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Research Article

Effectiveness of Badminton Physical Program on Mental Capacities in Healthy Older Adults

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ABSTRACT

Older people suffer from reduced mental and cognitive parameters such as executive function, working memory and cognitive flexibility. However, information about how racquet sports can improve mental skills in older adults requires greater analysis and research. To verify the effects of badminton physical program on cognitive function in older adults. We sought to examine the beneficial effects of badminton physical programs on multi-cognitive domains among healthy older adults. Specific cognitive functions were measured using the Stroop Test, the Digit Span Test, and the Mini-Mental State Examination. 40 older adults recruited from the University of Monastir were allocated into two groups: the intervention group (IG, $N = 20$), enrolled in a badminton program, and the control group (CG, $N = 20$) participants were given typical duties and asked to stick to their daily schedule (book reading, home tasks). The physical activity protocol was performed three times a week, one hour per session, for a total period of two months. The activities proposed were not systematized and were aimed at promoting social interaction among participants. Our findings show no significant difference in the initial components between the intervention and control groups. Significant improvements in cognitive parameters were found after the physical program in the IG ($p < 0.05$), except the Mini-Mental State Examination test ($p = 0.33$). Physical activity is considered one of the most therapeutic methods for improving mental capacities in older adults.

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INTRODUCTION

The link between physical activity and cognitive performance for older adults has been the primary objective of various research projects. Previous research states that the number of elderly people (65 and over) is predicted to double from 703 million globally in 2019 to 1.5 billion by 2050 (Kasai, 2021).

A comprehensive awareness of the lifestyle factors and interventions that can improve cognitive health and lower the risk of neurodegenerative disorders in this aging population is essential considering this substantial shift in demographics. Advanced cognitive capacity, or executive parameters/function (EP, EF), is the core of individuals' social, emotional, mental functions (Miyake et al., 2000), and it is composed of three components: mental flexibility, short-term/working memory, and inhibition (Diamond, 2013). The decreasing of executive parameters leads to cognitive dysfunction in individuals, and it can also lead to increasing behavioral and psychological disorders (Costanzo et al., 2013; Frost et al., 2019). Therefore, improving the executive function of older adults leads to enhancing the quality of life and realizing successful aging. Another important aspect of cognitive function is working memory (WM), particularly among the elderly population. In the brain, WM is responsible for acquiring and modulating numerous forms of information (Kato et al., 2018). The ability to retain information has been demonstrated to reach its maximum at age of 30 and to drastically decline around age of 60 (Elliott et al., 2011).

The value of physical activity is further highlighted by several recent long-term research studies demonstrating that frequently moderate-intensity physical activity can lower the risk of cognitive problems (Wilke, 2020; Livingston, 2020). Studies conducted throughout multiple scientific domains indicate that physical activity programs such as badminton enhance psychological health and well-being (Lawton et al., 2017), with a multitude of other benefits such as lowering the levels of stress, anxiety, and depression and increasing the beneficial effects of cognitive parameters. Furthermore, while many sports and exercises emphasize the physical and motor aspects of performance, others, such as racquet sports, necessitate a particularly advanced level of mental capacity. Badminton is an open-skills sport, a suitable game for both younger and older people. It requires participants to select appropriate actions that can positively improve brain activity and muscle contraction during physical exercise. Furthermore, it also enhances brain plasticity and cognitive function (Hülsdünker et al., 2019). The combination of these improvements ultimately enhances general well-being. The number of people engaging in dual sport racquets to perform physical qualities has increased considerably (Tator, 2008). A study conducted by Oja et al. (2017) showed that playing sports racquet has been linked to a lower death rate (47%) and reduced cognitive disorders (53%). It has been demonstrated that the time invested in playing racquet sports has an impact on biological and psychological factors.

While it is evident that regular engagement in a variety of physical activities has a positive impact on health, very limited studies have examined whether participation in racquet sports (such as badminton) influences mental abilities in older adults. This research aims to investigate whether playing different kinds of badminton exercises might change or improve cognitive abilities. We hypothesize that badminton physical programs will exhibit higher scores in the MMSE, Stroop, and Digit Span tests as instruments for measuring cognitive function in older adults.

METHODS

A controlled randomized experiment was created to address the research questions concerning the effect of a two-month badminton physical program on cognitive function in older adults. All cognitive tests (Stroop, Digit Span, and MMSE tests) were measured pre-and post-intervention. Participants were recruited with an invitation questionnaire addressing the procedure and the protocol with all details. Participants were selected under the same conditions and with the same staff members (medical and trainer staff). Participants must be accompanied by their relative partners or their family representative members.

Participants

40 older adults participating in this study (25 men and 15 women) were separated into two groups: intervention (n = 20) and control (n = 20). The participant's average age was 65.80 ± 3.93 years, with no significant difference between groups. Their height was 168.68 ± 10.29 cm, weight was 72.25 ± 14.25 kg, and BMI was 25.05 ± 4.12 kg/m2. Gender differences were assessed using crosstabs in SPSS version 22.0. The initial analysis revealed no significant distinctions among both groups in age, height, body mass, and BMI (all > 0.05). Table 1 displays the baseline characteristics.

The protocol was conducted from June to August 2023. The inclusion criteria were: (1) 60–70 years; (2) no previous badminton training; (3) no history of chronic disease; (4) no physical disorder, and a score of the Mini Mental State Examination test (MMSE) between 25 and 30. The exclusion criteria were: (1) attention disorders, (2) aggressive, (3) perception deficits, (4) and those unable to engage in the regular physical programs.

Table 1
Demographic Characteristics of the Participants

Groups Measurements	(IG; N=20)		(CG; N=20)	
Sex	Men (n=12) Women (n=8)	*p*	Men (n=13) Women (n=7)	*p*
Age (year)	66.00 ± 3.64	0.486	67.60 ± 4.32	0.371
Height (cm)	168.53 ± 9.23	0.378	170.83 ± 11.46	0.161
Body Mass (kg)	70.51± 12.98	0.467	73.98 ± 15.26	0.233
BMI	24.87 ± 4.52	0.378	25.24 ± 3.84	0.387

Note. BMI: body mass index, BMI = weight in kg divided by height in meters squared.

Procedures

After receiving the medical report, eligible participants who completed the initial screening process were invited to the Sport Physiology Laboratory (ISSEP Ksar Said, Tunis). Upon their arrival, participants received a full explanation regarding the objectives and procedures of the tests. Following anthropometric measurements individually. Participants spent 10 minutes in a quiet environment at a thermoneutral temperature of around 22°C. After that, all subjects were asked to complete the cognitive function assessments. The evaluation was based on two neurocognitive tests, which included the Digit Span test and the Stroop test. A two-minute interval was allowed between each test. The cognitive tests listed below were conducted both before and after the intervention.

Stroop test

We used the Stroop test (Stroop, 1935) to assess inhibition capabilities and executive malfunction, and for the evaluation of cognitive flexibility, we used a modified version incorporating a fourth board (Chatelois et al., 1996). The Stroop test consists of four boards, each representing a different condition. The first board represents the name, with rectangular items of red, yellow, blue, or green colors. Participants must name the colors they see. The second board represents the reading task, with the words yellow, blue, red, and green written in black. The aim is simply to read the words. For the third board, representing the interference, the words indicating colors are written with a different ink color, i.e. GREEN - YELLOW. The objective of this board is to disrupt the time takes to read the word and concentrate on indicating the color of the ink. The final board, which stands for flexibility, is identical to the third one after certain words have been framed; in this instance, the participant is required to read the word. The difficulty is the alternate reading of the word when it is framed and the designation of the color of the ink.

Each board consists of ten items per line on ten lines. The test consists of counting the total responses of correct answers in 45 seconds. Evaluation of the first two boards helps train and evaluate the time the practitioner needs to read and name the color. In contrast, the third and fourth boards are used to assess flexibility and inhibition.

Digit Span

Digit Span (DGS) is a validated test assessing both short-term and working memory, it can be administered in two formats: forward digit span and backward digit span. This is a verbal indicator instrument assesing tasks with stimuli produced auditorily, comments stated by the participant, and immediately scored by the software. A random sequence of numbers is shown to the participants, they are asked to repeat it according to the initial order (digit forward) or in the opposite order (digit backward). Tasks were almost very comparable; and both examine cognitive parameters: the forward span task evaluates short-term memory, while the backward span measures working memory ability (Wechsler, 1955).

Mini-Mental State Examination

Cognitive aging was assessed using the Mini-Mental State Examination test. This is the most frequently used test employed for rapid screening measures to determine the presence of cognitive impairments in older adults. The procedure of this test takes only 5–10 minutes, and the following aspects are examined: memory , language and praxis , perception , and attention. The total score is 30 points, a score below 24 indicates a typical cognitive level. A score under 24 signifies "mild dementia," 19-24 means "moderate dementia," and 10-18 reveals "severe dementia" (<10) (Folstein et al., 1983).

Badminton Intervention Program Development and Content

We established the exercise intervention with new technical modifications in this research on previous badminton intervention programs completed in relevant domains that used a total of around 20 to 24 weeks, 2-3 times per week, for sixty minutes each time (Yang, 2017). The training program was developed by a multidisciplinary team composed of exercise physiologists, psychologists, and physical education professionals with a specialization degree in badminton coaching, with proper care for the psychological and physical situations of older persons. The intervention content was designed to stimulate cognitive parameters, primarily short-term memory, working memory and inhibitory control. When participants learned and performed certain specific moves, they were capable of conducting them correctly using the instructions supplied. Furthermore, it was essential to strengthen their control to improve their ability to manage and prevent inappropriate activities.

For working memory, participants were required to regularly retain information, analyze data and maintain movements during the training. Participants were asked to switch between working memory states to exhibit cognitive flexibility. The physical program began with a preparation period, which consisted of warm-up exercises and jogging, followed by particular badminton skills training, gradually modifying the type of exercise task, followed by 10 minutes of static stretching period (Table 2). The level of exercise was evaluated. After each exercise session, six individuals were randomly selected, their heart rates were measured manually, and the supervisor reported their observed physical states. During the skills training period, the participants' average heart rate was 135.74 beats per minute, which is similar to 65-75% of the maximal heart rate for this age group, indicating moderate-intensity exercise. All sessions were carried out under the instructions of the same coaches.

Table 2
Badminton Intervention Protocol

Time Period	**Repartition of Badminton Program 12 Sessions**	**Lenght**
Week 1-2: Session 1 to 3:	Discovery of badminton/ equipment Handling Equipment Jongles exercises	60 min Session
Week 3-4: Session 3 to 6:	Muscle Strengthening Lower M/ put learning into practice Muscle Strengthening Lower M/ reverse service learning Muscle Strengthening Lower and Upper M/ reverse service / gait	60 min Session
Week 5-6: Session 6 to 9:	Service learning / gesture release Service learning / gait + coordination exercises Passing Exercises (Moving footwork practice + eye contact	60 min Session
Week 7-8: Session 9 to 12:	Transfer of learning during matches Quality training: full command footwork, (Moving footwork practice + eye contact)	60 min Session
Cool down	Static stretching	10 min

Data Analysis

The information obtained was analyzed using SPSS version 23.0 for MAC (IBM Corporation, Armonk, NY, USA). First, the Kolmogorov-Smirnov test was applied to determine whether the data followed a normal distribution. To investigate the impact of the badminton physical program, we used a student t-test on all cognitive variables. Statistical significance was determined at $p < 0.05$.

RESULTS

To verify if our two study groups had comparable baseline scores before establishing the physical training program, we compared diagnostic evaluation scores between both groups using the student *t*-test. All variables showed no significant difference between the control and intervention groups. Except for one variable, on the digit-backward test, the CG has a significantly higher working memory score than the intervention group ($p < 0.05$). The MMSE test indicates that both groups have normal cognitive scores <27 without any mental deficits. Table 3 presents the average and standard deviation of each group. The values obtained in the student test and their significance are also listed in this table.

Table 3
Comparison of Characteristics of the Control Group vs Intervention Group in Pre-program

Measurement	(IG) (N=20)	(CG) (N=20)	*t*	p
Stroop Test				
Reading Score	42.39 ± 12.98	51.31 ± 15.90	1.27	0.22
Inhibition	31.61 ± 12.62	36.06 ± 8.95	0.82	0.42
Cognitive flexibility	32.39 ± 11.01	40.68 ± 12.21	1.47	0.16
Digit Span Test				
Digit Forward	5.78 ± 1.48	7.50 ± 2.30	1.84	0.08
Digit Backward	2.56 ± 0.73	4.13 ± 1.96	2.24	0.04*
MMSE	28.87 ± 0.91	27.38 ± 2.87	0.99	0.33

Note. M = Mean; SD = Standard Deviation; MMSE = Mini Mental State Examination; *p<0, 05

Comparison of Post-to-Pre-Program Control Group Scores

To determine if there would be a test-retest effect on the control group, the student t-test was applied to assess the control group's results before and after the intervention. Table 4 summarizes the analysis findings, which show no significant change in cognitive parameters (i.e., p >.05).

Table 4
Comparison of Pre vs. Post-program Scores in the Control Group

Measurement	Before Intervention	After Intervention	*t*	p
Stroop Test				
Reading Score	51.31 ± 15.90	54.37 ± 14,87	0.85	0.42
Inhibition	36.06 ± 8.95	35.87 ± 10.28	0.06	0.96
Cognitive flexibility	40.68 ± 12.21	40.50 ± 8.5	0.04	0.96
Digit Span Test				
Digit Forward	7.50 ± 2.30	7.12 ± 2.69	2.04	0.08
Digit Backward	4.13 ± 1.96	4.37 ± 2.06	1.00	0.35

Note. M = Mean; SD = Standard Deviation.

Score Comparison of the Post-versus Pre-program Intervention Group

To test the impact of the badminton program on our different study variables, we compare the post-program scores with those of the pre-program. Our results were analyzed by a student t-test, showing significant improvements in executive function for the intervention group. Participants got a significantly higher reading score in the post-program (p = 0.001), and we also found that the inhibition score was significantly higher in the post-program (p = 0.05). Significant results were shown on the cognitive flexibility task (p = 0.05). Concerning the capacity of data related to the short-term memory function, we found a significant difference (p < 0.001) in working memory after the badminton program (p = 0.01). However, the mean score has changed for the MMSE test, but without any significant difference. The complete analysis and measures are presented in Table 5.

Table 5
Comparison of the Score of the Intervention Group Post Versus Pre-program

Measurement	Before Intervention	After Intervention	*t*	p
Stroop Test				
Reading Score	42.39 ± 12.98	49.6 ± 13.31	4.82	0.0013**
Inhibition	31.61 ± 12.62	35.94 ± 11.33	0.95	0.01*
Cognitive flexibility	32.39 ± 11.01	37.28 ± 10.28	0.91	0.02*
Digit Span Test				
Digit Forward	5.78 ± 1.48	7.00 ± 1.50	0.96	0.00003***
Digit Backward	2.56 ± 0.73	4.00 ± 1.41	0.36	0.01*

Notes. M = Mean; SD = Standard Deviation; *p<0,05; **p<0,01; ***p<0,001

Intergroup Comparison of Scores (Post-Pre Program)

To test the interest/impact of the adapted physical activity program on our various study variables, we created new variables called subtractions. These consist of subtracting the scores obtained in pre-program tests from those obtained in post-program tests. We obtain different scores that allow us to highlight the impact of our physical activity program on independent elderly individuals. The complete substractions measures are presented in Table 6.

Table 6
Comparison of Subtraction Scores (Pre and Post-Program) Between the Intervention and the Control Group

Measurement	Before Intervention (M±SD)	After Intervention (M±SD)	*t*	p
Stroop Test				
Reading Score	7.22 ± 4.49	3.06 ± 10.15	1.12	0.28
Inhibition	4.33 ± 4.05	-0.18 ± 9.55	1.29	0.21
Cognitive flexibility	4.89 ± 4.74	-0.19 ± 10.79	1.28	0.22
Digit Span Test				
Digit Forward	1.22 ± 0.44	-0.37 ± 0.52	6.87	< 0.001***
Digit Backward	1.44 ± 1.33	0.25 ± 0.70	2.26	0.03*

Note. M = Mean; SD = Standard Deviation; *p<0,05; **p<0,01; ***p<0,001.

DISCUSSION

This study examined the impacts of physical exercise programs based on multiple badminton activities on cognitive parameters in older healthy adults. 40 participants were taken for data analysis, and both groups were well matched in terms of demographic and initial variables. There was no statistically significant difference in age between the two groups (p = 0.371). However, there was no dropout; however, there was no dropout, and all the participants were stable during the entire follow-up period.

Our results showed that two months of physical exercise positively affected executive function, working memory, and cognitive flexibility, with faster reaction time and reading scores. However, no subcomponent of executive function among individuals in the control group showed significant changes. Patients in the control group have better baseline results in the Degit Backward test than the intervention group; this could be explained by the degree of social interaction with the medical staff and family assistance. According to the overall results of the current research and consistent with previous studies, we believe that a physical training program is a promising way to enhance cognitive characteristics in the elderly population.

Impacts of Physical Exercise on Executive Function

A large number of studies suggest that exercise is an essential method for older people to prevent cognitive decline and chronic diseases. The current study's findings demonstrate the positive effects of physical activity on cognitive function, particularly on executive and memory processes. Many research studies have revealed a significant correlation between cognitive performance and physical exercise (Pindus et al., 2019). The research evidence shows that physical exercise is beneficial for executive function and that improvements are related to the type of training (Colcombe & Kramer, 2003). The World Health Organization (WHO) survey additionally shows the connection between physical activity and enhanced neurocognitive function, especially memory and executive function (WHO, 2008). The findings in the present study are similar to those in other research studies. Low-to-moderate-intensity badminton training helps older people improve their executive function, which includes attention, memory, and calculation skills (Yu & Zhao, 2021). Different types of exercise, such as aerobic, anaerobic, and mental exercise activities, can help healthy older adults improve their mental and cognitive functions (Northey et al., 2018). The study of Takahashi (2019) demonstrates how badminton can stimulate cognitive function (the capacity to use self-control over behavior, emotions, thoughts, and concentration in order to demonstrate the link between physical exercise and cognitive function). An analysis of comparative data revealed that senior racket sport athletes with at least 20 years of experience had a 3.1% quicker reaction time than other athletes, and this improvement is directly linked to the duration and the exercise intensity (Culpin, 2018).

Effects of Physical Exercise on Working Memory

The brain's capacity to simultaneously store and process information is based on working memory, which is one of the most significant aspects of cognitive function. According to pertinent research, physical activity improves cognitive characteristics and has a good impact on working memory, a result similar to that of the present study (Guo, 2022). Different types of exercise may have favorable physiological and neurobiological impacts on WM. Accordingly, Wilke (2020) found that working memory performance does improve following a regular physical exercise program. Ikudome et al. found that even simple balance and resistance exercises can decrease the progression of aging factors and contribute to a healthy lifestyle in older people (Ikudome et al., 2017). Different workouts may stimulate various areas of the brain when playing badminton; the duration and intensity of the selected exercises are directly related to this activation, leading to physiological and psychological improvements. In a badminton match, players must rapidly analyze the shuttlecock information of their opponent, screen out irrelevant data, and then select the right stroke action from their conscious memory. This mechanism contributes to reorganizing brain information and contributes to the development of new skills.

Effects of Physical Exercise on Cognitive Flexibility

Multiple perspectives exist concerning how playing badminton enhances cognitive flexibility. Following previous research, we found in our study that ratings of cognitive flexibility significantly improved with a decreasing in mean values, which was statistically significant (p = 0.02). This enhancement could be attributable to increased concentration and the ability to select the right task and suppress extraneous actions. Several researchers say playing badminton may increase cognitive flexibility and attention (Yu et al., 2022). However, opposing data suggest that racquet sports do not reduce cognitive flexibility in older adults, but rather improve inhibitory control and working memory (Churchill et al., 2002). The chosen exercises in this study focused on distinct movements and approaches related to the activity of badminton, with dual exercises that require a high demand of cognitive performance. The challenges of conducting a trial with older patients should be mentioned as one of the barriers to reaching the established goals, the need for adequate coordination among the different professionals, and the necessary adherence to the physical exercise programs by the participants to obtain the expected benefits.

Limitations

This study has certain strengths and limitations that should be addressed. First, a strength of the current research was that a unique sample of elderly adults participating in badminton physical programs with a more varied range of exercise tasks was used to evaluate the impacts of physical exercises on cognitive function, which may more accurately reflect the psychological and cognitive functioning of older patients. In the Degit Backward test, the control group showed better performance than the intervention group; these differences can reasonably be attributed to the increased amount of personal contact (nursing home routine and social contact with clinical staff) (Katona, 2007). However, the process of two different tests measuring cognitive parameters before the physical intervention may negatively affect mental capacities. Second, social interaction may play a solid role in improving cognitive parameters. The selected program was enrolled between two groups in a social environment, which was beneficial for improving cognitive parameters. Larger sample sizes should be used in future research to provide more representative results. It might be beneficial to extend the intervention time and include multiple tests with the pre-intervention and post-intervention assessments, measuring the degree of physical activity of each patient, the use of drugs, and more baseline assessments such as marital status, work status, and many other variables that can be interesting.

CONCLUSION

In conclusion, this research highlights the importance of physical exercise on cognitive function, demonstrating that regular participation in a badminton physical program may improve and enhance cognitive function in older people. Badminton, due to its multi-component activities, appears to offer significant cognitive advantages. While participants in these physical exercises showed better executive function, short-term memory, working memory, and cognitive flexibility, no significant differences were found in the MMSE test between the two groups. More evaluation of cognitive abilities might be important in future studies.

PRACTICAL IMPLICATIONS

The data from this study reveals several practical applications important for future studies. Physical activity is considered to be an affective treatment in older, healthy adults and for those who suffer from chronic disease and needs to be prescribed to correspond to the mental and physical needs of each patient.

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Authors’ Contributions

The first author contributed to the conception of the article, the second author reviewed the conception and the design, the third author participated to the interpretation and statistical analysis, and the fourth author was responsible for the manuscript's submission and approval.

Declaration of Conflict Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics Statement

The study received ethical approval from the institutional review board committee of the university of Manouba, Higher Institute of Sport and Physical of Ksar Said and the ethical commission of Monastir Hospital on 27 Aprol 2023, numbered HE24FEB2006-B223877.

REFERENCES

Chatelois, J., Van Der Linden, M., Rouleau, N., De Courcy, R., Crépeau, F., & Malenfant, A. (1996). Stroop Flexibilité-4 couleurs.

Churchill, J. D., Galvez, R., Colcombe, S., Swain, R.A., Kramer, A.F., Greenough, W.T. (2002). Exercise, experience and the aging brain. *Neurobiology of Aging*, 23, 941–955. https://doi.org/10.1016/s0197-4580(02)00028-3

Colcombe, S., & Kramer, AF. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol. Sci*, 14,125–130. https://doi.org/10.1111/1467-9280.t01-1-01430

Costanzo, F., Varuzza, C., Menghini, D., Addona, F., Gianesini, T., & Vicari, S. (2013). Executive functions in intellectual disabilities: A comparison between Williams syndrome and Down syndrome. *Res. Dev. Disabil,* 34, 1770–1780. https://doi.org/10.1016/j.ridd.2013.01.024

Diamond, A. (2013). Executive Functions. Annu. Rev. Psychol, 64, 135–168.

Elliott, E. M., Cherry, K.E., Brown, J.S., Smitherman, E.A., Jazwinski, S.M., Yu, Q. (2011). Working memory in the oldest-old: evidence from output serial position curves. *Mem Cogn*, 39, 1423–34. https://doi.org/10.3758/s13421-011-0119-7

Folstein, M. F., Robins, L.N., Helzer, J.E. (1983). The Mini-Mental State Examination. *Archives of general psychiatry*, 40, 812. https://doi.org/10.1001/archpsyc.1983.01790060110016

Frost, N., Weinborn, M., Gignac, G., Markovic, S., Rainey-Smith, SR., Sohrabi, H. R., Martins, R., Peiffer, J., Brown, BM., & Castalanelli, N. (2019). Higher Cardiorespiratory Fitness Is Associated with Better Verbal Generativity in Community-Dwelling Older Adults. *J. Aging Phys*, 27, 703–710. https://doi.org/10.1123/japa.2018-0382

Livingston, G. (2020). "Dementia prevention, intervention, and care: 2020 report of the Lancet Commission," *The Lancet*, 396, 413–446.

Guo, X. (2022). The effect of 8-week Badminton Skills Practice and Stop Practice on Executive Function of junior Middle School students. In Proceedings of the 12th Session of National Sports Science Conference Paper Based Assembly. *Chinese Society of Sports Science*, 325–326.

Hülsdünker, T., Rentz, C., & Ruhnow, D. (2019). The effect of 4- week stroboscopic training on visual function and sport-specific visuomotor performance in top-level badminton players. *Int. J. Sports Physiol. Perform*, 14, 343–350. https://doi.org/10.1123/ijspp.2018-0302

Ikudome, S., Mori, S., Unenaka, S., Kawanishi, M., Kitamura, T., & Nakamoto, H. (2017). Effect of long-term body-mass-based resistance exercise on cognitive function in elderly people. *J Appl Gerontol*, 36, 1519–33. https://doi.org/10.1177/0733464815625834

Kato, K., Iwamoto, K., Kawano, N., Noda, Y., Ozaki, N., Noda, A. (2018). Differential effects of physical activity and sleep duration on cognitive function in young adults. *Journal of Sport and Health Science*, 7, 227–236. https://doi.org/10.1016/j.jshs.2017.01.005

Katona, C. (2007). International Psychogeriatric Association Consensus Statement on Defining and Measuring Treatment Benefits in Dementia. *International Psycho geriatrics*, 19, 345-354. https://doi.org/10.1017/s1041610207005145

Lawton, E., Brymer, E., Clough, P., & Denovan, A. (2017). The relationship between the physical activity environment, nature relatedness, anxiety, and the psychological well-being benefits of regular exercisers. *Frontiers in psychology*, 26, 10-58. https://doi.org/10.3389/fpsyg.2017.01058

Miyake, A., Friedman, N. P., Emerson, M.J., Witzki, A.H., Howerter, A., and Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cogn. Psychol*, 41, 49–100. https://doi.org/10.1006/cogp.1999.0734

Northey, J. M., Cherbuin, N., Pumpa, K.L., Smee, D.J., and Rattray, B. (2018). Exercise interventions for cognitive function in adults older than 50: a systematic review with meta-analysis. *Br. J. Sports Med*, 52, 154–160. https://doi.org/10.1136/bjsports-2016-096587

Oja, P., Kelly, P., Pedisic, Z., Titze, S., Bauman, A., Foster, C., Hamer, M., Hillsdon, M., & Stamatakis, E. (2017). Associations of specific types of sports and exercise with all-cause and cardiovascular-disease mortality: a cohort study of 80 306 British adults. *British Journal of Sports Medicine*, 51, 812–817. https://doi.org/10.1136/bjsports-2016-096822

Pindus, D. M., Drollette, E.S., Raine, L.B., Kao, S.C., Khan, N., Westfall, D.R. (2019). Moving fast, thinking fast: the relations of physical activity levels and bouts to neuroelectric indices of inhibitory control in preadolescents. *J Sport Health Sci*, 8, 301–14. https://doi.org/10.1016/j.jshs.2019.02.003

Culpin, S. (2018). "Effects of long-term participation in tennis on cognitive function in elderly individuals,".

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662. https://doi.org/10.1037/h0054651

Kasai, T. (2021). "Preparing for population ageing in the Western Pacific Region," *The Lancet* Regional Health–Western Pacific, 6. https://doi.org/10.1016/j.lanwpc.2020.100069

Takahashi, S., Grove, P. M. (2019). Comparison of the effects of running and badminton on executive function: A within-subjects design. *PLoS ONE*, 14, e0216842. https://doi.org/10.1371/journal.pone.0216842

Tator, C. H. (2008). Catastrophic injuries in sports and recreation: causes and prevention: A Canadian study. University of Toronto Press. https://doi.org/10.3138/9781442687561

Wechsler, D. (1955). Wechsler Adult Intelligence Scale. New York, NY: The Psychological Corporation.

Wilke, J. (2020). Functional high-intensity exercise is more effective in acutely increasing working memory than aerobic walking: an exploratory randomized, controlled trial. *Scientific Reports*, 10, 12335. https://doi.org/10.1038/s41598-020-69139-z

World Health Organization. (2008). Physical Inactivity: A Global Public Health Problem. Genéve.

Yang, H. (2017). An Experimental Study on the Influence of Different Sports Training on the executive function AND working memory. Master's Thesis. Nanjing Normal University; Nanjing, China.

Yu, Q., & Zhao, H. (2021). The effect of different durations of badminton exercise on executive function of smoking addicts: Evidence from behavioral and ERP studies. The 23rd national conference on psychology based (under). *Chinese Psychological Society*, 173–174.

Yu, Q., Zhao, H., Gao, H., & Qi, H. (2022). Effects of acute badminton exercise on executive function in smoking addicts: Evidence from behavioral and ERP studies. In Proceedings of the 12th Session of National Sports Science Conference Paper Based Assembly. *Chinese Society of Sports Science*, 319–320.