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Original Article

Influence of recreational badminton playing on blood pressure and cognitive function in the elderly: a cross-sectional analysis with playing time-stratified sampling

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Abstract
Habitual exercise may be the key to success for the primary prevention of cardiovascular diseases and cognitive decline in the ageing population. The aim of this study is to investigate whether playing badminton at different time durations will elicit changes in blood pressure indices and working memory (the measure of cognitive function). Ninety-eight elderly recreational badminton players (>55 years old) are screened. 36 eligible players are later stratified into high-playing time (n=18; 9.72 ± 2.16 hours·week^{-1}) and low-playing time (n=18; 3.34 ± 1.53 hours·week^{-1}) badminton groups. Non-racquet sports playing control subjects are also recruited. Blood pressure was measured using an automated sphygmomanometer, while working memory was measured using Sternberg working memory task. The results indicate that systolic blood pressure and mean arterial pressure are significantly lower ($p<0.01$; $p<0.05$) in the high-playing time group (122 ± 9.68 mmHg; 94.1 ± 6.4 mmHg) compared to the control group (129 ± 9.42 mmHg; 98.6 ± 6 mmHg), respectively. No differences in diastolic blood pressure are observed (p>0.05). The mean arterial pressure also tends to be lower in the low-playing time group compared to the control group ($p = 0.85$). No differences are found between the resting blood parameters of the high-playing time group and the low-playing time group. No significant differences are present in the accuracy and reaction time of the Sternberg working memory task for all three groups (p>0.05). Overall, the present study found that the elderly in the high weekly badminton playing group have a better blood pressure profile than the non-badminton playing group. No differences are detected in the working memory of all three groups (high-playing time, low-playing time and control subject groups).
Keywords: - Physical activity, Cognitive, Blood pressure, Working memory, Elderly

Introduction

Since its debut at the 1992 Olympic Games, badminton has become one of the most highly viewed sports worldwide. Badminton was established as a high-intensity intermittent sport due to its nature: the rapid and frequent transitions from low to high metabolic rates (Pardiwala et al., 2020). The combination of high-intensity short rallies and longer rallies during a badminton game requires work from both aerobic (approximately 30%) and anaerobic systems (approximately 60-70%) concerning the lactic anaerobic metabolism (Gomez et al., 2020). The physical demands of playing badminton have increased due to the game's evolution to longer rallies with a rapid number of strokes per rally (Pardiwala et al., 2020). Physical inactivity is responsible for 9% of all deaths worldwide (Lee et al., 2012). The lack of physical exercise is regarded as having far-reaching health, economic, environmental and societal implications. Awais et al. (2018) stated that physical inactivity can have serious consequences, especially for the elderly. A low level of physical activity is also related to the development of disabilities in older adults. Physical and physiological aspects are lost as a result of physical inactivity (Singh et al., 2002).

In model studies of both animals (Roh et al., 2020) and humans (Herrod et al., 2018; Linoby et al., 2020), physical activity has shown to have both short- and long-term favourable impacts on systemic blood pressure (BP). Regular participation in long-term exercise can reduce the BP level by 10–20 mm Hg (Pedralli et al., 2020). A systematic review and meta-analysis of randomised control trials by Herrod et al. (2018) found that both moderate to high-intensity training led to a significant reduction in systolic BP and mean arterial pressure. Logically, prolonged and intense badminton playing can lead to a positive outcome on the hemodynamic response. This is particularly relevant for the ageing population in which the prevalence of hypertension is high and may lead to a greater risk of cardiovascular disease (CVD) and mortality rate. Other than the benefit of reducing the risk of cardiovascular diseases, growing evidence indicates that physical activity can also positively influence cognitive function in the elderly population. One of the most important aspects of cognitive function is

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a working memory, especially among the senior population. Working memory is defined as the brain mechanism that provides temporary capture of information and manipulation for ongoing complex tasks (Kato et al., 2018). Working memory and enhanced general cognitive functions may be the favourable outcomes of performing long-term physical activity. Accordingly, Wilke et al. (2020) found that working memory performance does improve following moderate to high-intensity exercise training. Participation in racquet sports as a form of physical activity and fitness has increased in recent years (Tator et al., 2008). In a cohort study conducted by Oja et al. (2017), participation in racquet sports was associated with a reduction in all-cause mortality (47%) and cardiovascular disease death (53%). There is evidence that the time duration spent in playing racquet sports affects physiological and cardiometabolic responses. Docherty et al. (1982) discovered that the length of time spent playing racquet sports affects the heart rate response. It was also found that playing 30 minutes of badminton and squash could raise the heart rate by up to 80%-90% of the maximum heart rate. The study further stated that during gameplay, oxygen consumption could reach up to 65% of V_{O2max}, with caloric expenditure as high as 10 $kcal \cdot min^{-1}$. In this context, regularly playing badminton may provide an excellent non-pharmacological approach to slow age-related decline in cognitive deterioration and impairment for older adults.

Despite the obvious links between positive health effects and regular participation in various types of exercise, very few studies have investigated whether participation and overall playing time in racquet sports (such as badminton) elicit differences in BP status and cognitive function in the ageing population. Therefore, the objective of the present study is to investigate whether different badminton playing times cause variations in BP and working memory tasks. We hypothesise that the higher badminton playing time group will exhibit lower BP indices and higher scores in Sternberg working memory task (SWMT) as a measure of cognitive function in active, healthy seniors.

Material & methods

Participants

A population-based analytical cross-sectional design was adopted in the current study for assessing eligible populations in Negeri Sembilan, Malaysia. Participants were purposively recruited via email, social media channels (i.e., Twitter, Instagram and Facebook), instant messaging applications (i.e., WhatsApp) and printed advertisements. All study procedures were approved by the Research Ethics Committee (REC/06/2022-PG/MR/127) and completed in accordance with the requirements of the Helsinki Declaration 2013. Prior to its commencement, this study was registered in the UMIN Clinical Trials Registry with the registration identification number UMIN000047240 (Linoby et al., 2021). Accordingly, ninety-eight seniors (>55 years old) were initially screened for eligibility in participating in the current research. Based on the 15% estimated population of elderly badminton players from a total of 651 recreational badminton players (approximate data from badminton clubs across Negeri Sembilan) and a 5% absolute type 1 error, this study estimated a minimum sample size of 16 in each target condition (Charan & Biswas, 2013). A recreational badminton player is defined as an individual with no less than 5 years of badminton playing experience and plays at least once a week (in the past 2 years) for no less than 30 minutes per session. Non-racquet sports playing control subjects (CON) were recruited to serve as a baseline for this study. A similar inclusion criterion which applied to the badminton group was also used for the recruitment of the CON group. The only difference was that participants in the CON group did not recreationally play any type of racquet sports in the past 5 years.

Study Protocol

All eligible and voluntary subjects that passed the screening procedure conducted by the medical technician and medical assistant were requested to make themselves present at the Physiology and Nutrition Laboratory at the Faculty of Sport Science and Recreation at Universiti Teknologi Mara, Negeri Sembilan Branch, Seremban Campus, Malaysia. The elderly who are physically healthy (free from any medical diseases) and recreationally playing badminton (>50 years old and above) were recruited for this study. Following anthropometric measurements, the participants were placed in a quiet room with a thermoneutral temperature of ~22°C for a 10-min resting BP reading. Next, all subjects were asked to complete the cognitive function test and fill out the questionnaires (i.e., Global Physical Activity Questionnaire, GPAQ and modified Physical Activity Scale for Elderly, PASE) in a structured manner before leaving the testing centre (Linoby et al., 2020). The rank stratification analysis was used to assign participants to either the high-playing time (HPT) or low-playing time (LPT) badminton groups.

Measurement

The anthropometric measurements of weight (kg) and height (cm) were determined using a validated stadiometer (Seca 220; Seca, Ltd, Hamburg, Germany). Subjects stood upright against the wall-mounted stadiometer without shoes and in light clothing during the measurement, as advised by Asraff et al. (2022). The weight (kg) and height (cm) measurements were taken to calculate the body mass index (BMI). A measuring tape was used for the waist-to-hip ratio reading. The waist circumference was measured at the centre point between the last palpable rib at the lowest margin and the top of the iliac crest using the Seca 201 tape (Seca, Ltd, Hamburg, Germany) which provided constant pulling tension. Participants were then seated on a comfortable chair in a quiet room with a thermos-neutral temperature of ~22°C for 10 minutes to measure the resting BP using an automated sphygmomanometer (AccutorrPlus, Paramus, NJ, US). With the arm at heart level, 5 resting BP measurements were recorded for each participant with 15-second intervals between each measurement (Eguchi et al., 2009). The average of the final four measurements was recorded for data analysis. The systolic BP and diastolic BP data were examined to calculate the mean arterial pressure (MAP) using the standard formula: (⅓·systolic BP) + (⅔·diastolic BP).

The Sternberg working memory task was implemented using a psychological measurement tool (Inquisit® version 6.0, Millisecond Software, Seattle, USA) as described by Jumat et al. (2021) and Tang et al. (2021). Each task trial consisted of a set of two to five white digits presented in a sequence (1200 milliseconds each). A yellow probe digit appears after the last digit, at which point participants were required to press an appropriate button indicating whether the digit was present in the previously displayed sequence. Participants were provided with visual feedback regarding the accuracy of their response. All responses were recorded on the computer and subsequently tabulated for further analysis. Physical activity levels were determined using the GPAQ, as previously described by Goenarjo et al. (2020). The total time spent and energy expenditure for specific activities during a week were measured and converted to metabolic equivalents (MET-min·week^{-1}). The badminton playing time was evaluated using the weekly badminton-playing records and a modified Physical Activity Scale for Elderly (PASE) questionnaire. To stratify the badminton group, the total playing time (hr·week^{-1}) was ranked as reported by the group. From a total of 36 eligible participants in the badminton playing group, ranks #18 and #19 were selected with a total playing time of 6.6 hr·week^{-1} and 7.5 hr·week^{-1}, respectively. Hence, the median of 7.05 hr·week^{-1} was used as the cut-off value to divide the badminton group into HPT (9.72 hr·week^{-1}) and LPT (3.34 hr·week^{-1}).

Statistical Analysis

Differences in badminton playing history characteristics were analysed using an independent sample *t*-test. A one-way repeated measure using Brown-Forsythe and Welch ANOVA was accomplished to detect the differences between the groups regarding physical attributes (height, weight, BMI and age), resting BP indices (systolic BP, diastolic BP and MAP) and cognitive function (working memory response). The origins of any significant effects were subsequently identified via Dunnett's T3 multiple comparison test. The GraphPad Prism software (version 9.0, GraphPad Software Inc., La Jolla, California, USA) was used for all data analyses, with statistical significance accepted at $p<0.05$.

Results

From the 98 individuals screened for eligibility, 36 (36.7%) participants successfully completed this study (HPT, *n*=18; LPT, *n*=18 and CON, *n*=18). As for the individuals excluded from the study, 5 (5.1%) from the badminton group stated that they were unable to continue due to personal reasons, and 22 (22.5%) were excluded for recreationally participating in sports other than badminton. The considerable number of screened individuals (*n*=35, 35.7%) did not meet the inclusion criteria. Table 1 outlines the anthropometric measurements, badminton playing history and physical activity characteristics of the three groups. A total of 32 participants (58.2%) are men, and 22 participants (41.8%) are women. No differences were present in basic anthropometric characteristics (height, weight, BMI, age and waist-to-hip ratio) between HPT, LPT and CON groups ($p>0.05$). The table shows that the years of experience in playing badminton are similar between the HPT and LPT groups ($p>0.05$). The frequency of playing badminton per week, the hours of play per day and the total time of play per week were higher in the HPT group than the LPT group ($p<0.05$). The vigorous physical activity derived from GPAQ was higher in HPT compared to LPT and CON ($p<0.05$), with no difference present between LPT and CON ($p>0.05$). No significant differences were found in the GPAQ's total physical activity level between HPT (3397 ± 913 MET-min·wk^{-1}), LPT (3308 ± 1037 MET-min·wk^{-1}) and CON (3180 ± 1186 MET-min·wk^{-1}) ($p>0.05$).

Table 1. Physical measurements, badminton-playing history, and physical characteristics between groups.

Parameter	HPT	LPT	CON
Age	64.2 ± 2.81	63.3 ± 2.59	64.9 ± 2.89
Weight (kg)	64.8 ± 4.52	6.72 ± 4.58	66.3 ± 6.39
Height (cm)	165 ± 3.95	165 ± 3.58	164 ± 3.48
BMI (kg·m^{-2})	23.9 ± 1.46	24.8 ± 2.34	24.6 ± 2.31
Waist-to-hip ratio	0.90 ± 0.19	0.91 ± 0.12	0.92 ± 0.11
Playing experience (yrs)	28.6 ± 1.33	24.3 ± 3.03	-
Badminton playing frequency (day·week^{-1})	4.72 ± 1.13^{a}	2.28 ± 1.02	-
Badminton playing hours (hrs·day^{-1})	2.14 ± 0.56^{a}	1.51 ± 0.50	-
Total badminton playing time (hrs·week^{-1})	9.72 ± 2.16^{a}	3.34 ± 1.53	-
Total physical activity level (METs)	3397 ± 913	3308 ± 1037	3180 ± 1186
Light intensity physical activity	1224 ± 160	1218 ± 513	1360 ± 452
Moderate intensity physical activity	1167 ± 252	1290 ± 409	1181 ± 477
Vigorous intensity physical activity	1114 ± 198	823 ± 248	716 ± 370

^{a} Significantly different from LPT ($p<0.05$).

Blood pressure

Figure 1 presents the differences in resting BP between the three groups. Resting systolic BP and mean arterial BP are affected by group conditions ($F_{[2–51]} = 2.4$; $p = 0.91$; $\eta^2_p = 0.08$ and $F_{[2–51]} = 2.7$; $\eta^2_p = 0.09$, respectively), but not resting diastolic BP (p>0.05). Follow-up tests revealed that resting systolic BP and mean arterial pressure were lower in both HPT and LPT compared to CON (p<0.05). The mean arterial pressure was lower in the LPT group compared to CON (p=0.85), but not systolic BP (p>0.05). No differences between the HPT and LPT groups were detected for resting BP parameters.

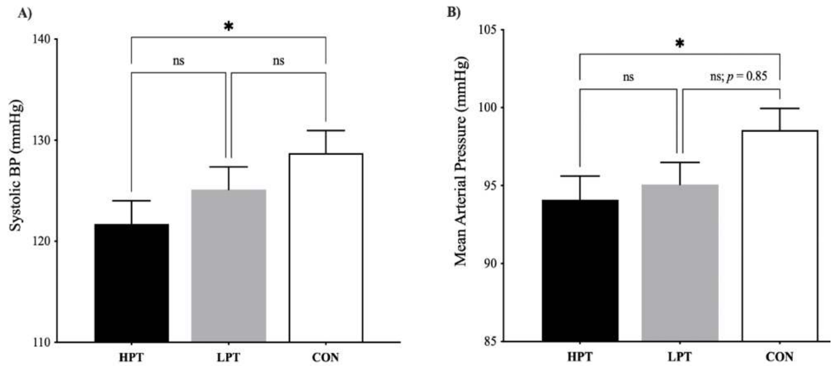

Fig. 1 Resting blood pressure (BP) indices measured for high-playing time (HPT), low-playing time (LPT) and control (CON) groups. * Significant differences between groups ($p < 0.05$). a non-significance statistical result is denoted as 'ns' (p>0.05). Note that mean arterial pressure tended to be lower in LPT compared to the con group (p=0.85).

Working Memory

For the working memory task (a measure of cognitive function), no significant differences were found in the accuracy and reaction time of SWMT for all three groups (Table 2; $p > 0.05$).

Table 2. Differences in Sternberg working memory task score in high-playing time (HPT), low-playing time (LPT), and control (CON) groups.

Parameter	**HPT**	**LPT**	**CON**
Sternberg working memory task (*accuracy*)	0.97 ± 0.03	0.97 ± 0.04	0.95 ± 0.06
Sternberg working memory task (*reaction time*)	0.97 ± 0.19	0.97 ± 0.14	0.96 ± 0.15

Discussion

This is the first study that compares the extent of racquet sports activity time and its effect on BP and cognitive health in those aged 55 years and above. The key finding from this study is that under the condition of similar daily physical activity levels, badminton participants in the HPT group exhibited lower resting BP compared to the CON group. No differences in working memory were found between the three groups. Habitual participation in physical activities may be the key factor for the primary prevention of chronic diseases in the elderly population. Badminton is one of the world's most popular sport, enjoyed by people of all ages. The game's intermittent nature places considerable demand on both aerobic and anaerobic systems, with a bigger contribution from the alactic anaerobic system compared to the lactic anaerobic energy contribution(Pardiwala et al., 2020). These characteristics include total playtime that lasts around 30–50 minutes of highly explosive bursts (range between 4–8 seconds) followed by short recovery periods (range between 5–15 seconds) (Gomez et al., 2020). It has been conclusively shown that the work density (i.e., the ratio of performance time to rest time) of badminton games is greater compared to other intense team sports, such as soccer (Lam et al., 2018).

The beneficial effects of regular exercise on BP have been previously demonstrated by Caminiti et al. (2019). The present study found that resting systolic BP and MAP in the HPT group were lower by ~5.4% and ~4.8%, respectively. This is because the HPT group played badminton more frequently during a week as compared to the CON group ($p < 0.05$). Indeed, regular participation in high-intensity intermittent exercise has shown to improve the hemodynamic response of the elderly in both clinical (Fu et al., 2020) and non-clinical trials (Linoby, Nurthaqif, et al., 2020; Roh et al., 2020). Consistent with the current study, Ramirez-Jimenez et al. (2021) found that a month of high-intensity intermittent training significantly reduced the resting systolic BP by ~5.7%, but not diastolic BP. The hypotensive effect in older adults was even greater in high-intensity intermittent exercise when compared to other exercise modalities, such as resistance training and moderate continuous training (Pimenta et al., 2019).

However, not all studies have observed the beneficial BP-lowering effects of high-intensity intermittent exercise in the elderly population. A systematic meta-analysis of 13 relevant studies on older adults found that both systolic BP and diastolic BP only improve with intermittent training, yet they were not statistically lower than the control group (Maturana et al., 2021). Such discrepancies may be due to the differences in various training intensities used in the mentioned studies. Further analysis of the same research revealed that training at 80% $\dot{V}_{O2max}$ or greater intensity resulted in better hemodynamic response (Huang et al., 2019). Therefore, such differences in BP levels between the groups in the present study may be due to longer involvement in moderately vigorous intermittent activities (i.e., badminton). Reductions in BP within the normal range is clinically significant, especially among ageing adults. While the absolute difference in systolic BP (Δ 7 mmHg) and MAP (Δ 5 mmHg) between HPT and CON may seem insignificant in absolute terms, it is substantial when considering that a mere 5 mmHg reduction in BP is related to a 35% decrease in the risk of strokes and coronary heart disease (Dewhurst-Trigg et al., 2018; Filippone et al., 2021). This is significant since cardiovascular disease is very common and the leading cause of preventable illness and death in older adults.

Regular physical exercise may provide an excellent non-pharmacological approach to slow age-related decline and reduce disease-related cognitive impairment in seniors (Wheeler et al., 2020). There is growing evidence that physical activity, such as aerobic exercise, improves cognitive functions; especially prefrontal cortex-dependent cognition (Wilke et al., 2020). Involvement in regular physical activity has been shown to increase the volume of the hippocampus, prefrontal cortex and basal ganglia, allowing the brain to work more efficiently and improve overall cognitive function (Linoby, Jumat, et al., 2020; Srinivas et al., 2021). Srinivas et al. (2021) found that physical activity and fitness are associated with larger bilateral hippocampal volume. Greater fitness and hippocampal volume are associated with better spatial memory performance. Research that measured brain connectivity using Functional Magnetic Resonance Imaging suggest that the brain of older adults with higher levels of fitness work more efficiently than those with lower levels of fitness (Herold et al., 2020; Linoby, Md Yusof, et al., 2020). However, the present study did not detect any significant difference in the accuracy and reaction time from the Sternberg task results between the three groups. The exact reason why remains unclear. It has been suggested that two or more psychometric tests that analyse different components of cognitive function are needed to precisely assess the mental capacity of a human subject, particularly in the ageing population (Manohar et al., 2019).

Conclusion

The results of the current investigation demonstrate that with similar daily physical activity levels, the elderly in the high badminton playing time group exhibited better BP status than the control group. This does not apply to cognitive function levels measured by the working memory task since the outcomes were similar between the groups. It was also noted that elderly individuals, whether spending more or less time playing badminton, have no differences in both parameters of interest (i.e., BP and cognitive function). This study will benefit physicians and encourage the elderly population to stay active and play recreational badminton. The lifespan of elderly individuals may lengthen if they spend more time playing badminton since greater benefits in blood pressure and cognitive function were seen. The elderly who participates in recreational badminton with appropriate playing durations will significantly benefit by enhancing their health. The present study contributed to providing additional knowledge on how playing recreational badminton positively alters physiological and cognitive health, especially in the ageing population.

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