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Can an active lifestyle maintain cognitive efficiency in older adults? A pilot study of the relationship between physical activity and graphic fluency

Noemi Passarello[1], Emahnuel Troisi Lopez[2], Onofrio Gigliotta[1], Patrizia Turriziani[3], Fabio Lucidi[4,5] and Laura Mandolesi[1*]

Abstract

Background Physical activity (PA) significantly impacts brain function and counteracts age-related changes in cognitive and motor abilities.

Methods This pilot study delved into exploring the cognitive benefits of PA in older adults, focusing on their fluency abilities. We assessed verbal and graphic fluency in 45 older participants (mean age = 68.11 ± 3.34 years) using the Fluency Test (FAS) and modified Five-Points Test (m-FPT). They were divided into Active and Sedentary based on International Physical Activity Questionnaire cut-off scores.

Results The results revealed significant findings regarding the relationship between PA level and executive functions. Generalized linear model analyses indicated that sedentary individuals exhibited poorer performance in the number of unique drawings, drawings performed with a cognitive strategy, and strategy index (ISs). Regarding gender differences, we found a significant positive prediction of verbal fluency abilities in males compared to females. However, no significant effects of gender were observed for the m-FPT.

Conclusions These preliminary findings strengthen existing evidence highlighting PA's beneficial impact on cognitive function in older adults. This study highlights a distinctive support for graphic abilities over verbal fluency due to PA, emphasizing a specific connection to cognitive efficacy. It also prompts consideration of graphic fluency as a possible marker for successful ageing.

Keywords Physical exercise, Successful aging, Modified five-points test, Executive functions

*Correspondence:
Laura Mandolesi
laura.mandolesi@unina.it
[1]Department of Humanities, University of Naples "Federico" II, Naples, Italy
[2]Department of Education and Sport Sciences, Pegaso Telematic University, Naples, Italy
[3]Department of Psychology, Educational Sciences and Human Movement, University of Palermo, Palermo, Italy
[4]Department of Social and Developmental Psychology, Faculty of Medicine and Psychology, University of Rome "Sapienza", Rome, Italy
[5]Forensic Science and Social Governance Disciplinary Innovation Base of Zhongnan, University of Economics and Law, Wuhan, China

Introduction

Given the global increase in life expectancy, it is vital to understand factors that influence the quality of ageing process. Healthy ageing refers to a state of overall well-being that encompasses physical, mental, and social dimensions, rather than merely the absence of illnesses. Peel and colleague [1] according to many researchers, defined healthy ageing as a reduced risk of disease and disability, strong cognitive and physical functioning, and active engagement in life. Consequently, identifying the factors contributing to healthy ageing represents a significant challenge for recent studies. Experimental and clinical research have shown that maintaining an "enriched lifestyle" has the potential to significantly enhance cognitive functioning [2], offering a beneficial "reserve-like" advantage during old age [3]. In this context, physical activity (PA) stands out as a crucial environmental factor that significantly influence the quality of ageing [4]. Namely, PA has been shown to have an impact on brain plasticity, cognitive functioning and well-being across the lifespan [2, 5, 6]. Moreover, PA is able to reduce the risk of neurological diseases and protect the brain from the detrimental effects of ageing [7]. Cross-sectional studies have shown that physical exercise programs with a chronic, moderate-to-vigorous intensity enhance memory abilities, improve attentional processes' efficiency, and boost executive functioning in middle-aged and older individuals [2, 3, 6–8].

Regarding the cognitive benefits of physical activity (PA), it's crucial to highlight its significant impact on executive functions, which are integral to daily life. Executive functions allow to plan, organize, control, and regulate adaptive and goal-oriented behavior, determining thus a significant impact on individual's ability to exhibit appropriate behavioral reactions [9]. In older adults, executive functions are deemed vital in executing complex motor tasks, compensating for possible declines in automated motor control related to aging [10]. Implementing physical activity (PA) training to counteract the decline in regular functions is pivotal for acquiring cognitive and brain reserves [8]. Furthermore, the impact of PA on executive cognitive control, encompassing coordination, inhibition, scheduling, planning, and working memory, is well-documented [11, 12]. However, most of these studies are limited to analysing specific executive domains, such as attention, planning, inhibition, and cognitive flexibility. Exploring fluency abilities in older adults provides valuable insights into the impact of physical activity (PA) on executive functions and the potential for early detection of cognitive decline. These abilities, crucial for executive functions, represent the capacity to plan complex motor sequences. While verbal fluency often takes center stage in aging studies, graphic fluency remains underexplored and inadequately measured in this demographic. Namely, graphic fluency represents an aspect of executive functions that is closely related to the complexity of motor action. As in verbal fluency there are declarative components that enrich the production of words, in the same way in graphic fluency, procedural aspects compete with spatial declarative ones for the production of drawings. Considering how much action is cognition, the analysis of the relationship between graphic fluency and physical activity becomes crucial to promote intervention strategies based on active lifestyles in old age.

To bridge this gap, our pilot study aimed to examine whether physical activity (PA) could predict the cognitive performance of older individuals -without cognitive impairment- in tests assessing both verbal and graphic fluency. Specifically, we administered a battery of neuropsychological tests (Mini Mental State Examination; FAS Fluency Test; modified Five-Points Test) to 45 older individuals (mean age = 68.11 ± 34.34 years). We also used the International Physical Activity Questionnaire (IPAQ) cut-off scores [13], to categorize our sample in Active and Sedentary. Graphic and verbal fluency tests outputs were then used within a generalized linear model (GLM) with PA (Active and Sedentary) and Gender (Male, Female) as predictors.

Materials and methods

Ethics

This research was approved by the Local Ethics Committee of the *Federico II University* (protocol number: 14/2023) and adhered to the principles outlined in the Declaration of Helsinki. Participants were provided with an information sheet before taking part and gave written informed consent before participating.

Participants

The study included a sample of 45 healthy older individuals, with 18 males and a mean age of 68.11 ± 3.34 years. Participants were recruited from the Campania and Lazio regions, primarily around Naples and Rome. Most of the physically active participants were canoeists, while the remaining older participants were recruited through local elderly organizations and care homes. We divided the sample into two groups based on their level of physical activity (PA), namely Active (n = 27, mean age = 67.56 ± 3.78 years) and Sedentary (n = 18, mean age = 68.94 ± 5.06 years). The classification of PA levels was determined using standardized cut-off scores from the International Physical Activity Questionnaire (IPAQ). Participants in the Active group had a total MET score greater than 2520, indicating higher levels of physical activity, while those in the Sedentary group had a total MET score below 700, indicating lower or minimal physical activity. This distinction allowed us to explore differences in cognitive functioning between individuals who engage in higher levels of physical activity and those who are less active.

Detailed demographic information, including age, years of education, body mass index (BMI), was collected from all participants (Table 1).

Inclusion criteria for participation in the study were normal or corrected-to-normal vision and right-handedness. Exclusion criteria included a Mini Mental State Examination (MMSE) score below 24 (refer to following section), the presence of current or past psychopathology, psychiatric, neurological, or motor disorders, or any other significant medical illness. Information on health history was collected directly from participants through a survey administered in an initial meeting.

Measures

International Physical Activity Questionnaire (IPAQ). The short version of IPAQ [14] comprises 7 items on PA providing information about time spent on walking, on vigorous and moderate intensity activity, on sedentary activity and demographic information (gender, age, educational level and work); 4 items relate to demographic data (age, gender, educational level, type of work) and the 7 last items concern comprehension of the questionnaire. Through the results of IPAQ questionnaire, our sample was divided in two groups according to their PA-level: Active (mean IPAQ score = 3449.55; Sedentary (mean IPAQ score = 1523.53). As reported in the Italian validation of the instrument [15] Cronbach's alpha is 0.673.

Mini Mental State Examination (MMSE). The current study employed the Italian version of the Mini-Mental State Examination (MMSE) provided by the Italian Society of Neuropsychology to registered members as a cognitive screening tool to assess cognitive function and identify potential signs of cognitive impairment. The MMSE consists of a series of questions and tasks that evaluate various cognitive domains, providing a comprehensive assessment [16]. To initiate the examination, participants were asked questions to determine their orientation to time, place, and person. Following this, the registration task was administered, wherein participants were presented with a list of three unrelated words and asked to repeat them immediately. Later in the examination, participants were prompted to recall the previously presented words, assessing their short-term memory and ability to retrieve information after a delay. The MMSE also included attention and calculation tasks to evaluate participants' concentration and working memory. Language abilities were assessed through various tasks, including object naming, following simple commands, sentence repetition, and a written sentence task to evaluate written language skills. The examination further incorporated tasks assessing visuospatial abilities. The MMSE yield a total score ranging from 0 to 30, with higher scores indicating better cognitive function. Standard cut score of 24 (≤ 23) [17] has determined that participants with scores below 24 ($n = 3$) were not included in our sample.

Verbal Fluency Test (FAS). To assess participants' verbal fluency abilities, we used the Italian version of FAS fluency test [18], a widely used measure of phonological fluency. This test evaluates individuals' ability to generate words starting with specific phonemic letters under a given time constraint. In our study, participants were instructed to produce as many words as possible that begin with the letters F, A, and S within a set time limit, one minute per letter. Participants were asked to verbally articulate their responses, while the administrator recorded the words generated. Scoring for the FAS fluency test involves counting the total number of correct words produced for each letter. The FAS test provides insights into phonemic and executive functioning abilities, including word retrieval, cognitive flexibility, and response generation. Test score was corrected for age and instruction years.

Modified Five-Points Test (m-FPT). The modified Five-Point Test (m-FPT) is a reliable non-verbal measure that assesses executive functioning by evaluating participants' graphic-figural fluency [19]. This test measures an individual's ability to produce unique geometric drawings within a specified time interval of 3 min. The m-FPT involves an A4 sheet with 40 square matrices, each containing five dots positioned at the vertices and one in the centre. Participants are instructed to connect two or more dots within each square using straight lines, while adhering to specific rules such as avoiding repeated shapes and lines that do not connect the dots. The m-FPT provides insights into three subdomains of executive functions: flexibility, rule-breaking, and strategic performance. Several parameters were evaluated, including the number of unique drawings (UDs), produced without breaking the rules or repeating shapes; the error index (IE) calculated as the number of drawings with errors divided by the total number of drawings multiplied by 100; the number of drawing performed with a cognitive

Table 1 Participants' demographics (age, education years, BMI, MMSE score) means and standard deviations

PA level	*N* (no.)	Age (mean ± SD)	Education years (mean ± SD)	BMI (mean ± SD)	MMSE score (mean ± SD)
Active	27	67.56 ± 3.78	13.24 ± 4.84	26.74 ± 3.77	26.97 ± 1.53
Sedentary	18	68.94 ± 5.06	13.35 ± 6.38	27.99 ± 5.20	27.06 ± 1.46

strategy (DSs) (i.e., rotate the same pattern; add or subtract elements to the pattern); and the strategy index (ISs) calculated as the number of drawings with strategy divided by the number of unique drawings. In this study, we applied norm-correction for age and instruction years according to the Italian validation of the test in older individuals [20].

Data analysis

Independent samples t-tests were used to assess differences between Active and Sedentary in demographic variables (age; instruction years; BMI). Chi squared test was used to assess gender differences.

To test if PA level affected cognitive functioning, we used separate generalized linear models (GLM) with PA level (Active; Sedentary) and Gender (Male, Female) as categorial predictors and FAS (correct number of words) and m-FPT (UDs; IE; DSs; ISs) scores as dependent variables. GLM outputs were adjusted through Holm test, considering 95% Confidence Interval Lower (LCI) and Upper (UCI) bounds. Models' fit were assessed through Pearson goodness of fit; while models' multicollinearity was diagnosed through Variance Inflation Factor (VIF). All analyses and graphic work were performed on JASP Team (2024), Version v. 0.17.0.1.

Results

Independent sample t-test revealed no significant differences between Active and Sedentary in age (t=-1.01; *p* =.32), instruction years (t=-0.07; *p* =.95), BMI (t=-0.09; *p* =.37), and MMSE score (t=-0.07; *p* =.94). Chi squared test revealed no significant difference for gender (χ^2=0.06; *p* =.93). Participants' demographics are summarized in Table 1.

Pearson fit indices were good for all models (*p* =.28). Also, VIF value was acceptable for all models (VIF < 5).

GLM outputs revealed significant PA level predictions for several m-FPT parameters. Specifically, PA level (Sedentary) negatively predicted m-FPT UDs (t=-2.60; p_{Holm}=0.01**) (Fig. 1A), DSs (t=-3.02; p_{Holm}=0.005**) (Fig. 1B) and ISs (t=-2.75; p_{Holm}=0.009**) (Fig. 1C) parameters, while both m-FTP IE (t=-0.44; p_{Holm}=0.66) parameter (Fig. 1D) and FAS total score (t = 1.08; p_{Holm}=0.29) were not predicted by PA level.

No m-FPT parameter by Gender. However, Gender (Male) positively predicted FAS total score (t = 2.32; p_{Holm}=0.02*) (Fig. 2).

PA level- Gender interaction significantly predicted m-FPT UDs (t = 2.30; p_{Holm}=0.02*) (Fig. 1A), DSs (t = 3.08; p_{Holm}=0.004**) (Fig. 1B) and ISs (t = 2.87; p_{Holm}=0.007**) (Fig. 1C) parameters, revealing that being Female and Sedentary lead to worst m-FTP performance. Whereas, both m-FTP IE (t=-0.35; p_{Holm}=0.73) parameter (Fig. 1D) and FAS total score (t = 1.70; p_{Holm}=0.09) were not predicted by PA level- Gender interaction (Fig. 2). All GLM outputs, including Estimate, SE, p-significance and 95% LCI and UCI are reported in Table 2 for all variables.

Discussion

This pilot study aimed to evaluate the verbal and graphic fluency abilities of Active and Sedentary older individuals, seeking to understand the potential influence of physical activity (PA) in maintaining these cognitive capacities in older adults. Our findings underscore the specific and direct positive effects of PA on cognitive performance, with an association between an active lifestyle and enhanced graphic fluency, while sedentary behavior was linked to poorer performance. On the contrary, no discernible association was found between levels of physical activity (PA) and older adults' performance in verbal fluency.

First, it is important to underline that these results align with previous researches, reinforcing the notion that participation in physical activity correlates positively with executive functions, whereas a sedentary lifestyle is associated with a decline in these specific cognitive domains [12, 21]. In fact, clinical and experimental research has highlighted the positive effects of PA on attention, cognitive flexibility, working memory, and so on, also suggesting the modality in which it should be done [2, 3, 5, 8].

Our findings, though preliminary, extend the current literature by providing a more nuanced understanding of the intricate relationship between individuals PA levels and distinct cognitive domains, with a specific emphasis on the less-explored aspect of graphic fluency in the older population. The results suggest a predictive link, indicating that a sedentary lifestyle is associated with a noticeable decline in performance across graphic fluency tasks, reflecting compromised cognitive flexibility, rule-breaking ability, and strategic thinking. Notably, Sedentary participants exhibited inferior performance in m-FPT parameters like unique drawings (UDs), drawings executed with a cognitive strategy (DSs), and the strategy index (Iss) compared to their Active counterparts (Fig. 1).

In the context of verbal fluency, participants' performance was not predicted by PA levels (Fig. 2). This observation calls for further exploration and suggests a distinctive relationship between verbal language practice and cognitive proficiency, potentially less influenced by variations in physical activity levels compared to graphic abilities.

The sustained practice of verbal language in daily activities may elucidate the maintenance of proficiency in verbal fluency, irrespective of individuals' physical activity levels. Numerous studies support this interpretation, documenting that healthy older individuals consistently excel in both phonetic and semantic fluency tasks, highlighting the enduring nature of these language-related

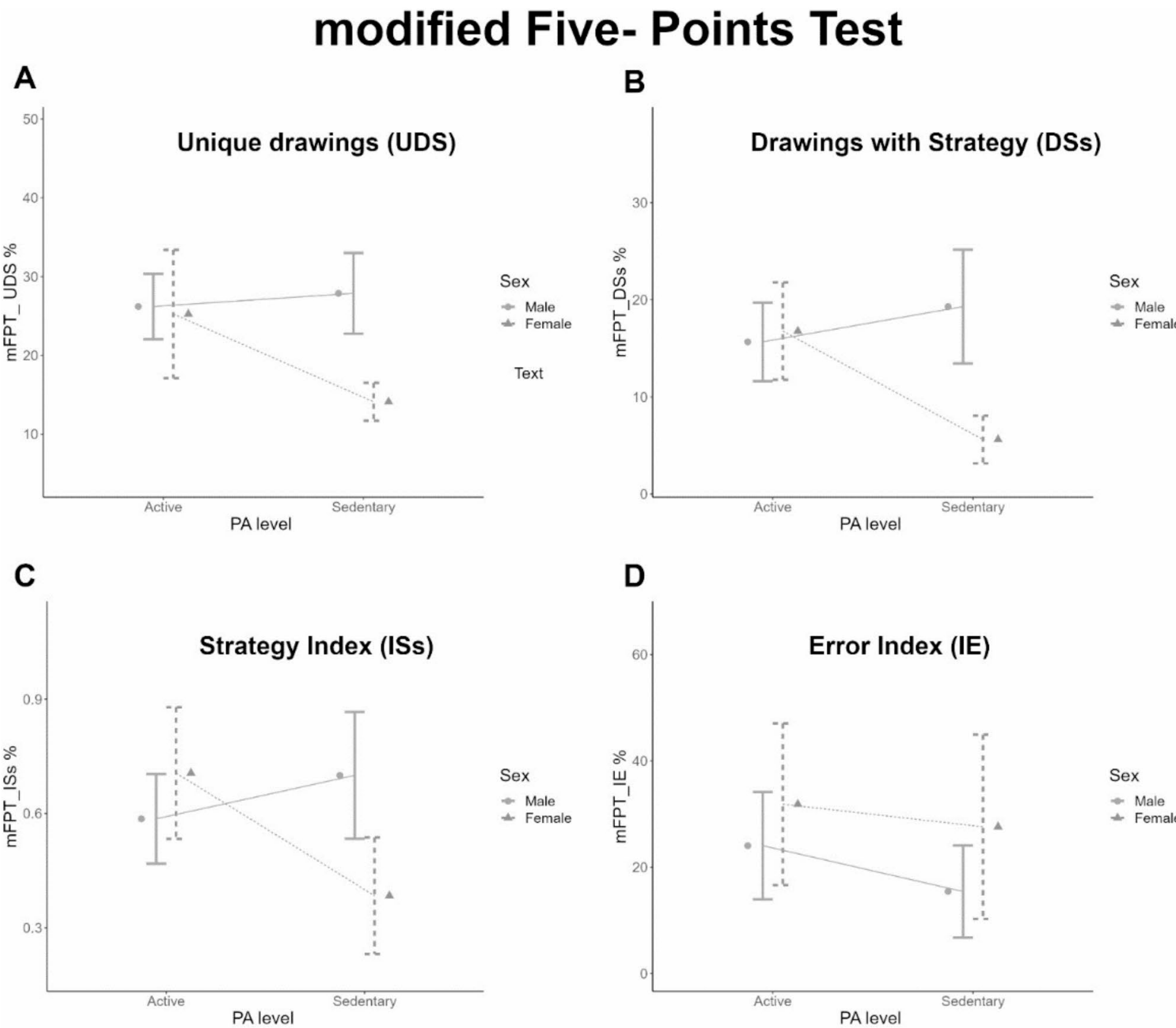

Fig. 1 GLM outputs for m-FPT. On x axis = PA level; on y axis = m-FPT parameters (**A** = Unique drawings, UDS; **B** = Drawings with Strategy, DSs; **C** = Strategy Index (ISs); **D** = Error Index (IE)

competencies [22]. On the other hand, graphic fluency presents a unique scenario in ageing. As individuals grow older, there's a natural decline in motor skills including fine motor ones mainly correlated to graphic fluency. It has also been suggested that the degeneration of motor control with aging could be associated with the development of compensatory strategies such as emitting more motor commands to generate an adequate movement for a given task [23]. Following this hypothesis and taking into account that action is also cognition (in fact, to carry out a motor act, it is necessary to plan, design, decide and so on) [2], the PA could guarantee a better possibility of developing motor strategies to carry out a graphic gesture. Moveover, graphic fluency can be preserved and even enhanced through practice, such as handwriting or drawing [24]. PA indirectly influences these abilities by making the use of the hands necessary, allowing continuous interaction with objects in the environment during motor exercise, stimulating planning, the development of strategies and adaptation, triggering the mechanisms of executive functions [7]. This perspective aligns with the hypothesis proposed by Cabeza and colleagues [25] and the concept of 'brain maintenance,' suggesting that physical exercise contributes to preserving neural resources and counteracts age-related cellular and molecular damage [26]. Maintenance of brain function is critical throughout life but becomes increasingly essential in old age.

Further speculation leads us to emphasize the pivotal role of PA in brain activation. Movement orchestrates the simultaneous engagement of multiple brain circuits, fueling the planning, programming, and decisions behind our

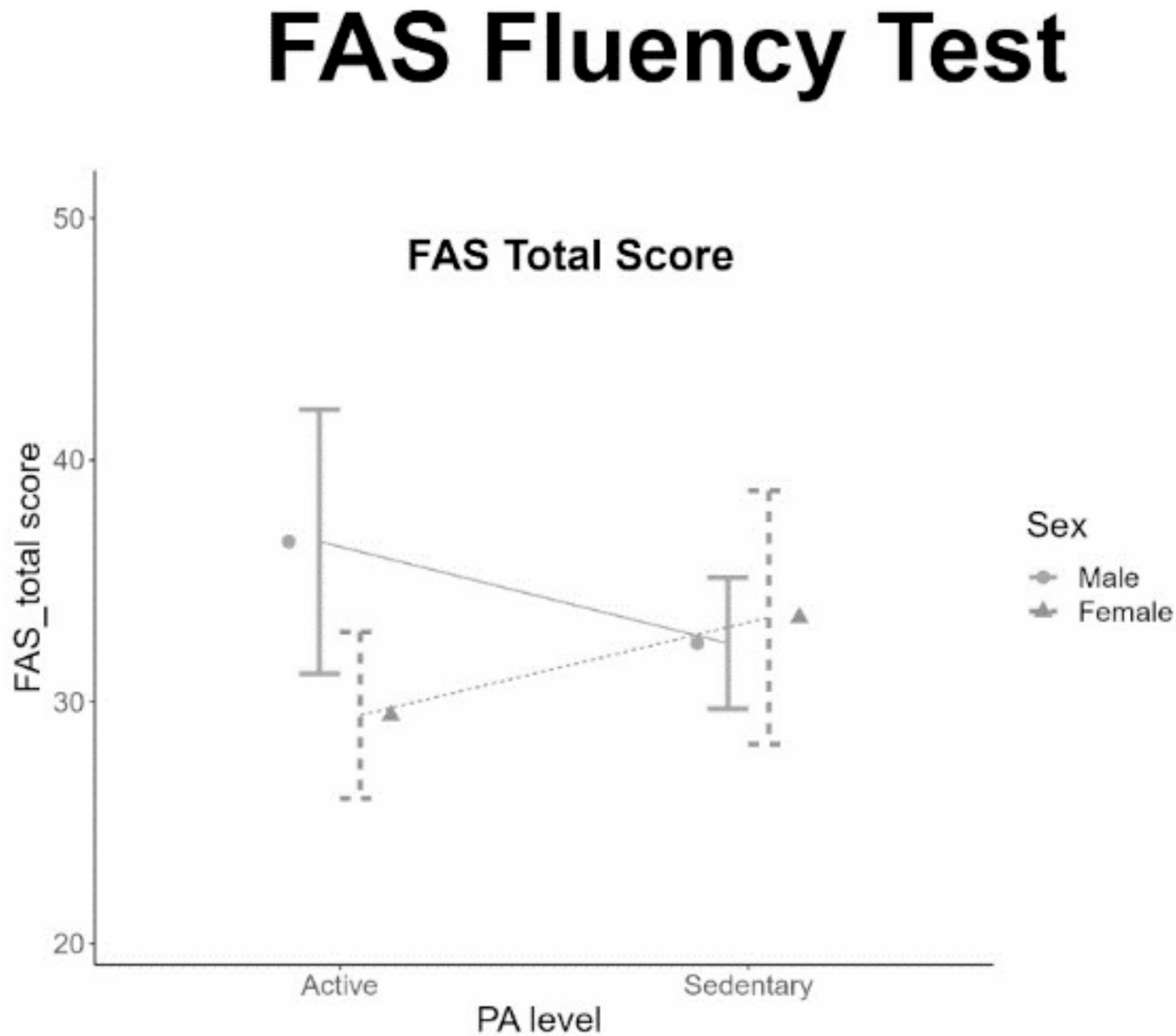

Fig. 2 GLM outputs FAS. On x axis = PA level; on y axis = FAS total score

motor actions [27]. It's widely believed that an actively engaged hemisphere tends to perform functions more efficiently. The continuous exercise of speech potentially serves to train the left hemisphere [28], explaining why PA didn't predict verbal fluency abilities in our study. Conversely, the holistic engagement of both brain hemispheres during PA likely contributes to training a wide spectrum of functions, encompassing graphic fluency. Our observations suggest that Active participants, engaging in regular PA, exhibit enhanced functions that extend beyond speech-related abilities [8, 29]. Regarding gender differences, our study found a significant positive prediction of FAS total score by Gender (Male), indicating that males had better verbal fluency abilities compared to females. However, Gender was not associated with any m-FPT parameters (Fig. 1). It is important to note that the sample size of males ($n = 18$) was relatively small compared to females ($n = 27$), which may have influenced the statistical power to detect Gender differences in the m-FPT parameters. Furthermore, the interaction between physical activity level and Gender significantly predicted participants' performance on m-FPT. Specifically, being Female and Sedentary was associated with the worst performance in UDs, DSs, and ISs (Fig. 1A, B,C). This finding suggests that the combination of low PA level and being female may have a cumulative negative impact on executive functioning in older individuals. The results support previous research indicating that PA interventions have a more pronounced positive effect on cognitive function, including executive functions, in females [30].

Table 2 GLM outputs with PA-level (active, sedentary), gender (male, female) and PA-level-gender interaction as categorial predictors for m-FPT and FAS. Estimate, SE, t, p-significance, LCI and UCI are reported. Abbreviations: m-FPT = modified five-points test; UDs = percentage of unique drawings; DSs = percentage of strategy drawings; ISs = strategy index; IE = error index. *= $p \leq .05$; ** $p \leq .01$

Variables	Predictors	Estimate	SE	t	p_{Holm}	LCI	UCI
mFPT UDs	PA level	-11. 14	4.30	-2.59	**0.01****	-19.57	-2.72
	Gender	0.95	3.56	0.26	0.79	-6.03	7.93
	PA level* Gender	12.82	5.58	2.30	**0.02***	1.88	23.76
mFPT DSs	PA level	-11.17	3.70	-3.02	**0.005****	-18.42	-3.91
	Gender	-1.11	3.07	− 0.36	0.72	-7.12	4.90
	PA level* Gender	14.80	4.81	3.08	**0.004****	5.38	24.22
mFPT ISs	PA level	− 0.32	0.12	-2.75	**0.009****	− 0.55	− 0.09
	Gender	− 0.12	0.09	-1.24	0.22	− 0.31	0.07
	PA level* Gender	0.44	0.15	2.87	**0.007****	0.14	0.73
mFPT IE	PA level	-4.25	9.62	− 0.44	0.66	-23.11	14.60
	Gender	-7.81	7.97	− 0.98	0.33	-23.43	7.82
	PA level* Gender	-4.37	12.49	-0.35	0.73	-28.85	20.12
FAS score	PA level	4.05	3.74	1.08	0.29	-3.28	11.37
	Gender	7.19	3.10	2.32	**0.02***	1.12	13.26
	PA level* Gender	-8.25	4.85	-1.70	0.09	-17.77	1.26

In light of our findings and the established evidence linking PA to enhanced cognitive function in old age, a crucial inquiry emerges regarding the intricate mechanisms through which PA modulates cognitive processes. These processes are multifaceted and encompass various physiological and psychological processes. A pivotal mechanism involves the augmentation of cerebral blood flow. Exercise induces an increase in blood flow to the brain, facilitating the enhanced delivery of oxygen and nutrients to brain cells. This heightened blood flow supports neuronal activity, thereby contributing to improved cognitive function, especially in tasks associated with executive functions and memory. Research conducted by Ainslie et al. [31] and Smith et al. [32] underscores the positive association between physical activity (PA), cerebral blood flow, and cognitive performance.

Another crucial mechanism is neuroplasticity, signifying the brain's adaptability to reorganize itself in response to environmental demands. Regular PA fosters neuroplastic changes in the brain, promoting the growth of new neurons, heightened synaptic connectivity, and the release of neurotrophic factors like brain-derived neurotrophic factor (BDNF). These changes enhance the structural and functional integrity of the brain, resulting in improvements in cognitive processes such as attention, learning, and memory [2].

Lastly, epigenetics has revealed how PA can modulate the expression of specific genetic factors, allowing our brain to implement maintenance, reserve, and compensation mechanisms for successful aging [24].

Limitations and future directions

Several limitations of this preliminary study should be acknowledged, along with directions for future research. First, as a pilot study, it was conducted with a small sample size, which limits generalizability and restricts our ability to robustly examine gender differences. Although we used rigorous statistical models to generate reasonable insights, larger samples will be essential in future studies to validate and expand upon these initial findings. Longitudinal studies are also necessary to better understand the effects of physical activity on cognitive function over time and to explore potential causal relationships.

The use of the MMSE as a cognitive screening tool presents another limitation. While effective for identifying severe cognitive impairment, the MMSE is less sensitive to detecting mild cognitive impairment, which may have influenced our findings. Additionally, our reliance on the IPAQ for assessing physical activity levels introduces limitations, as this measure is subject to recall bias and reflects only the previous seven days of activity. For these reasons, it is not very reliable and other studies using actigraphs will be necessary for a more accurate evaluation of the results.

Future research should also focus on age stratification within the older population, allowing for a more nuanced understanding of cognitive aging processes across different age groups. Graphic fluency abilities, in particular, show promise as early indicators of cognitive decline, and further studies should explore this potential. Examining the underlying mechanisms by which physical activity may support cognitive health could pave the way for targeted interventions that enhance cognitive resilience and promote healthy aging. Additionally, exploring gender differences in the relationship between physical activity and cognitive function will be important for tailoring interventions to specific demographic needs.

Conclusions

In conclusion, this study contributes to the growing body of evidence supporting the cognitive benefits of physical activity in older individuals. The findings highlight the importance of reducing sedentary behaviour and engaging in regular physical activity to maintain and enhance executive functioning, particularly in females. Future research should further investigate the underlying mechanisms and explore the potential of physical activity interventions to improve cognitive function and promote healthy ageing.

Abbreviations

PA	Physical activity
FAS	Fluency Test
m-FPT	Modified Five-Points Test
IPAQ	International Physical Activity Questionnaire
GLM	Generalized linear model
BMI	Body mass index
MMSE	Mini Mental State Examination

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40359-025-02466-w.

Supplementary Material 1

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Author contributions

Conceptualization = N.P.; P.T.; F.L.; L.M.; Data curation = N.P; Formal analysis = N.P.; E.T.L.; Funding acquisition = L.M; Investigation = N.P.; P.T.; F.L.; L.M; Methodology = N.P.; P.T.; F.L.; L.M; Project administration = P.T.; F.L.; L.M; Resources = N.P; Software = N.P; O.G.; P.T.; L.M.; Supervision =O.G.; P.T.; F.L.; L.M.; Writing - original draft = N.P.; L.M.; and Writing - review & editing = All authors.

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Data availability

Data will be made available on request to the corresponding author.

Declarations

Ethics approval and consent to participate

This research was approved by the Local Ethics Committee of the Federico II University of Naples (protocol number: 14/2023) and adhered to the principles outlined in the Declaration of Helsinki. Participants were provided with an information sheet before taking part and gave written informed consent before participating.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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