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# Research on Common Technical Errors and Correction Methods of Tennis Serve Movements

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## Abstract

Focusing on the technical defects and corrective training methods of tennis serve, this paper adopts three research methods, including literature review, logical induction and content analysis, to systematically sort out relevant domestic and foreign research achievements from 2004 to 2024. Based on the kinetic chain theory, this paper clarifies the standard movement principle of tennis serve, summarizes the typical technical errors and stage characteristics in serve practice, and analyzes the multi-dimensional causes of movement deformation. Meanwhile, it sorts out two sets of mature corrective training systems suitable for amateur teaching and professional competitive training respectively. By comparing the differences between domestic practical teaching research and foreign biomechanical quantitative research, this paper sorts out the deficiencies of the current research system and puts forward the optimization direction for follow-up research. The systematic sorting and theoretical discussion of this paper can provide a solid theoretical basis and practical reference for college tennis teaching, tennis coaches and practitioners, at all levels to carry out tennis serve technical error correction.

### Keywords

tennis serve, technical error, biomechanical kinetic chain, corrective training, physical education teaching

## 1. Introduction

### 1.1 Research Background

Serving is the only core technique in tennis, that is completely controlled by athletes without interference from opponents. As the initiating movement of single-point confrontation and a key tactical means for athletes to take the initiative to attack and score directly, it has an irreplaceable core value in mass amateur training, youth reserve talent training and professional event competitions. The standard serve movement follows a complete mechanical logic: lower limb pedaling for force accumulation, trunk torsion for energy storage, and shoulder girdle driving the coordinated whipping force of the upper limbs. The whole kinetic chain operation process is complex, requiring extremely high human limb coordination, force rhythm control and movement accuracy, making it the most error-prone and most likely to solidify wrong muscle memory in the tennis technical system [1].

In front-line teaching and daily training, most tennis practitioners generally have typical technical problems, such as deviated ball tossing direction, unstable hitting point, insufficient trunk rotation amplitude, and



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excessive reliance on upper limb force [2]. Long-term repeated wrong movements will form intractable neuromuscular memory that is difficult to correct, which will not only reduce the initial speed, rotation quality and landing accuracy of the serve, may weaken the tactical deterrence of the serve, but also concentrate the force load on key parts, such as shoulders, elbows and lumbar spine. Long-term overload compensatory force is highly likely to cause special sports injuries such as rotator cuff injury, tennis elbow and chronic lumbar muscle strain [3].

With the continuous advancement of national fitness cause in China and the growing enthusiasm for mass sports participation, college tennis elective courses have been fully popularized and the scale of tennis participants has been continuously expanded, leading to an increasing number of practical teaching researches on tennis serve error correction [2]. At the same time, relying on high-speed camera technology, three-dimensional motion capture system, dynamic force-measuring equipment and other precision instruments, foreign sports science circles have carried out a large number of biomechanical quantitative experiments on tennis serve, forming mature theoretical achievements in joint force sequence, limb angle changes and muscle activation rules [4]. However, domestic relevant research results are scattered in various journals and dissertations, lacking systematic integration and sorting. In addition, there are significant differences between domestic and foreign research in research ideas, experimental conditions and applicable training scenarios, resulting in the lack of a scientific, systematic and implementable theoretical guidance system for serve error correction in grassroots tennis teaching.

### 1.2 Research Objectives

By sorting out domestic and foreign relevant literature in the past two decades, existing studies have discussed the standard movement mode of tennis serve, single error correction and biomechanical characteristics of serve, but the overall research framework still has obvious shortcomings. Most studies analyze single wrong movement in isolation, fail to establish a systematic classification system combined with the complete serving process, and do not distinguish the differentiated technical defects of practitioners at different levels. Most correction methods only focus on the correction of external movement forms, ignoring the comprehensive influence of physical quality, cognitive deviation, teaching mode and psychological factors, resulting in single and one-sided intervention means.

## 2. Literature Review

### 2.1 Standard Movement System of Tennis Serve Based on Kinetic Chain Theory

#### 2.1.1 Force Conduction Law of Full-Body Kinetic Chain for Serving

According to the core principle of sports biomechanical kinetic chain, the momentum transmission of human explosive movements follows the law of gradual transmission from proximal lower limb muscle groups to distal upper limb muscle groups, realizing efficient force generation through multi-joint coordinated linkage and effectively avoiding local limb compensatory force problems [1]. As a full-body explosive technique, the complete force path of tennis serve has a rigorous mechanical logic: the ground reaction force generated by foot pedaling is transmitted step by step through pelvic rotation, trunk back arch stretching and energy storage, chest and shoulder expansion, and upper arm backward swing. Finally, the elastic potential energy accumulated by the whole body is transmitted to the tennis through the racket via high-speed forearm internal rotation whipping movement [3].

A large number of biomechanical empirical studies have confirmed that the speed, rotation effect and stability of serve mainly depend on the fluency and timing accuracy of kinetic chain conduction, rather than the absolute strength of upper limb muscles [4]. Once practitioners have problems such as reversed force sequence and interrupted limb linkage, a single-arm compensatory force mode will be formed, which will not only greatly reduce the serve quality, but also cause continuous overload of rotator cuff muscles, and easily lead to shoulder strain, tennis elbow and other sports injuries after long-term training [3]. According to the formation principle of sports physiology skills, the acquisition of motor skills has clear stage characteristics. Establishing a standardized kinetic chain force mode in the early stage of learning can form stable positive muscle memory; on the contrary, the solidification of early wrong force habits will greatly increase the difficulty and cost of subsequent correction [5].



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### 2.1.2 Key Points of Standard Movements in Four Serving Stages

Combined with the current academic consensus, the complete tennis serve movement can be divided into four closely connected core stages: preparatory posture, ball tossing and backswing, swing hitting, and follow-through movement, each with independent and interconnected functions. Slight deviations in any link will affect the force quality and stability of the overall movement [2]. In the preparatory posture stage, reasonable stance spacing, center of gravity distribution and standard continental grip can provide sufficient space for lower limb pedaling force; non-standard grip will directly limit the wrist whipping amplitude and force effect. In the ball tossing and backswing stage, the height, direction and trajectory of ball tossing directly determine the optimal hitting point, and the trunk fully leans back to form a back arch for energy storage, which is the core link of force storage in the whole serving movement [6]. In the swing-hitting stage, it is necessary to synchronously complete trunk rotation, elbow lifting and forearm internal rotation, and control the type of serve rotation through accurate racket surface angle, with clear biomechanical standard intervals for the range of motion of each joint [4]. In the follow-through stage, the residual kinetic energy is released, and body balance is maintained through forward movement of the center of gravity. Incomplete or interrupted movements will lead to insufficient force and damage the integrity of the movement. Throughout the serving process, ball tossing stability and full-body force coordination are the two links with the highest error rate [2].

## 2.2 Hierarchical Characteristics and Multi-dimensional Formation Mechanism of Tennis Serve Errors

### 2.2.1 Analysis of Hierarchical Characteristics of Serving Movements

Sports physiology clearly proposes that motor skill acquisition can be divided into three progressive stages: generalization, differentiation and automation. Learners at different stages have significant hierarchical differences in movement cognition, neuromuscular control and movement stability. This classic theory is the core theoretical basis for analyzing the serve error characteristics of practitioners at different levels and carrying out hierarchical training [5]. Based on this theory and existing teaching research results, tennis serve errors show obvious link aggregation and crowd stratification characteristics [2]. In terms of error probability, the technical error rate of the ball-tossing link is the highest, followed by the swing hitting link; the preparatory posture and follow-through movements are mostly slight habitual deviations, which have limited impact on the overall serve quality. In terms of practitioner level, zero-basis learners in college elective courses at the skill generalization stage have vague movement cognition, with errors mainly manifested as non-standard grip, unreasonable stance and chaotic ball tossing trajectory [2]. Intermediate practitioners at the differentiation stage are restricted by insufficient core strength and limited shoulder and hip joint flexibility, prone to insufficient trunk rotation, incomplete back arch opening and blocked kinetic chain conduction [6]. High-level amateur practitioners gradually enter the automation stage with basically finalized movement frameworks, and their errors are mostly subtle defects such as floating hitting points and incomplete whipping force. Professional athletes have highly mature motor skills and standardized daily training movements, and movement deformation mostly occurs in high-pressure competition scenarios or physical fatigue states, mainly induced by emotional and psychological fluctuations [7].

### 2.2.2 Five-dimensional Incentive System for Serving Movement Errors

Current academic circles generally believe that tennis serve technical errors are not caused by a single factor, but by the coupling of five dimensions: physical quality, technical cognition, teaching training, psychological state and biomechanics. The superposition of multiple incentives eventually leads to the solidification of wrong movements [2, 7]. At the physical quality level, insufficient core strength, lack of lower limb explosive power and limited shoulder and hip joint mobility prevent the body from supporting standardized kinetic chain force, forcing practitioners to produce compensatory movements, destroying the coherence of the whole-body force chain, and causing interrupted force transmission and disjointed upper and lower limb force [6]. At the technical cognition level, most practitioners have cognitive misunderstandings, one-sidedly believing that serving relies only on arm force, lacking professional cognition of full-body coordinated force, thus forming solidified wrong movement thinking. At the teaching and training level, teachers' abstract explanation, inadequate movement decomposition demonstration, and rigid single training mode fail to correct subtle movement deviations in the early stage of learning, which are solidified into intractable muscle memory after repeated practice [2]. At the psychological level, on-site tension and anxiety will cause muscle stiffness, disrupt



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the rhythm of ball tossing and trunk rotation force, and lead to on-site movement deformation [7]. At the biomechanical level, reversed force sequence and interrupted momentum transmission are the core mechanical incentives for technical errors. Single technical training cannot completely eliminate errors [1, 4], and comprehensive multi-dimensional intervention is essential.

## 2.3 Existing Tennis Serve Corrective Training System and Its Defects

### 2.3.1 Multi-dimensional Sports Intervention Theory

The multi-dimensional sports intervention theory points out that limb movement deformation results from the coupling of physical quality, technical cognition, teaching training, psychological state and mechanical conduction. Correcting only external movement forms cannot eradicate solidified wrong muscle memory, and comprehensive all-round intervention is required, which provides core theoretical support for the construction of tennis serve corrective training system [2, 7]. Relying on this theory, long-term teaching practice and scientific research achievements, domestic tennis serve error correction training has formed a standardized process of "movement decomposition shaping - special quality strengthening - complete movement integration - movement consolidation and maintenance", and derived two sets of mature training modes adapted to different scenarios and crowds [2]. The first set is the equipment-free basic correction mode suitable for college classroom teaching and youth amateur training, including fixed-point ball tossing shaping, no-ball trunk rotation whipping, static grip standardization, no-ball back arch stretching and other training contents. It has the advantages of low threshold, easy operation and no venue and equipment restrictions, which can effectively correct basic technical errors of beginners [2, 6]. The second set is the intelligent fine correction mode for professional athletes, which relies on high-speed cameras, three-dimensional motion capture systems, force-sensing rackets and other intelligent equipment to carry out quantitative analysis on multi-dimensional data such as joint movement angle, force peak value and center of gravity displacement trajectory, accurately locate subtle technical defects, and is mainly used for technical fine optimization and post-injury movement reconstruction of high-level athletes [8]. The two sets of modes complement each other and constitute the core system of current tennis serve error correction training.

### 2.3.2 Four Limitations of the Corrective Training System

Combined with existing research results, the current tennis serve corrective training system still has prominent shortcomings. First, the hierarchical correction system is imperfect. Existing research and training schemes mostly focus on zero-basis learners, and personalized and step-by-step correction schemes for youth intermediate players and professional athletes are scarce [2, 6]. Second, training evaluation lacks quantitative standards. Grassroots corrective training mostly relies on teachers' subjective experience without unified biomechanical quantitative indicators, resulting in large individual differences and insufficient standardization of training effects [4]. Third, the research orientation is unbalanced, with a problem of "emphasizing post-event remediation and neglecting early prevention". Most studies focus on the correction of formed wrong movements, ignoring the standardized intervention research in the early stage of skill learning. Fourth, the intervention mode is single. Existing corrective training is mostly limited to technical movement adjustment, without systematic integration of special physical fitness strengthening and sports psychological regulation, and a perfect interdisciplinary three-dimensional comprehensive intervention system has not been constructed [7].

## 2.4 Differences and Integrated Development Ideas of Chinese and Foreign Tennis Serve Research Paradigms

### 2.4.1 Comparison of Research Focuses Between China and Foreign Countries

Chinese and foreign tennis serve research have formed research paradigms with respective advantages and strong complementarity [4]. Domestic research is based on campus physical education and mass amateur training scenarios, focusing on summarizing common technical errors in classroom teaching and developing simple correction methods suitable for college students and youth practitioners, with strong operability and practicality. However, most domestic studies adopt empirical induction, lacking biomechanical quantitative experimental support, resulting in insufficient theoretical depth and academic rigor [2]. Foreign research relies on professional sports laboratory resources, takes professional athletes as the core research samples, and carries



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out quantitative analysis with precision instruments, forming a complete theoretical system in serve force mechanism, sports injury mechanical mechanism and standardized movement parameters [4]. However, its experimental conditions and physical quality of research samples are quite different from domestic mass practitioners, so the research conclusions cannot be directly adapted to grassroots teaching scenarios.

### 2.4.2 Integrated Development Path of Chinese and Foreign Research

Chinese and foreign research paradigms have significant complementarity, and two-way integration is the core development trend of future research in this field [4]. Domestic grassroots teaching research can learn from foreign mature kinetic chain quantitative indicators and joint force standards, make up for the subjectivity and unscientificity of traditional empirical teaching, and promote the transformation of tennis serve correction training from empiricism to data-based precise training [1]. Foreign biomechanical research can further expand research samples such as teenagers and amateur practitioners, optimize experimental design and research content combined with grassroots simple training conditions, promote the landing and application of high-end scientific research achievements, and improve the adaptability of professional theories to domestic mass tennis teaching scenarios.

## 3. Core Research Conclusions

### 3.1 Serve Mechanical Operation Law and Compensatory Injury Mechanism

Consistent with existing biomechanical research conclusions, standardized tennis serve is a highly coordinated full-body kinetic chain movement that strictly follows the human progressive force conduction principle from proximal to distal [1, 4]. According to functional differences, the complete tennis serve movement can be divided into four temporally connected core stages: preparatory posture, ball tossing and backswing, swing force generation, and follow-through movement, which undertake the exclusive functions of energy storage, force transmission, force generation and posture stability respectively. Structural deviation or temporal disorder in a single link will directly affect the force efficiency and completion quality of the overall movement [2]. Among various technical variables, the stability of ball tossing and the coordination accuracy of full-body force sequence are the two core factors determining serve speed [2], rotation quality and landing accuracy.

Most amateur tennis practitioners generally have the problem of single upper limb compensatory force, abandoning the full-body linkage force mode from lower limbs and trunk to upper limbs [3]. This wrong mechanical force method not only reduces the overall power and tactical deterrence of the serve, but also causes long-term repeated overload pressure on the rotator cuff, elbow joint and lumbar spine, which is the core biomechanical inducement of special sports injuries such as rotator cuff impingement syndrome, tennis elbow and chronic lumbar muscle strain in amateur training [3].

### 3.2 Distribution Characteristics of Serving Errors Among Different Crowds

Combined with various teaching observations and statistical research results, tennis serve technical errors show significant link aggregation and differentiated crowd stratification characteristics [2]. In terms of the error probability of movement links, the technical deviation rate in the ball tossing stage is the highest, mainly manifested as unstable ball tossing height, forward and backward and left-right deviation, chaotic movement trajectory and inconsistent shot timing, which directly lead to unstable hitting points and insufficient release of stored elastic potential energy; the error rate of the swing hitting stage ranks second, with core problems including insufficient trunk rotation amplitude, inadequate scapula contraction and incomplete forearm internal rotation whipping. In contrast, deviations in preparatory posture and follow-through movements are mostly minor habitual problems with limited negative impact on overall serve quality [2].

Based on the three-stage theory of motor skill formation in sports physiology, the error characteristics of practitioners at different levels show regular differences [5]. Zero-basis learners at the skill generalization stage mainly have basic errors such as non-standard grip, unreasonable stance and chaotic ball tossing framework [2]. Intermediate practitioners at the differentiation stage are restricted by insufficient core strength and limited shoulder and hip joint flexibility, prone to problems such as unopened trunk back arch, blocked kinetic chain conduction and disjointed upper and lower limb force [6]. High-level amateur practitioners have formed stable



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movement frameworks, with errors concentrated on fine control defects such as floating hitting points and incomplete whipping force. Professional athletes have standardized movements in conventional training, and movement deformation mostly occurs in high-pressure competitions and physical fatigue states, with psychological fluctuations as the main inducing factor [7].

### 3.3 Multi-dimensional Cause Logic of Technical Movement Deformation

A number of existing studies have confirmed that the occurrence and solidification of tennis serve errors are not simply caused by technical defects, but the coupling result of five dimensions: physical quality, technical cognition, teaching intervention, psychological state and biomechanical mechanism [2, 7]. At the physical quality level, insufficient core muscle stability, lack of lower limb explosive power and limited joint mobility prevent practitioners from supporting the standardized full-body kinetic chain force mode, break the coherence of the force chain, and easily lead to compensatory problems such as interrupted force transmission and disjointed limb force [6]. At the technical cognition level, most beginners have cognitive deviations, over-rely on upper limb force, ignore the systematic momentum transmission value of lower limbs and trunk, and form deep-rooted wrong movement thinking. At the teaching and training level, teachers' general explanation, inadequate movement decomposition demonstration and single training mode fail to correct subtle movement deviations in the early stage of skill learning, resulting in wrong movements being solidified into stable muscle memory after repeated practice [2]. At the psychological level, competition anxiety and emotional tension will cause muscle stiffness and disordered force rhythm, destroying the coordinated cooperation of ball tossing, trunk rotation and hitting [7]. At the biomechanical level, reversed force sequence and interrupted momentum transmission are the essential mechanical roots of movement deformation [1, 4].

Therefore, single technical corrective training can only temporarily improve superficial movement problems. Only multi-dimensional collaborative intervention integrating physical fitness improvement, cognitive reconstruction, standardized teaching and psychological regulation can completely eradicate solidified wrong muscle memory and realize the all-round optimization of the tennis serve movement system [2].

### 3.4 Advantages and Internal Deficiencies of Existing Training System

Integrating current training practice and academic research achievements, the existing tennis serve correction system has formed two sets of mature training modes adapted to different scenarios and crowds, covering grassroots mass teaching and high-end professional training fields respectively [2, 8]. The first is the equipment-free basic correction mode, which is widely used in college public physical education courses and youth amateur training. It has low requirements for venue and equipment and strong operability, and mainly corrects framework technical errors of beginners through basic training such as fixed-point ball tossing shaping, no-ball whipping simulation and static posture standardization. The second is the intelligent fine correction mode, which relies on professional instruments such as high-speed cameras, three-dimensional motion capture and force-sensing equipment to carry out quantitative analysis on multi-dimensional biomechanical data such as joint angle changes, force peaks and center of gravity displacement. Accurately identify subtle technical defects, and is suitable for technical fine optimization and post-injury movement reconstruction of professional athletes.

However, a large number of practical studies have confirmed that the current corrective training system still has systematic shortcomings: personalized hierarchical correction schemes for intermediate trainers and semi-professional athletes are scarce, resulting in insufficient training pertinence [6]; grassroots corrective training mostly relies on teachers' subjective experience, lacking unified biomechanical quantitative evaluation standards [4]; the training orientation focuses on remediation and correction after errors are formed, ignoring standardized intervention in the early stage of skill learning; meanwhile, a three-dimensional comprehensive training system integrating technical correction, special physical fitness training and psychological adaptation regulation has not been constructed, restricting the systematicness and scientificity of tennis serve error correction training [7].



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## 4. Discussion

Combined with the above research conclusions and existing literature results, this paper analyzes the existing limitations and optimization directions of current tennis serve error correction research from four dimensions: theoretical application, hierarchical teaching, research orientation and achievement transformation, and clarifies the key points and improvement ideas of follow-up research in this field.

At the theoretical application level, there is a general problem of disconnection between theory and practice in domestic grassroots tennis teaching. Most coaches carry out error correction training based on subjective experience, without scientifically applying theories such as serve kinetic chain conduction and compensatory injury mechanical mechanism, leading to random and unscientific corrective training. Subsequent teaching needs to integrate biomechanical quantitative indicators, clarify core parameters such as joint motion range and force sequence of standardized serves, and promote the transformation from empirical teaching to accurate and scientific teaching.

At the hierarchical teaching level, the existing correction schemes adopt a unified standardized design, which cannot adapt to the differentiated characteristics of practitioners at different levels. Beginners focus on standardizing basic movement frameworks, young players need to supplement special physical fitness training and optimize kinetic chain conduction, and high-level athletes focus on improving movement stability and psychological quality in high-pressure scenarios. A single training mode cannot meet the differentiated needs of crowds at all levels, and the refined and hierarchical intervention system still needs further improvement.

At the research orientation level, there is an unbalanced pattern of "emphasizing correction and neglecting prevention" in this field. Most studies focus on remedial training of formed wrong movements, ignoring the value of standardized movement shaping in the early learning stage. According to the law of motor skill formation, early standardized training can avoid wrong muscle memory and sports injury risks from the source, improve training quality at low cost, and research on early prevention needs to be supplemented and improved to build a closed-loop training system of "prevention + correction".

At the level of scientific research integration and achievement transformation, there is a paradigm separation between Chinese and foreign tennis serve research. Domestic research is closely combined with grassroots teaching practice but lacks quantitative data support; foreign biomechanical research has a complete system and accurate data but poor adaptability to domestic amateur and campus teaching scenarios. Future research needs to promote the in-depth integration of the two research paradigms, transform professional quantitative theories into low-cost and easy-to-implement grassroots training methods, break the barrier between scientific research theories and teaching practice, and improve the localized tennis serve error correction research system.

## 5. Conclusion

Tennis serve is a refined special technique that requires extremely high full-body kinetic chain coordination, movement accuracy and force rhythm stability. Practitioners with different training levels and skill stages present differentiated tennis serve technical error characteristics, and the essence of movement deformation is the coupling result of physical quality, cognitive level, teaching mode, psychological state and mechanical conduction mechanism. Domestic and foreign academic circles have carried out a lot of research on tennis serve correction training, forming a basic training system framework that include basic correction modes suitable for amateur teaching and intelligent fine correction modes suitable for professional competitions, which has strong practical guiding value. However, the overall research system still has many deficiencies, mainly reflected in insufficient connection between theory and practice, imperfect hierarchical differentiated training system, lack of early prevention research, separation of Chinese and foreign research paradigms, and insufficient localization transformation of scientific research achievements. This paper can provide theoretical support and practical reference for college tennis classroom teaching, youth amateur training and professional athlete technical optimization, and clarify ideas and point out directions for in-depth research such as follow-up special empirical research on tennis serve teaching and biomechanical quantitative experiments.



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## Conflicts of Interest

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