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Brief Report

Association Between Accelerometer-Assessed Physical Activity and Cognitive Function in Older Adults: A Cross-Sectional Study

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ABSTRACT

Objective: *Research suggests that physical activity (PA) improves cognitive function across various domains. However, the specific role of different PA measures, including step count, remains to be explored. Our aim was to assess the correlation between objectively measured PA and cognitive function.* ***Methods:*** *We included 663 adults, aged ≥66 years, from the Swedish SNAC-K study (2016−2019). Global cognition and three cognitive domains (processing speed, executive function, and episodic memory) were assessed with validated tests. PA was measured through ActivPAL3 accelerometers. We applied age-stratified (<70 vs. ≥80 years), multi-adjusted, quantile regression to examine the cross-sectional associations between cognitive function and PA, considering steps/day and time spent in moderate-to-vigorous PA (MVPA).* ***Results:*** *Each 1000-step increment (β = 0.04; 95% CI: 0.01, 0.07) and each additional hour of MVPA per day (β = 0.28; 95% CI: 0.02, 0.54) were correlated with better processing speed in the youngest-old, but not in the oldest-old. When further stratifying by MVPA (<60 min vs. ≥60 min/week), each 1000-step increment was associated with better processing speed in the youngest-old, regardless of their MVPA*

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levels. ***Conclusion:*** *Our study links accelerometer-assessed PA (steps and MVPA) with better processing speed in the youngest-old adults. Step count correlated with processing speed regardless of intensity. Further research is needed to determine the directionality of these associations.* (Am J Geriatr Psychiatry 2025; 33:575−582)

Highlights

- **What is the primary question addressed by this study?**
  To investigate the association of global cognition, processing speed, executive function, and episodic memory with the number of steps and moderate-to-vigorous physical activity (MVPA) using objective measures in community-living older adults.
- **What is the main finding of this study?**
  Accelerometer-assessed physical activity (both steps and MVPA) was positively associated with better processing speed in the youngest-old adults. There was a significant association between a higher number of steps and better processing speed in the younger group, regardless of whether they performed less or more than 60 min/?week of MVPA.
- **What is the meaning of the finding?**
  These findings hold promise for understanding how step count and activity intensity impact cognitive impairment in older adults, potentially informing preventive strategies.

BACKGROUND

Physical activity (PA) is crucial for healthy aging.[1–3] An integral aspect of healthy aging is maintaining cognitive function, which refers to the mental processes that enable information reception, processing, and elaboration.[4] Systematic reviews and meta-analyses suggest that higher levels of PA may improve cognitive function,[5,6] but a reverse association could also exist. Research indicates that people with cognitive impairment and dementia tend to be less active than their cognitively intact peers of the same age.[7,8] However, further exploration is needed to understand the specific correlations between different PA measures, including step count.[5] While the potential cognitive benefits of PA are likely mediated by physiological mechanisms involving cytokines and exerkines, other mechanisms could also be at play.[9]

Accelerometers are the most reliable and precise tools for objectively measuring PA.[10] Research on the association between objectively assessed PA and cognitive function has yielded varying results with inconsistent evidence.[8] Moderate-to-vigorous PA (MVPA), characterized by higher energy expenditure (>3 metabolic equivalents), is important for overall health.[11] In a review by de Oliveira et al., six studies showed a positive association between MVPA measured with accelerometers and global cognitive function, memory, and processing speed.[5] However, the interpretation and comparison of study results are limited by an insufficient description of the accelerometer data extraction methodology.[12,13] While the number of steps has been suggested to be crucial for overall health outcomes regardless of intensity,[14] few studies have examined their associations with specific cognitive domains (e.g., processing speed, executive function, and memory), and it remains unclear whether this association varies based on MVPA.[5,6] Furthermore, despite previous research suggesting that the associations between PA and cognitive function are more pronounced in younger age groups, it remains uncertain whether these associations also vary across age groups.[15]

This study aimed to investigate the cross-sectional association between global cognition, processing speed, executive function, episodic memory, and the number of steps and MVPA using objective measures of PA in older adults. Additionally, we aimed to

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explore potential age-related variations in these associations and whether the association between step count and cognitive function varies based on MVPA.

METHODS

We used data from the sixth wave (2016−2018) of the Swedish National Study on Aging and Care in Kungsholmen (SNAC-K) *(see supplementary material part 1).* Of the 1310 randomly sampled participants in the age groups 66, 81, 84, 87, 90, 93, and ≥96 years examined during this period, 684 were considered eligible (excluding those with severe cognitive impairment or inability to move indoors without assistance) and agreed to wear the accelerometer activPAL3 *(PAL Technologies Ltd., Glasgow, UK)* for seven consecutive days. Of these, 21 were excluded for the following reasons related to the accelerometry measure: the device was not worn according to instructions (n = 2), they had <4 valid days of recording (n = 17), or daytime usage was less than 10 hours per day (n = 2), leaving an analytical sample of 663 people. Data were collected through interviews and tests by trained staff at the data collection facilities or participants' homes (*see the flowchart of included and excluded participants in supplementary material part 2).*

Socio-Demographic and Health Variables

Data on age, sex, and highest level of education (elementary or high school vs. university) were obtained from interviews. The five-chair stand test (time in seconds) was administered by SNAC-K nurses. Multimorbidity burden was operationalized as the number of chronic diseases based on a previously described methodology.[16]

Cognitive Function

The following domains of cognitive function were assessed: processing speed (a composite score consisting of digit cancellation and pattern comparison tests), executive function (Trail-Making-Test-B), episodic memory (a composite score comprising free recall and recognition tests), and global cognition (a composite score consisting of all three cognitive domains).[17] All cognitive measures were converted to normalized scores using the baseline mean and standard deviation as the standardization base. Standardization was performed separately for the younger and older age groups (<70 vs. ≥80 years) *(see supplementary material parts 3 and 4 for additional details on the construction of these variables)*. Furthermore, we used the Mini-Mental State Examination (MMSE) to describe the global cognitive function in the study population.[17]

Physical Activity

The thigh-worn ActivPAL3 (*PAL Technologies Ltd., Glasgow, UK)* accelerometer was used to assess PA. This device uses accelerometer-derived information about thigh position to determine the start and end of each period spent sitting/lying, standing, walking, step counts, and postural transitions.[12] We considered valid assessments from subjects who wore the accelerometer for at least four consecutive days and whose wear time was at least ten hours during waking hours. We used 24-hour blocks (midnight to midnight) for the data extraction, excluding half days based on previously described recommendations.[18] The Excel macro-HSC PAL 2.21 analysis software developed by Dr. Philippa Dall and Prof. Malcolm Granat, Faculty of Health and Life Sciences, Glasgow Caledonian University,[19] was used to extract the data from the devices. The software utilizes second-by-second events to classify posture based on inclination and to determine the duration and number of steps taken, thereby increasing the robustness of the measurements.[20] For the PA variables, we assessed [1] the number of steps (step count) and [2] minutes of moderate-to-vigorous intensity PA (MVPA) (we utilized the cadence of walking periods, with a threshold of ≥100 steps/min)[21] (*see supplementary material part 5 for additional details on accelerometer configuration and how data were extracted).*

Statistical Analysis

The characteristics of the participants across age groups were compared using chi-square tests for categorical variables and t-tests or analysis of variance for continuous variables. Age-stratified quantile regression was used to examine the associations of the number of steps and MVPA with the different domains of cognitive function. The associations between cognitive function and steps per day were further stratified

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by age and more or less than 60 minutes of MVPA per week. This threshold was determined according to the U.S. guidelines for minimum PA, which suggest that individuals who walk at least 60 minutes per week have a lower risk of cardiovascular events compared to those who are inactive.[22] All analyses were adjusted for age, sex, educational level, chair stand test, and multimorbidity burden. Data were analyzed using Stata 18.0 (Stata-Corp LP, College Station, TX, USA).

RESULTS

Table 1 presents participants' clinical characteristics, PA levels, and global cognitive function (n = 663), stratified by age. The mean age for the oldest age group (≥80 years) was 83.5 years. Compared to the oldest-old, the youngest-old had higher education, fewer chronic diseases, better performance on the chair stand test, higher levels of PA, and better MMSE scores (*see the comparison of baseline characteristics between those excluded and included in supplementary material part 6*).

As shown in Figure 1, each 1000-step increment ($\beta = 0.04$; 95% CI: 0.01, 0.07; p-value = 0.02) and each additional hour spent in MVPA ($\beta = 0.28$; 95% CI: 0.02, 0.54; p-value = 0.03) were associated with better processing speed in the younger group but not in the older group. There were no associations between the number of steps or MVPA and executive function, episodic memory, or global cognition in either age group.

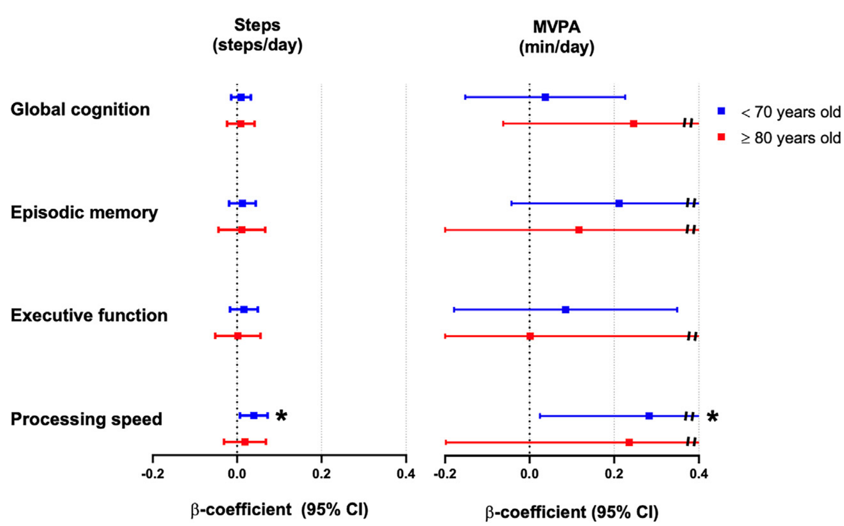
As shown in Figure 2, there was a significant association between processing speed and each 1000-step

TABLE 1. Characteristics of the Study Population by Age (n = 663)

Characteristics	Age < 70 (n = 381)	Age ≥80 (n = 282)
Age	65.9 (0.5)	83.5 (3.5)
Women	229 (60.1%)	196 (69.5%)
Education level		
Elementary or high school	125 (32.8%)	155 (55.0%)
University	256 (67.2%)	127 (45.0%)
Chronic diseases, total number	3.6 (2)	6.7 (2.9)
Chair stand test, seconds	10.2 (8)	25 (26)
Wear time, hours/day	14.7 (1.1)	14.1 (1.1)
Steps/day	10,146 (3512)	6706 (3126)
Daily time spent on MVPA, min	40.6 (25.8)	19.2 (20.1)
MMSE	29.1 (1)	28.2 (1.5)

Note: Data are presented as means (SD) for continuous variables, and n (%) for categorical variables. MVPA= moderate-to-vigorous physical activity; MMSE= Mini-Mental State Examination. Percentage of missing: 1.7% for chair stand test.

FIGURE 1. Beta coefficients and 95% confidence intervals for the associations between cognition and physical activity stratified by age.



Note: *p <0.05. MVPA= moderate-to-vigorous physical activity. To facilitate the interpretation, the number of steps is operationalized as 1000 steps per day, and the MVPA as one hour of MVPA per day.

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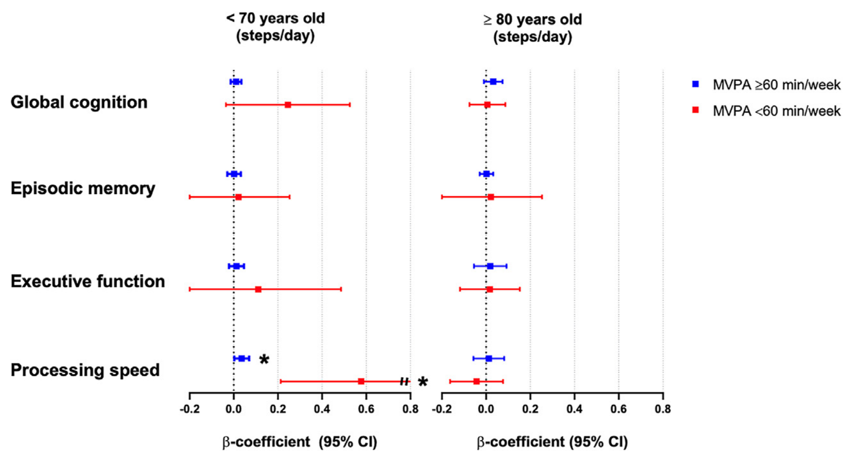
FIGURE 2. Beta coefficients and 95% confidence intervals for the associations between cognition and steps/day stratified by age and MVPA levels (<60 min vs. ≥60 min/week).



Note: *p <0.05. MVPA= moderate-to-vigorous physical activity. To facilitate the interpretation, the number of steps is operationalized as 1000 steps per day

increment in the younger group performing less than 60 min/week of MVPA (β = 0.58; 95% CI: 0.21, 0.94; p-value <0.01) and in those performing more or equal than 60 min/week of MVPA (β = 0.36; 95% CI: 0.00, 0.07; p-value = 0.04).

DISCUSSION

In this population-based study of older adults, we found that a higher number of steps and higher levels of MVPA were associated with better processing speed in youngest-old adults. The association between the number of steps and processing speed remained consistent even after stratifying based on whether the individuals performed more or less than 60 minutes of MVPA per week.

As people age, various cognitive domains, including processing speed, executive function, and memory, undergo changes.[23] The age-related decline in cognitive function is particularly marked in processing speed abilities.[24] Impaired processing speed negatively affects functioning in activities of daily living.[25] Previous research suggests that higher levels of PA are associated with better cognitive function in older adults, particularly in tasks related to working memory and processing speed.[26] Our results align with these findings and indicate that younger older adults who accumulate more steps and perform longer periods of MVPA also show better processing speed. It is plausible to hypothesize that higher levels of PA may serve as a protective factor against a decline in processing speed. The lack of significant associations with global cognition, executive function and episodic memory in our selected, cognitively healthy sample may be due to a ceiling effect that masks subtle cognitive changes.[27] However, the observed associations with processing speed, a subdomain of executive function, highlight its sensitivity to early cognitive changes. These findings support its use as an early indicator in cognitive health studies,[28] emphasizing the importance of early detection and preventive interventions.

In a US cohort of older adults without stroke or dementia, a slower processing speed was shown to have a bidirectional association with gait speed.[29,30] While the association appears bidirectional, slower gait and reduced PA might be influenced by slower processing speed. Lower levels of PA could serve as an early marker of cognitive impairment, sometimes detectable before cognitive testing. The prefrontal cortex, known for its role in executive functions, including processing speed, plays a crucial part in this interplay. In addition, PA stimulates hippocampal volume, neurogenesis, vascular function, and growth factor cascades.[9] This may explain the connection

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between high levels of PA and enhanced cognitive processing speed.

The number of steps and MVPA levels were found to be significantly associated with processing speed in the youngest-old, but not in the oldest-old adults. These findings corroborate previous research, which suggests that the links between cardiovascular risk factors, including low PA, and cognitive decline and dementia weaken with age.[15] Our findings, together with those of other studies, emphasize the importance of encouraging increased PA early in the aging process as a strategy to prevent cognitive decline.[5,6] A plausible explanation for the age-related differences is that age-related chronic diseases may accelerate physiological decline, rendering the oldest-old more vulnerable to physical and cognitive frailty, independent of PA levels.[31] Additionally, our strict exclusion criteria might have resulted in an analytical sample that is healthier than the target population. Furthermore, selective mortality may play a role, whereby older adults with lower PA and cognitive function are less likely to survive to older ages.[31]

Previous research suggests that the benefits of PA on cognition are more evident at higher PA intensity levels.[32] Our findings partly align with this finding, as we observed a significant association between MVPA and better processing speed in the younger age group. A study of older women also found that taking more steps and spending more time in MVPA were associated with a lower risk of mild cognitive impairment and dementia.[33] Our study, however, revealed that, irrespective of whether younger-old adults engaged in more or less than 60 minutes of MVPA per week, the number of steps was significantly associated with better processing speed. This is in line with previous research, suggesting that the number of steps is linked to health outcomes independent of cadence.[17] However, this study is the first to show this in relation to cognitive function. As people age, their physical function and mobility often decline, potentially limiting the number of steps they can take, especially at higher step cadence.[14] Therefore, it is encouraging that, even at lower cadences, increasing the number of steps may offer health benefits.[34] Increasing the number of steps is a straightforward and effective strategy for promoting PA in the community. Health professionals frequently use step counts as a valuable tool for prescribing PA, and recent technological advancements have made tracking steps more accessible.[14]

This study has several strengths. First, it benefits from the objective measurement of PA and the transparent data extraction based on current evidence.[12,13] The use of accelerometers and a robust extraction method contributes to the reliability of measurements, thereby minimizing misclassification bias from potential measurement errors. Second, the study used specific variables related to cognitive function, allowing for a more precise analysis of the various cognitive domains. The study also has limitations. Despite controlling for relevant confounders, residual confounding may exist, and our cross-sectional design prevents us from determining the direction of the associations. Our study cohort resides in a relatively affluent region in Sweden. Additionally, we excluded participants with severe cognitive impairment or those who required assistance to move indoors, resulting in a healthier and more physically active sample than the general population. As a consequence, our analysis is constrained across the cognitive spectrum, and the generalizability of our results to broader populations is limited. Future research should include a more diverse demographic profile and expand its geographical scope to enhance generalizability. Additionally, longitudinal studies are needed to clarify the directionality of the associations.

In conclusion, our study revealed a cross-sectional association between PA, in terms of number of steps and MVPA levels, and processing speed in young older adults. Importantly, the number of steps correlates with processing speed regardless of intensity. Our findings suggest a positive association between daily steps and processing speed, particularly within this demographic, emphasizing the importance of mobility for cognitive health. Future longitudinal studies are needed to determine the directionality of these associations.

DISCLOSURES

The authors declare no conflict of interest. Data collection of the Swedish National study on Aging and Care (SNAC-K) was supported by the Swedish Research Council (ongoing/current grant: 2021-00178); the Swedish Ministry of Health and Social Affairs; the participating County Councils and Municipalities. In addition, this

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AUTHORS CONTRIBUTIONS

Study concept and design: Joan Ars, Anna-Karin Welmer, Amaia Calderón-Larrañaga, Giorgi Beridze; Acquisition of data: Anna-Karin Welmer, Amaia Calderón-Larrañaga, Erika J Laukka; Analysis and interpretation of data: Joan Ars, Anna-Karin Welmer, Amaia Calderón-Larrañaga, Giorgi Beridze, Erika J Laukka; Drafting of the manuscript: Joan Ars; Critical revision of the manuscript for important intellectual content: Joan Ars, Amaia Calderón-Larrañaga, Giorgi Beridze, Erika J Laukka, Pau Farrés-Godayol, Laura M Pérez, Marco Inzitar, Anna-Karin Welmer; Final approval of the manuscript submitted to the journal: Joan Ars, Amaia Calderón-Larrañaga, Giorgi Beridze, Erika J Laukka, Pau Farrés-Godayol, Laura M Pérez, Marco Inzitar, Anna-Karin Welmer.

ETHICS APPROVAL

The study was approved by the Regional Ethics Review Board in Stockholm (dnr: 2016/730−31/1.) All participants provided written consent to participate.

DATA STATEMENT

This study's preliminary results were presented in poster format at the European Geriatric Medicine Society Congress (Helsinki, 2023).

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.jagp.2024.09.017.

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