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The Role of Multi-Shuttle Training in Rear-Court Techniques in Badminton: A Study of Chinese University Students

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Abstract

The paper discusses the categories and methods of multi-shuttle training in badminton elective courses and the role and necessity of multi-shuttle training in backcourt technique through the study of multi-shuttle training in badminton sports training. This study selected 50 students majoring in physical education of Guangxi Science and Technology Normal College to conduct group experiments, and the results show that badminton multi-shuttle training in backcourt technique training not only contributes to stereotypes of movement techniques, additionally, it enhances the quality and stability of badminton strokes., multi-shuttle training also helps to improve students' cardiorespiratory function and physical fitness, and also helps to cultivate students' mental resilience.

Keywords: Multi-Shuttle Training, Rear-Court Techniques, Badminton Training, Cardiorespiratory Fitness, Skill Development

Introduction

Badminton, recognized as one of the fastest racket sports in the world, is not only a popular recreational activity but also a demanding competitive discipline requiring precision, speed, and endurance (Manrique & Gonzalez-Badillo, 2003). Over the years, advancements in training methodologies have become pivotal to enhancing athletic performance, particularly in China, where badminton holds a significant position in sports culture. Among these methodologies, multi-shuttle training has emerged as a cornerstone for developing key techniques in badminton, especially rear-court techniques, such as lofting, slinging, and killing (Blomqvist et al., 2001). These techniques are key to determining the outcome of competitive badminton matches (Li et al., 2017). Its execution requires a combination of technical skills, physical fitness, and mental toughness, making the training of Rear-court technique both challenging and essential. Multi-shuttle training, with its high-intensity and repetitive practice, offers an efficient solution to these demands. By simulating match-like conditions, it helps athletes improve consistency, accuracy, and adaptability—key factors for competitive success. This further highlights the value of multi-shuttle training in fostering technical and physical excellence (Wee et al., 2017).

Multi-shuttle training offers a high-intensity, repetitive practice regime that not only enhances athletes' technical precision and stability but also significantly contributes to their cardiovascular fitness, muscular strength, and mental toughness (Tang & Lim, 2025; Zhou Jianwei, 2005). Its practical applications are vast, enabling athletes to replicate match-like conditions, refine their techniques, and build the physical and mental fortitude required for high-stakes competition. These benefits underscore its effectiveness as a training method, especially in educational settings where students are transitioning from foundational skills to competitive play (Xiaotong, 2024).

This study focuses on evaluating the role and impact of multi-shuttle training on the rear-court techniques of badminton players, with a particular emphasis on university students specializing in physical education. By conducting group experiments with students from Guangxi Science and Technology Normal College, this research seeks to provide empirical evidence supporting the effectiveness of multi-shuttle training in improving technical performance, physical conditioning, and mental resilience.

As the demands of modern badminton continue to evolve, the need for effective, evidence-based training methods becomes increasingly critical. The findings of this study are expected to have significant implications for both academic and practical domains. Academically, it contributes to the growing body of literature on sports training methodologies, offering insights into the mechanisms through which multi-shuttle training influences performance. Practically, it provides actionable guidance for coaches, educators, and trainers in optimizing their training programs to better meet the needs of aspiring badminton players. In doing so, this research aims to bridge the gap between theory and practice, ensuring that training innovations translate into tangible performance improvements. This not only addresses a key challenge in badminton training but also paves the way for wider adoption of innovative practices in physical education and professional coaching.

Research Question and Objectives

a) How does multi-shuttle training affect the accuracy and consistency of badminton backcourt techniques (lofts, slings and kills)?

The aim of this question is to explore the specific effects of multi-shuttle training on athletes' backcourt technical movement stereotypes and how multi-shuttle training influences stroke accuracy and consistency throughout the training process.

b) What is the mechanism of action of multi-shuttle training in improving athletes' physical and mental fitness?

This question focuses on the effects of multi-shuttle training on cardiorespiratory fitness, muscular endurance, and stress tolerance, and analyzes how high-intensity repetitive training promotes the development of athletes' overall quality.

Literature Review

With the rapid development of badminton in China, the science and rationality of training methods have become an important factor in improving athletes' competitive level (Siwei et al., 2023). In this context, multi-shuttle training has been widely used and researched as an efficient and targeted training method (Gang, 2022; Hui, 2015; Xingfan & Minglu, 2024; Ying, 2023). Literature has shown that multi-shuttle training not only strengthens the

standardization of technical movements, but also effectively improves athletes' overall quality and playing ability (Jun, 2017).

First of all, the theoretical foundation of multi-shuttle training provides important support for its scientific nature. Among them, the The theory of motor memory suggests that through high-frequency action repetition, athletes can form a stable action memory pattern, which in turn improves the accuracy and consistency of technical movements (Wulf & Mornell, 2008). In addition, the principle of overload emphasizes that high-intensity and high-density exercises are effective in improving cardiorespiratory fitness, muscular strength and durability, enabling athletes to better cope with the physical demands of competition (Furrer et al., 2023). Similarly, the theory of technical reinforcement and fatigue confrontation highlights that training in a simulated high-intensity competition environment allows athletes to gradually adapt to fatigue and improve the stability of their movements and the efficiency of their technical outputs (Li, 2025).

Secondly, the practical application of multi-shuttle training in badminton backcourt technique has been widely validated (Fei & Qiang, 2024; Xinxin et al., 2019). As the core of the backcourt technique, the lob, slice and kill can be significantly improved through multi-shuttle training. It was found that the focus of training for the long ball is on consistency of movement and proper distribution of power in hitting the ball (Min & Ling, 2011). Through multi-shuttle training, athletes can optimize their power delivery and improve the stability and consistency of their strokes through repetitive exercises (Wee et al., 2017). For the hanging ball technique, multi-shuttle training can strengthen the wrist control and the precision of the landing point, so as to better realize the tactical intention in the actual battle. As the main means of offense, kill ball can significantly improve the muscle explosiveness and ball speed through multi-shuttle training, and enhance the stability and scoring ability of continuous kill ball (Heng, 2007).

Multi-shuttle training also has significant advantages in improving the comprehensive quality of athletes. The first is the comprehensive improvement of physical quality. High-intensity multi-shuttle training can improve the athlete's cardiorespiratory endurance and lactic acid tolerance, so that they can maintain a high level of competitive status for a longer period of time during the game (Wee et al., 2017). In addition, psychological enhancement is another key role of multi-shuttle training. Simulation training in high-pressure environments can help athletes develop mental toughness and resilience, so that they can remain calm and focused during critical matches. Finally, multi-shuttle training can also promote the development of tactical awareness. Through targeted practice, athletes are able to more flexibly understand and apply the tactical value of different technical maneuvers, and develop the ability to react quickly to game situations (Ying, 2022).

Tube multiball training has many advantages, but it also has certain limitations (Wei, 2015). For example, high levels of repetition in the training process can lead to athlete burnout and reduce the effectiveness of the training. In addition, the design of training content needs to be adapted to athletes of different levels and needs, otherwise it can lead to poor training results or even increase the risk of injury. (Xiantao, 2018). Over-reliance on high-intensity training may also lead to sports injuries, which puts higher demands on the rational distribution of training loads (Zhang & Chang, 2022).

As a scientific and efficient training method, multi-shuttle training plays an important role in badminton teaching and training, but at the same time, multi-shuttle training also has certain limitations. In the daily teaching and training, the boring multi-shuttle training can helps students to better strengthen their movement techniques and consolidate the precise landing point of the ball, to achieve excellent results in the game, needs to be confirmed by a more detailed training plan and rigorous training experiments. In addition, it can also be confirmed through experiments whether the multi-shuttle training can improve the overall sports quality and psychological quality of students. Through this study, we can optimize the multi-shuttle training method and make multi-shuttle training play a greater role in the future development of badminton.

Methodology

Objects of Study

50 students majoring in Physical Education at Guangxi Normal University of Science and Technology.

Research Methodology

Literature Review Method

Check and collect the results of domestic research on the theory and method of badminton multi-ball training, physiological functions of badminton sports, physical quality and other aspects in recent years, from which to seek to influence the effective role of multi-shuttle trainingin badminton sports.

Expert Interview Method

Through interviews with badminton teachers and professors from the physical education departments of Wuhan Institute of Physical Education and Huazhong Normal University, it was concluded that the multi-shuttle trainingmethod has been widely adopted by teachers because of its feasibility, scientificity and effectiveness in the teaching and training arrangements of badminton.

Group Experiments

A group experiment was carried out on 50 students who participated in badminton lessons in Guangxi Science and Technology Normal College. In the same training time, the players were divided into two groups, the control group and the experimental group. There were 25 students in each group, and the experimental group had multi-ball training, while the control group had regular “one-to-one” single-ball training. Multi-shuttle trainingis, in the class to multi-ball training, one person continuously feed the ball several times, one person to practice the backcourt high long ball, hanging, kill the ball, and then rotate, generally 15 balls a group, each person to practice three groups after the change. Single-ball training, as the name suggests, is to use a ball for multi-shot, multi-round practice. Two people use a ball for multi-tap practice, a person will pick the ball to the back court, a person to practice the back court high ball, hanging, kill the ball, the two people in turn, the general training for each person to practice for five minutes and then change.

After three months of study and training, in the final stage of training for two groups of students were tested, by the teacher to feed each student 30 balls, the ball will be hit to the designated area to be considered a success, arranged for a person to test the results of the

statistics, calculated the success rate. The training includes forehand backcourt overhead, overhead backcourt overhead, forehand backcourt sling, overhead backcourt sling and kill.
There are more categories of multi-ball training, mainly including fixed-point multi-ball training, indeterminate multi-ball training, two-point multi-ball training, four-point multi-ball training, and full-court multi-ball training, and the fixed-point multi-shuttle trainingwas mainly used in this experiment.

Conceptual Framework

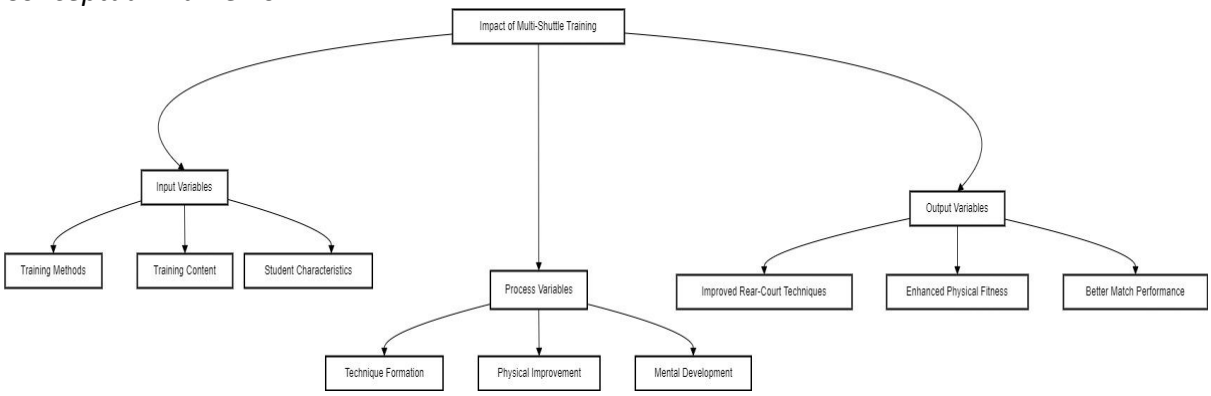

Figure 1. Conceptual framework

The framework integrates input, process, and output variables to systematically explain the effects to systematically explain the effects of multi-shuttle trainingon badminton backcourt skills. The input variables include training methods, training contents and student characteristics, which provide the key prerequisites and basic conditions for multi-ball training; the process variables include movement formation, physical enhancement and psychological development, which reveal the dynamic process of technical progress and athlete's comprehensive quality enhancement during the training process; and the output variables focus on the improvement of backcourt technique, the enhancement of physical fitness, and the optimization of game performance, which clearly demonstrate the final results of multi-ball training. The output variables focus on the improvement of backcourt technique and the enhancement of physical quality and the optimization of game performance, clearly demonstrating the final results of multi-ball training. The framework not only provides a structured analytical tool for understanding the core mechanism of multi-ball training, but also helps to further optimize badminton training methods, thus enhancing students' technical ability and competitive level.

Results and Discussions

Implications of Multiball Training

Meaning and Significance of Multiball Training

Multi-shuttle training, as the name suggests, is a method in which the coach serves the ball continuously during the lesson and the practitioner repeats the training with multiple balls for a certain period of time. In terms of athletic training theory, multi-shuttle training is an interval training method. Interval training method put forward by the German cardiologist Reindl and instructor Beischler, they believe that the training of athletes in the heart rate up to 170-180 times / minute, within a certain period of time to adjust the recovery so that the heart rate reaches 100-125 times / minute and then train, so that intermittent and constantly to the heart of the aerobic metabolic capacity of the stimulus, can effectively improve the athlete's heart pumping function, so that the heart's blood supply capacity is sufficient, very good. The

blood supply capacity is sufficient to complete aerobic metabolism well. The advantage of this training method is that the intermittent recovery time is strictly controlled during the training, so that the heart rate recovery is always within a good range, optimizing the heart pump function, so that the energy supply capacity of the lactic acid energy system can be effectively developed and improved. Therefore, multi-shuttle training has an irreplaceable role in the improvement of athletes' cardiopulmonary function, the improvement of lactic acid glycolysis, the development of aerobic metabolism energy supply capacity and the improvement of movement techniques.

Classification of Badminton Multi-Shuttle Training Mechanisms

Fixed-Point Multi-Shuttle Training

Fixed-point multi-shuttle training refers to a method where the feeder continuously delivers shuttles to a specific spot, and the trainee practices by repeatedly hitting each shuttle at the fixed point with a "one-shot-per-shuttle" approach.

Random-Point Multi-Shuttle Training

Random-point multi-shuttle training involves the feeder delivering shuttles to two or more different directions, requiring the trainee to move (or run) to hit the shuttle. Random-point multi-shuttle training can be further categorized into two-point, four-point, and full-court multi-shuttle training.

Two-Point Multi-Shuttle Training

The coach stands on the opposite side of the net and feeds shuttles to two specific points, either in the rear court or the forecourt.

Four-Point Multi-Shuttle Training

The coach stands on the opposite side of the net and feeds shuttles using a racket to four points: two net-front positions (either overhead or underhand) and two rear-court positions. This primarily trains footwork and endurance, emphasizing the importance of footwork.

The coach stands on the same side of the net as the trainee and throws shuttles by hand to two mid-court points and two forecourt underhand positions. This primarily trains reaction speed and small-step movements.

Full-Court Multi-Shuttle Training

Full-court multi-shuttle training in badminton typically involves six points: two net-front points, two mid-court interception points, and two rear-court points. Depending on the trainee's skill level and specific requirements, the coach may assign fixed-point full-court training or random-point full-court training. Random-point full-court multi-shuttle training, however, places higher demands on the trainee's reaction speed and footwork proficiency.

Results and Analysis

Experimental Results

Experimental criteria: forehand and overhead backcourt lofted ball test criteria, the hitting point of landing in the backcourt baseline and the back serve line between the 50cm * 50cm box, forehand and overhead hanging slash test criteria, the hitting point of landing in the near-

network 50cm * 50cm box, in a period of three months of training, the coach feeds each person 30 balls to test, and make a good record to analyze the results of the test are as follows:

Table 1
Success rate of 30 balls in experimental and control groups

Technique	**Experimental Group (%)**	**Control Group (%)**
Forehand Rear-Court Clear	80%	50%
Overhead Rear-Court Clear	75%	43.7%
Forehand Rear-Court Drop (Cross-Court)	74%	42%
Overhead Rear-Court Drop (Cross-Court)	68%	41%
Smash	64%	35%

During the three-month training period, we tested the heart rhythm of each player in both the experimental and control groups after training and recorded the results as follows:

Table 2
Average Heart Rate (beats/min)of Students in the Experimental and Control Groups Before and After Training

	Before training	After multi-shuttle training / after one-on-one training
Experimental group	65.3	180.6
control group	65.5	153.7

Experimental Results Analysis

The test results (Table 1) clearly show that students in the experimental group outperformed those in the control group in forehand rear-court drop shots, overhead rear-court drop shots, forehand clear shots, and overhead clear shots. In terms of shot placement accuracy, the experimental group achieved a success rate approximately 20%–30% higher than the control group. Regarding technical execution, the experimental group demonstrated more standardized movements, stronger awareness of continuous play, and better control over the shuttle. In contrast, the control group exhibited higher error rates, poor shot judgment, and a lack of concentration during practice.

Analysis of Table 2 indicates that multi-shuttle training significantly benefits the establishment of proper movements and postures while effectively increasing training intensity and improving the functionality of the cardiovascular and respiratory systems. Table 2 compares heart rates recorded after 3 minutes of rear-court two-point multi-shuttle training with those recorded after 3 minutes of one-on-one high-clear two-point training. The results show that post-training heart rates in the experimental group were higher than those in the control group.

It is well-known that heart rate is linearly related to oxygen uptake, making it a reliable indicator of training intensity and physiological status (Cooper et al., 1984; Springer et al., 1991). Typically, a heart rate above 180 beats per minute (bpm) is considered high intensity, 150–180 bpm is moderate intensity, and below 150 bpm is low intensity. The data from Table 2 reveal that, after completing the training sessions, students in the experimental group reached a heart rate of 180 bpm, significantly higher than that of the control group. This indicates that the cardiovascular load during multi-shuttle training is substantially greater than that during single-shuttle training, confirming that the training intensity of multi-shuttle drills is notably higher than that of single-shuttle drills.

At the same time, through the experiment we can also clearly understand that multi-shuttle training can improve the speed, power and movement speed of the ball. For this reason, we increase the difficulty of training at the same time, the students will be through a continuous rapid movement to hit the ball, in a relatively short period of time to be able to quickly and vigorously hit the ball intensity will be increased accordingly; compared to one-on-one training, the speed of hitting the ball back and forth will be relatively stable, there will be no excessive behavioral way, students can have enough time to hit the ball. Therefore, in order to improve the technical level, that is, in a shorter period of time to carry out high-intensity athletic ability, it is necessary to choose a badminton movement tempo, technical level and quality of training together, however, multi-shuttle training method can be very good to achieve this desired effect. Multi-shuttle training can solve a lot of single-ball training can not solve the problem, effectively make up for the limitations of single-ball training methods.

The Role of Multi-Shuttle Training in Badminton Backcourt Technique Training

The Science of Badminton Multi-Shuttle Training in Backcourt Technology Teaching Training

Competitive sports require speed, precision, and intelligent decision-making for optimal performance in competitive sports, fast, accurate to become a key factor in the athletes to win, however, badminton is no exception, badminton is known for its fast, accurate and varied changes in your sport often require athletes to have the body, mind, brain high degree of coordination and cooperation in order to make their own competitive ability to reach a certain level. However, the coordination of body, mind and brain can not be separated from the long-term repetitive training, that is, badminton training methods in the multi-shuttle training, multi-shuttle training can be very good exercise athletes body, mind and brain coordination ability, in the long-term training so that the athletes can be very good sports technology fixed in the brain, so that a high degree of coordination of action to form a memory, athletes in the continuous practice, the formation of a correct In the constant practice, the athletes form a deep memory of the correct movements, so that they can make offensive movements without thinking when they encounter offensive opportunities.

The Effectiveness of Badminton Multi-Shuttle Training in Backcourt Technique Teaching and Training

In the teaching and learning of badminton, badminton training can be roughly divided into four stages, namely, first, the stage of understanding badminton; second, the stage of learning basic technical movements of badminton; third, the stage of improving comprehensive badminton techniques; fourth, the stage of applying technical movements of badminton.

In the first stage, students have just begun to contact the badminton sport, do not understand any technical movements, at this time, it is required that the coaches can teach patiently, according to the students' learning situation to repeat the action practice, and can be deepened by watching videos and other methods of students for the action of the understanding of the understanding of the students, so that the students in the learning of badminton in the first stage can be very good mastery of the correct action. In the second stage, the students basically mastered the correct swing action, in this stage it is necessary for teachers to use the fixed-point multi-shuttle training methods, repeated training for students, so that the students' action to deepen and consolidate, and improve the students' ability to memorize the correct action. In the third stage, students are required to be able to achieve comprehensive application of badminton technical movements, as the saying goes, “practice makes perfect” can be well reflected in the multi-shuttle training, in the second stage, due to the cycle of multi-shuttle training, so that the correct movements are familiar with the heart, so in the third stage, it is required to have the ability to change, therefore, the multi-shuttle training. In the third stage, students are required to have the ability to change, therefore, multi-shuttle training is especially important for the third stage to improve the variation of the comprehensive technique. In the fourth stage, it is mainly based on the use of action technology, mainly based on the actual training methods, to improve the students' practical ability.

In summary, the consolidation and improvement of any part of the badminton training, and even the final application of the link, can not be separated from the basis of multi-shuttle training. Every badminton player can't get away from the boring and repetitive multi-shuttle training in order to make himself reach a certain level of sports.

Improve Students' Movement, Speed and other Qualities through Multi-Shuttle Training

Chinese badminton training requirements to “fast” known, only “fast” and not broken, any technical action training are centered on “fast” and carry out, fast that is, the quality of the speed of the sports training Only fast speed can win more time to hit the ball, therefore, the Chinese team's badminton training, to “fast” as the core. The speed in badminton includes the speed of footwork, the speed of starting, the speed of changing direction, the speed of swinging, the speed of hitting, and the speed of completing the whole action of the coherent speed and so on. Among them, the multi-shuttle training can improve the students' speed quality, the coach for multi-shuttle training when the fast and slow mastery of the speed of the ball can effectively exercise the speed of the students, the fast speed of the ball requires students must be fast footwork, start fast and fast change of direction, combined with the overhand at the same time hit the ball, effectively improve the speed of the shot and reaction speed. Finally, multi-shuttle training can also effectively exercise the students' will quality, boring multi-shuttle training can make the students concentrate, sharpen their will, stimulate the fighting spirit, and develop the spirit of perseverance and never give up.

Summary and Recommendations

Summary

(1) For the first stage of badminton training, multi-shuttle training can effectively strengthen the students' movement qualitatively, improve the students' hitting stability, and make the students form a deep memory of the basic movements.

(2) Multi-shuttle training can improve the students' ability to change their strokes, the so-called “what can be made clever”, multi-shuttle training can effectively help the students to face the incoming ball calm and self-knowledge of the ability to change.
(3) Multi-shuttle training is the most effective training method to improve athletes' cardiorespiratory function and enhance students' physical fitness. The improvement of athletes' sports endurance is a powerful weapon for them to win in the game.
(4) Multi-shuttle training can perfect students' skills and abilities. The boring multi-shuttle training can not only improve students' comprehensive ability, but also help to hone students' will quality, so that students develop the spirit of perseverance and never give up.

Recommendations

(1) Lack of entertainment, should change the teaching content at the right time
the method of multi-shuttle training is relatively rigid, and to some extent it is easy to make students develop the fault of relaxation of thought and dull and mechanical technical movements, in which case it will affect the improvement of the tactical level and reduce the motivation of students to learn. Therefore, the training program should be adjusted appropriately, so that the training content is diversified, so that a variety of training methods cross each other, through, integration, so that the whole training mechanism is organically integrated to achieve good training results and training purposes. Avoid students due to a single training method and produce boring resistance to psychology.

(2) greater intensity, should be combined with the traditional teaching mode
For students who are not specialized, multi-shuttle training will make the body to withstand a larger sports load, making it easier for students to fatigue and physical decline, which will not be conducive to the body function to play the maximum potential. Therefore, in the arrangement of the usual training sessions should be scientific and reasonable, hierarchical, so that students can have the high morale of training, but also to overcome the relatively difficult training tasks, which is also indirectly on the coach's training arrangements have higher requirements.

Conclusion

This study examined the impact of multi-shuttle training on the development of rear-court techniques in badminton, focusing on its role in enhancing technical accuracy, physical fitness, and psychological resilience among students. The findings revealed that multi-shuttle training significantly improves the consistency and precision of key rear-court techniques, such as clears, drops, and smashes, while also contributing to players' cardiovascular endurance, muscular strength, and ability to perform under pressure. However, the repetitive nature of multi-shuttle training may lead to mental fatigue and reduced motivation among trainees, highlighting the need for diversified training methods and engaging practices.

To address these limitations, future research should explore the integration of AI-driven technologies, such as intelligent shuttle feeders and motion tracking systems, which can provide precise feedback and adaptive training solutions tailored to individual players. Additionally, the incorporation of psychological training, including mental resilience and stress management exercises, could complement the physical and technical aspects of training, fostering well-rounded athlete development.

This study is limited by its focus on a single training context and a relatively homogeneous participant group, which may not fully capture the diverse needs of athletes at different skill levels or in varied environments. Future research could investigate the long-term effects of multi-shuttle training across broader populations and explore its combination with other innovative training methods. In conclusion, multi-shuttle training, when enhanced by modern technology and psychological conditioning, holds great potential to advance the technical, physical, and mental capabilities of badminton players, contributing to the ongoing evolution of badminton training methodologies.

References

Blomqvist, M., Luhtanen, P., & Laakso 1, L. (2001). Comparison of two types of instruction in badminton. *European journal of physical education*, *6*(2), 139-155.

Cooper, D. M., Weiler-Ravell, D., Whipp, B. J., & Wasserman, K. (1984). Growth-related changes in oxygen uptake and heart rate during progressive exercise in children. *Pediatric research*, *18*(9), 845-851.

Fei, A. Z., & Qiang, L. G. (2024). The use of multi-shuttle training method in badminton training. *Contemporary Sports Technology*, *14*(29), 39-42. https://doi.org/10.16655/j.cnki.2095-2813.2024.29.012

Furrer, R., Hawley, J. A., & Handschin, C. (2023). The molecular athlete: exercise physiology from mechanisms to medals. *Physiological Reviews*.

Gang, Z. (2022). *A study on the effect of multi-shuttle training method on the basic badminton backcourt skills of 8-9 year old children* [Master's degree,

Heng, L. S. (2007). The role of multi-ball practice method in improving badminton specific skills. *Junior sports training*(03), 44.

Hui, S. (2015). *A study of multi-shuttle training styles and their energy expenditure in college students specializing in badminton* [Master's degree,

Jun, G. W. (2017). *An experimental study of multi-shuttle training on stroke landing stability of sophomore badminton specialized students* [Master's degree,

Li, M. (2025). EMG sensor and infrared thermal radiation image analysis in martial arts training activities: Muscle thermodynamic simulation. *Thermal Science and Engineering Progress*, 103222.

Li, S., Zhang, Z., Wan, B., Wilde, B., & Shan, G. (2017). The relevance of body positioning and its training effect on badminton smash. *Journal of Sports Sciences*, *35*(4), 310-316.

Manrique, D. C., & Gonzalez-Badillo, J. (2003). Analysis of the characteristics of competitive badminton. *British journal of sports medicine*, *37*(1), 62-66.

Min, L., & Ling, X. Y. (2011). A study of badminton multi-shuttle training on improving the training effect of physical education students. *Journal of Jilin Institute of Physical Education*, *27*(06), 124-125.

Siwei, Y., Xiaohui, B., Meng, G., & Yin, Y. (2023). Evaluation and diagnosis of specialized physical quality of excellent badminton players in China. Thirteenth National Sports Science Congress, Tianjin, China.

Springer, C., Barstow, T. J., Wasserman, K., & Cooper, D. (1991). Oxygen uptake and heart rate responses during hypoxic exercise in children and adults. *Medicine & Science in Sports & Exercise*, *23*(1), 71.

Tang, Y., & Lim, S. P. (2025). Mental training for college athletes: A comparative analysis of Chinese and Western approaches and innovations. *Journal of Human Sport and Exercise*, *20*(1), 266-279.

Wee, E. H., Low, J. Y., Chan, K. Q., & Ler, H. Y. (2017). Effects of High Intensity Intermittent Badminton Multi-Shuttle Feeding Training on Aerobic and Anaerobic Capacity, Leg Strength Qualities and Agility. icSPORTS,

Wei, D. W. (2015). Exploration of multi-shuttle training techniques in badminton training. *youth sports*(12), 116-117+167.

Wulf, G., & Mornell, A. (2008). Insights about practice from the perspective of motor learning: a review. *Music Performance Research*, *2*, 1-25.

Xiantao, W. (2018). Application of multi-shuttle training method in table tennis combination technique and tactics. *Contemporary Sports Technology*, *8*(34), 28+30. https://doi.org/10.16655/j.cnki.2095-2813.2018.34.028

Xiaotong, L. (2024). Analysis of the application status of domestic badminton multi-ball training method. The 11th National Conference on Physical Training Science in China, 2024., online meeting.

Xingfan, X., & Minglu, X. (2024). Research on the application of serving machine in badminton training. *Sporting Goods & Technology*(22), 129-131.

Xinxin, W., Bo, L., Xiaotian, L., Lu, J., Le, F., Lei, S., Song, L., Wei, H., Haipeng, L., Xiaoping, C., & Ming, L. C. (2019). Characterization of energy supply in badminton simulated matches and multi-ball practice. *China Sports Science and Technology*, *55*(09), 3-8. https://doi.org/10.16470/j.csst.2019157

Ying, H. (2022). Exploration of multi-shuttle training techniques in badminton training. *Sporting Goods & Technology*(21), 70-72.

Ying, Z. (2023). *A study on the application of multi-shuttle training in high school badminton training* [Master's degree,

Zhang, Y., & Chang, Y. (2022). [Retracted] Optimal Modeling and Simulation of the Relationship between Athletes' High-Intensity Training and Sports Injuries. *Scanning*, *2022*(1), 8447453.

Jianwei, P. W., Meixian, D. (2005). A study of badminton multi-ball training on improving physical fitness ability. *China Sports Science and Technology*(03), 92-94+102. https://doi.org/10.16470/j.csst.2005.03.028