Yi et al. BMC Public Health (2025) 25:1081
https://doi.org/10.1186/s12889-025-22321-2

BMC Public Health

RESEARCH

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# Physical activity and cognitive function among community-dwelling older adults: a mediating role of functional fitness

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## Abstract

**Background** The positive correlation between physical activity and cognitive function has been increasingly documented, while the underlying mechanisms remain unclear.

**Methods** This study aimed to investigate the association among physical activity (PA), functional fitness, and cognitive function in community-dwelling older adults, and to examine whether functional fitness mediates this association. This study utilized a cross-sectional design, encompassing 224 participants aged 65 or above, with 41.07% male and 58.93% female. The data were collected in 2023 using the Mini-Mental State Examination, Physical Activity Scale for the Elderly, and Senior Fitness Test. Pearson correlation analysis was conducted to assess associations among the variables, and mediation analysis was performed using the PROCESS macro for SPSS.

**Results** The results indicated that PA had a moderate positive correlation with cognitive function ($r = 0.437$, $p < 0.01$) and with most functional fitness domains. In addition, significant positive correlations were found among most functional fitness domains and cognitive function. The association between PA and cognitive function was partially mediated by cardiorespiratory endurance (Effect = 0.0519, 95% CI= [0.0205, 0.0889]).

**Conclusion** This study demonstrated a positive correlation between PA and cognitive function in older adults, with cardiorespiratory endurance mediating this association. Our study provides valuable preliminary evidence that cardiorespiratory endurance exerts a mediating role between PA and cognitive function. Future longitudinal research is warranted to elucidate the causal relationship and underlying mechanisms between PA and cognitive function.


**Keywords** Cognitive performance, Elderly, Fitness, Physical exercise, Mediating effect

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## Introduction

Cognitive impairment refers to the impairment of one or more cognitive functions, such as memory, language, and visuospatial ability [1], and it has become one of the most common geriatric symptoms [2]. As the global population ages, the susceptibility to age-related cognitive impairment increases. The prevalence of cognitive impairment worldwide ranges from 5.1 to 41%, with a median of 19% [3], whereas the prevalence in China exceeds the global average was 22.24% [4]. This presents significant challenges for the economic system, healthcare providers, and the families of patients [5, 6]. Therefore, examining the influencing factors of cognitive function and elucidating their mechanisms to provide scientific insights for preventing cognitive impairment is a public priority.

The Lancet has updated the key modifiable factors that could potentially prevent or delay up to 40% of dementia cases, with lack of PA listed as one of the vital factors [7]. PA refers to any bodily movement that results in energy expenditure caused by skeletal muscle contraction [8]. Currently, the positive association between PA and cognitive function has been increasingly documented [9–11]. In addition, studies have reported that PA benefits cognitive function across various populations, including older adults with normal cognition [9], mild cognitive impairment [10], and dementia [11]. The potential mechanisms by which PA enhances cognitive function are primarily centered on neuroplasticity. During PA, skeletal muscle contractions release myokines (e.g., cathepsin B), which cross the blood-brain barrier to stimulate hippocampal neurogenesis [12, 13]. Aerobic exercise elevates the synthesis of brain-derived neurotrophic factor (BDNF), thereby enhancing synaptic plasticity [14, 15]. Additionally, aerobic exercise improves cardiorespiratory endurance, which, in turn, enhances cerebral blood flow, strengthens functional connectivity across brain regions, and stimulates axonal growth in prefrontal networks [16–19]. From the perspective of mediation effects, current literature primarily focuses on pathways such as reducing depressive symptoms [20, 21], improving efficient sleep [22, 23], and enhancing social contacts [24]. Overall, research on the mediating mechanisms between PA and cognitive function is relatively scarce and predominantly centered on psychological variables.

The available evidence also supports the point that functional fitness was positively associated with cognitive function [25–28]. Functional fitness is defined as the physiological capacity to carry out daily activities safely and independently, encompassing muscular strength, flexibility, cardiorespiratory endurance, and agility [29]. Functional fitness is essential for maintaining independence and quality of life in older adults [30]. Existing literature has reported that PA is positively associated with upper body strength [25, 26, 28], lower body strength [25, 26, 28], upper body flexibility [25, 26, 28], lower body flexibility [25–27] flexibility, cardiorespiratory endurance [25–27], and dynamic balance [25–27]. Research on the association between functional fitness and cognitive function is also attracting growing interest. Yang et al., for example, conducted a cross-sectional study that reported that the tests of 30-second chair stand, chair sit-and-reach, 30-second arm curl, and 2-minute step were positively correlated with cognitive function, while the 8-foot up-and-go test was negatively correlated [31]. Another study involving 107 older adults indicated a positive correlation between grip strength, cardiorespiratory endurance, and cognitive function, a negative correlation with the five-repetition sit-to-stand test, and no significant associations with the timed up-and-go test, the sit-and-reach test, or the one-leg balance test with eyes open [32].

To summarize, regular participation in PA effectively improves cognitive function, while functional fitness can be enhanced through PA [33], and functional fitness is positively correlated with cognitive function [32, 33]. Notably, the model proposed by Blair, Cheng, and Holder [34] indicates that PA may indirectly improve health outcomes by enhancing functional fitness. Thus, it is reasonable to hypothesize that functional fitness could mediate the enhancement of PA on cognitive function. Currently, only two studies have examined whether functional fitness mediates the association between PA and subjective well-being [35] or life satisfaction [36], with one study confirming the mediating role [35] and another refuting it [36]. However, no study has investigated whether functional fitness mediates the association between PA and cognitive function. Addressing this knowledge gap is essential, as the findings could provide initial evidence on whether certain functional fitness indicators mediate this association, which further clarifies how PA benefits cognitive health. In addition, the findings could support the role of enhanced functional fitness in improving cognition, and offer a scientific basis for developing more targeted intervention strategies.

Therefore, we conducted a cross-sectional study to examine the correlation between PA, cognitive function, and functional fitness among older adults, as well as investigate their mediating mechanisms. This study aimed to answer two primary questions: [1] Is there a positive correlation between PA, cognitive function, and functional fitness among community-dwelling older adults in China? We proposed Hypothesis 1: PA is positively correlated with cognitive function and functional fitness [2]. Do certain functional fitness domains mediate the association between PA and cognitive function? We proposed Hypothesis 2: the association between PA and cognitive function can be mediated through certain functional fitness domains.

## Methods

### Participants

This cross-sectional study, conducted from July to October 2023, recruited 224 community-dwelling older adults (aged 65–90 years) from Kunshan City, China. Convenience sampling was used to recruit eligible older adults from seven Senior Day Care and Activity Center (Day Care Center) and nearby communities in the High-Tech Zone and Development Zone of Kunshan City, China. The recruitment plans included posting posters, distributing brochures, holding presentations in the Day Care Center, and disseminating project information in community senior WeChat groups. Inclusion criteria: (1) Participants were aged 65 years older or above; (2) living within a reasonable commute to the Day Care Center in Kunshan City; (3) basically able to take care of themselves; (4) voluntarily signed informed consent. Exclusion criteria: (1) individuals who have no history of substance abuse; (2) individuals with impaired hearing or vision that hinders them from answering the questionnaires; (3) unable to care for themselves. Data collection was conducted by a multidisciplinary team: neurologists collected data on cognitive function, sports researchers (with a master's degree in sports science) gathered data on PA, and certified fitness trainers performed functional fitness assessments. This study complies with the ethical requirements of the latest version of the Declaration of Helsinki.

## Measures

### Cognitive function

The Mini-Mental State Examination (MMSE), is a classic cognitive function assessment tool. The Chinese version of the MMSE for Alzheimer's disease patients, patients with depression, or the general population has good validity and reliability [38, 39]. The MMSE measured the cognitive level of older adults in terms of (1) temporal and spatial orientation: 10 points; (2) immediate memory: 3 points; (3) recall: 3 points; (4) attention: 5 points; and (5) language: 9 points. The MMSE score ranged from 0 ~ 30 points, with a higher score indicating better cognition. Global cognitive function was measured by using a modified Chinese version of the MMSE, score range (0–30) [40]. Most items were translated literally from the original version without modification, while some items were adapted to meet the Chinese cultural context according to pilot survey interviews [41].

### Physical activity

Physical Activity Scale for the Elderly (PASE) is an easily administered and scored instrument that measures the level of PA in individuals aged 65 years and older. The instrument comprises self-reported leisure activities, household tasks, and paid or volunteer work over one week and may be administered by telephone, mail, or in-person [42]. For leisure activities, participants indicated their frequency of engagement using responses such as "never," "rarely," "sometimes," or "often." The average daily time spent on each activity was recorded. For family activities and paid or volunteer work, participants provided "yes" or "no" responses, along with details on hours worked and types of tasks performed [42]. The PASE scoring algorithm was derived from PA measured by movement counts from an electronic PA monitor, activity diaries, and self-assessed activity levels in a general population of noninstitutionalized older adults. The validity and reliability of the Chinese version of the PASE have been well-established [43].

### Functional fitness

Senior Fitness Test (SFT) was designed specifically for use in clinical or field (nonlaboratory) settings and, particularly, to be capable of providing continuous-scale measurements across the wide range of ability levels typically found in the community-residing older adult population [29]. The SFT's measurement indicators and methods include lower body strength (30-s chair stand), upper body strength (arm curl), cardiorespiratory endurance (6-min walk or 2-min step test), lower body flexibility (chair sit-and-reach), upper body flexibility (back scratch), agility/ balance (8-ft up-and-go).

### Statistical analysis

Statistical analysis was conducted using SPSS 25.0. Descriptive statistics were performed on variables such as age, gender, and education. Continuous data conforming to a normal distribution were expressed as (mean ± standard deviation), and categorical data were described using frequencies or percentages. Pearson correlation analysis was used to examine the associations among variables like PA, functional fitness, and cognitive function. Pearson correlation coefficients were interpreted as follows: small ($r = 0.10–0.29$), medium ($r = 0.30–0.49$), and large ($r \geq 0.50$) based on Cohen's guidelines [44]. These cutoffs are widely accepted benchmarks for interpreting effect sizes in correlational analyses.

PROCESS (version 3.5) was employed with Model 4 to test simple mediation effects, assessing the pathways between PA, functional fitness, and cognitive function, with Bootstrap sampling set to 5000 [45]. This method provides comprehensive estimates of both the direct and indirect effects. Bootstrapping with 5,000 samples was employed to estimate the confidence interval of the indirect effects, a robust method for testing indirect effects in mediation models [45]. In our analysis, the independent

**Table 1** Demographic characteristics of the participants [(mean ± sd), N (%)]

| Variables | Total($n = 224$) |
|---|---|
| Age (years) | 73.75 ± 5.57 |
| Education level | |
| *Illiterate* | 35(15.63%) |
| *Primary school* | 77(34.40%) |
| *Middle school* | 62(27.70%) |
| *High school* | 44(19.60%) |
| *College* | 6(2.20%) |
| Height (cm) | 161.31 ± 8.20 |
| Weight (kg) | 62.39 ± 9.55 |
| BM I(kg/m$^2$) | 23.85 ± 2.63 |
| PA (score) | 113.83 ± 42.73 |
| Cognitive function (score) | 24.51 ± 3.72 |
| Upper body strength (n) | 16.56 ± 2.70 |
| Lower body strength (n) | 15.62 ± 2.70 |
| Upper body flexibility (inch) | -2.38 ± 4.79 |
| Lower body flexibility (inch) | 0.42 ± 4.50 |
| Cardiorespiratory fitness (n) | 83.16 ± 14.50 |
| Agility/dynamic balance (s) | 5.93 ± 0.80 |

Abbreviations: sd = standard deviation

variable was PA, functional fitness served as the mediator, and cognitive function was the dependent variable, all treated as continuous variables. In this study, age, gender, and education level were included as covariates to control for potential confounding effects. The $p < 0.05$ was considered significant.

## Results

### Demographic characteristics of participants

As shown in Table 1, this study included 224 participants, with 132 females and 92 males. The average age of participants was 73.75 ± 5.57. The distribution of participants' educational levels is 35 illiterate (15.63%), 77 primary school (34.40%), 62 middle school (27.70%), 44 high school (19.60%), and 6 college (2.20%). The average cognitive function score was 24.51 ± 3.72, and the average PA score was 113.83 ± 42.73. For functional fitness, the average values of upper body strength were was 16.56 ± 2.70, lower body strength was 15.62 ± 2.70, upper body flexibility was − 2.38 ± 4.79, lower body flexibility was 0.42 ± 4.50, cardiorespiratory endurance was 83.16 ± 14.50 and agility was 5.93 ± 0.80.

### Correlations coefficient between PA, functional fitness, and cognitive function

Table 2 illustrates a significantly positive correlation between PA and cognitive function, with a correlation coefficient of $r = 0.437$ ($p < 0.01$). PA was also significantly positively correlated with upper body strength ($r = 0.309$, $p < 0.01$), lower body strength ($r = 0.390, p < 0.01$), upper body flexibility ($r = 0.132, p < 0.05$) and cardiorespiratory endurance ($r = 0.395, p < 0.01$), but not with lower body flexibility ($r = 0.127$, $p > 0.05$); and PA was significantly negatively correlated with agility ($r$ = -0.283, $p < 0.01$). In addition, upper body strength ($r = 0.494$ ($p < 0.01$)), lower body strength ($r = 0.520$, $p < 0.01$), lower body flexibility ($r = 0.168$ ($p < 0.05$)), cardiorespiratory endurance ($r = 0.537$, $p < 0.01$) was positively correlated with cognitive function, while upper body flexibility was not. Agility, however, was negatively correlated with cognitive function ($r = -0.319$, $p > 0.05$). The above findings confirmed hypothesis 2.

The mediating effect of functional fitness on the association between PA and cognitive function was tested using model 4 of the PROCESS plugin in SPSS software. As shown in Fig. 1; Table 3, the direct effect (Effect = 0.0109, 95% CI [0.0037, 0.0182]) and total effect (Effect = 0.1041, 95% CI [0.0557, 0.1559]) of PA on cognitive function were significant. In addition, the indirect effect of the pathway PA → cardiorespiratory endurance → cognitive function was 0.0519(95% CI=[0.0205, 0.0889], accounting for 49.86% of the total effect, which supports Hypothesis 2. This indicates that cardiorespiratory endurance mediates the association between PA and cognitive function.

**Table 2** Correlation coefficient between PA, functional fitness, and cognitive function

| Variables | 1 PA | 2 Cognitive function | 3 Upper body strength | 4 Lower body strength | 5 Upper body flexibility | 6 Lower body flexibility | 7 Cardiorespiratory endurance | 8 Agility |
|---|---|---|---|---|---|---|---|---|
| **1** | 1 | | | | | | | |
| **2** | 0.437** | 1 | | | | | | |
| **3** | 0.309** | 0.494** | 1 | | | | | |
| **4** | 0.390** | 0.520** | 0.702** | 1 | | | | |
| **5** | 0.132* | 0.130 | 0.134* | 0.163* | 1 | | | |
| **6** | 0.127 | 0.168* | 0.029 | 0.188** | 0.294** | 1 | | |
| **7** | 0.395** | 0.537** | 0.447** | 0.431** | 0.122 | 0.133* | 1 | |
| **8** | -0.283** | -0.319** | -0.300** | -0.352** | -0.204** | -0.003 | -0.461** | 1 |

Note: ***p* <0.01, ***p* <0.05

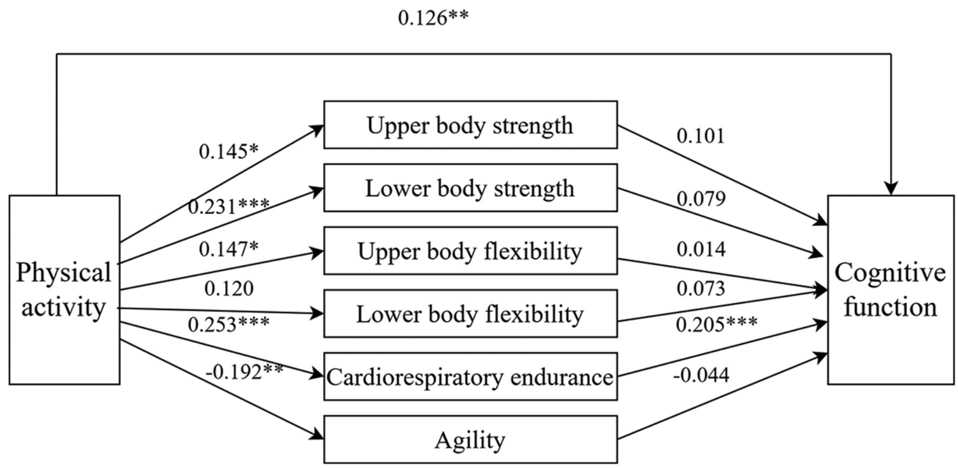


**Fig. 1** Model diagram of mediating effect. Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; the values are reported as standardized coefficient

**Table 3** Decomposition of total effect, direct effect, and mediating effect of functional fitness on cognitive function due to PA

| Effect Type | Mediation Pathway | Effect | SE | 95%CI | | Effect Proportion |
|---|---|---|---|---|---|---|
| | | | | LLCI | ULCI | |
| Direct Effect | | 0.0109[b] | 0.0039 | 0.0037 | 0.0182 | |
| Indirect Effect | Upper body strength | 0.0146[a] | 0.0101 | -0.0013 | 0.0370 | 14.02% |
| | Lower body strength | 0.0182[a] | 0.0129 | -0.0038 | 0.0464 | 17.48% |
| | Upper body flexibility | 0.0021[a] | 0.0055 | -0.0092 | 0.0137 | 2.02% |
| | Lower body flexibility | 0.0087[a] | 0.0076 | -0.0024 | 0.0271 | 8.36% |
| | Cardiorespiratory endurance | 0.0519[a] | 0.0176 | 0.0205 | 0.0889 | 49.86% |
| | Agility | 0.0085[a] | 0.0086 | -0.0087 | 0.0262 | 8.17% |
| Total Effect | | 0.1041[a] | 0.0254 | 0.0557 | 0.1559 | |

Abbreviations: LLCI = low limit for confidence interval; ULCI = upper limit for confidence interval; Standard Error = SE; CI = 95% confidence intervals; [a] Standardized effect; [b] effect

## Discussion

To our knowledge, this is the first study to examine whether certain functional fitness domains could mediate the association between PA and cognitive function in older adults. The results demonstrated that PA has a positive link with both cognitive function and most functional fitness domains, and significant positive correlations were also identified between cognitive function and most functional fitness domains. Importantly, cardiorespiratory endurance was found to mediate the association between PA and cognitive function.

This study confirmed Hypothesis 1: PA is positively correlated with cognitive function among community-dwelling older adults. Consistent with our findings, a cross-sectional study investigating 715 Chinese older adults found a positive correlation between total PA, household PA, and cognitive function [46]. Another study reviewed 23 studies and found that moderate to vigorous PA was favorably associated with cognitive function in older adults [47]. The neural and physiological mechanisms through which PA improves cognitive function primarily include the following aspects: alterations in the structure and functional dynamics of the central nervous system; enhanced cerebral blood flow; and regulation of neurotransmitter release [48, 49]. For instance, aerobic exercise can improve cognitive function through various mechanisms, including cardiovascular fitness [50], boosting cerebral blood flow, increasing oxygen and glucose supply to brain tissue, improving neurotransmitter availability [51], as well as stimulating the synthesis of neurotrophic factors [52]. Moreover, some studies interpret the cognitive benefits of PA through the selective improvement hypothesis [53], the cardiorespiratory endurance hypothesis [54], and mediation effects like reducing depressive symptoms [20] and improving sleep quality [22].

In addition, this study utilized the SFT to comprehensively evaluate the functional fitness of older adults, which verified Hypothesis 1: PA is positively correlated with functional fitness among older adults. The results demonstrated a positive correlation between PA and upper and lower body strength, upper body flexibility, and cardiorespiratory endurance, as well as a negative correlation with agility, consistent with previous studies [31]. Aerobic exercise is the most common form of PA among community-dwelling older adults, contributing significantly to cardiovascular fitness by improving oxygen uptake efficiency, increasing maximal oxygen uptake, and promoting cardiovascular and pulmonary adaptations [55–57]. In addition, some older adults engage in strength and resistance training, which can enhance neuromuscular efficiency [58], muscle hypertrophy [59], and increased muscle fiber recruitment [60] significantly benefiting muscle strength. In addition, flexibility exercises, widely accessible in Chinese community settings, improved joint range of motion and tendon flexibility, reducing connective tissue stiffness and enhancing overall flexibility. Notably, most fitness equipment is designed for upper body flexibility, while facilities targeting lower body flexibility exercises are lacking. This may explain why no significant correlation between PA and lower limb flexibility was observed in this study.

The most suggestive finding is cardiorespiratory endurance plays a significant mediating role between PA and cognitive function, which confirms Hypothesis 2. This study indicated that cardiorespiratory endurance is one of the most widely studied fitness factors in older adults with impaired cognitive ability and is also a key predictor of cognitive decline [61]. Previous studies have shown a positive correlation between cardiorespiratory endurance and cognitive function [62, 63]. Additionally, Sampaio et al. [30], conducting a cross-sectional study with 102 older adults, found that cardiorespiratory endurance is the fitness component most closely related to cognitive function. Previous research has shown that higher cardiorespiratory endurance is often associated with cerebrovascular health [64], oxygenation levels in the prefrontal cortex [65], functional connectivity of the default mode network [66], neurovascular plasticity, neurogenesis, and the upregulation of neurotrophic factors, mechanisms that contribute to improved cognitive health [67, 68]. For instance, Dupuy et al. [65] utilized near-infrared spectroscopy to measure prefrontal oxygenation and found that individuals with higher cardiorespiratory endurance levels can increase prefrontal oxygenation when performing complex tasks, thereby enhancing cognitive performance. In addition, the cardiorespiratory endurance hypothesis strongly supports our view, positing that cardiorespiratory endurance serves as a physiological mediator that explains the mechanisms by which PA provides various mental health benefits [54].

This study offers valuable insights through its rigorous methodology. The SFT, an internationally recognized assessment tool specifically designed for older adults assessment tool specifically designed for older adults, was employed to evaluate their functional fitness. This approach facilitated a comprehensive analysis of potential functional fitness indicators that could mediate the association between PA and cognitive function. Additionally, all data were collected during one-on-one sessions conducted by professionally qualified personnel, which greatly ensured the accuracy of the data. Nonetheless, this study still has three limitations. First, this study is a cross-sectional design, which has certain limitations in exploring causal association. Future longitudinal studies are planned to further explore the related factors and specific pathways of cognitive impairment. Secondly, the participants of this study were only elderly residents from urban communities in Kunshan, a developed city in China. This may limit the generalizability of the findings. Future studies are needed in varied regions to more accurately identify these mediating pathways and enhance the findings' generalizability. It is also recommended that different countries conduct relevant studies to provide cross-cultural empirical evidence. Lastly, although the data collectors in this study were professionally trained researchers, the data for PA were self-reported by the subjects, which may lead to some bias in results. In future studies, it is recommended to employ objective measurement methods for PA data collection, such as using the ActiGraph GT3X + accelerometers.

## Conclusions

This study investigated the association between PA, functional fitness, and cognitive function, and verified whether functional fitness mediates this association. The study demonstrated that PA is positively correlated with most functional fitness domains and cognitive function. In addition, cognitive function was significantly positively correlated with most functional fitness domains. As for functional fitness indicators, only cardiorespiratory endurance was found to mediate the association between PA and cognitive function. This study provides initial evidence that cardiorespiratory endurance could play a mediating role in the association between PA and cognitive function. More longitudinal studies should be conducted to investigate the causal relationship between PA and cognitive function and the associated pathways.

### Abbreviations

| | |
|---|---|
| PA | Physical activity |
| MMSEMini | Mental State Examination |
| PASE | Physical Activity Scale for the Elderly |
| SFT | Senior Fitness Test |
| BDNF | Brain-derived neurotrophic factor |

### Acknowledgements

Heartfelt gratitude to the Day Care Centers in Kunshan City's High-tech Zone and Economic Development Zone, where the staff offered support during participant recruitment and experimental data collection.

### Author contributions

QY, VS and JC were responsible for designing the study. QY obtained the data. QY and CY performed data analysis; QY wrote the manuscript. QY, CY and YQ performed data visualization. JC, VS, XF, XS and JT completed review & editing; and VS and JC held primary responsibility for the final content. All authors have read and approved the published version of the manuscript.

### Funding

This research received no external funding.

**Data availability**
Some or all the data and models that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study approved by University Malaya Research Ethics Committee granted ethical approval for this study (UM.TNC2/UMREC_2507). All participants signed an informed consent prior to data collection.

**Consent for publication**
Not Applicable.

**Competing interests**
The authors declare no competing interests.

Received: 24 November 2024 / Accepted: 13 March 2025
Published online: 21 March 2025

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