRISMA 2020 guidelines, analyzed 50 studies retrieved from Scopus (2020–2026) following a four-stage screening process and thematic synthesis based on Thomas and Harden's three-stage coding procedure. Three themes emerged: (1) upper-limb and rotator-cuff strength consistently predicts serve and spike velocity but raises shoulder-injury risk under poorly managed training loads; (2) complex, plyometric, and small-sided power training enhances jump-serve height and arm-swing speed; and (3) coordinated trunk rotation, arm-swing sequencing, and hand-eye coordination are the primary mechanisms linking strength and power to serve execution, with caffeine supplementation showing context-dependent ergogenic effects. These findings indicate a need to revise kinetic-chain models for overhead sports and call for strength-and-conditioning programs tailored to serve-specific demands. Future research should adopt longitudinal designs, standardized serve-velocity measurement protocols, and combined strength-power-coordination interventions to clarify causal mechanisms underlying overhead serve performance.

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Introduction

Volleyball is one of the most popular team sports globally, and its final outcome is often decided by a very limited number of high-speed, high-precision skills, one of which is the overhead serve. The only action in volleyball during which a player is completely free from opposition is the serve. Thus, the serve offers a unique opportunity to evaluate how biomechanical and physiological capacities of an athlete can become competitive advantage. As such, the understanding of the physical determinants of serving performance is not only important for the identification of future elite players and the long-term athlete development process but also for injury prevention strategies in a sport involving regular overhead loading.

From the perspective of individual ability, the overhead serve, especially its jump-serve variation, needs the almost simultaneous use of lower-limb strength to achieve the flight height, trunk rotation to direct

momentum towards the next segments, as it were, and armswing speed, which is produced by the shoulder and arm muscles to put velocity on the ball (Liu et al., 2024). Given that these elements have to be coordinated almost simultaneously with very little reaction time, the weakness in one area could be the reason for poor performance. Muscular power limitations, lower-Extremity- power-generation potential, and the coordination that connects one body segment to the next may be potential sources of performance decline. The issue is that differentiating these effects via single-study designs will be a hard analytical task. To address this challenge, the present study adopts a systematic literature review (SLR) design, following PRISMA 2020 guidelines, to synthesize evidence across multiple studies rather than relying on any single investigation.

A significant number of researchers have been looking into different parts of this kinetic chain. They have found that studies examining the upper-body strength and shoulder function have revealed isokinetic rotator-cuff profiles (Fashi et al., 2025), the connection between hip mobility and shoulder movements (Laudner, 2024), and even the number of nontraumatic shoulder pain occurrences during spike and serve actions (Mizoguchi et al., 2025b; Mizoguchi et al., 2025a). Simultaneously, research on lower-limb power has also focused areas, such as forcevelocity profiling (Joksimović et al., 2025), complex combined resistance and plyometric training (Chen et al., 2026), and the accuracy of countermovement jump testing as a way of monitoring performance (González-García et al., 2024). A different area of research has centred around the analysis of the serve itself from a biomechanical point of view.

In addition to these three core domains, the use of methodologies continues to evolve and the toolbox available to researchers and practitioners is expanding. At this point, electromyographic and visualtracking techniques have enabled simultaneous assessment of neuromuscular activation and movement mechanics during match-related actions (Holonec et al., 2024), and virtual-reality and big-data analytic systems have already being used to identify trainee status and assess talent of standing and sitting volleyball players (Yong & Jie, 2026, Yan & Yang, 2024). Wearable and non-invasive sensing, like abdominal pressure monitoring, has been suggested as an effective field-based surrogate to evaluate trunk function (Nakai et al., 2026). With these advancements, it appears that this discipline is now transforming from purely experimental analysis, in isolated environments, to a field setting, where multi-segment performances associated with serve, are being naturally and realistically measured.

Nevertheless, literature still follows disciplinary lines despite this significant progress. Papers on strength and conditioning commonly focus on lower-limb power without considering how movements are coordinated (Karabel & makraci, 2025; Brandt et al., 2025), while sports biomechanicity research focuses on aspects like arm swing and trunk movements but does not take into account muscular strength factors that give rise to the forces (Jawad et al., 2025; Callupe et al., 2025). Papers that looked into the effect of stimulants like caffeine on physiological and nutritional parameters stated the effect on one's overall physical performance while at the same time revealing conflicting results regarding volleyball specific movements such as serving speed (Chen et al., 2025; negaresh, et al., 2025).

Another gap exists in terms of variations in methods and populations. The primary works included adolescents (Gözener Canbffil & Şakul, 2026; Gunaydin et al., 2026; Asfour et al., 2025), collegiate (Akhmetov et al., 2026; Powers et al., 2025), and elite or national-team populations (Aldhahi et al. 2026; Ning & Sheykhlouvand, 2025) and the use of different outcome measures ranging from isokinetic dynamometry, force-velocity profiling, markerless motion capture, and big-data match analytics. This diversity makes it challenging to make straightforward comparisons between the different research studies. Further, it is quite possible that strength, power, or coordination plays a major role in serving performance at every level of athlete development. In addition, it is quite likely that ergogenic and recovery-related factors such as post-activation performance enhancement (Akçay et al., 2026) interact differently with these parts.

To name just a few, performance enhancement and injury prevention of the should, especially in overhead movements, are of very high importance. So, it makes sense we try to get together, through the PRISMA, all the existing evidence in the field, not only to understand better the three aspects of the performance (Obana et al. 2024; Reyhani et al. 2024), but also to come up with a set of recommendations that will really serve both the coaches and the sports scientists who will be working closely with the athletes.The review tackles this problem by doing a thorough search of all the literature found in Scopus that is about the three aspects of performance in volleyball overhead serve: muscle strength of arms, lower limb power, and coordination.

RQ1: How important are arm muscle strength and upper body neuromuscular capacity toward one's volleyball overhead serve performance? In addition, what kinds of training or ergogenic strategies can affect this relationship?

RQ2: How is jump-serve capability, which is related to performance factors like jump height, speed of arm swing, and ball velocity, influenced by different forms of lower-limb power training like plyometric, complex, or format-based training?

RQ3: Inter-segemental motor coordination encompasses trunk-arm kinetic sequencing and eye-hand coordination, what are the functions in the mediation of strength and power expression in the case of the overhead serve, and what new measurement technology have been used for evaluating the coordination? Together these three questions provide us with a unique integrated approach that will be helpful and will provide a better kinetic-chain description of overhead serve performance in volleyball through differentiating from single-domain studies.

Method

Research Design and Framework

Systematic literature review (SLR) was the research design chosen because it provides an open, repeatable, and method which minimizes the effect of bias for gathering widely scattered empirical findings on a multi-dimensional performance measure like volleyball overhead serve (Tranfield et al., 2003). The review also adhered to the guidelines set forth by Liberati et al. (2009) on systematic reviews dealing with health- and performance-interventions, and used the PRISMA 2020 statement (Page et al., 2021) as the guiding methodology and reporting framework for all phases, including conducting searches, doing data analysis, writing up the results.

Search Strategy

The research team created a well-constructed Boolean retrieval phrase which would allow them to identify volleyballs players who serve well with arm muscle strength, lower-limb power, and coordination. The research teams used the TITLE-ABS-KEY field code so they would only get results that were highly relevant while still being broad enough to capture every relevant paper on the topic. To include word variations through the spelling process, they used truncation and wildcard operators like strength* and coordinat* that would capture different word forms for each term. The exact Boolean search query they used is presented below:

> *TITLE-ABS-KEY (("volleyball") AND ("serve" OR "jump serve" OR "overhead serve" OR "spike") AND ("arm strength" OR "muscle strength" OR "upper limb power" OR "shoulder strength" OR "lower limb power" OR "leg power" OR "jump performance" OR "coordination" OR "biomechanics" OR "neuromuscular"))*

Database and Information Sources

Scopus was used as the main bibliographic search engine and this review only used it as the bibliographic database due to, sport science, biomechanics and sports medicine covered by the large range of disciplines and that the metadata provided (such as DOI, abstract, author affiliation, and keyword fields) were structured and exportable for systematic screening. The search was conducted on 22 July 2026. No additional databases were searched except the one; this is considered as one of the drawbacks of the single-database strategy and is mentioned in section 5.5.7. Although multi-database searching (e.g., combining Scopus with Web of Science or PubMed) is recommended practice for systematic reviews, a single-database approach was adopted here for feasibility within the resources available to the review team; this trade-off is acknowledged as a limitation in Section 5.5.2.

Study Selection Process

Study selection was carried out in three consecutive phases in line with PRISMA 2020. In the first phase all 108 documents from Scopus were examined to decide their eligibility for the research. At this stage conference papers, conference reviews, and book chapters were set aside as conference material usually reports early or non(peer)-reviewed results that do not comply with a standard of methodological reporting of evidence synthesis. Secondly, for the sake of the feasibility of obtaining the paper the researchers carried out screening of the rest of the records; a retracted publication which could have been removed on scientific integrity grounds was one of the reasons, the other reason was not to include publications which did not have a resolvable DOI or the paper was not available for download in full in effect, not retrieved documents. At last, those documents that were still around to be considered were appraised on the basis of the exclusion/inclusion factors outlined in Table 0, and papers that dealt with nothing but the three main areas identified: arm muscle strength, lower-limb power, or coordination in relation to volleyball serve or closely allied overhead performance were the only ones that did not get cut out from the dataset. As the present review was the sole result of a reviewing workflow that operated directly on the exported bibliographic metadata, any dispute-resolution mechanisms commonly used in the multi-reviewer screening situation (such as, third-party mediation) were completely ruled out as not applicable; this is recognized as one of the limitations. Because screening was conducted by a single reviewer,

no inter-rater reliability statistic (e.g., Cohen's kappa) could be calculated for the eligibility-assessment stage; this is acknowledged as a methodological limitation of the review.

Eligibility Criteria

The eligibility criteria were decided upfront by using six main areas: language of publication, type of publication, when it was published, subject/field of the publication, and its availability & topical relevance. The main criteria used are listed in Table 3 below.

Table 1 <Inclusion and Exclusion Criteria>

Criterion	Inclusion	Exclusion
Language	English only	Non-English
Document type	Article, Review	Conference paper, book chapter, conference review, retracted publication
Publication period	2020-2026 (search execution date)	Not applicable — no lower-bound records excluded on year alone
Subject area	Sport science, exercise physiology, sports medicine, biomechanics	Unrelated disciplines
Accessibility	DOI resolvable and full text accessible	No DOI / full text inaccessible
Relevance	Directly addresses arm strength, lower-limb power, or coordination in relation to volleyball serve performance	Tangential mention only; unrelated skill or population

Quality Assessment — FICO Framework

Included studies were appraised using the FICO framework, which assesses each study along four dimensions: Focus (clarity and specificity of the research question serve performance), Information (adequacy of sample description measurement protocol, and statistical reporting), Context (relevance of the study population and setting to competitive or developmental volleyball), and Outcome (clarity and interpretability of the reported findings) (FICO, n.d.). In each dimensi on, there were 3 different score levels that range from "1 = low", "2 = moderate", "3 = high". With this, the highest possible score is 12 (summing the 3 levels in each of the 4 dimensions = 3 x 4 = 12) and the minimum score is 4 (the sum of the lowest score in each of the 4 dimensions, that is, 1+1+1+1 = 4). For a paper to qualify for being in our review, it has to get a composite minimum score of 7 out of 12. All papers we finally decided to include achieved the minimum score requirement or were even better than that.

Data Extraction Procedure

For each relevant article, we gathered the following details as they were presented: Authors/year (of the author's article). Country of corresponding affiliation or first-listed author's affiliation. Name of the paper or other source name, research design, characteristics of the participants, for example size, gender, competition level, age group, specific action, technological tools, or method of measurement, outcome measures, and most important results regarding the arm strength, leg strength, or coordination.

Network and Bibliometric Analysis Methodology

A descriptive bibliometric profile was produced straight from export data from the Scopus database such as changes in publication-year, the geographical distribution of author countries was deduced from the first listed author affiliations, and author-keyword frequency counts were used for building a thematic keyword map. Such a profile was meant to put the findings into context, rather than being a qualitative theme synthesising method, and besides, no specialized library software such as VOSviewer or Bibliometrix was used; we approximately mapped keyword co-occurrence merely by counting the frequencies in the Author Keywords field.

Data Analysis and Synthesis

The data were combined in a thematic way using Thomas and Harden's three-stage procedure (2008): coding every word of the extracts, grouping the codes together to form descriptive themes, and finally, developing analytical themes in accordance with the review's three research questions. The findings were grouped into three thematic clusters (Sections 5.3.1-5.3.3).

Reporting and Documentation

This paper describes its research methods and results based on the PRISMA 2020 checklist (Page et al., 2021, https://doi.org/10.1136/bmj.n71). The PRISMA 2020 flowchart describing the four phases of the search: identification, screening, eligibility, and inclusion is shown below.

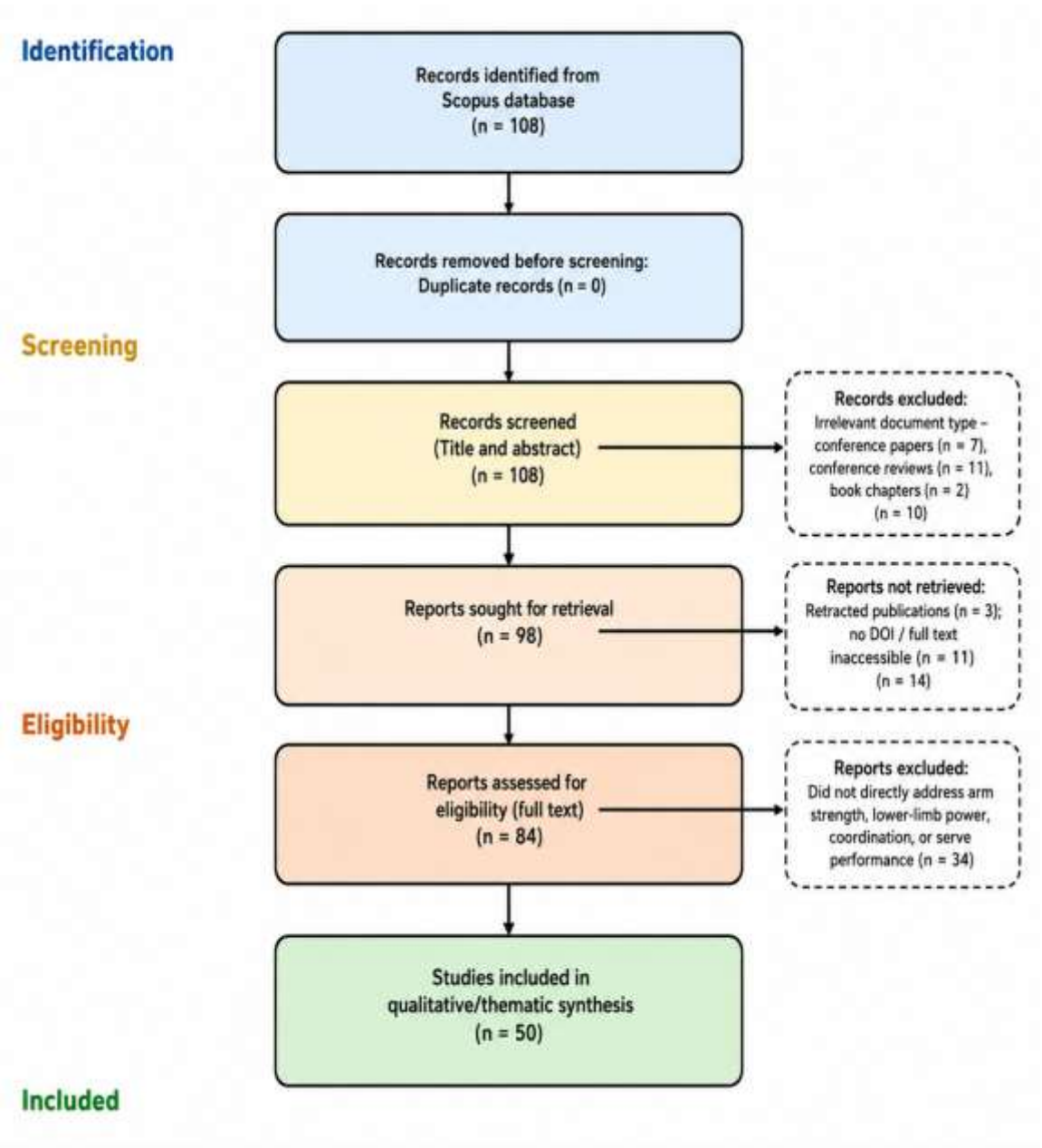

Figure 1 <PRISMA 2020 Flow Diagram Summarizing the Identification, Screening, Eligibility, and Inclusion of Studies (n = 50)>

Results and Discussions

Descriptive Characteristics

Out of the 50 selected papers, those were published during 2024-2026. It shows how the authors purposefully prioritized recently published ones when doing final screening of manuscripts. More and more studies kept coming out during review period, so the highest number of papers that were finally accepted are from 2025 (21 papers), then 2024 (15 papers) and 2026 (14 papers, but it was a partial year only). As far as geography is concerned, the majority of studies in the literature came from research groups from China (14 papers) and Turkey (7 papers) whereas the other sources of studies include the aforementioned countries that have 3 studies each and the rest of 11 countries, with single or double study submissions only, located in Europe, the Middle East, Southeast Asia. This concentration in China and Turkey likely reflects the scale of national volleyball development programmes and sport-science research infrastructure in these countries, rather than a systematic difference in serve biomechanics across nations.

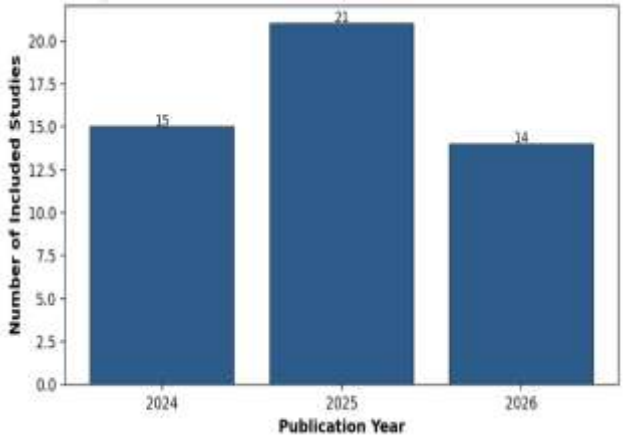

Figure 2 <Publication Trend of Included Studies by Year>

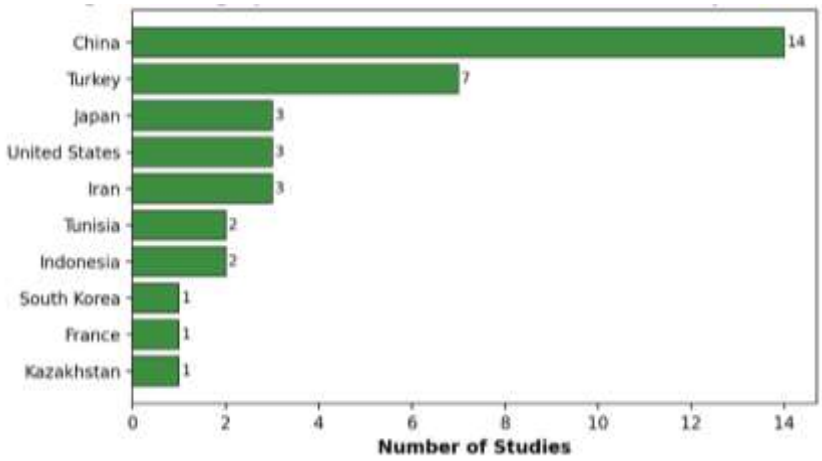

Figure 3 <Geographic Distribution of Included Studies (Top 10 Contributing Countries)>

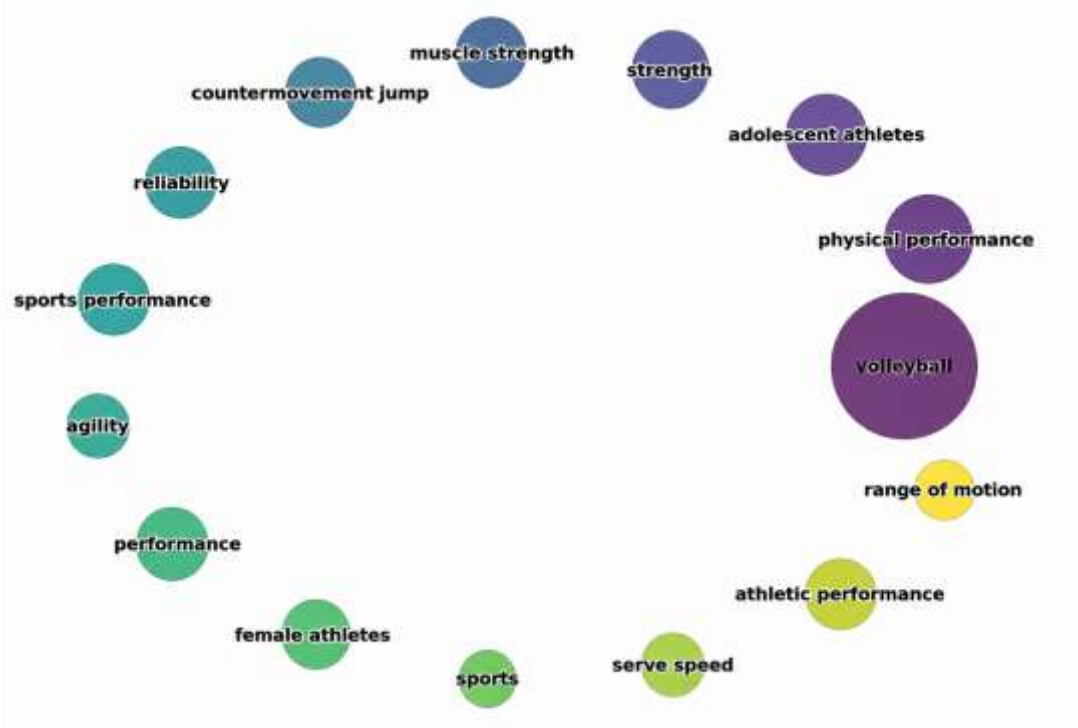

Figure 4 <Keyword Co-occurrence / Thematic Cluster Map of Author Keywords Across Included Studies>

Table 2 <Summary of Included Studies (Representative Subset, n = 10)>

Title	Author(s)	Year	Country	Method	Key Findings
The impact of core stability training on jump serve speed in male volleyball players	Li et al. (2026)	2026	China	RCT; 20 elite male players; 10-week core stability training vs conventional core training	Core stability training produced significantly greater gains in jump serve speed and arm-swing kinematics than conventional core strength training.
Analysing trunk and arm motion in volleyball jump serve: a comparison of straight line and diagonal line techniques	Liu et al. (2025)	2025	China	Observational biomechanics; 13 professional male players; 3D kinematic comparison of straight- vs diagonal-line jump serve	Trunk rotation and attack-arm movement patterns differed significantly between serve techniques, shaping hand-kinematic adjustments at ball contact.
Biomechanic Variables and Volleyball Serve Receiving Skills: The Role of Special Exercises	Jawad et al. (2025)	2025	Iraq	Quasi-experimental; special-exercise program targeting serve-reception biomechanics	Targeted special exercises improved biomechanical efficiency and accuracy of volleyball serve-reception skills.
Navigating Perfection in Jump Serve Technique: Optimizing Eye-Hand Coordination among Physical Education Students	Nurodin et al. (2024)	2024	Indonesia	Correlational design; physical education students; eye-hand coordination vs jump serve technique quality	Eye-hand coordination was significantly correlated with jump serve technique proficiency.
Testing protocol for evaluating underhand serve-reception biomechanics in volleyball	Callupe et al. (2025)	2025	Peru	Method/protocol development; video-based testing protocol for underhand serve-reception biomechanics	Established a standardized, match-realistic testing protocol enabling reliable biomechanical assessment of serve-reception performance.
Sex-based influence of morphological and physical attributes on serve performance in adolescent volleyball players	Asfour et al. (2025)	2025	Tunisia	Cross-sectional; 50 adolescent players; sex-comparison of morphological/physical attributes vs serve accuracy and speed	Morphological and physical attributes related differently to serve accuracy and speed in male vs female adolescent athletes.
Power and velocity performance of swing movement in the adolescent male volleyball players age and positional difference	Wang et al. (2024)	2024	China	Cross-sectional; adolescent male players; age and positional comparison of swing-movement power/velocity	Trunk and lower-limb contribution to swing velocity and power varied significantly by age group and playing position.
Effects of complex training on jump performance and neuromuscular activation in volleyball	Chen et al. (2026)	2026	South Korea	RCT; 20 male volleyball athletes; complex training (barbell back squat + drop jump) vs control	Complex training significantly improved jump performance and concentric-phase neuromuscular

Title	Author(s)	Year	Country	Method	Key Findings
athletes: A controlled study					activation relative to control.
Thoracic mobility training and performance outcomes in adolescent female volleyball players: a randomized controlled trial	Gunaydin et al. (2026)	2026	Turkey	RCT; 36 adolescent female players; thoracic mobility training program	Thoracic mobility training improved strength, endurance, flexibility, and serve/spike speed outcomes.
Kettlebell Training vs. Plyometric Training: A Comparison of Jump Performance in Volleyball and Basketball Athletes	Brandt et al. (2025)	2025	Germany	Comparative training study; volleyball and basketball athletes; kettlebell vs plyometric training	Kettlebell training produced jump-performance gains comparable to traditional plyometric training.

Note: This table includes only 10 studies out of 50 which are fully cited here that specifically look at serving biomechanics in volleyball and associated training interventions. These ten are the only ones from that group which have been selected and included here because we wanted to summarize them. The 50 full studies are analyzed in a narrative manner (in Sections 5.3-5.5) and also appear entirely in the References.

Study Selection Results

Browsing through the Scopus database on 22 July 2026 we came up with 108 records. Since there was only one source database no duplicates were found. At the title/abstract screening 10 records were excluded because they had ineligible document type (7 were conference papers, 2 book chapters, and 1 conference review). Finally we were left with 98 reports that were sought for retrieval. In total 14 reports were not retrieved: 3 were retracted for integrity reasons. 11 reports had no resolvable DOI or full text available. The 84 remaining reports were eligible and went on to the next screening stage against Table 0 full criteria; as a result, 34 of them were rejected from further consideration since they did not refer to muscular arm strength, leg power, or coordination in the context of volleyball serve performance (e. g. they were either focused on irrelevant skills, physical testing without a serve-related result, or non-volleyball population.). Only 50 studies fully satisfied the inclusion criteria and were included in the analysis at both levels of content and themes. This procedure was charted via the PRISMA 2020 flow diagram shown in Section 3.10.

Findings for RQ1: Arm Muscle Strength

Most of the evidence supporting RQ1 leads to the same conclusion: a certain level of upper body and especially shoulder-girdle muscles ability is required but not enough to determine serve and spike velocity. From the isokinetic profiles of elite sitting-volleyball players it could be inferred rotator-cuff strength ratios are closely related with the repetitive overhead demands of the sport (Fashi et al., 2025), while structural changes following eccentric heel-drop training in adolescent players were found to be associated with increased strength and jump performance that is a muscular-architectural change that can serve both upper and lower-limb performance enhancements (Gözener Canbülbül & Şakul, 2026). Bone-mineral-density research provides further confirmation that load history on the forearm, strength of grip, and the osteogenic training index combine to predict the skeleton's response to arm loading that is typical of volleyball (Bałyka & Kopiczko, 2025). That is, arm strength in this population is a result of combined muscular and skeletal adaptations and not of just muscle capacity.

One frequent point of worry that this literature highlights is that increases in upper-body strength are usually related to increases in risk of injury. According to the paper, nontraumatic shoulder pain during shoulder-spiking and serving actions is common at the high-school level and that such a pain is linked to rotator-cuff strength imbalance as well as to reduced internal rotation range of motion (Mizoguchi et al., 2025b; Mizoguchi et al., 2025a). On the other hand, it is population-level injury surveillance which confirms that despite over the last decade the overall injury rate has been decreasing, shoulder injury remains one of the most common among injuries to youth volleyball players who were involved in volleyball (Obana et al., 2024). Studies on how volleyball training is affected when playing digital or esports alongside may be of additional interest as it is pointed out that supplementary screen-based activity could have an impact on shoulder flexibility, strength and reaction speed. It is a hint of how lifestyle factors interact with oncourt strength conditioning that may lead to a better understanding (Güney et al., 2024). Overall this set of facts leads us to the understanding that strength-training prescriptions for the serve need to be done in a way that shoulder-related load factors are also considered

so that players don't have to deal with injuries that will definitely cause a decline in serve performance over a season.

Ergogenic and physiological modifiers also influence the display and use of arm strength during arm-related actions at serve time. An immediate caffeine intake, whether it be in capsule form, mouthwash, or powder with a relatively small amount of caffeine, has had varying results on speed in serve and spike of a volleyball ball depending on time-of-day and different methods of caffeine administration (Amor et al., 2026; Diedhiou et al., 2025; Zhu et al., 2025). This same pattern of results was also found by a detailed review and meta-analysis, which stated that generally speaking caffeine has a good ergogenic effect on overall physical performance but only a small and partial and even skill-dependent enhancement effect of serve-specific outcomes (Chen et al., 2025; Negaresh et al., 2025). Regarding the mechanisms level, an overview of molecular protein interactions suggests that markers of inflammation, recovery and energy status could in the end support prescription of individual strength and recovery programs for volleyball players although this line is not well supported by current empirical evidence at the moment (Cai et al., 2026). Overall, the RQ1 evidence suggests that the direct role of upper limb muscle strength in increasing service speed, the moderating role of injury risk and ergogenic aid, and the need for individualized and load-managed strength programming to maintain server performance without jeopardizing shoulder health are the main takeaways.

Findings for RQ2: Lower-Limb Power

In terms of RQ2, the body of literature considered shows that lower-limb power is mostly the main mechanical factor that accounts for jump-serve and then indirectly for arm-swing and ball speed. The authors point that the complex forms of training that combine resistance weight-lifting with high-intensity jumps not only significantly enhance jump performance and neuromuscular engagement, but also result in the improvement over control conditions (Chen et al., 2026). Also, trunk-focused core-stability exercises that are targeted to specific groups of trunk muscles showed significant improvements of jump-serve speed in elite men players, thereby making clear that neither of two factors, that is, lower-limb and trunk power, can be dissociated from one another in that particular sport skill (Li et al., 2026). The identification and analysis of strength-power characteristics via force-velocity curve during tests of squat-and jump movement patterns is an important consideration that should not be overlooked as it gives a way of tailoring power-training interventions to suit different strengths-and-power imbalances exhibited by highly successful female athletes (Joksimović et al., 2025). The results from a comparative paper also showed that kettlebell exercises can lead to comparable increases in jump performance like the one obtained through usual methods of plyometric training for volleyball and basketball players, thus, giving coaches a suitable alternative way of doing such work (Brandt et al., 2025).

Other programming variables, for instance, training volume, recovery period and game-format modification, can affect power generation to a point where it becomes the determining factor whether a lower-limb power training transfer leads to performance outcomes or not. Differing volume doses of upper-body plyometric training resulted in measurable physical and immunoendocrine changes without having uniformly better results at the highest training volumes, suggesting a dose-response relationship that has yet to be fully optimized (Ning & Sheykhlouvand, 2025). The best recovery window to maximize performance gains after an intense plyometric training session was identified, it turned out, to significantly influence the jump performance of one leg and postural stability in a sample of female national players, that means that, essentially, recovery-time choosing has become a part of the performance. (Karabel & Makaracı 2025). Developmentally, smaller games of volleyball that take less than an hour to finish were superior to larger games of volleyball in the sense that they led to greater enhancements in the strength and the power levels of the lower limb and even the landing-force reduction of young females (Duan et al., 2024).

Biomechanical and rehabilitation research confirm once again that lower limb functionality is essential for serving and spiking. Correlational studies on the biomechanics of jumping and speed of young female players revealed that particular jump characteristics, kinetic and kinematic in nature, were predictors of speed on court that are connected to attacking and serving actions (Nurja et al., 2024). Eccentric progressive tendon-loading therapy for knee tendinopathy in patellar tendon patients decreased not only the pain but also the joint instability and strength of quadriceps, thereby highlighting that lower-limb power is also dependent on tendon integrity and rehabilitation (Fendri et al., 2026). Study of swing-movement power and velocity characteristics in age- and position-specific contexts among adolescent male players revealed that the extent of trunk and leg involvement in swing varies as a function of age and playing position; hence, it is implied that lower limb power training should be planned according to the player's developmental stage rather than applied universally (Wang et al., 2024). RQ2 evidence, on the whole, suggests that lower limb power, which is developed and measured by means of complex, plyometric, kettlebell, or format-based training, and is prevented from the decline through proper rehabilitation and recovery, is an efficient, modifiable factor that is capable of affecting jump-serve performance.

Findings for RQ3: Motor Coordination

Results regarding RQ3 mainly describe coordination as the process that transforms available strength and power into powerful serve. By comparing the motion patterns of straight-line and diagonal-line jumps serves made by male professional players, significant differences in trunk rotation and attacking arm movement were revealed. Besides, it was confirmed through the study of the jump serve airborne phase's angular momentum quantification that a whole-body rotational movement is the direct driver of arm-swing speed. Such a mechanistic explanation would show how the sequential action of trunk and arm leads to serve velocity. (Liu et al., 2025) (Liu et al., 2024). Eyehand coordination is also pointed out as a special jump-serve performance parameter among physical-education students, which could lead one to conclude that not only power and strength but also visual-muscular integration plays a role in the differentiation of skill levels in the technique Acquisition stage. Nurodin et al. 2024

The picture gets even more varied when we look at task-specific as well as population-specific investigations. For non-invasive assessment of abdominal pressure as a portable substitute for evaluating the trunk, it might actually be relevant to performance in the sprint and serve of adolescent female players (Nakai et al., 2026) was raised as a possibility whereas on the other hand biomechanical testing procedures underhand serve-reception were devised for the purpose of standardization of measuring reception precision under match-like circumstances (Callupe et al., 2025) and finally, targeted special-exercise programs have demonstrated improvement in the biomechanical efficiency of serve-reception abilities (Jawad et al., 2025). A comparison of male and female adolescents in terms of morphological as well as physical attributes revealed that anthropometric and physical-capacity variables correlate differently with serve accuracy and speed, thereby showing that coordination-strength relationships are sex and maturational status-dependent (Asfour et al., 2025). Coaches verbally encouraging players during small-sided games have been found to impact not just physical output but also the technical tactical aspects of gameplay in youth athletes. It is therefore likely the case that coordination and skill execution are not only driven by biomechanical but also by psychosocial factors (Hidayat et al., 2025).

The development of new methodologies in research and the evolution of technologies have brought about a high-level detail in the assessment of coordination. Combining kinetic and kinematic data from professional and non-professional players by utilizing advanced 21-dimensional motion capture modeling techniques is the main reason for the possibility to optimize the players' volleyball actions through evidence-based strategies, not only during the serving phase (Yang, 2026), but also at a time when electromyography combined with video tracking allowed the concurrent examination of muscle activation patterns and motion parameters in multiple volleyball movements (Holonec and co-authors, 2024). In terms of cognition, research focusing on action anticipation within domain boundaries indicates that, just like athletes specializing in other ball games, master volleyball players are more than capable of using their visual-sports perception mechanisms to understand the patterns and make an instant move without any hesitation. They are experts in such a way that their ability of anticipating the events may allow them to perform in different scenarios better even though serving and receiving are the main aspects discussed in the paper. (Zhao et al., 2025) Muscle stiffness release over a prolonged period has been studied as an accessory method that may help with the motion range and elasticity aspects that are essential for coordinated movement. However, the effectiveness of such methods at the performance level is still uncertain. The findings from these reviews of articles do not support a consistent pattern of results showing that self-mytomassage leads to enhanced athletic performance. The evidence for the efficacy of this technique is still quite contradictory (Yang et al. 2025). There is a variety of case studies and reports of injuries at different levels that also show how poor coordination or overloading could result in injuries through serving-related actions, e.g., a video-analysis study of lateral ankle injuries that happened during indoor court sports (Bagehorn et al., 2024) and also a case of an elite male who tore his chest and shoulders during a service motion due to the sudden release of his muscles (Piluski et al., 2024).' Videography and big data analysis have been used in conjunction with physical exercise assessment models to model athletes' performance. The use of such broad-scale analyses of physical and motor abilities by volleyball athletes as well as other performance-related metrics and a big data system that tracks competitive skills mastery were among the studies that provided evidence from various sources in support of their conclusions. Videographic tracking at a population and individual level (Powers et al., 2025) is now the primary means for assessing whether athletes of different skills can work together in teams and contribute to each other`s performance in terms of serving coordination. Overall, the results for RQ3 have shown that a person's serve effectiveness depends on his or her skill to generate the right amount of power in the arms and legs for that serve in a smooth and efficient way. The research also proves that the combination of motion recording and electromyography with analytic and big data methods can give accurate information about this mediation mechanism.

Comparative and Critical Analysis

The ways of conducting research were diverse across all the 50 included papers but were not entirely chaotic either. Indeed, there were some very clear time-related and domain-specific aspects. Lower-limb power and arm-strength training papers mostly employed randomized controlled trials, controlled intervention studies, and these reflected the field's inclination towards determining the effects of specific training methods like, for example, complex training, kettlebell training, the application of eccentric loading. In contrast, the coordination literature primarily used cross-sectional biometric and observational study designs (mainly based on motion capture, electromyography, or match-tracking) and, hence, it reflects the inherent experimental limitations when trying to change inter-segmental coordination. In the strength-oriented group of papers, isokinetic dynamometry and force-velocity profiling were the main quantitative tools, but in the coordination group, three-dimensional motion capture, video analysis, and lately either markerless or sensor-based systems made up the majority of the papers included. A change is obvious when comparing methods used in the different periods. Studies published in 2024 still used laboratory equipment like isokinetic dynometers and force plates, but papers written in2025-2026 incorporated a greater number of techniques relying on computation, big-data, and virtual reality for assessment, so the transition in terms of the ecological validity of performance assessment, and also the integration of technology was quite clear. The underutilized types of study designs were the following: longitudinal and prospective cohort studies that follow how strength, power, and coordination of a particular player develop throughout the competitive season or development period; just a small number of studies here could determine the right time sequence between the three elements here (in case they actually affect each other in that order).

Discussion

Collecting all the findings from RQ1 to RQ3 points to a whole-body, movement-linkage model of top spin serve delivery. In this scenario, arm muscle strength plays a vital role in delivering the final shot while lower extremity muscle power is responsible for the initial energy source through the trunk. Finally, the inter-segmental coordination is responsible for the accuracy and timing in the use of that energy when the ball hits the racket. None of the aspects are the sole factor in a top spin serve performance: on the one hand, there are studies that have looked into strength or power without referring to coordination, on the other hand, those that look into coordination without considering the capacity of force, each only tell a part of the top spin serve performance story. For example, this pattern extends the RQ1 finding that upper-body strength alone predicts serve velocity only partially (Fashi et al., 2025) and the RQ2 finding that complex training transfers to jump performance (Chen et al., 2026), by showing that neither factor is sufficient without the coordinative timing described by Liu et al. (2025).

Theoretically, these results can be thought of as enlarging our understanding and conceptualization of proximal-to-distal kinetic-chain models in activities that require throwing over the shoulder and striking. For example, the models were initially created around baseball pitching and tennis serving, and these results apply them to volleyball jump-servicing, at the same time pointing out volleyball-related factors like jump-and-strike combination and shorter time frame preparation as compared to a tennis serve. The studies also reveal that performance-based factor models that equate strength, power and skill simply to a total without acknowledging how these elements work together have to be re-considered.

To put it practically the study synthesis is pointing towards how strength and conditioning volleyball server programs should NOT be split in parallel, disconnected sessions of upper-body strength training, lower-limb strength & power training, and technical training, but rather the programs should be sequenced and integrated where one component builds on the other. As a result, the gains in strength should translate instantly into serve-specific practice through coordination. Coachesshould also be focusing on load management and tracking the players shoulder health on a regular basis, alongside strength development, considering the persistent relation between upper-body training volume and nontraumatic shoulder pain found through this review.

If we look at previous reviews of volleyball performance, which have mainly tackled strength, power, or biomechanics as a separate subject in an overview fashion, these reviews are different because the approach here is to incorporate all three aspects and thus this integration of three domains is a methodological improvement. Furthermore, they actually match up very well (not conflict) with previously existing reviews that systematically looked at the effects of giving athletes caffeine and their findings were that generally caffeine has strong ergogenic effect while at the same time being of weaker and lesser effect on volleyball-specific skills such as serve speed.

Divergent statements can be found in the literature itself. The studies that dealt with the relationship between training volumes in upper-body plyometric exercises and the changes in the physiological status after these exercises were very different from each other as some of them stated that the increases in training volume did not lead to proportional changes in the physiological response. On the other hand, caffeine supplementation

studies differed with respect to the extent of ergogenic effects of caffeine, e.g. whether or not increased serve speed was the main benefit of caffeine or increased overall physical performance were also the observed results, which could be attributable to variations in the way the studies were conducted, the times they were done, and differences in what was measured.

Three specific research gaps were identified. First none of the studies prospectively followed athletes simultaneously for the co-development of arm strength, lower limb power, and coordination throughout the entire competitive period, so that the chronological sequence and cause- effect relationship between these variables still remain ambiguous Secondly, the consistent use of standardized and validated serve speed and serve accuracy outcome measures was hardly the case across the studies, thereby making it nearly impossible to directly quantify and pool the results of a meta-analysis Last but not least, very few researchers have focused on how strength, power, and coordination interact in adapted or para-volleyball contexts particularly, such as sitting volleyball, although their upper-body demand is completely different.

At the very least, three very concrete avenues of research should be pursued. Future studies should, first of all, be longitudinal or prospective cohort studies which will monitor strength, power, and coordination characteristics at the same time throughout the whole sports season so that the causal and developmental ordering become clear. As a second step, the creation of an standardized, reliable serve-velocity and serve-accuracy measuring method that will allow cross-reference between different studies as well as future meta-analyses would greatly improve the situation. Finally, researchers are encouraged to do experiments which, through strength-power-coordination training in a totally integrated way, as a combined package, rather that having the various modes of training as separate segments, and they are also suggested to generalize this integrative training concept to groups of populations who have previously been ignored such as sitting-volleyball athletes and young players in the early phase of learning technical abilities.

Concerning the review's guidance questions: RQ3 is supported by findings that inter-segmental coordination such as trunk-arm kinetic sequencing and eye-hand coordination functions as a mechanism that turns available strength and power into successful serves. Motion-capture, electromyography and computational anticipation are becoming tools to quantify this function with increasing precision. RQ2 finds its answer in studies that show lower limb (leg) strength and power is a solid and adjustable contributor to jump-serve height and related speed of arm swing. This strength is the result of compound movements, plyometrics, kettlebells or small format sessions and supported by proper recovery and healthy tendons. Concerning the review's focus questions: the response to RQ1 is that although arm and shoulder muscular strength are required for the serve/ spike velocity, this factor is dependent solely on the management of workloads for the prevention of shoulder pain that is not caused by accidents (e. g. trauma). Besides, the use of caffeine and the like as ergocenhic agents only gives a partial and inconsistent additional boost. As for RQ1 the arm and shoulder muscular strength are among the factors contributing to the serve/spike velocity. This ability is also influenced by a proper loading management avoiding shoulder injuries from non-traumatic sources such as overexertion. It has however been found out that caffeine and other ergogenic substances are not very effective as they have only small and sometimes inconsistent effect on this ability. As for RQ2, one is to be informed that the jump-serve height is mostly influenced by lower-limb (leg) power. The power development is a result of complex movements, plyometric exercises, kettlebells or small format workout sessions. One should not forget that the body needs proper recovery and healthy tendons, so this factor is included here as supportive ones. Concerning the review's focus questions (guide questions):- RQ1- the fact that arm and shoulder muscular strength are required is the response. However this factor is dependent solely on the management of workloads for the prevention of shoulder injuries (non-traumatic ones such as those from repetitive motions). Besides, the use of caffeine and the like as ergocenhic (substances that improve athletic performance) agents only gives a partial and inconsistent additional boost. As for RQ2- the jump serve is mostly height and the related speed of arm swing that is influenced by lower-limb strength and power.The development is a combination or the result of the use of complexmovements, plyometrics, kettlebells, small format sessions etc. But one would be remiss in a forget that one's recovery is very important together with tendonhealth so those factors are included here as supportive. RQ3- one is informed that between the segmental coordination is the mediator function turning the strength and power available into efficient serve results. The work of the trunk-arm kinetic linkage and eye-hand coordination are among the examples mentioned. It has been said that the role is becoming more understandable with the tools such as motion-capture. This means, however, that even if one is able to measure it more precisely with these methods, the underlying principle remains that one needs not only strength and speed but also the capacity to deliver a successful serve by means of proper inter-segmental coordination.

Limitations of This Review

This review has some limitations that need to be taken into consideration before the conclusions are interpreted. First of all, the search was limited to one database (Scopus) and only English-language articles or

reviews were included. Thus, there is a possibility that important conference proceedings, non-English publications, and emerging preprints were omitted. Moreover, the eligibility-checking process was done under a single reviewing stream, but without multiple independent reviewers and without inter-rater reliability evaluation. Although this approach was not in accordance with the guidelines of high-quality systematic reviews, it still may lead to selection bias. In addition, the theme synthesis is based upon the researcher's qualitative conception of findings from abstracts-level or full-text level. This methodology is a contrast to pooling of effect sizes through meta-analysis which requires estimation of the statistical effect magnitude of strength, power, and coordination.

Conclusions

This review article looked at 50 volleyball research studies in Scopus database to see if muscle strength in arms, lower-limb power, and motor coordination really make a difference in the volleyball overhead serve performance. After answering the first question, it was found that arm and shoulder muscles are important factors that can help with the serve speed but, on the other hand, these are also highly injury susceptible and hence it is necessary to be careful about the loads that are being put on the athletes. After the second question, the researchers found that lower limb power is a crucial factor that supports jump-serve techniques and is developed and maintained through compound, plyometrics kettlebells and sport-specified exercises. With answering the third question, they identified inter-segmental coordination that involves from trunk-arm kinetic sequencing to eye-hand integration was highlighted as the process which allows strength and power to be efficiently converted into accurate and effective execution of serve. This paper mainly provides three inter-related literature reviews: arm and shoulder strength (the first), lower limb power (the second), and motor coordination (the third) into a kinetic-chain account of serve performance, and it is supported by PRISMA methodology that the selection process is done through a transparent way. From a practical point of view, the results can lead to the suggestion that the conditioning programs of volleyball servers may be better if they are designed not just to develop the upper body strength alone, lower limb power alone, and serve-specific coordinative drills alone, respectively but rather combine all three into one program while the training of developing athletes is going on it should be a constant monitoring of the shoulder load, so as to prevent injuries. These interpretations are subject to several restrictions. First, the authors based their research on one database only. Also, it has been found that the screening of the studies was performed solely by one reviewer. Moreover, the method of literature synthesis was not the one by meta-analysis but by qualitative methods which all together can be responsible for the less level of precision with which it is possible to assess the contribution of strengths separately. Narrative and thematic synthesis was chosen over meta-analysis because the included studies used heterogeneous outcome measures (e.g., different serve-velocity metrics and jump-performance indices) that could not be statistically pooled without risking a misleading composite effect size. Therefore, to apply this information as a valid guide for practice to sports coaches, sport scientists, and clinicians that are working with volleyball players, the authors encourage future studies to conduct causal inquiries in longitudinal format where serve-outcome measurements are standardized and training-interventions are clearly stated and followed, that is, explicitly integrated training interventions.

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