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The Interplay Between Table Tennis Skill Development and Sports Performance: A Comprehensive Review

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Abstract: This study presents a comprehensive literature review on skill development in table tennis, focusing on various factors that influence expertise in the sport. The research synthesizes findings from multiple studies to understand the effectiveness of mental training programs, the relationship between cognitive functions and table tennis skills, differences between elite and sub-elite players, the impact of visual attention on performance, the effects of plyometric training on serve performance, and the comparison of practice schedules for skill learning and retention. Additionally, the paper explores the stages of tennis forehand attacking technique development, encompassing generalization, differentiation, consolidation, and automation stages, while discussing individual and environmental factors influencing skill development, highlighting the importance of early learning experiences, motivation, intelligence, and family support. Furthermore, the research delves into the history of table tennis performance evaluation methods, including video observation, expert interviews, and the four-stage index evaluation, establishing the reciprocal relationship between skill development and sports performance, emphasizing how enhanced athletic performance fosters skill mastery and vice versa. The findings underscore the significance of mental preparation, cognitive functions, technical proficiency, visual attention, and practice structuring in the pursuit of expertise in table tennis, indicating that incorporating mental training, cognitive training, specialized practice, and plyometric exercises can be beneficial for skill development and performance improvement in the sport.

Keywords: Table tennis; Skill development; Athletic performance; A forehand drive

Introduction

Table tennis is a fast-paced and skill-intensive sport that demands a combination of physical prowess and mental acuity from its players[1]. Over the years, researchers have dedicated their efforts to understanding various aspects of table tennis skill development, seeking to uncover the factors that contribute to expertise in this captivating game.

This study delves into the realm of table tennis skill development, aiming to shed light on its impact on sports performance. To achieve this, the research synthesizes findings from diverse studies that have explored different facets of table tennis skill acquisition. Notably, prior investigations have revealed the effectiveness of mental training programs in improving players' accuracy, consistency, and decision-making abilities during matches. Moreover, the link between cognitive functions, such as reaction time and attention, and table tennis skills has emerged as a critical factor in executing complex motor actions and making effective decisions on the court. The differences between elite and sub-elite players have also been examined, with elite players displaying higher levels of technical proficiency, decision-making skills, and strategic variability. Additionally, studies have explored the impact of visual attention on table tennis performance, highlighting the significance of efficient visual processing for better anticipation and decision-making during matches.

Furthermore, this paper delves into the influence of plyometric training on the table tennis serve performance, underscoring the potential benefits of incorporating plyometrics to enhance specific aspects of table tennis skills. Additionally, it investigates the comparison of practice schedules for skill learning and retention, emphasizing the importance of structuring practice sessions for optimal skill acquisition and retention in table tennis.The research process of skill development is examined, incorporating insights from related theories, such as the pyramid model of motor skill development and the hourglass model from an ecological perspective. The stages of tennis forehand attacking technique development are also analyzed, ranging from the generalization stage to the automatic formation stage. Moreover, influencing factors of skill development are explored, encompassing individual factors, like learning experiences and physical characteristics, as well as environmental factors, such as teacher guidance and practice environments.

Literature Review

Table tennis is a fast-paced and skill-intensive sport that requires players to possess a combination of physical and psychological abilities. Over the years, researchers have investigated various aspects of table tennis skill development to better understand the factors that contribute to expertise in the game.

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Effectiveness of Mental Training Program:
Lidor and Ziv conducted a study examining the impact of a mental training program on young table tennis players. The results demonstrated that the mental training intervention significantly improved players' accuracy, consistency, and decision-making abilities during matches. This finding highlights the importance of mental preparation in enhancing table tennis performance and suggests that incorporating mental training can be beneficial for skill development[2].
Relationship Between Cognitive Functions and Table Tennis Skills:
In their research, Liu, Li, and Zhan investigated the association between cognitive functions and table tennis performance in adolescent players. The study revealed a positive correlation between cognitive abilities, including reaction time, attention, and working memory, and table tennis skills. This indicates that cognitive functions play a crucial role in executing complex motor actions and making effective decisions during game play[3].
Differences Between Elite and Sub-Elite Players:
Marques, Garganta, and Mesquita examined the technical and tactical differences between elite and sub-elite table tennis players during matches. The findings suggested that elite players demonstrated higher levels of technical proficiency, decision-making skills, and variability in game strategies compared to sub-elite players. This emphasizes the importance of honing technical expertise and tactical acumen to reach the elite level in table tennis[4].
Impact of Visual Attention on Performance:
Xu, Ke, and Fan investigated the effects of visual attention on table tennis performance. The research revealed that expert players exhibited more efficient visual attention patterns, focusing on relevant cues and ignoring irrelevant information. This superior visual attention contributed to better anticipation and decision-making during the game, showcasing the significance of visual processing in table tennis skill execution[5].
Effects of Plyometric Training on Serve Performance:
Zhu, Qin, and Zhang explored the effects of plyometric training on the table tennis serve performance. The study demonstrated that plyometric exercises significantly improved the power and accuracy of the table tennis serve. These findings suggest that incorporating plyometric training can enhance specific aspects of table tennis skills, leading to improved performance in key areas of the game[6].
Comparison of Practice Schedules for Skill Learning and Retention:
Menescardi, Monteiro, and Mesquita (2020) investigated the effects of different practice schedules on learning and retention of table tennis skills in novice players. The research showed that distributed practice, with spaced practice sessions over time, resulted in better skill learning and long-term retention compared to massed practice with concentrated sessions in a shorter period. This highlights the importance of structuring practice sessions for optimal skill acquisition and retention in table tennis[7].

1 Research process of skill development

1.1 Related theory studies

Seefeldt proposed the "pyramid" model of motor skill development based on age-related characteristics of adolescents' motor development[8]. The model comprises four stages:
1 Reflex-response stage.
2 Stage of basic motor skills, including grasping, crawling, volleyball, one-foot jump, throwing, stride jump, stopping the ball with feet, etc.
3 Transitional motor skills stage, involving skills such as basic water survival, rope skipping, sponge ball, hockey games, volleyball games with a ball, etc.
4 Specialized activities stage, which includes activities like archery, canoeing, diving, fencing, gymnastics, football, tennis, volleyball, wrestling, judo, rugby, etc.
In 1998, Gallahue et al. introduced an "hourglass" model of motor skill development from an ecological perspective, emphasizing three factors influencing motor development: individual characteristics, environment and tasks. The model consists of four stages:
1 Reflex action stage, with information collection and processing stages.
2 Autonomic action stage, encompassing reflex inhibition and precontrol stage.
3 Basic motor skill stage, involving the acquisition of body movement skills, object operation skills, and stability control skills, each with initial, basic, and natural development stages.
4 Specialized motor skill stage, including the general transition stage (related to transferring basic motor skills), the sports-related specific stage (mastery of a physical activity), and the specialization stage (engaging in a physical activity as an adult)[9].
Clark and Metcalfe proposed the "motion development peak" model in 2002, based on the motion development dynamic system framework. This model divides human motor development into six stages: reflex period, pre-adaptation period, basic motor skill period, special motor skill period, skill proficiency period, and compensation period. Age is not the primary factor influencing motor skill development in this model; individual experience and environmental factors play more significant roles[10].
Ryan et al. proposed the lifelong physical activity model, which categorizes the development of movement into five stages:

1 Reflex activity stage, involving activities like sucking.
3 Basic movement stage, including grasping, standing, sitting, crawling, walking, etc.
4 Basic motor skill stage, encompassing traditional skills like running, jumping, throwing, as well as non-traditional skills like swimming, cycling, weight squats, squats, push-ups, lunges, etc.
5 Specialized motor skill stage, comprising traditional activities such as basketball, volleyball, soccer, and non-traditional activities like weightlifting, diving, rock climbing, etc.
Lifelong motor skill stage, involving activities like cycling, jumping rope, skiing, yoga, kickball, etc.
From the theory of skill development, it is evident that specialized motor skills are built upon basic motor skills such as walking, running, jumping, and throwing. Unlike reflexes, both basic and specific motor skills are acquired through repeated motor exercises, and the lack of environmental stimuli can impact skill development and, consequently, motor performance. This paper focuses on investigating special motor skills as the primary subject of inquiry.

1.2 Stage Characteristics of Tennis Forehand Attacking Technique
The development of tennis forehand attacking technique can be divided into four stages: the generalization stage, differentiation stage, consolidation stage, and automatic formation stage.
1.2.1 Generalization Stage
Physiologically, during this stage, there is a diffusion of cerebral cortex excitation, insufficient internal inhibition, temporary unstable connection of conditioned reflexes, rigidity of movement, uncoordinated muscle tension, and a lack of movement control. This period represents the mechanical learning phase of the technical movement, characterized by relatively dull forms. Teaching in this stage involves three processes: teacher demonstration, students' freehand decomposition exercise, and practical exercise.
Initially, the teacher demonstrates the forehand attack's technical action in table tennis, aiming to help students understand the action's information and requirements. This demonstration enables students to grasp the key points of the forehand attack, mentally construct the directional image of the technique, and begin the process of imitation. As most students have been exposed to table tennis before, they may already possess their playing style. Hence, standardizing the technical action and breaking their previous dynamic patterns become challenging during subsequent learning. The next step involves students performing freehand decomposition exercises based on their understanding. This crucial process ensures the establishment of fixed movements. Correcting mistakes promptly is essential to guide students toward grasping the movement's essentials gradually. Finally, the practice phase involves multiple-ball exercises, allowing students to experience and familiarize themselves with the swing movements. It is common at this stage to observe poor stability and flexibility in hitting movements, with vision largely controlling the actions.
The freehand decomposition exercise is particularly significant during the generalization stage. Students need to engage in cognitive processes, identify and feel the movement technique, understand the lead and swing positions, recognize changes in their movements, and compare the feel and impact of incorrect and correct movements, strengthening the memory of the correct swing movement. Repetitive practice, focusing on finding the exact spot, facilitates better transition to the next stage.
1.2.2 Differentiation Stage
Physiologically, the differentiation stage is characterized by more concentrated cortical excitation and inhibition processes, with gradual development and consolidation of internal inhibition and initial establishment of the dynamic pattern. In this stage, students have a preliminary grasp of the movement essentials and begin to apply the decomposed movement in practice, enabling them to complete the entire swing movement. A notable feature is that students can only execute the conditioned response under specific stimulus conditions. If the teacher serves the ball in a fixed position, students can perform the correct action after a reminder. However, without such reminders or when the position changes, the action may become distorted. This stage's teaching involves two processes: correcting mistakes and practicing.
Teachers, in this stage, demonstrate and analyze common wrong movements of the tennis forehand attacking technique. During practice, real-time guidance, language prompts, and individual movement demonstrations are combined to help students correct their mistakes and perform the forehand attacking technique correctly. Addressing wrong movements is crucial, as failure to overcome them can hinder learning other technical movements. Practice exercises mainly focus on single-ball round practices. If available, a service machine can aid students in practicing forehand attacks, experiencing the round ball. In the absence of a service machine, a teacher or skilled student assistant can set the ball to a fixed position, allowing students to independently practice attacking the ball by swinging the racket. The teacher continually reminds students of key technical movement points and existing issues to continuously improve their attacking skills.
During the differentiation stage, multi-ball practice is commonly used to reinforce the dynamic pattern of the forehand drive. Students should understand the key points of forehand attack in table tennis and their cognitive process of swing strokes. By recognizing the difference between correct and wrong movements and engaging in repeated exercises, students can strengthen correct movements and avoid developing a dynamic pattern of wrong actions during the learning process.
1.2.3 Consolidation Stage

During the consolidation stage, the physiological characteristic is the concentration and firm inhibition of cerebral cortex stimulation, resulting in a well-established dynamic pattern. At this point, students have developed a solid foundation for a single technique, enabling them to adjust any incorrect movements, complete the full swing action consistently at a fixed point, and quickly return to the ready position after executing the stroke. They can perform multiple rounds of forehand attack action at the same fixed point. Repetition becomes the primary practice method during this stage. Additionally, it is crucial to enhance body quality and flexibility while incorporating pace into the forehand technical movement.

Repetition exercises should encompass both multi-ball exercises and multi-ball single exercises to continually refine movement details, strengthen muscle memory, and increase proficiency. Teachers play a crucial role in providing timely prompts when students make mistakes, allowing students to self-adjust and grasp the correct swing movements and ball contact sensations. Furthermore, attention should be given to improving students' physical fitness levels. Integrating specific physical fitness exercises in pre-class preparation can focus on enhancing sensitivity and coordination, which are vital attributes in table tennis. Sensitivity exercises enable students to better judge and return the ball accurately, while coordination exercises help students improve the synchronization of their hands and feet, understand the importance of footwork connection, and grasp the adjustment of the center of gravity during ball contact.

1.2.4 Automation Phase

Achieving the automation stage in practical teaching activities can be challenging. This phase is characterized by highly concentrated neural activity, fine motor differentiation, and coordination between motor nerves and vegetative nerves. Students have mastered the skills, and they can execute correct and continuous swings at a given point. They possess an understanding of movement essentials, and their muscles have memorized the movement skills. Moreover, they develop swing awareness during movement. At this stage, if students have previously learned footwork, they can perform the practice of two-point walking more smoothly. Footwork is pivotal for connecting technical movements. By incorporating footwork, students can consistently strike each ball with the same position and distance as the initial stroke, further perfecting their technical moves. During practice, the use of strengthening exercises and cycle exercises aids in enhancing the movement's fluency and return quality.

In intensive practice of forehand attack, teachers can reinforce students' skills by varying attack rhythms, increasing round speed, reducing round arc, and setting requirements for landing points to improve ball control. This process helps students achieve automation in individual forehand attack techniques, laying the foundation for subsequent skill development. Continuation of cycle practice, multi-ball practice, and multi-ball single practice with increased intensity and exercise volume further consolidates forehand attack skills.

1.3 Influencing Factors of Skill Development

1.3.1 Individual Factors

Individual factors encompass subjective aspects such as learning experience, physical characteristics, and psychological factors. In the context of learning table tennis skills, individual factors such as early learning experiences, learning interests, motivation levels, intelligence, internal and external characteristics, athletic abilities (including body form and muscle strength), self-confidence, and willpower may influence students' acquisition of table tennis forehand attack skills.

Firstly, students who have prior exposure to or systematic learning of table tennis before the school course may have their existing sports experience positively or negatively impact their subsequent classroom learning. Secondly, students with a genuine interest in table tennis tend to display more active learning behavior during class, possessing a strong desire for knowledge and exploration of table tennis forehand attack techniques. Conversely, lack of interest may manifest as passive learning behavior. Thirdly, students' learning motivation for table tennis can stem from internal factors, such as the desire to master sports skills and improve physical health, or external factors, like earning credits or winning prizes, which can also influence their skill acquisition. Fourthly, as table tennis involves high strategic skills, students with higher intelligence levels may find it easier to comprehend table tennis skills and utilize tactics effectively. Moreover, students with strong self-confidence and willpower are more likely to excel in the development of table tennis skills. Additionally, individuals with distinct personalities, traits, and physical qualities may exhibit varying levels of mastery in table tennis skills. Of course, genetic and other congenital factors also play a role and cannot be overlooked.

1.3.2 Environmental Factors

Environmental factors, considered objective in nature, encompass vital elements such as teacher guidance and demonstration. To effectively guide students, teachers must demonstrate the essential features of lead, swing, hitting, and recovery in the tennis forehand technique, utilizing both action and speech demonstrations to maximize visual and auditory impact. Concise and focused instruction is paramount in helping students grasp the essentials of the table tennis forehand attack action.

Practice also holds significant sway over the development of table tennis forehand skills. Throughout the learning process, students should understand general practice principles, commencing with faster progress and gradually transitioning to slower progress, recognizing the plateau phenomenon, emphasizing repeated and intensive practice, and utilizing various methods to enhance their mastery of forehand attack technology.

Feedback plays a crucial role as well, providing students with timely information about their practice results. With prompt feedback from teachers or classmates, students gain insights into their strengths and weaknesses, reinforcing correct forehand attack movements and facilitating faster acquisition of table tennis forehand attack skills. Additionally, feedback serves as motivation, inspiring students to continue striving for their goals and achieving higher levels of performance.

Furthermore, the sports atmosphere and social environment within students' families can significantly impact their table tennis skill development. Exposure to a sports-oriented family environment, where engaging in sports activities with parents and relatives is common, positively influences acceptance of table tennis. Moreover, access to supporting facilities in proximity to students' living or learning environment can enhance their proficiency in table tennis skills, providing ample opportunities for practice during leisure time.

2. Research History of Table Tennis Performance

2.1 Table Tennis Performance Overview

Sports performance refers to the observable results produced by spontaneous movement or motor skills, including sustained mental activity, behavior, and action outcomes [10]. Individual sports performance can be influenced by motivation, arousal levels, fatigue, and physical conditions [11]. According to most foreign scholars, motor skills are acquired through practice, and sports performance emphasizes achieving predetermined goals with the highest accuracy, in the least amount of time, and with the most efficient energy consumption - a characteristic specific to motor skills, referred to as motor performance [12]. The sports performance of table tennis players comprises observable cognitive elements of motor skills, motor elements, and action outcomes [13].

The cognitive element of table tennis skill comprises several parts. Firstly, participants must observe the opponent's hitting technique and the ball's flight path, assess the ball's rotation, speed, and landing point, and then decide on the appropriate body movement and technical actions for returning the ball. Therefore, cognitive elements involve four aspects: (1) perception of environmental information, i.e., identifying the situation. (2) Decision-making, including determining what to do, how to do it, and when. (3) Motor instructions, generating organized muscle activity, and executing the action. (4) Collecting feedback information about sports performance.

The movement elements also consist of several components. Players need to be in a ready position to receive the ball, and when the opponent's ball is in play, they must move promptly to achieve an optimal batting position. Therefore, movement elements include three components: (1) posture components, providing a stable support platform for movement. (2) Movement components, facilitating body and limb movement to the action position. (3) Operational components, executing the action.

The action result of table tennis includes several factors, such as whether the ball is on the table, if the ball scores a point, the flight speed of the ball after hitting, and the rotation speed, among others.

2.2 Measurement of table tennis performance

Refinement of Table Tennis Performance Measurement Paradigm

Table tennis performance can be assessed using various measurement paradigms, such as table tennis special tests, instrument tracking analysis in sports, and table tennis performance scales. Special tests in table tennis encompass both special quality and special technical assessments. For instance, the special quality test involves candidates sliding back and forth between two tables, touching them with one hand, and completing 30 rounds while timing the activity. On the other hand, the professional skills test requires the examiner to hit the ball to the examinee's forehand position, and the examinee responds by hitting the ball back to the opponent's forehand or backhand position within 30 seconds. The examinee's forehand attack action should be standardized and correct, demonstrating adequate strength and speed.

Instrument tracking analysis is utilized to track the motion trajectory of individuals during play, and neurobiological indicators such as EEG, skin electroencephalography, and eye movement can also be collected and analyzed. However, unlike mature tennis performance evaluation scales, a specific table tennis performance evaluation scale has not yet been established. One option is to consider using the Sports Performance Scale developed by Rees, T., Hardy, L., & Langledew, D. K. (2000) for evaluating table tennis performance, or a custom table tennis performance evaluation scale can be compiled to suit the specific context.

Evaluation of Table Tennis Performance

2.3.1 Video Observation Method

The video observation method involves analyzing high-level athletes' videos from major events, including national games, national championships, table tennis Super League matches, international open competitions, and WTT Macau Competitions. In practice teaching, students' forehand attack practice clips can be recorded and analyzed to assess the fluency and standardization of their technical movements, allowing identification of existing problems and improvement of their table tennis forehand attack skills.

2.3.2 Expert Interview Method

Expert interviews with national and provincial table tennis team head coaches, researchers from the General Administration of Sport and Institute of Physical Science, and professors and doctors from renowned sports universities can provide valuable professional guidance and insights. This method allows for a comprehensive understanding of the characteristics and rules of table tennis from a professional standpoint. In practice teaching or skill

examination, multiple table tennis teachers can be invited to evaluate students' forehand attack and other skills, achieving a comprehensive evaluation by integrating the opinions of various experts.

2.3.3 Four-Stage Index Evaluation Method

The four-stage index evaluation method is commonly used for technical and tactical evaluation in table tennis. It divides the match into four stages, namely the first stage, stalemate I stage, second stage, and stalemate II stage. Compared to other methods, the four-stage index evaluation is more suitable for technical and tactical analysis, providing accurate segmentation data and facilitating multi-angle analysis of players' skills and tactics in each batting section. In daily table tennis teaching, the essence of this method can be used as a reference by dividing the table tennis forehand attack technique into several sub-technical movements for individual evaluation. For example, evaluating the lead racket, swing racket, stroke, recovery, continuous hitting round ball, and other aspects of students' table tennis forehand attacking technique, and then comprehensively assessing their overall performance by comparing various scores.

3. Research on the Relationship Between Table Tennis Skill Development and Sports Performance

3.1 The Impact of Skill Development

Early childhood motor skill development forms the basis for adult motor and physical activity levels. Insufficient motor skills in adulthood can be traced back to inadequate early motor skill mastery due to a lack of appropriate environmental stimulation and exercises. Skill development shows a correlation with athletic performance and can predict sports outcomes. The learning process for tennis forehand involves four stages: generalization, differentiation, consolidation, and automation. Proper technical guidance at each stage fosters forehand ball skill development and enhances sports performance. Teachers can incorporate various practice forms during table tennis sessions to improve students' coordination, posture, strength, speed, and other essential aspects of the game. Basic skill exercises also enhance students' physical abilities, contributing to improved sports performance.

3.2 The Reciprocal Relationship

Enhanced athletic performance drives skill mastery and development. As students engage in table tennis, they apply sports knowledge and methods to competitions, elevating their skills and problem-solving abilities. They gain independence in extracurricular exercise plans and develop a deeper appreciation for table tennis events. Motor skill development relies on repetitive practice, fostering proficient motor performance through internal information integration and adaptation to the practice environment. Enhanced athletic performance, in turn, advances skill development. Teachers should integrate table tennis knowledge and skills, focusing on progressive complexity and difficulty to promote the reciprocal connection between sports performance and skill development effectively.

Conclusion:

This study investigated various aspects of table tennis skill development and its impact on sports performance. The literature review provided valuable insights into the effectiveness of mental training programs, the relationship between cognitive functions and table tennis skills, differences between elite and sub-elite players, the impact of visual attention on performance, effects of plyometric training on serve performance, and the comparison of practice schedules for skill learning and retention.

The findings from the literature review reveal the significance of mental preparation in enhancing table tennis performance. Mental training interventions were shown to improve players' accuracy, consistency, and decision-making abilities during matches. Additionally, cognitive functions such as reaction time, attention, and working memory were found to play a crucial role in executing complex motor actions and making effective decisions during gameplay. Moreover, the study highlighted the differences between elite and sub-elite players, emphasizing the importance of honing technical expertise and tactical acumen to reach the elite level in table tennis. Visual attention patterns of expert players were found to be more efficient, contributing to better anticipation and decision-making during the game. Furthermore, incorporating plyometric training was found to enhance specific aspects of table tennis skills, leading to improved serve performance. The comparison of practice schedules demonstrated the importance of structuring practice sessions for optimal skill acquisition and retention in table tennis, with distributed practice showing better results than massed practice.

In conclusion, the study provides valuable insights into the factors that contribute to expertise in table tennis and offers practical implications for coaches, players, and practitioners seeking to improve performance in the sport. A comprehensive approach that considers both physical and psychological aspects of skill development is essential for maximizing table tennis performance and achieving success in competitive play.

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