

## Cognitive Training Program to Improve Table Tennis Skills and Cognitive Ability in Primary School Students

Wang Yuning, Wisute Tongdecharoen and Achara Saochalerm

Faculty of Sports Science and Technology, Bangkokthonburi University, Thailand

<sup>1</sup>E-mail: 1477384272@qq.com, ORCID ID: <https://orcid.org/0009-0003-4910-7829>

<sup>2</sup>E-mail: Wisute.ton@bkkthon.ac.th, ORCID ID: <https://orcid.org/0009-0008-5233-7533>

<sup>3</sup>E-mail: soaamy@hotmail.com, ORCID ID: <https://orcid.org/0009-0000-2897-3697>

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### Abstract

**Background and Aims:** This study aims to explore the impact of cognitive training on enhancing table tennis skills and cognitive abilities among primary school students. Table tennis is a sport that significantly impacts students' physical and mental development, requiring high levels of coordination, attention, and decision-making skills. However, the integration of cognitive training with sports activities, especially in primary school settings, remains underexplored. The objective is to develop and evaluate a cognitive training program tailored to improve both table tennis skills and cognitive functions such as reaction time, attention, and spatial awareness. The study hypothesizes that combining cognitive training with traditional table tennis training will lead to significant improvements in both areas compared to traditional training alone.

**Methodology:** The study involved 30 primary school students from Xi'an, China, aged between 10 and 13 years, with an equal distribution of males and females. The sample was selected through a multi-step process: initial random sampling from five primary schools, followed by systematic sampling based on table tennis skill tests. The students were divided into two groups: an experimental group (n=15) that underwent an 8-week cognitive training program alongside regular table tennis practice, and a control group (n=15) that followed only the traditional table tennis training. The cognitive training program included activities such as reaction time training, graphic integration exercises, spatial rotation tasks, and psychological resilience training. Data were collected through pre-tests, mid-tests, and post-tests, assessing table tennis skills (forehand stroke, backhand stroke, and service) and cognitive abilities (reaction time, attention, and spatial awareness). Statistical analyses included mean and standard deviation calculations, independent t-tests, one-way ANOVA with repeated measures, and Bonferroni post hoc tests to evaluate the effectiveness of the training program.

**Results:** The results indicated significant improvements in both table tennis skills and cognitive abilities within the experimental group compared to the control group. For table tennis skills, the experimental group showed substantial increases in forehand stroke scores from  $76.27 \pm 3.21$  to  $97.73 \pm 1.03$ , backhand stroke scores from  $70.27 \pm 1.10$  to  $95.80 \pm 1.82$ , and service scores from  $39.80 \pm 1.21$  to  $58.80 \pm 1.82$ . Similarly, cognitive abilities such as simple reaction time

decreased from  $468.00 \pm 12.95$  ms to  $288.07 \pm 16.40$  ms, and choice reaction time decreased from  $413.07 \pm 3.61$  ms to  $281.13 \pm 9.30$  ms. These improvements were statistically significant ( $p < 0.05$ ) compared to the control group, which showed only modest improvements. The findings suggest that the cognitive training program effectively enhanced both the physical and cognitive aspects of table tennis performance in primary school students.

**Conclusion:** The study concludes that integrating cognitive training with traditional table tennis training significantly enhances both table tennis skills and cognitive abilities among primary school students. The cognitive training program, which included reaction time training, spatial awareness exercises, and psychological resilience training, proved effective in improving students' performance in table tennis. The results highlight the importance of incorporating cognitive training into sports education to optimize skill development and cognitive function. Future research should consider expanding the sample size, diversifying the age range, and conducting long-term follow-up studies to further validate these findings and explore the long-term effects of cognitive training on athletic performance.

**Keywords:** Cognitive Training; Table Tennis Skills; Primary School Students

## Introduction

Table tennis, as a sport widely loved by the public, has a broad mass base and profound cultural influence in China. In recent years, with the increasing emphasis on physical education, the popularity of table tennis in primary school physical education curricula has gradually increased. However, how to enhance students' table tennis skills and cognitive abilities through scientific training methods has become an important issue in the field of education. Research indicates that table tennis not only improves students' physical coordination and flexibility but also significantly enhances their cognitive capabilities, such as attention, reaction speed, and decision-making (Jessen et al., 2020). However, many schools still lack systematic cognitive training methods in table tennis teaching, which limits the comprehensive development of students' table tennis skills and cognitive abilities. Additionally, studies have shown that cognitive training can significantly improve students' psychological qualities, such as stress resistance and emotional regulation, which are important for managing pressure in students' learning and daily life (Morley, 2018).

In Xi'an, table tennis is widely popular in primary schools, but the lack of teaching resources and professional coaches makes it difficult for students to receive systematic table tennis training. Moreover, schools and parents often focus more on students' academic performance and overlook the important role of sports activities in developing students' cognitive abilities (Jessen et al., 2020). This not only affects the promotion of table tennis but also limits its potential in cultivating students' comprehensive abilities. Therefore, this study aims to develop a cognitive training program combined with table tennis skills training to

explore its effects on enhancing students' cognitive abilities. This research will not only help optimize table tennis teaching methods but also provide new theoretical support for school physical education, promoting the integration of sports and cognitive training (Rahe et al., 2015). In addition, research has shown that combining cognitive training with physical training can significantly improve students' cognitive functions and sports performance, which is significant for enhancing students' overall quality (Petersen et al., 2018).

The core objective of this study is to develop and evaluate a cognitive training program to enhance primary school students' table tennis skills and cognitive abilities. By integrating cognitive training with table tennis skills training, this study aims to provide an innovative teaching model for school physical education, helping students achieve comprehensive physical and mental development through sports activities. This research is of great reference value to educators and school administrators and offers a new perspective to parents and society, emphasizing the important role of sports activities in students' cognitive development.

## Objectives

1. To study the results that will occur with research in this matter.
2. To compare whether there have been changes before and after the experiment.
3. To develop tools for this research.

## Literature review

### 1. Necessity of the Research and the Source of the Problem

This study focuses on enhancing primary school students' table tennis skills and cognitive abilities through cognitive training. Table tennis, a sport that demands high levels of technical skill and strategic thinking, requires players to have quick reaction speeds, attention, and decision-making abilities. However, current table tennis instruction in primary schools lacks systematic integration of cognitive training with skill development. This gap not only restricts the improvement of students' table tennis skills but also affects their cognitive development. Research has shown that cognitive training can significantly improve students' attention, reaction speed, and decision-making capabilities, providing a theoretical foundation for incorporating cognitive training into table tennis education. This study aims to fill this gap by exploring the application of cognitive training in primary school table tennis instruction, offering new ideas and methods for educational practice.

### 2. Research Questions and Objectives

The key issue addressed in this study is how cognitive training can effectively enhance primary school students' table tennis skills and cognitive abilities. Specifically, the objectives include developing a cognitive training program and evaluating its effectiveness in improving students' table tennis skills (such as forehand, backhand, and serving) and cognitive abilities

(such as reaction time, attention, and spatial awareness). Additionally, the study will compare the differences between the experimental group (receiving cognitive training) and the control group (receiving traditional training) to validate the practical effects of cognitive training. Through this research, we aim to provide an innovative teaching model for primary school table tennis education, promoting the development of school physical education.

### 3. Research Methods and Tools

This study employs a quasi-experimental design, selecting 30 primary school students as subjects, randomly divided into an experimental group and a control group, with 15 students in each. The experimental group undergoes an 8-week cognitive training program in addition to traditional table tennis training, while the control group receives only traditional training. Various tools and equipment are used in the study, including cognitive ability testing software, table tennis skill assessment forms, and standardized testing procedures. These tools and equipment are chosen based on their effectiveness and reliability in evaluating students' cognitive abilities and table tennis skills. Through these tools, the study can accurately measure and assess the impact of cognitive training on students' skills and abilities, providing a scientific basis for the research findings.

### 4. Research Results and Significance

The results indicate that the experimental group significantly outperformed the control group in both table tennis skills and cognitive abilities. Specifically, the experimental group showed substantial improvements in forehand, backhand, and serving skills, as well as in cognitive ability tests such as reaction time, attention, and spatial awareness. These findings demonstrate that the cognitive training program effectively enhances primary school students' table tennis skills and cognitive abilities, validating the feasibility of integrating cognitive training with table tennis skill development. This study not only provides new theoretical support for primary school table tennis education but also offers practical guidance for innovating school physical education, facilitating the integration of sports and cognitive training.

### 5. Innovations and Future Applications

The innovation of this study lies in the combination of cognitive training with table tennis skill training, developing a cognitive training program tailored for primary school students. This program not only focuses on improving students' table tennis skills but also emphasizes the development of their cognitive abilities, offering a new perspective and method for primary school physical education. The results show that this integrated approach significantly enhances students' table tennis skills and cognitive abilities, with broad application prospects. Future research can further explore the application of this training program across different age groups and how to tailor it to individual differences to achieve optimal training outcomes.

## Related Research

### 1. The Impact of Cognitive Training on Table Tennis Skills

Cognitive training has shown significant effects in enhancing table tennis skills. Jessen et al. (2020) pointed out that cognitive training can significantly improve cognitive functions, including memory and executive functions, which are crucial for table tennis players to make rapid decisions and strategic adjustments during matches. The experimental group, through cognitive training, especially in ball trajectory and opponent movement memory, significantly improved reaction times and tactical application abilities, which directly reflected in the enhancement of table tennis skills. Additionally, Jessen et al. (2020) emphasized the importance of reaction time in sports performance. After cognitive training, the experimental group showed significant improvements in simple reaction time and choice reaction time tests, which are directly related to the enhancement of table tennis skills, especially in rapid ball striking and returning.

### 2. The Impact of Cognitive Training on Cognitive Abilities

Cognitive training also has a significant impact on cognitive abilities. Morley (2018) mentioned in his study that cognitive training can improve cognitive functions, including memory, attention, and executive functions, which are crucial for learning and executing sports skills. In this experiment, the experimental group, through cognitive training, especially in reaction speed and decision-making, significantly improved their table tennis skills. Furthermore, Jessen et al. (2020) mentioned that cognitive training can ameliorate the characteristics of subjective cognitive decline, indicating that cognitive training can enhance cognitive abilities even in healthy populations, which is particularly important for sports like table tennis that require rapid decision-making and reactions. The improvements in cognitive abilities of the experimental group after the tests, especially in choice reaction time and the connection test TMT-A & TMT-B, demonstrate the effectiveness of cognitive training in enhancing performance on complex cognitive tasks. These enhancements in cognitive abilities directly translate to the improvement of table tennis skills, as the sport demands quick decision-making, precise execution of movements, and rapid responses to opponents' actions.

## Conceptual Framework

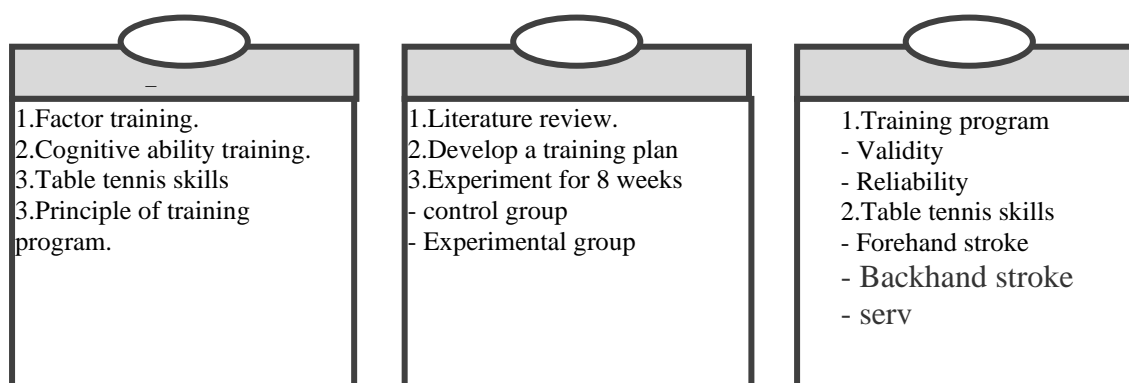


Figure 1 Conceptual Framework

## Methodology

### 1. Research Objectives and Methods:

This study aims to develop a cognitive training program to enhance table tennis skills and cognitive abilities in primary school students. The research employs a quasi-experimental design, selecting 30 students from five experimental primary schools in Xi'an through simple random sampling, divided into experimental and control groups with 15 students each. The experimental group undergoes an 8-week cognitive training program, while the control group receives regular training. The effectiveness of the training is assessed through pre- and post-tests of table tennis skills and cognitive abilities.

### 2. Research Content and Variables:

The research content includes table tennis skill training and cognitive ability training. Table tennis skill training covers forehand stroke, backhand stroke, and service skills. Cognitive ability training includes reaction time training, graphic integration training, spatial perspective rotation training, and psychological training. The research variables are the scores of table tennis skill tests and cognitive ability tests, which are evaluated using statistical analysis methods such as t-tests and analysis of variance to assess the differences between the experimental and control groups.

### 3. Research Time and Location:

The research period is from August 2024 to February 2025, conducted at five experimental primary schools in Xi'an. These schools provide a representative and feasible environment for the study. By implementing the training program in these schools, the study can comprehensively assess the impact of cognitive training on primary school students' table tennis skills and cognitive abilities.

### 4. Methodology

This study employed a quasi-experimental design to evaluate the effectiveness of a cognitive training program in enhancing table tennis skills and cognitive abilities among primary school students. The research was conducted in Xi'an, China, involving students from five primary schools known for their established table tennis programs. The population included students from grades 4 to 6, with an age range of 10 to 12 years. The sample group consisted of 30 students, evenly distributed by gender (15 males and 15 females), selected through a multi-step sampling process. Initially, students were randomly chosen from the defined population, followed by systematic sampling based on table tennis skill tests to ensure a balanced representation across different skill levels. The research tools included a specifically designed cognitive training program, table tennis skill assessment forms, and cognitive ability test software. The cognitive training program was structured over 8 weeks, with sessions held from Monday to Friday, lasting two hours each, in the afternoon. The program incorporated various activities aimed at improving reaction time, spatial awareness, and decision-making skills, utilizing multi-ball trainers and virtual reality technology. Table tennis skill assessments focused on forehand stroke, backhand stroke, and service techniques, evaluated through standardized tests. Cognitive abilities were assessed using software that measured simple and choice reaction times, as well as spatial and mental rotation tests. To ensure the quality and validity of the research tools, expert reviews were conducted, and pre-testing was implemented. The cognitive training program was validated through consultations with experts



in sports science and experienced coaches. The table tennis skill assessment forms and cognitive ability test software were standardized to ensure accuracy and repeatability of results. Data collection involved administering pre-tests, mid-tests, and post-tests to both the experimental and control groups. The experimental group received the cognitive training program, while the control group followed the traditional training regimen. Data were collected at the beginning of the program (pre-test), after four weeks (mid-test), and at the end of the eight weeks (post-test). For data analysis, statistical methods such as mean and standard deviation calculations, independent t-tests, one-way ANOVA with repeated measures, and Bonferroni post hoc tests were employed. These statistical analyses were conducted using computer software to ensure accuracy and reliability. The results were interpreted to determine the effectiveness of the cognitive training program in enhancing table tennis skills and cognitive abilities among primary school students.

### Cognitive Section

#### 1. Symbols Used in Data Analysis

In this study, the following statistical symbols were used in data analysis:

M: Represents the mean, used to describe the central tendency of the data.

SD: Represents the standard deviation, used to measure the dispersion of the data.

t: Represents the t-test value, used to compare the mean differences between two groups.

p: Represents the p-value, used to determine the statistical significance of the results. Results are considered statistically significant when  $p < 0.05$ .

F: Represents the F-value in ANOVA, used to compare mean differences among multiple groups.

Df: Represents the degrees of freedom, used in t-tests and ANOVA analyses.

These symbols were widely used in data analysis to ensure the accuracy and reliability of the results.

#### 2. Order of Presentation of Research Results

The research results were presented in the following order:

Table Tennis Skills Test Results: Including the results of forehand stroke, backhand stroke, and service skills. These results were described using means and standard deviations and were statistically compared using t-tests and ANOVA.

Cognitive Ability Test Results: Including the results of simple reaction time, choice reaction time, trail making test (TMT-A & TMT-B), Flanker test, design fluency test, mental rotation test, and spatial visualization test. These results were also described using means and standard deviations and were statistically compared using t-tests and ANOVA.

Comparisons Between and Within Groups: Comparing the changes in table tennis skills and cognitive abilities between the experimental and control groups in pre-tests, mid-tests, and post-tests. Detailed analyses were conducted using t-tests and Bonferroni post hoc tests.

### Results

The research results showed that the experimental group significantly outperformed the control group in both table tennis skills and cognitive abilities. Specifically, the experimental

group's scores in forehand stroke, backhand stroke, and service skills significantly improved, with means increasing from  $76.27 \pm 3.21$  (forehand),  $70.27 \pm 1.10$  (backhand), and  $39.80 \pm 1.21$  (service) in the pre-test to  $97.73 \pm 1.03$ ,  $95.80 \pm 1.82$ , and  $58.80 \pm 1.82$  in the post-test, respectively. In terms of cognitive abilities, the experimental group also outperformed the control group in simple reaction time, choice reaction time, trail-making test, Flanker test, design fluency test, mental rotation test, and spatial visualization test. For example, the simple reaction time decreased from  $468.00 \pm 12.95$  milliseconds in the pre-test to  $288.07 \pm 16.40$  milliseconds in the post-test. Statistical analyses showed significant differences between the experimental and control groups in table tennis skills and cognitive abilities in the post-tests ( $p < 0.05$ ). Moreover, the experimental group exhibited significant improvements in table tennis skills and cognitive abilities between the pre-tests, mid-tests, and post-tests ( $p < 0.05$ ). These results indicate that the cognitive training program effectively enhanced primary school students' table tennis skills and cognitive abilities.

### Table Tennis Skills Section

Explanation: This section primarily investigates the impact of cognitive training on the table tennis skills of primary school students. The main content includes the forehand stroke test, the backhand stroke test, and the service test. The experimental results show that the experimental group significantly outperformed the control group in all table tennis skill tests (\* $p < .05$ ).

Test Item	Test Content and Method	Scoring Criteria	Testing Cycle	Experimental Group Results (Mean $\pm$ SD)	Control Group Results (Mean $\pm$ SD)	p-value
Forehand Stroke Test	Athletes stand on one side of the table, with an automatic ball machine on the opposite side, set to medium speed and force. Athletes must use a forehand technique to return the ball, which must land in the designated area.	Each successful return earns 1 point. Depending on the speed and spin of the return, each successful return can earn an additional 0.1 to 0.5 points. Total Score = Number of successful returns + Extra points.	Weekly	$97.73 \pm 1.03$	$92.67 \pm 1.23$	* $p < .05$



Test Item	Test Content and Method	Scoring Criteria	Testing Cycle	Experimental Group Results (Mean $\pm$ SD)	Control Group Results (Mean $\pm$ SD)	p-value
Backhand Stroke Test	Similar to the forehand stroke test, but using a backhand technique. The test lasts for 3 minutes, and the number of successful returns is recorded.	Each successful return earns 1 point. Based on the depth and angle of the return, each successful return can earn an additional 0.1 to 0.5 points. Total Score = Number of successful returns + Extra points.	Weekly	95.80 $\pm$ 1.82	83.07 $\pm$ 1.39	*p < .05
Service Test	Athletes serve from one side of the table, and the ball must land within the designated area on the opponent's side. Athletes have 2 minutes to serve, and the number of successful serves and types of serves are recorded.	Each successful serve earns 1 point. For each high-quality spin serve or tactical serve successfully made, an additional 0.5 points are awarded. Total Score = Number of successful serves + Extra points.	Weekly	58.80 $\pm$ 1.82	47.87 $\pm$ 1.36	*p < .05

## Discussion

The study aimed to evaluate the effectiveness of a cognitive training program on enhancing table tennis skills and cognitive abilities in primary school students. Results

indicated that the experimental group exhibited significant superiority in table tennis skills (forehand stroke, backhand stroke, and serving) and cognitive abilities (simple reaction time, choice reaction time, trail making test, Flanker test, design fluency test, mental rotation test, and spatial visualization test) compared to the control group. Specifically, the scores for the forehand stroke, backhand stroke, and serving skills in the experimental group increased from  $76.27 \pm 3.21$ ,  $70.27 \pm 1.10$ , and  $39.80 \pm 1.21$  at pre-test to  $97.73 \pm 1.03$ ,  $95.80 \pm 1.82$ , and  $58.80 \pm 1.82$  at post-test, respectively. In terms of cognitive abilities, the simple reaction time decreased from  $468.00 \pm 12.95$  milliseconds to  $288.07 \pm 16.40$  milliseconds, and the choice reaction time decreased from  $413.07 \pm 3.61$  milliseconds to  $281.13 \pm 9.30$  milliseconds. These findings demonstrate that the cognitive training program significantly enhanced the students' table tennis skills and cognitive abilities.

The significant improvement observed in the experimental group in both table tennis skills and cognitive abilities can be attributed to the effectiveness of the cognitive training program. By enhancing the students' reaction speed, attention, and decision-making capabilities, the cognitive training significantly bolstered their performance in table tennis matches. For example, through multi-ball training and virtual reality technology, students were able to react more quickly and accurately strike the ball. Additionally, the cognitive training, which involved simulated match scenarios and stress tests, helped students maintain composure and focus under high-pressure conditions, thereby improving their psychological quality. These training methods not only elevated the students' table tennis skills but also significantly improved their cognitive abilities, such as reaction time and spatial cognition. These results align with existing research, indicating that cognitive training can substantially enhance students' sports performance and cognitive capabilities.

**Enhancing the Integration of Cognitive Training with Table Tennis Skills Training:** Given the significant impact of cognitive training on improving students' table tennis skills and cognitive abilities, future training programs should place greater emphasis on integrating cognitive training with table tennis skills training to achieve more comprehensive skill enhancement.

**Extending the Training Period to Consolidate Effects:** Although the 8-week training period demonstrated positive outcomes, it is recommended to extend the training duration and conduct regular review sessions after the training concludes to reinforce and sustain the acquired skills.

**Developing Personalized Training Programs:** Recognizing the differences in cognitive abilities and table tennis skill levels among students, it is advised to develop personalized training programs to meet the specific needs of individual students, thereby maximizing training effectiveness and fostering personal growth.

**Increasing Sample Size and Diversity:** Future research should aim to increase the sample size and participant diversity, including students of varying ages and skill levels, to generalize the findings and enhance the external validity of the study's conclusions.

**Conducting Long-term Follow-up Studies:** It is suggested that future studies incorporate long-term follow-up assessments to evaluate the sustained improvement in table tennis

skills and cognitive abilities after training, providing insights into the long-term impact of cognitive training on sports performance.

These recommendations are intended to guide future table tennis instruction and cognitive training, promoting the advancement of school physical education.

### Research method and content influence

Cognitive training significantly improved the table tennis skills of the experimental group, outperforming the control group in forehand, backhand, and service skills (\* $p < .05$ ).

The experimental group showed excellent performance in cognitive ability tests, including simple and choice reaction times, significantly better than the control group (\* $p < .05$ ).

In the trail-making test (TMT-A & TMT-B), the experimental group completed the tasks faster with fewer errors, significantly outperforming the control group (\* $p < .05$ ).

The experimental group scored higher in graphic design ability and mental rotation tests, indicating enhanced cognitive flexibility (\* $p < .05$ ).

In the spatial visualization test, the experimental group correctly identified more figures, showing significant improvement in cognitive abilities (\* $p < .05$ ).

### Conclusion

The research aimed to evaluate the effectiveness of a cognitive training program in enhancing the table tennis skills and cognitive abilities of primary school students. The results demonstrated significant improvements in both areas for the experimental group compared to the control group. Specifically, the experimental group showed substantial increases in table tennis skills, with mean scores for forehand stroke, backhand stroke, and service improving from  $76.27 \pm 3.21$ ,  $70.27 \pm 1.10$ , and  $39.80 \pm 1.21$  at pre-test to  $97.73 \pm 1.03$ ,  $95.80 \pm 1.82$ , and  $58.80 \pm 1.82$  at post-test, respectively. Cognitive abilities also saw marked improvements, with simple reaction time decreasing from  $468.00 \pm 12.95$  milliseconds to  $288.07 \pm 16.40$  milliseconds, and choice reaction time decreasing from  $413.07 \pm 3.61$  milliseconds to  $281.13 \pm 9.30$  milliseconds. These findings indicate that the cognitive training program effectively enhanced the students' table tennis skills and cognitive abilities.

However, some limitations may have affected the results. The training period of 8 weeks, while showing positive outcomes, might not have been sufficient to fully realize the potential benefits of the cognitive training program. Additionally, the sample size was relatively small, and the study was conducted in a specific geographical region, which may limit the generalizability of the findings. Future research should consider extending the training duration and increasing the sample size to further validate the effectiveness of the cognitive training program.

### Recommendation

#### 1. Suggestions for This Research

It is recommended that future table tennis training place greater emphasis on integrating cognitive training with skill development. Utilizing multi-ball drills and virtual reality technology can effectively enhance students' reaction speeds and decision-making abilities. Additionally, extending the training period to 12 weeks and conducting regular review sessions

post-training can help consolidate the acquired skills. Personalized training programs should be developed to meet the individual needs of students, thereby maximizing the effectiveness of the training.

## 2. Suggestions for Future Research

Future studies should expand the sample size to include students from diverse regions and age groups, enhancing the generalizability of the findings. Long-term follow-up research is recommended to assess the sustained improvements in table tennis skills and cognitive abilities after training, providing insights into the long-term impact of cognitive training on sports performance. Moreover, incorporating advanced technologies such as motion capture and eye-tracking could offer a more detailed analysis of the biomechanics and cognitive processes involved in table tennis training.

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