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Multidimensional analysis of serving speed in volleyball players by position, sets, and league types: interactions and statistical differences



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Abstract

Purpose Our study explores the multifaceted factors influencing serve speed in volleyball, including player position, match progression, and league level, providing actionable insights for performance optimization and injury prevention strategies.

Methods Using a cross-sectional approach, the study analyzes 15.347 serves from various leagues. A multifactorial ANOVA analysis was conducted to assess how player positions, sets, and league types influence serving speed.

Results Significant differences were observed in serve speed between player positions (F = 375.844, p < .001), throughout match sets (F = 17.624, p < .001), and across different league types (F = 356.914, p < .001). Players in higher leagues, especially the 1st Men's league, displayed higher serve speeds compared to those in lower leagues (like the 2nd Women's league). Various serve types (jump float, jump spin, tennis serve) significantly impacted serve speed. Notable interactions between player positions and sets, as well as between positions and league types, were found. However, a three-way interaction among position, sets, and league type was not significant.

Conclusions The study emphasizes the need for targeted training interventions considering competitive level, gender, and match progression to optimize serving speed. This research contributes to the field of sports science, especially for performance enhancement in competitive volleyball.

Keywords Volleyball, Serving speed, Player position, Match sets, League type

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Background

The sport of volleyball, characterized by its swift, highintensity exchanges and strategic depth, demands a multifaceted understanding of the various elements influencing player performance. Previous research has identified multiple factors that can influence serving speed in volleyball. One critical factor is player position, as servers consistently generate higher speeds than receivers due to the preparatory phase and effective momentum transfer during serve execution. For instance, Baena-Raya et al. [1] emphasized the significance of the force-velocity profile in determining serve speed among top-level male volleyball players, highlighting the biomechanical advantages servers possess [1].

Match progression is another influential factor, with studies, such as that by Pawlik and Mroczek [2], demonstrating a decline in serve speed as fatigue accumulates across sets. This aligns with findings by Rusdiana [3], who explored the biomechanical and muscular impacts of fatigue on the jump serve, underscoring the dynamic interplay between physical condition and technical execution.

Furthermore, league level also plays a pivotal role, with players at higher competitive tiers exhibiting greater serving speeds due to superior training, advanced techniques, and physical preparedness. This perspective is supported by de Leeuw et al. [4], who modeled match performance in elite volleyball players and found jump load and strength training characteristics to be integral components affecting serve speed.

Together, these factors—player position, match progression, and league level—stand out as determinants of serving speed, a critical element that can significantly influence the outcome of a match. By incorporating insights from recent research, this study builds on the current understanding and aims to provide actionable recommendations for enhancing serve performance in volleyball.

Volleyball's evolution, particularly with the advent of the jump serve in the 1980s, has underscored the serve as not merely a game-initiating action but a strategic tool capable of securing points and setting the stage for defensive and offensive setups [5]. Consequently, the effectiveness of serving has become a focal point in competitive volleyball, with serve speed emerging as a critical determinant of success [6, 7]. This acknowledgment has spurred a wealth of research within sports science, aiming to dissect the components of an effective serve.

Building upon this foundation, the current study expands the scope of inquiry to consider how the interplay between positional roles, in-game strategies across different sets, and the intensity of competition inherent to various league types contribute to serving speed variations. This approach recognizes that factors such as accumulated fatigue over successive sets, different positions' distinct physical demands, and strategic responsibilities can influence a player's serving capabilities [8]. Additionally, it posits that players participating in highertier leagues might demonstrate superior serve speeds attributable to advanced skill levels, rigorous training regimens, and enhanced physical conditioning [9, 10]. By explicitly linking these aspects to practical implications, such as tailored training regimens and performance monitoring, this study seeks to provide actionable insights for coaches and sports medicine practitioners. This integration of scientific exploration with practical application underlines the study's value for the volleyball community, aiming to bridge the gap between research and practice.

The significance of this research lies in its comprehensive analysis, which aims to unravel the complex interactions and statistical differences affecting serving speed among volleyball players. By examining the variables of position, sets, and league types, this study offers novel insights that could inform targeted training interventions, elevate player performance metrics, and guide strategic decision-making in competitive volleyball. Through meticulous statistical examination, it aspires to identify patterns and trends that could elucidate strategies for optimizing serving speed, thereby contributing to the broader discourse on performance enhancement in volleyball.

The study investigates the factors influencing serving speed in volleyball, focusing on three key aspects: player positions, match progression (sets), and league levels across Turkey. It aims to explore how these elements interact to affect serving performance and provide insights for improving competitive strategies.

Methods

Study design and participants

This longitudinal study explores the factors influencing serving speed among volleyball players from different competitive levels. The study targets volleyball teams from the Sultans League, Women's 1st League, Women's 2nd League, Efeler League, Men's 1st League, and Men's 2nd League, covering a total of four volleyball seasons. Our research analyzed 6943 serves from female athletes, and 8404 serves from male athletes. A comprehensive dataset of 15,347 serves (comprising 2,935 from setters, 4,836 from middle blockers, 2,477 from opposites, and 5,099 from wing spikers) was analyzed to assess variations in serving speed. The types of serves included in the analysis were the jump float serve (9,896 instances), jump spin serve (3,144 cases), and tennis serve (2,307 instances).

To participate in the study, volleyball players were required to actively compete in one of the specified leagues, be at least 18, and have a minimum of two years of competitive playing experience. Players who had sustained injuries (surgical operations) within the six months preceding the study, which could potentially impact their serving performance, were excluded from the analysis to maintain data integrity.

The study adhered to the ethical standards of the Declaration of Helsinki and received approval from the Kütahya Dumlupinar University Review Board (Approval Number: 27.07.2023-314). This ensures that the research was conducted to respect the rights and welfare of the participants, highlighting the study's commitment to ethical research practices.

Data collection

Data collection during this study was meticulously conducted by two experienced sports trainers who observed and recorded data during competitions, ensuring high precision in capturing serving speeds. A single examiner performed all tests across the participant group to eliminate any inconsistencies that might arise from having multiple testers. A Pocket Radar device (Pocket Radar, Santa Rosa, CA, USA) was utilized to accurately measure the velocity of the volleyball, registering the speed in kilometers per hour (km/h). This technology operates by emitting and receiving radio waves, a method proven effective in recording the speed of moving objects [11].

The radar device was strategically positioned on a platform reserved for statistical trainees at the back of the court. It was placed 5 m behind the service line and 1.5 m above the ground to align perfectly with the server's position, ensuring consistent data collection. The direction of the radar was adjusted based on the server's position in the service area, a technique supported by previous research [12, 13].

Participants in the study were asked to execute a series of serves, incorporating both jump and float serve techniques, to adequately represent the range of serving styles. This task was carried out during actual competitive matches or under simulated match conditions, from the initial to the final sets, to examine the potential effects of match progression on serving speed. Additionally, detailed records were kept of each participant's position (e.g., setter, outside hitter, middle blocker, libero) and their respective league levels to comprehensively analyze serving speed across diverse variables.

Statistical analyses

Descriptive statistics will be used to summarize the participant characteristics and serving speeds. ANOVA (Analysis of Variance) will examine the differences in serving speed across player positions, match sets, and league levels. The interaction effects between these factors on serving speed will be assessed using a factorial ANOVA. Post-hoc Post-hoc analyses, utilizing Bonferroni correction for multiple comparisons, will explore pairwise differences among the levels of significant factors. The Bonferroni correction was specifically chosen in this context to control for the increased likelihood of Type I errors when conducting multiple comparisons. Given the study's multifactorial design, involving comparisons across player positions, match sets, and league levels, this statistical adjustment ensures a robust approach to maintaining the validity of the results. This choice aligns with the methodological rigor required in sports science research, where multiple variables often interact, necessitating careful control of error rates to draw meaningful conclusions. A p-value of <0.05 will be considered statistically significant. Data analysis was performed using R studio and SPSS software version 26.0 (SPSS, Inc., Chicago, IL, USA) program.

Results

The analysis shows that serve speed is influenced by player position (F=375.844, p<.001), with front-row players achieving higher speeds, and match progression (F=17.624, p<.001), where speeds decline due to fatigue across sets. League type (F=356.914, p<.001) also impacts speed, with higher-level leagues showing faster serves due to better training.

Different serve types (F=4176.340, p<.001, η^2 =0.345) and service qualities (F=82.978, p<.001, η^2 =0.010) further affect performance. Additionally, significant interactions exist between position and sets (F=2.869, p<.001), position and league type (F=105.273, p<.001), and sets and league type (F=2.988, p<.001), showing how these factors collectively shape serve performance.

The analysis reveals key interactions between serve type, service quality, and player position. Serve type and service quality show a significant interaction (F=19.877, p<.001, η^2 =0.005), indicating that the effectiveness of a serve depends on both the technique used and its quality. Additionally, a significant interaction is found between serve type and position (F=21.143, p<.001, η^2 =0.005), suggesting that different player roles influence how various serves are executed. There is also an interaction between service quality and position (F=2.624, p=.005, η^2 =0.0009743), meaning that certain positions may deliver more precise or powerful serves.

However, the three-way interaction among position, sets, and league type was not statistically significant (F=1.165, p=.179), indicating that these variables do not collectively impact serve speed in a meaningful way. Detailed results of these analyses are provided in Tables 1 and 2.

There was also a significant difference in serve speed between the different league types, with players in the 1st Men's league having the highest serve speed and players in the 2nd Women's league having the lowest serve speed.

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Cases	Sum of Squares	đt	Mean Square	Ŧ	р	η ²
Serve Type	825576.480	2	412788.240	4176.340	< 0.001	0.345
Service quality	24604.681	Ω	8201.560	82.978	< 0.001	0.010
Serve Type * Service quality	11787.618	9	1964.603	19.877	< 0.001	0.005
Position	4046.962	Ω	1348.987	13.648	< 0.001	0.002
Serve Type * Position	12538.737	9	2089.790	21.143	< 0.001	0.005
Service quality * Position	2334.485	6	259.387	2.624	0.005	9.743×10^{-4}
Serve Type * Service quality * Position	3121.060	18	173.392	1.754	0.025	0.001

Discussion

This study examines how player positions, match progression (sets), and league levels affect serving speed in volleyball, revealing key interactions between these factors. The insights gained highlight practical strategies that coaches and athletes can use to optimize performance through tailored training and role-specific adjustments. The findings from our analysis present significant implications for understanding and enhancing serving speed in volleyball, illuminating the complex interplay of factors such as player position, match progression, league type, serve type, and service quality. These results align with previous research and extend our knowledge by exploring the nuanced interactions between these variables [1–4]. For example, Baena-Raya et al. [1] highlighted the role of force-velocity profiles in serve performance, while Pawlik and Mroczek [2] demonstrated the impact of fatigue on serving efficiency throughout match progression. Similarly, Rusdiana [3] explored the effects of muscle fatigue on jump serve mechanics, and de Leeuw et al. [4] emphasized the importance of jump load and strength training in elite-level performance. Together, these studies provide a comprehensive foundation for understanding the multifactorial influences on serving speed in volleyball. The multifaceted analysis of serving speed across different player positions, match sets, and league types in volleyball illuminates the intricate dynamics that influence this critical aspect of the game. This comprehensive examination, drawing on a wealth of research, underlines the pivotal role of serve speed in determining match outcomes and underscores the evolutionary trajectory of volleyball, particularly with the advent of the jump serve in the 1980s. The strategic significance of serve speed is magnified by its direct impact on the defensive and offensive setups of the game, making it a focal point in competitive volleyball. This study on volleyball players provides comprehensive insights into how various factors influence serve speed, an essential component of competitive gameplay. The analysis identified statistically significant differences across several key factors: Position, Sets, and League Type, as well as Serve Types and Service Qualities, each affecting serve speed distinctly.

The remarkable variance in serve speed according to player position (F=375.844, p<.001) corroborates the specialized roles within volleyball teams and their training focus, echoing the findings of previous studies that highlighted position-specific skills and physical attributes [11, 12, 14]. The position factor indicates a substantial variance in serve speed among different playing positions. This suggests that the specific roles and responsibilities associated with each position may demand varying serve speeds; for example, front-row players might prioritize precision and technique over

Cases		Su	im of Squares	df	Mean Square	F		р
Positic	on	18	2069.457	3	60689.819	375.844		< 0.001
Sets		11	383.191	4	2845.798	17.624		< 0.001
League type		28	8165.854	5	57633.171	356.914		< 0.001
Position * Sets		55	59.405	12	463.284	2.869		< 0.001
Position * League type		25	4985.442	15	16999.029	105.273		< 0.001
Sets 🛠 League type		96	50.926	20	482.546	2.988		< 0.001
Position * Sets * League type		/pe 11	291.453	60	188.191	1.165		0.179
	League type: 1st Men	League type: 1st Women	League type: 2st Men	League type: 2st Women	League type: Efeler	League type: Sultans		Position
400 - 200 - 0 -	618\$ccangageP#+	P ⁴ 8200-9484948	hatun 6100	• • • • • • • • • • • • • • • • • • •	Matter pige	<u></u>	Sets: 1.Set	 Middle Blocker Opposite Setter Wing Spiker
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Table 2 ANOVA for position, sets, and league type - serve speed km/h

Fig. 1 Descriptive Of serve speeds according to position, league type, and service type

speed compared to back-row players, who may focus on maximizing serve speed to challenge the opposition's reception. The difference in serve speeds across sets (F=17.624, p <.001) could be attributed to fatigue factors, strategic changes, or psychological pressures as matches progress, a phenomenon previously noted in sports science literature [5].

The insights from Costa et al. [15] into the determinants of successful attacks from different attack zones offer a compelling perspective on volleyball's tactical depth, emphasizing the significance of reception quality, attack tempo, and attack type. These elements resonate with our findings on serve speed, suggesting a symbiotic relationship between the initial serve and subsequent phases of gameplay. The implication is that a well-executed serve, in terms of speed and placement, can challenge the receiving team and strategically shape the ensuing reception and attack opportunities. This underscores the necessity for serving strategies to be crafted with a holistic view of their impact on the game flow, particularly on reception quality and attack setup.

Similarly, Silva et al. [16], which investigate the skills distinguishing successful from unsuccessful outcomes based on the setter's position, further illuminate the nuanced strategic landscape of volleyball. Their findings highlight the critical role of tactical versatility and the strategic nuances of serving that can exploit particular game scenarios. By understanding how different serve strategies can influence the setter's options and attack efficacy, teams can effectively tailor their serving tactics to disrupt opponents' game plans. This approach complements our analysis of serve speed. It enriches the broader strategic framework within which volleyball is played, emphasizing the interconnectedness of all game phases from serve to attack and the pivotal role of adaptability in achieving competitive advantage.

The observed variances in serve speed across different league types (F=356.914, p < .001) might reflect the distinct competitive environments, including differences in tactical approaches and physical conditioning regimes among leagues. This finding aligns with Garciade-Alcaraz et al. [17], who emphasized the significant role of competitive level in influencing key performance metrics in the sports field. The substantial differences in serve speed according to league type suggest that players in higher-tier leagues likely benefit from superior physical conditioning and refined technical skills, enabling them to execute faster serves. Furthermore, the tactical complexity inherent to higher levels of competition may require players to adapt their serve speeds strategically in alignment with more sophisticated game plans. This nuanced understanding of how league type influences serve speed underscores the importance of considering competitive level as a critical factor in sports performance analysis, highlighting the interplay between physical abilities, technical proficiency, and tactical demands in shaping player performance.

The present study analysis extends the existing literature by quantitatively demonstrating significant variations in serve speed across different serve types (F=4176.340, p<.001, η^2 =0.345) and service qualities (F=82.978, p<.001, η^2 =0.010). These findings suggest that the serve type, whether a powerful jump serve or a strategic float serve, substantially impacts serve speed, an observation that aligns with the work of Zhang and Tao [18] on serve technique. The interaction between serve type and service quality (F=19.877, p<.001, η^2 =0.005) further highlights the complexity of achieving optimal serve performance, underscoring the need for a nuanced understanding of how technical execution impacts outcome quality. Serve types and service qualities underscore the technical aspects affecting serve speed. Different serve techniques and the quality of the serve, whether it's aimed at power, placement, or spin, profoundly impact serve speed. The significant F value for serve types suggests that the technique significantly determines serve speed. Our findings are supported by studies like Moras et al. [19], which explored the effectiveness of different serve modes and speeds in high-level volleyball, demonstrating the strategic significance of serve selection based on its impact on match outcomes. The nuanced understanding of serving strategies, as reflected in our analysis, suggests that the optimization of serve speed involves physical and technical prowess and strategic decision-making that considers the interplay of multiple game-related factors.

The observed significant interactions between position and sets (F=2.869, p<.001), position and league type (F=105.273, p<.001), and sets and league type (F=2.988, p<.001) elucidate the complex fabric of factors

influencing volleyball performance. This complexity is further highlighted by the nuanced interplay among different variables, emphasizing the contingent nature of their effects. For example, the influence of a player's position on serve speed is not static. Still, it varies across different sets and league types, illustrating a dynamic interrelation contingent upon the context of play. Such findings align with current literature, which advocates for a multifaceted understanding of sports performance. They suggest that the effectiveness of specific skills or strategies can only be fully appreciated considering contextual factors' interplay [20–22]. This perspective emphasizes the importance of recognizing how environmental conditions, psychological states, and team dynamics influence overall performance in sports.

Furthermore, the intricate relationships between serve type and service quality, as well as between serve type and player position, underline the critical balance between technical execution and match-specific dynamics. These interactions indicate that maximizing serve efficiency requires more than technical prowess; it also demands an acute awareness of how factors like match progression (sets) and competitive environment (league type) might influence or be leveraged to enhance performance.

Interestingly, the lack of a statistically significant threeway interaction among position, sets, and league type (p=.179) suggests that while each factor and their pairwise combinations significantly impact serve speed, the amalgamation of all three does not provide additional predictive value. This insight posits a potential ceiling to the multiplicative effects of these variables, indicating that the complexity of volleyball performance might be comprehensively captured by examining two-way interactions. This limitation in interaction complexity emphasizes the importance of strategic focus on how dual combinations of variables-such as the synergy between player position and the tactical phase of the game (sets) or the adaptability required across different league types—can be optimized to enhance serve speed and, by extension, overall match performance.

The analytical review of serve speed across varying league types and positions reveals distinctive patterns in performance, with the 1st Men's league showcasing the highest speeds across serve types such as Smac, Jump, Float, and Tenis. This trend, evidenced by data points representing consistently higher serve speeds in this league, can be attributed to physiological factors, advanced training regimens, and the tactical acumen honed through high levels of competition. The 2nd Women's League, while exhibiting the lower end of serve speeds, demonstrates the impact of these same factors at a different competitive tier. The disparity in serve speeds is not an artifact of match conditions but a reflection of

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ingrained differences between the leagues' competitive demands and player development.

Significant differences in serve speeds between the 1st and 2nd Women's leagues, though less stark than between genders, corroborate the notion that competitive level is a strong indicator of performance capabilities, including serve speed, across genders. This pattern aligns with empirical evidence from research on elite volleyball players, which indicates gender-based preferences in serve types, with males often opting for the more vigorous jump topspin serves and females typically favoring the jump float serve. Such preferences may be rooted in physiological attributes and tactical considerations unique to gender-specific gameplay.

The evolution in serve types, particularly the increased adoption of jump serves among female players, speaks to the sport's dynamic nature and the continuous advancements in training and strategy. It aligns with male players' techniques, reflecting a strategic shift toward more technically challenging serves. This adaptation is a testament to the players' increasing athletic prowess and to volleyball's strategic depth, where choices in serve types are both a response to and a driver of the evolving nature of the game.

The statistical underpinnings of these serve speed variations provide a robust foundation for actionable insights. The observed trends should guide coaching and training emphases, highlighting speed as a critical performance component. This focus is particularly salient for teams vying for competitive excellence, where strategic and training adaptations can be the fulcrum for superior in-game execution. The current analysis, therefore, not only enriches the existing body of literature on performance indicators in volleyball but also sets a precedent for the integrated approach to training and strategy formulation tailored to the nuances of competitive level, gender, and tactical evolution in the sport.

This research, while comprehensive, has its limitations. The cross-sectional design precludes causality inference, and the study's observational nature limits the control over external variables that might influence service speed. Furthermore, excluding injured players could have introduced a selection bias, possibly affecting the serve speed averages. While the Pocket Radar device used for measurement is validated, there may be minor discrepancies in serve speed detection due to environmental conditions or human error during data recording. Future studies could address these limitations by adopting a longitudinal design that tracks players over multiple seasons, thereby providing insights into the long-term effects of training and injury history on serve speed. Additionally, including injured players and assessing the impact of targeted rehabilitation or preventive shoulder exercises could offer valuable data on performance variations and recovery outcomes.

Conclusion

The multifaceted study conducted on the dynamics of serving speed across various levels and positions in volleyball offers a granular look into the sport's performance metrics. Our findings reinforce the notion that serve speed is not merely a function of athletic prowess but a composite outcome influenced by a combination of factors, including the players' position, the progression of the match, and the competitive level of the league. The study highlights the heightened serve speeds in the 1st Men's league, underscoring the impact of advanced training and technical skills honed through rigorous competition. In contrast, the discernible difference in serve speeds in the lower-tier leagues points to the importance of these factors in player development and performance optimization.

Given these findings, practical implications for coaches and sports practitioners emerge. For instance, incorporating targeted training regimens that focus on improving serve speed through biomechanical analysis and individualized strength programs could benefit players across all league levels. Additionally, monitoring serve speed variations across match progression can help coaches identify fatigue patterns and implement effective recovery or substitution strategies. For lower-tier leagues, structured programs emphasizing technical skill development and physical conditioning could narrow the performance gap with elite levels.

The absence of a three-way interaction among position, sets, and league type challenges the assumption of additive effects of these variables on serve speed, refining our understanding of the intricacies of volleyball performance. These insights offer actionable recommendations for practitioners, such as integrating position-specific serve training and implementing recovery-focused interventions across match sets to optimize player performance.

Future directions

To build upon the current study's insights, future research should consider longitudinal designs that capture changes over time, including interventions to improve service speed. Exploring the psychological aspects of serving, such as the effects of stress and fatigue on serve speed and accuracy, would provide a more holistic understanding of the factors at play. Additionally, incorporating biomechanical analysis could offer a deeper insight into the physical aspects of effective serving techniques. Further research could also consider the application of machine learning models to predict serve speed and its outcomes based on the identified influential factors, potentially offering new avenues for coaching and training optimization.

While this study focused on the Turkish Volleyball Federation's leagues, replicating this research across different national and international contexts could validate the findings and assess the universality of the observed trends. Furthermore, including players with injury histories and tracking the long-term impacts of targeted rehabilitation programs or preventive exercises on serve speed could add depth to the current understanding. As the sport evolves, continuously evaluating these performance metrics will be paramount in keeping pace with competitive volleyball's changing demands and advancements.

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Author contributions

Conceptualization, E.A., C.S, and Z.A; methodology, E.A., C.S, and Z.A; formal analysis, E.A., C.S, and Z.A; data curation, E.A., C.S, and Z.A; data analysis, E.A., C.S, and Z.A; writing—original draft preparation, E.A., C.S, and Z.A; writing—review and editing, E.A., C.S, and Z.A; supervision, Z.A. All authors have read and agreed to the published version of the manuscript.

Data availability

Data is available at a reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Kütahya Dumlupinar University Ethics Committee. Kütahya Dumlupinar University Ethics Committee approved all experimental protocols (Approval Number:27.07.2023-314). Written informed consent was obtained from the participants to publish this paper.

Consent for publication

No individual or indemnifiable data is being published as part of this manuscript.

Competing interests

The authors declare no competing interests.

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