Effect of single bout exercise modalities on multi-domain cognitive function in recreationally active older adults

Efecto de modalidades de ejercicio de una sola sesión en funciones cognitivas multidominio en adultos mayores recreativamente activos

Authors

Syed Murshid Syed Zubir [1]
Adam Linoby [2]
Raja Nurul Jannat Raja Hussain [3]
Tengku Fadilah Tengku Kamalden [4]

[1,2,3] Faculty of Sport Science and Recreation, Universiti Teknologi MARA, Negeri Sembilan (Malaysia)
[4] Department of Sport Science and Recreation, Faculty of Education, Universiti Putra Malaysia, Serdang, Selangor (Malaysia)

Corresponding author:
Syed Murshid Syed Zubir
syedmurshid25@gmail.com

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Abstract

Introduction: The cognitive benefits of a single session of physical activity in older adults are still being studied.
Objective: This study explored the effects of single bout exercise of open-skill and closed-skill on cognitive functions, in physically active older adults.
Methodology: Ninety-nine health elderly were recruited and assigned to three groups: badminton (n = 33), close skill (n = 33), and control (n=33). Cognitive assessments, such as the N-back, Stroop, and Trail Making Tests, were administered before and after the exercise sessions.
Results: ANOVA showed a primary effect of group on N-back reaction time (p = 0.57), with the badminton group (812.3±25.0 ms) showing faster reaction than both the closed-skill (825±35 ms) and control groups (842.1±41.6 ms). In terms of accuracy, the badminton group (75.7±10.4%, p = 0.001) also scored higher than the control group (70.7±12.1%, p=0.001). Both exercise groups showed measurable improvements in TMT-A performance (p = 0.0002), with the badminton group (26.09±3.97s, p = 0.0001) completing the task significantly faster than the control group (32.36±5.92s, p = 0.0001).
Discussion: These findings are in line with studies suggesting that open-skill exercises provide cognitive improvement than closed-skill exercise due to the nature of the exercise.
Conclusions: It is suggested that open-skill exercises may offer result in immediate cognitive improvement than closed-skill activities, particularly in working memory and executive function.

Keywords

Badminton; cognitive function; close-skills; elderly; open-skills.

Resumen

Introducción: Los beneficios cognitivos de una sola sesión de actividad física en adultos mayores aún están siendo estudiados.
Objetivo: Este estudio exploró los efectos de una única sesión de ejercicio de habilidades abiertas y cerradas en las funciones cognitivas de adultos mayores físicamente activos.
Metodología: Se reclutaron noventa y nueve adultos mayores saludables y se asignaron a tres grupos: bádminton (n = 33), habilidad cerrada (n = 33) y control (n = 33). Se realizaron evaluaciones cognitivas, como las pruebas N-back, Stroop y Trail Making Test, antes y después de las sesiones de ejercicio.
Resultados: El ANOVA mostró un efecto principal del grupo en el tiempo de reacción del N-back (p = 0.57), donde el grupo de bádminton (812.3±25.0 ms) mostró una reacción más rápida que los grupos de habilidad cerrada (825±35 ms) y control (842.1±41.6 ms). En términos de precisión, el grupo de bádminton (75.7±10.4%, p = 0.001) también obtuvo una puntuación más alta que el grupo de control (70.7±12.1%, p=0.001). Ambos grupos de ejercicio mostraron mejoras significativas en el rendimiento de la prueba TMT-A (p=0.0002), con el grupo de bádminton (26.09±3.97s, p = 0.0001) completando la tarea significativamente más rápido que el grupo de control (32.36±5.92s, p = 0.0001).
Discusión: Estos hallazgos están en línea con estudios que sugieren que los ejercicios de habilidades abiertas proporcionan una mayor mejora cognitiva en comparación con los ejercicios de habilidades cerradas, debido a la naturaleza de la actividad
Conclusiones: Se sugiere que los ejercicios de habilidades abiertas pueden generar una mejora cognitiva inmediata mayor que las actividades de habilidades cerradas, particularmente en la memoria de trabajo y la función ejecutiva.

Palabras clave

Badminton; función cognitiva; habilidades cerradas; adultos mayores; habilidades abiertas.

Introduction

The relationship between physical exercise and cognitive function throughout the lifespan has been consistently reported, with special focus on its role during aging, when cognitive decline is prevalent (Oishi & Yamasaki, 2024). Most research has focused on the effects of long-term exercise routines, exploring how consistent exercise influences cognitive functioning. Recently, however, there has been a growing interest in the cognitive benefits of single-bout exercise, as independent interventions combined with regular exercise programs (Park et al., 2019). This change is based on the hypothesis that physical activity induces physiological changes such as increased heart rate, shifts in plasma catecholamine levels associated with enhanced stimulation and the production of brain-derived neurotrophic factors that support hippocampal growth, all of which may aid cognitive enhancement (Chen & Nakagawa, 2023). Although meta-analyses generally indicate a small beneficial impact of acute exercise on cognitive function, results are inconsistent with some studies showing negligible, or even adverse effects. This variation may be due to factors such as tiredness in subjects, the duration and intensity of exercise, and the specific type of activity performed.

Cognitive functions refer to the mental processes involved in acquiring and processing knowledge, including memory, attention, and executive functions (Bluma & Lipowska, 2018). Executive functions, which are higher-order cognitive processes, are important for regulating thoughts and actions, including working memory, cognitive flexibility, and problem-solving, all of which are important, for daily functioning (Moreau & Chou, 2019). Regular physical activity has been related with improvements in various cognitive domains, particularly in processing speed, visuospatial abilities, and executive functions, especially among older adults. Over the past two decades, research has regularly shown the cognitive benefits of exercise, with a notable attention on effects in executive function (Zheng et al., 2022). This is especially important given the vulnerability of executive functions to age-related decline. However, while several studies suggest a positive link between exercise and cognitive enhancement across different domains, the overall impact of exercise on cognitive health is not unclear. Further investigation is needed to determine how various forms of exercise may influence this relationship.

Different types of exercise may affect cognition in distinct ways, depending on their cognitive demands and skill requirements, classifying them as open-skill or closed-skill activities. Open-skill exercises, such as badminton, require rapid responses to unpredictable stimuli in dynamic, fast-paced settings (Zhu et al., 2020). As one of the world's most widely played sports, badminton includes mixed-gender participation and allows participation by individuals of different ages and abilities. With its intermittent actions, badminton engages both aerobic (70%) and anaerobic (30%) energy systems (Phomsoupha & Laffaye, 2015). The high physical requirement in badminton may contribute to aerobic capacity, cardiovascular health, metabolic function, body composition, cardiac adaptation, and muscle performance (Alder et al., 2019). In contrast, closed-skill exercises, such as swimming and running, take place in predictable environments and demand less cognitive effort (Ke et al., 2021). This dissociation in effects between and within the same study addresses on widely debated topic of the specificity of the effect of exercise modalities on cognitive function. To date, most research has focused on the inhibitory aspect of executive function which has led to the relative neglect of other subcomponents, including short-term memory and, more broadly, working memory, which is also known to deteriorate with aging (Guo et al., 2016; Peiffer et al., 2015). Interestingly, acute exercise produced stronger effects and more substantial effects (small to moderate effects) on working memory compared to chronic exercise (Rathore & Lom, 2017). Therefore, according to the literature, exercise between two aspects of cognitive function have not been sufficiently studied so far, perception and specifically multisensory perception, and immediate memory.

The present study had the objective to investigate the acute effects of open-skill (badminton) and closed-skill (cycling, swimming, and gym circuit) exercises on multi-domain cognitive functions in older adults, with a focus on working memory and executive functions.

Method

Study populations

A quasi-experimental study design was implemented among an eligible population in Negeri Sembilan, Malaysia. This study design was chosen due to logistical constraints in randomizing participants into different exercise groups and to study naturally occurring behaviors in recreationally active populations while minimizing ethical concerns related to random assignment. Participants were purposefully recruited via email, social media platforms (Twitter, Instagram, and Facebook), instant messaging applications (WhatsApp), and printed poster advertisements. Initially, a total of ninety-nine physically capable elderly individuals (aged > 60 years) were screened for eligibility in the open-skills group, with 33 participants participating in all tests, questionnaires assessments and cognitive function assessment. The minimum required sample size for each target condition was estimated based on an anticipated 15% proportion of elderly badminton players within a population of 351 recreational badminton players in Negeri Sembilan. With a 5% absolute error and type 1 error accounted for, the study determined a minimum sample size of 16 participants per target condition (Charan & Biswas, 2013). The badminton group (RBP) consisted of elderly individuals participating recreationally in badminton, while the closed-skills participant group (CSP) included those involved in cycling, swimming, and gym circuit activities. The control group (CON) was recruited from a regularly participating senior community centre. This selection criterion allowed for any differences observed within the badminton group to be attributed to varying levels of game participation. All female participants were in the postmenopausal phase and had not undergone hormone replacement therapy for at least one year prior to the study. All participants were in and had abstained from dietary supplements, medications, and investigation agents. Written informed consent was obtained from each participant after a detailed briefing on the study protocol, including a detailed explanation of potential risks and benefits. The study protocol received was accepted by the Institute Research Ethics Committee of Universiti Teknologi MARA (REC/UITM/2023/224) and adhered to the guidelines outlined in the latest version of the Declaration of Helsinki.

Procedure

Eligible participants who successfully completed the screening process, directed by a medical personnel, were instructed to report to the Physiology and Nutrition Laboratory at the Faculty of Sport Science and Recreation, Universiti Teknologi MARA, Malaysia. The study included physically healthy elderly individuals, aged 60 and above, who frequently participate in recreational badminton. Upon arrival, participants were provided with a detailed explanation of the study's objectives and procedures. Their weight, height, and waist-to-hip ratio were recorded. The research focused on analysing the lower range of Metabolic Equivalent (MET) values associated with various physical activities in an older population. The activities evaluated assessed were badminton (MET 4.5), cycling (3.5), swimming (4), and gym circuit training (3). To regulate the comparison of MET values, the activities were adjusted to match the MET output of a 30-minute badminton session, which had the maximum-minimum MET value. The 30-minute interval between exercise and cognitive assessment was based on prior research indicating that this timeframe captures the peak physiological and neurochemical effects of acute exercise on cognition (Silakarma & Sudewi, 2019). Consequently, the exercise durations were adjusted as follows: 30 minutes for badminton, 50 minutes for table tennis, 40 minutes each for cycling and swimming, and 50 minutes for gym circuit training. Control sessions consistently lasted 60 minutes. Within 30 minutes of completing their activities, participants returned to the laboratory to answer a questionnaire and undergo computerized cognitive assessments for elderly, including the N-Back Task, Stroop Task, and Trail Making Test (TMT) (Wang et al., 2013; Wu et al., 2016).

Anthropometric measurement

Participants' weights (in kilograms) and heights (in centimeters) were measured using a validated standardized stadiometer (Seca 220; Seca, Ltd., Hamburg, Germany) to calculate their body mass index (BMI). Waist-to-hip ratios were calculated by measuring waist circumference at the midpoint between the last palpable rib and the iliac crest using the Seca 201 tape (Seca, Ltd., Hamburg, Germany), ensuring standardized tension.

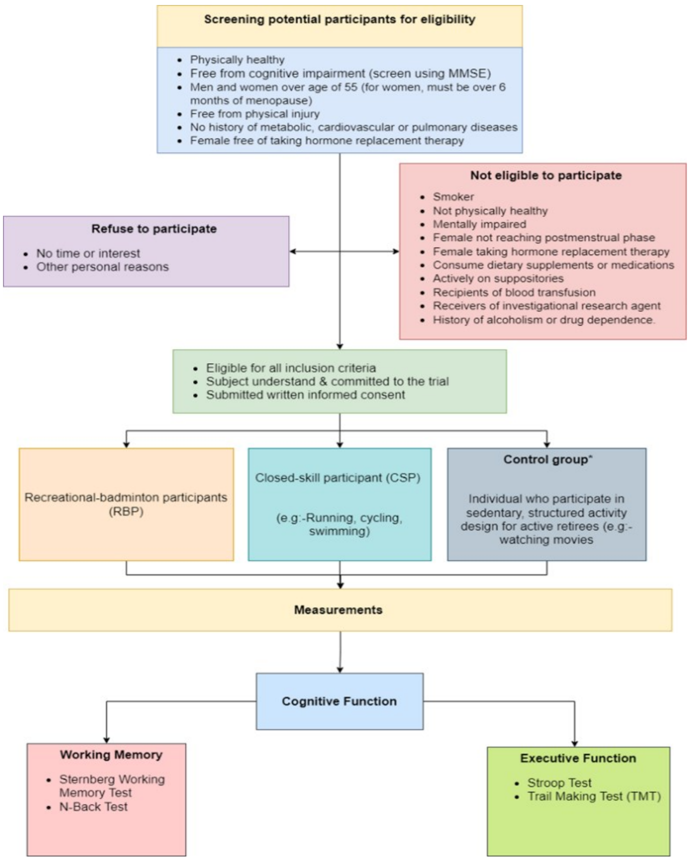
Assessment of working memory

Working memory was assessed using the N-back task and the Sternberg Working Memory Task. The N-back task, a computer-based software task, requires participants to update their mental set-in response to previous stimuli continuously (Jacola et al., 2014). This task includes 14 trials featuring stimuli appearing for 0.4 seconds, with an inter-stimulus interval of 1.4 seconds, under conditions of 0-back, 1-back, and 2-back. The Sternberg Working Memory Task was administered through the Inquisit® software (version 6.0, Millisecond Software, Seattle, USA) (Zakrzewska & Brzezicka, 2014). Each trial involved displaying a sequence of two to five white digits, each for 1200 milliseconds. Participants received visual feedback on the accuracy of their responses. All responses were recorded on the computer for subsequent extraction and analysis. The reliability of the N-back and Sternberg working memory was measured through a coefficient of variation analysis, yielding a reliability of 2.5% (N-back) and 2.3% (Sternberg working memory) from data collected from five participant.

Physical Activity Quiz

Executive function was evaluated using two measures: the Trail Making Test (TMT) and the Stroop test, both administered via Inquisit® software (version 6.0, Millisecond Software, Seattle, USA) (Hirota et al., 2010). TMT assesses attentional capacities and is divided into two segments: TMT-A, which tests rote memory through the sequential connection of numbered circles, and TMT-B, which measures executive function by requiring participants to alternate between connecting numbers and letters. The completion time for each test, including time taken for error correction, constituted the scoring metric for the TMT. The Stroop test required participants to respond to text strings on a custom keyboard, prioritizing speed and accuracy (Goenarjo et al., 2020). This test, lasting 90 seconds per session, measured reaction times and response accuracy. The reliability of the TMT and Stroop test was quantified through a coefficient of variation analysis, yielding a reliability of 2.3% (TMT) and 2.1% (Stroop) from data collected from five participants.

Figure 1. CONSORT of participant requirement. Consolidated Statement of Reporting Trials: [RBP; recreational-badminton participants, CSP; close-skilled participants, CON; control group]



Source: Author

Data analysis

Descriptive statistics were utilized to delineate the basic characteristics of the participants. To investigate differences in cognitive functions working memory and executive function, a one-way repeated measures ANOVA was implemented, supplemented by Brown-Forsythe and Welch tests for robustness. Detailed examination of any noted differences was conducted using Dunnett's T3 multiple comparison tests. In instances of significant disparities, 95% confidence intervals were provided to delineate the probable range of the true values within the sample population. The effect sizes were quantified using partial eta squared (ηp^2) and Cohen's d (dz), categorized as trivial (0 – 0.19), small (0.20 – 0.49), moderate (0.50 – 0.79), or large (> 0.80). All statistical analyses were performed using GraphPad Prism software (version 9.0, GraphPad Software Inc., La Jolla, California, USA), with a threshold for statistical significance set at $p < 0.05$.

Results

Table 1 presents the demographic and anthropometric data of the study cohort, which comprised three groups: RBP, CSP, and CON. These groups exhibited no significant differences in general demographic and anthropometric characteristics. Statistical analysis indicated that the levels of physical activity between the RBP and CSP groups were not significantly different (p > 0.05). In contrast, both exercise groups engaged in significantly more physical activity than the CON group (p < 0.05). Additionally, the years of sports experience and the weekly frequency of sports activities did not differ significantly between the RBP and CSP groups (*p* 0.05). However, the RBP group tended to spend slightly more time in daily sports activities than the CSP group, although this difference was not statistically significant (p > 0.05).

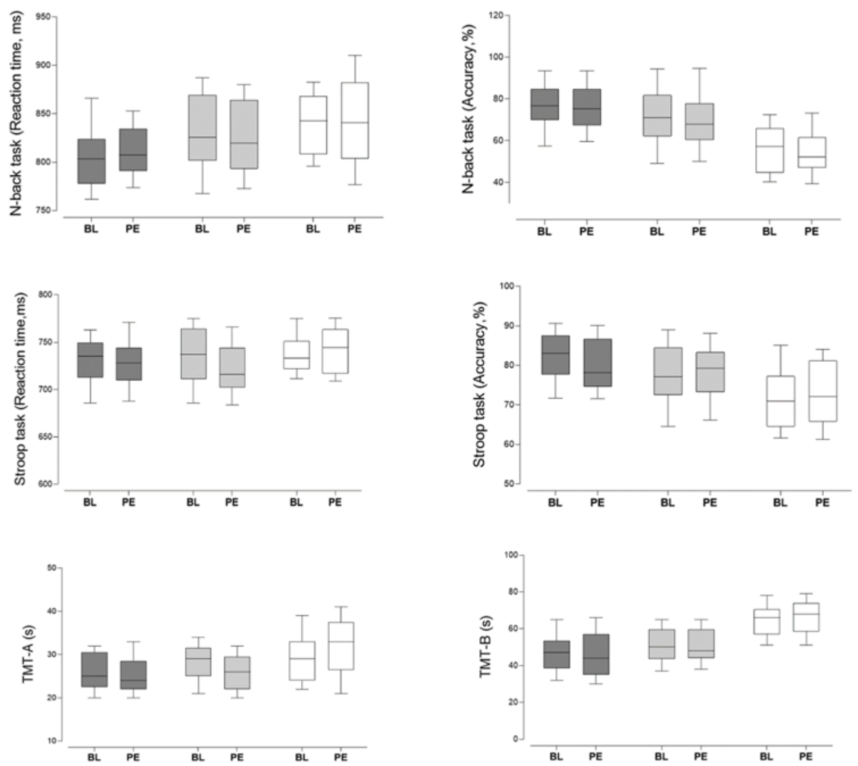
Table 1. Anthropometric, health and physical characteristics in RBP, CSP and CON group

	RBP	CSP	CON
Age	65.7±4.7	65.0±4.4	64.2±2.6
Weight	64.8±4.5	67.2±4.5	66.3±4.5
Height	165±3.9	165±3.5	164±3.4
Playing experience (years)	30.2±6.4	34.5±7.4	-
Playing frequency (days/weeks)	3.57±1.2	3.50±1.2	-
Playing hours (hours/weeks)	7.92±1.7	7.0±3.5	-
IPAQ physical level (MET-min/weeks)	3687±270.2	3581±324.9	3255±416.0

*Significant differences, p<0.05.
Nota: Physical characterisrics.

Figure 1 presents a comparison between groups (RBP vs. CSP vs. CON) and within groups (Baseline: BL vs Post-exercise: PE) across various cognitive tasks, including the N-back task, SWMT, Stroop task, and TMT. ANOVA on N-back task revealed the main effect of group in both reaction time [F (2, 96) = 0.56, p = 0.57] and % accuracy [F (2, 96) = 0.01, p = 0.98, ηp^2:xxx], whereas the main effect of time was significant for reaction time [F (1, 96) = 0.14, p = 0.70] but not for accuracy [F (1, 96) = 0.58, p = 0.44]. Planned comparisons using Bonferroni corrected unpaired samples t-tests revealed that in terms of reaction time, the RBP group (812.3± 25.0.; t(32) = 1.755, p = 0.08, 95% CI = [-32.43 to 6.323], d: 0.42) significantly outperformed both the CSP (825±35; t(32) = 1.755, p = 0.08, 95% CI = [-36.09 to 2.659], d: 0.42) and CON groups (842.1±41.6; t(32) = 3.050, P=0.08, 95% CI = [-49.14 to -10.39], d: 0.88). However, no significant difference between the CSP and CON group in reaction time (p > 0.05) was observed. Accuracy trends paralleled these findings, with the RBP group (75.7± 10.4 t(32) = 2.080, p < 0.05, 95% CI = [14.75 to 25.06], d: 0.45) demonstrating better % accuracy compared to the CON group (70.7±12.1; t(32) = 10.66, p < 0.05, 95% CI = [14.75 to 25.06], d: 0.45), as did the CSP group (55.1±9.7; t(32) = 6.378, P=0.045, 95% CI = [9.521 to 21.61], d: 2.08). Yet, there was no significant difference in % accuracy between the BAD and CSP groups (p > 0.05). Time-dependent changes following single exercise session in accuracy using Holm-Bonferroni corrected paired samples t-tests were notable only in the RBP group, showing a significant improvement post-acute exercise (BL: 76.9±9.8 vs. PE: 75.7±10.4; t(32) = 10.96, P=0.045, 95% CI =[15.24 to 26.02], d: 0.12), while the CSP and CON groups demonstrated no such effect (p > 0.05).

Figure 2. Box plots illustrate group comparisons-recreational badminton participants (RBP, dark grey), closed-skills exercise (CSP, light grey) and control (CON, white) – as well as within group changes from baseline (BL) to post-single exercise session (PE) across cognitive task.



Source: Author

Analysis of reaction time in SWMT revealed a significant main effect of group [F (2, 96) = 10.80, P<0.05], but not of time [F (1, 96) = 1446, P=0.232], and the time x group interaction [F (2, 64) = 2.636, P=0.07]. Notably, the reaction time in the RBP group (1205.1± 24.1 ms; t(32) = 5.120, p < 0.05, 95% CI = [-45.25 to -19.58], d: 0.76) was significantly faster than that of the CON group (1227.4±34.2 ms; t(32) = 5.120, p < 0.05, 95% CI = [-45.25 to -19.58], d: 0.76), as was the reaction time in the CSP group (1238.1±24.6 ms t(32) = 1.457, p = 0.155, 95% CI = [-34.66 to -8.979], d: 1.38) compared to the CON. However, there was no significant difference between the RBP and CSP groups (p > 0.05). In terms of accuracy, there was a significant main effect of group [F (2, 96) = 75.37, P<0.001], but the main effect of time was not significant [F (1, 96) = 0.433, p = 0.512]. The % accuracy in the RBP group (77.8 ± 7.51; t(32) = 7.964, p < 0.05, 95% CI = [8.106 to 16.00], d: 1.88) was significantly higher compared to the CON group (65.7± 5.35; t(32) = 7.964, p < 0.05, 95% CI = [8.106 to 16.00], d: 1.88), as did the accuracy in the CSP group (74.7 ± 8.52; t(32) = 5.305, p < 0.05, 95% CI = [-0.8271 to 7.070], d: 0.39). However, the comparison between RBP and CSP groups in terms of % accuracy revealed no significant difference (p > 0.05).

Analysis of reaction time in Stroop task indicated a significant difference between time x group interaction [F (2, 96) = 1.483, P = 0.2322], significant main effect of group [F (2, 96) = 3.0305, p = 0.0409] and no significant main effect of time (F (2, 96) = 2.056, P = 0.1549]. Conversely, in terms of % accuracy, the results were more varied. While the time x group interaction was not significant [F (2, 96) = 1.483, p = 0.2322], there was a significant main effect of group (F (2, 96) = 28.92, P<0.001]. However, the main effect of time was not significant [F(1, 96) = 0.006977, p = 0.9336] Post-hoc comparison revealed a significant difference between the RBP group (79.9 ± 6.35; t (32) = 4.948, P<0.001, 95% CI = [3.669 to 10.29], d: 1.05) and the CON group (73.5 ± 5.93; t (32) = 4.948, p < 0.05, 95% CI = [3.669 to 10.29], d: 1.05). However, no significant differences were found when comparing the RBP group with the CSP group (both p > 0.05). For the TMT-A test, the time x group interaction was significant [F (2, 96) = 9.647, P=0.0002], a significant main effect of group also was found [F (2, 96) = 17.53, p < 0.05]. The main effect of time was not significant [F (1, 96) = 0.00536, P=0.9418]. Post-hoc analyses revealed a significant difference between the RBP and CON groups, with the RBP group completing TMT-A faster (26.09 ± 3.97 vs. 32.36 ± 5.92; t(32) = 4.661, p < 0.05, 95% CI = [-9.824 to -4.540], d: 1.26) and significant difference between CSP and CON group, with CSP completing TMT-A faster (25.18 ± 3.18 vs. 32.36 ± 5.92; t(36.44)

= 2.528, p = 0.016, 95% CI = [-8.915 to -3.631], d: 1.53). However, no significant differences were observed between the RBP and CSP groups (p > 0.05). For the TMT-B test, significant main effects of group [F (2, 96) = 70.82, p < 0.05] were present. In the post-hoc analysis, the RBP group (45.42 ± 10.9, t(32) = 8.729, p < 0.05, 95% CI = [-25.87 to -15.16], d: 2.11), significantly outperformed the control group (65.93±8.70; t(32) = 8.729, p < 0.05, 95% CI = [-25.87 to -15.16], d: 2.11), as did the CSP group (50.00 ± 8.47; t(32) = 7.388, p < 0.05, 95% CI = [-21.30 to -10.58], d: 1.88) compared to the CON group (65.93±8.70; t(32) = 7.388, p < 0.05, 95% CI = [-21.30 to -10.58], d: 1.88). No significant difference was found between the RBP and CSP groups (p > 0.05).

Discussion

This study aimed to investigate the effect of single-bout exercise modalities on cognitive function in recreationally active older adults. Following several psychometric measurements, the results indicate that participation in a single bout of badminton yielded greater improvements in cognitive performance, particularly in working memory and executive function, compared to closed-skill exercises and sedentary control conditions. These findings provide useful insights into the cognitive advantages of specific exercise types in older adults, suggesting that open-skill sports may provide specific cognitive advantages not seen in rigid activities.

Our study showed that participants in the RBP group exhibited significant improvements in working memory performance and reaction time (N-back task, Sternberg working memory task), compared to the CSP group and the CON group. These findings are consistent with previous studies that suggest open-skill sports, such as badminton encourage greater cognitive flexibility and quicker reaction times due to the unpredictable and dynamic nature of the activity (Zhu et al., 2020). In contrast to close-skill sports, which typically involve repetitive and less cognitively demanding tasks, open-skill sports require continuous modification to external stimuli (Gökçe et al., 2021), which may explain the enhanced cognitive performance observed in the badminton groups. The improvements in reaction time and accuracy among badminton players further support corroborate the notion that dynamic sports positively affect processing speed and decision-making (Ke et al., 2021). Furthermore, the RBP group consistently performed better than both the close-skill and control groups in tasks assessing cognitive processing speed and accuracy. The improvements in the N-back task and Stroop test suggest that participation in open-skill sports improves both cognitive speed and precision. This is due to more substantial concentration demands during gameplay (Formenti et al., 2021). Prior research has indicated that dynamic sports contribute to faster cognitive responses because of the need for quick and accurate decision-making in unpredictable environments (Wang et al., 2023). This may account for the badminton for higher performance levels in both reaction time and accuracy compared to the close-skill group (Gu et al., 2019). Another finding that stands out from the results reported earlier is executive function, particularly cognitive flexibility and inhibition was significantly improved in the RBP group, was evidenced by their superior performance on the Stroop and Trail Making Tests (TMT-A and TMT-B). These findings are in line with studies suggesting that sports involving rapid decision-making and motor adaptation lead to greater improvements in executive function (Feng et al., 2023). The higher cognitive load imposed by open-skill sports, such as the need to anticipate opponents' actions and adjust movement patterns in real time, may strengthen neural networks associated with executive function (Möhring et al., 2022). Although the closed-skill exercise group also demonstrated improved executive function compared to the control group, the differences were less pronounced. This suggests that while physical activity in general supports cognitive health, the degree of cognitive engagement required by a specific activity plays a crucial role in determining the extent of cognitive benefits (Tsai et al., 2016). Previous studies have indicated that closed-skill exercises contribute to executive function improvement through increased blood flow, neurotrophic factor release, and metabolic regulation (Tsai et al., 2017). However, the relatively passive nature of closed-skill activities likely explains the lesser improvements observed in this study compared to open-skill sports. Moreover, both exercise groups demonstrated improvements in TMT-A performance, which assesses visual attention and task-switching ability. However, the badminton group showed a more significant reduction in completion time compared to the closed-skill group. This supports the hypothesis that exercise modalities requiring continuous adjustment and adaptive motor planning may have stronger effects on attentional control and cognitive flexibility (Tsai & Wang, 2015).

The findings of this study have significant implications for cognitive and emotional health in older adults, particularly those involved in recreational physical activities. The superior performance of the badminton group in working memory, executive function, and processing speed indicates demonstrates that open-skill sports, which require continuous adaptation to dynamic environments, yield cognitive advantages distinct from those provided by close-skill exercises. These results have practical relevance for designing cognitive health interventions targeting aging populations. Open-skill sports such as badminton in regular physical activity programs may be an effective approach to mitigating age-related cognitive decline and fostering cognitive stability. Furthermore, the emotional well-being improvements observed in the badminton group, such as lower levels the depression and anxiety, underscore the possibility of these activities to promote both mental and emotional health. These findings imply that open-skill sports may be integrated into interventions for older adults, addressing both cognitive and emotional aspects of well-being.

From a public health standpoint, the study suggests the endorsement of open-skill sports in community programs for older adults. The cognitive and emotional benefits observed in this study emphasize the importance of diverse physical activities for aging populations. As life expectancy increases, and more individuals seek ways to maintain cognitive function and independence in later life, integrating dynamic physical activities into public health strategies is important. Badminton, a low-cost, socially interactive activity, provides a feasible option that can be implemented in various community settings to promote both physical and cognitive health. Additionally, these findings could assist policymakers and healthcare providers in recognizing the specific advantages of open-skill activities for long-term mental health, encouraging the development of tailored exercise programs that support both cognitive function and emotional well-being in older adults.

One key limitation of this study is its relatively limited sample size, which narrows the scope of the findings. Although the study included 36 recreationally active participants across three groups (RBP, CSP, and CON), this sample might not fully reflect the larger population of older adults, potentially affecting strength and precision of the results. Additionally, the limitation to one geographical area further limits the relevance of the findings to populations with different demographic or cultural backgrounds. Another limitation is the short-term nature of the exercise intervention, as the study measured cognitive and emotional outcomes based on a single bout of exercise. While these results offer an understanding into the acute effects of various exercise modalities, they do not capture extended outcomes. Future research should expand the sample size, include more diverse populations, and adopt a longitudinal approach to examine the sustained cognitive and emotional benefits [ongoing psychological and emotional advantages, long-lasting cognitive and emotional outcomes, enduring cognitive and emotional effects of continued engagement in open- or close-skill sports.

Conclusions

In conclusion, the results of this study suggest that open-skill exercise, specifically badminton, provides greater cognitive benefits compared to closed-skill activities and sedentary behavior in older adults. The observed improvements in working memory, executive function, and processing speed highlight the potential of cognitively engaging sports as effective interventions for maintaining cognitive health in aging populations. These findings emphasize the importance of considering the cognitive demands of exercise when designing physical activity programs for older adults. Future research should explore the long-term impact of different exercise modalities on cognitive aging and investigate potential neurobiological mechanisms driving these effects.

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Authors' and translators' details:

Syed Murshid Syed Zubir	syedmurshid25@gmail.com	Author
Adam Linoby	linoby@uitm.edu.my	Author
Raja Nurul Jannat Raja Hussain	nuruljannat@uitm.edu.my	Author
Tengku Fadilah Tengku Kamalden	tengku@upm.edu.my	Author