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Physical activity, home and leisure activities, and neuropsychological performance in middle-aged and older adults living in the community

BACKGROUND

There is a large body of evidence linking physical activity (PA) with improved cognition in later life. The present study aimed to investigate the associations between current neuropsychological functioning and PA, as well as home and leisure activities in middle-aged and older people. Visuospatial functions were of particular interest.

PARTICIPANTS AND PROCEDURE

Fifty men and 54 women aged 50-81 years participated in the study. The assessment included standardised or experimental neuropsychological tasks and PA monitoring with a pedometer. In addition, home and leisure activities were examined. These included daily activities related to free time – physical, social, cultural, intellectual and spiritual. The cognitive tasks assessed perceptual processing speed, visuospatial abilities, construction, attention, working memory and executive function. To obtain more general measures of cognitive function, two cognitive factors were extracted using principal components analysis. Correlation analysis and a general linear model examined whether PA, as measured by walking, engaging in home and leisure activities, and age were cross-sectionally associated with neuropsychological performance.

RESULTS

In the study group, engaging in a variety of domestic and leisure activities was linked to better performance in the Visuospatial/Executive Function and Working Memory/Executive Function factors. Older age was associated with lower Visuospatial/Executive Function factor scores. Walking volume was not associated with the cognitive factors.

CONCLUSIONS

The results of this study support the hypothesis that having a rich cognitive and physical lifestyle can be beneficial to cognitive function in middle and older adulthood. Further research is needed to better understand the links between neuropsychological performance, physical activity and home and leisure activities in these age groups.

KEY WORDS

neuropsychology of cognitive ageing; physical activity; home and leisure activities

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BACKGROUND

Daily physical activity (PA) is a recommended modifiable behaviour for maintaining or improving somatic and mental health (World Health Organization, 2020). Physical activity is defined broadly to include daily exercise, active transport, leisure activities and sport for health rather than performance. There is a large body of evidence for correlational and causal relationships between exercise and better cognition in later life (Biddle et al., 2021; Erickson et al., 2022; Stenling et al., 2021). In healthy people, positive associations have been found between PA and global measures of cognitive function, as well as specific domains such as attention, executive function, working memory and learning. In a systematic review of cross-sectional and longitudinal studies across the adult lifespan, moderate-to-vigorous leisure-time physical activity (MVPA) was associated with global cognitive function, executive function and memory (Engeroff et al., 2018). Another meta-analysis found positive relationships between light-intensity PA and levels of executive function, working memory, attention, processing speed, memory and global cognition (Erlenbach et al., 2021). A further meta-analytic review of studies in older people found that regular walking was associated with improved executive function, particularly attention switching and inhibition (Scherder et al., 2014). In another research review, older adults scored better on measures of working memory, including n-back, verbal span, Corsi block tapping, and letter and digit sequencing, after PA interventions (Zhidong et al., 2021). The beneficial effects of PA on cognition, and aerobic exercise in particular, have been attributed to increased cortical thickness in those who are more physically active, particularly in the prefrontal and hippocampal regions. People who are more physically active have also been found to have larger brain volumes, better functional connectivity and better white matter myelination (Boa Sorte Silva et al., 2024).

Cross-sectional studies have also reported associations between increased participation in PA by older adults and cognitive outcomes, particularly in the areas of executive function and processing speed. In one study, higher levels of light PA, as measured by accelerometry, were associated with better set shift performance on the Trail Making test, after controlling for age, smoking history, alcohol intake and education (Johnson et al., 2016). Similar findings were reported by Umegaki and colleagues (2018), who found that participation in light PA was correlated with better performance on the Digit Symbol Substitution test and the Trail Making test. The Leukoaraiosis And DISability (LADIS) study of non-cognitively impaired older people with age-related white matter changes found associations between PA levels and measures of processing speed, such as the Trail Making test, Part A and the Digit Cancellation test, executive function, as measured by the Trail Making (B-A) test, Stroop test, verbal fluency, and symbol-digit modality test (Frederiksen et al., 2015). Physical activity has also been found to have a positive association with visual memory and face name recognition in older adults (Hayes et al., 2015). Elsewhere, higher lifelong or last year activity, as assessed through a survey, was linked to better overall cognitive functioning (Gill et al., 2015; Szepietowska & Dąbal, 2023). However, these are the results of a small number of studies, and other investigations have not found a significant relationship between cognitive performance and PA (Bernstein et al., 2022; Phillips et al., 2016).

Studies have also explored the relationship between PA and visuospatial skills in older adults. Spatial processing is the ability to perceive, remember and act on where things are in the world. It is a fluid ability and is used in everyday activities such as handling and manipulating objects, planning and controlling body movements, orienting in space and navigating. Spatial memory and the ability to navigate new places decline with age (Postma & van der Ham, 2017). Visual-spatial skills can be assessed using mental rotation tasks, i.e. the imagined rotation and movement of objects in space (Shepard & Metzler, 1971). Another type of task involves constructing three-dimensional structures, such as arranging patterns of blocks on the Block Design subtest of the Wechsler Adult Intelligence Scale (WAIS). Block Design performance has been suggested as a possible non-verbal indicator of cognitive reserve (Corujo-Bolaños et al., 2023).

Not much is known about the associations between the visuospatial domain and PA in older adults. In one investigation, physically active groups of seniors participated in exercise (e.g., jogging, swimming, table tennis) for at least 1 year. A sedentary control group took part in exercise on an irregular basis. Their ability to perform a visuospatial short-term memory task and a visuospatial mental rotation task was assessed. The stimuli in both tasks were 4 × 4 matrices with four black squares. In one task, participants were instructed to mentally rotate the probe matrix by 90° and to decide whether the subsequent matrix stimulus matched the mentally rotated one. In the second task, participants had to compare pairs of matrices and decide whether the matrices displayed on the right corresponded to the matrices rotated by 90° displayed on the left. Both physically active groups achieved higher accuracy than the sedentary group in both tasks (Guo et al., 2016). In another study, cognition was assessed using a range of tests, including the stick test for spatial function and memory. Participants were given 4 wooden sticks and asked to accurately copy the examiner's model and to recall the previous pattern after copying the current one. After copying the

10 patterns, participants were asked to construct the reverse pattern of the examiner's model. The findings showed that cognitive activity engagement and high PA were associated with the best performance on the stick test and on tests of executive function, memory, language, and global cognition (Wu et al., 2024).

Here we extended previous research by examining the relationship between cognitive function and current PA. Of particular interest were visuospatial functions, as there was little previous research and few studies had shown associations with PA. We examined whether paper-and-pencil and computer tasks assessing mental rotation, construction, perceptual speed, attention, working memory and executive function were associated with walking time in neurologically healthy individuals over 50. We also examined participation in diverse home and leisure activities in the months before the assessment. These included physical, cultural, intellectual and social activities. We expected that more active participants would have better cognitive performance than less active participants.

PARTICIPANTS AND PROCEDURE

PARTICIPANTS

A total of 104 participants, comprising middle-aged and older 54 women (M_{age} = 63.1, SD_{age} = 7.3) and 50 men (M_{age} = 64, SD_{age} = 8.1), with normal neurological function, entered this study. The age range was set at 50 and older based on other known studies of ageing, e.g. the Survey of Health, Ageing and Retirement in Europe – SHARE (https://share-eric.eu), and similar studies. According to psychological theories of development and cognitive models of ageing, the age of 50 falls within the range of middle age (Cavanaugh & Blanchard-Fields, 2011). Inclusion criteria were therefore age 50 years or older, as well as intact or corrected vision and hearing, good general health, and sufficient motor function to complete the assessment. Exclusion criteria were current or past psychiatric and neurological conditions, such as Alzheimer's disease, Parkinson's disease, epilepsy, stroke, traumatic brain injury, meningitis, brain tumour, depression, schizophrenia, bipolar disorder, other conditions, especially those affecting the brain, vision, hearing, or mobility. Participants reported their history of any common medical conditions, systolic and diastolic blood pressure, heart rate and smoking. Another factor that excluded a person from the study was lack of experience with a standard laptop computer.

Participants provided age, height, weight, education, relationship and employment. Step length was estimated by sex and height (https://www.wikihow.com/Measure-Stride-Length) and BMI was estimated using the standard formula (www.nhs.uk). Participants reported their main occupation or the occupation in which they had worked the longest.

MEASURES

The measures included nine standardised or experimental neuropsychological tasks, PA monitoring with a pedometer and a home and leisure activity survey. The cognitive tasks assessed perceptual processing speed, visuospatial ability, construction, attention and working memory in a variety of ways, as well as some executive function demands. The mental rotation task, the n-back task and the choice reaction task were programmed and administered using Labvanced software (Finger et al., 2017). Participants were assessed individually in two sessions on 7 to 14 consecutive days.

Cognitive measures

In the *Mental Rotation Task* (Shepard & Metzler, 1971), participants had to decide whether two figures on the computer screen were identical or mirror images. The test consisted of 96 stimuli, preceded by a practice block with feedback after each response. Participants were asked to respond as quickly and accurately as possible. Each stimulus consisted of two geometric figures, one next to the other (Ganis & Kievit, 2015). In each pair, one of the figures was rotated by 0°, 50°, 100°, or 150° along the vertical axis with respect to the other. Fifty percent of the stimuli were figures mirroring each other. The stimuli appeared in a fixed order. Accuracy and reaction times were collected and analysed for identical or mirrored figures for each angle of rotation. The total number of correct responses and the total reaction time for correct responses are reported.

The Block Design subtest of the Polish version of the WAIS (WAIS-R(PL); Brzeziński et al., 1996) measures the ability to reconstruct an abstract pattern from coloured plastic blocks. The test involves spatial visualisation, visual-motor coordination and non-verbal concept formation. The overall score is reported.

The Link's Cube test (Kopp et al., 2014) measures construction ability. The test requires respondents to make a cube by combining 27 small cubes in such a way that only the outer painted surfaces of the small cubes are visible. The task was administered using an experimental procedure. The time taken to place the whole cube correctly or to quit, the number of errors in placing the small cubes, and memory for the cube are reported.

The Choice Reaction Task (Albinet et al., 2012) was used to measure perceptual processing speed. Participants had to respond as quickly and accurately as possible to a visually presented arrow pointing to the right (>) or left (<) by pressing the spatially compatible key. There were two test blocks of 44 trials each, preceded by a practice block. The arrows were displayed on the computer screen until a response was made. Total accuracy and total (aggregated) reaction times are reported.

The Digit Span Forward subtest of the Polish version of the WAIS-R (WAIS-R(PL); Brzeziński et al., 1996) was used to assess short-term memory. Participants had to immediately recall and reproduce orally presented series of numbers in the order of their presentation. The number of series reproduced correctly is reported.

The Digit Span Backward subtest of the Polish version of the WAIS-R (WAIS-R(PL); Brzeziński et al., 1996) measured working memory. This task requires respondents to verbally repeat strings of digits presented in reverse order. The number of correctly repeated reverse strings is given.

The n-back task is a measure of attention, working attention and inhibitory control (Miller et al., 2009). In the task, participants saw consonants appear one after another on a computer screen. The 0-back condition required a response when the letter X appeared on the screen, thus requiring sustained attention but not working memory. The 1-back condition involved responding to a letter that was identical to the immediately preceding letter. The 2-back condition required responding to a letter that was identical to the letter presented two trials earlier. Participants completed one block of trials in the 0-back, one block in the 1-back, and one block in the 2-back condition. The order of conditions was counterbalanced across participants (0, 1, 2-back). Before starting the task, participants received a practice block for each condition. The rate of correct performance and total reaction times for correct responses are provided.

The Color Trails Test (CTT; Łojek & Stańczak, 2012) is used to examine processes related to attention and executive function, particularly object search, attentional maintenance and shifting, sequential information processing, visuomotor skills, and self-monitoring. The Color Trails Test Form A Section 1 and CTT Form A Section 2 performance time and error ratio (CTT2 – CTT1) / CTT1) are given.

The Digit Symbol subtest of the WAIS-R(PL) (Brzeziński et al., 1996) is a paper-and-pencil task that requires the individual to match symbols to numbers according to a key at the top of the page. The test consists of filling as many empty boxes as possible with a symbol corresponding to each number in 90 seconds. The test measures processing speed, working memory, visuospatial processing, motor performance and attention. The number of correct symbols is scored.

Home and leisure activities assessment

An experimental questionnaire recorded the number and frequency of domestic and leisure activities. Home activities are activities outside work related to household, family and self-care. Leisure activities are those undertaken during free time for pleasure or relaxation – physical, social and intellectual. Individuals rated their usual frequency of participation in 48 activities on a 5-point scale: almost every day, 1-2 times a week, once a month, less than once a month, never. They were asked to rate their participation in activities "recently", i.e. within several months before the survey date. Scores could range from 0 points (if the respondent answered "never" for all activities) to 192 points ("almost every day" for all activities). Examples of activities that the interviewees rated were doing the housework, reading, browsing the internet, cooking, listening to music, driving, taking care of children, taking care of the elderly, going to church, going to museums, receiving visitors, gardening, going to the swimming pool, walking, biking, other sports, repairing equipment, going to the hairdresser or beauty salon. The total score is reported.

Physical activity assessment

Participants were instructed to wear an Onwalk 900 pedometer for seven consecutive days. This device, an analogue pedometer, recorded the number of steps taken. Study participants wore the pedometer between sessions at the APS. Each person was given a reset pedometer and returned it at their second visit to the APS, 7-8 days later. Settings were adjusted according to the participants' weight, height and stride length. Volunteers were instructed to wear the pedometer every day and kept it on until evening. The Onwalk 900 is a sturdy device that can be attached to clothing or a belt. As the study took place during different seasons, people wore it on different parts of their clothing. The device shows total steps, calculates distance, time of use, and average walking speed in kilometres per hour after each day, but does not show continuity of use throughout the day. However, the data obtained in the current study sample indicate an acceptable continuity of pedometer use throughout the week. Out of 103 people, with 7-8 days of wear by each person, only 13 days of data are missing. Physical activity was also assessed using the long form of the International Physical Activity Questionnaire. The results have been published separately (Gawron et al., 2024).

The tasks were then administered to each participant in the following order: session 1 – Digit Span subtest of the WAIS-R(PL), Choice Reaction task, Mental Rotation task, Link's Cube task; Home and Leisure Activities survey, providing the participant with a pedometer after establishing height, weight and stride length; session 2 – n-back task, Digit Symbol subtest of the WAIS-R(PL), Block Design subtest of the WAIS-R(PL), CTT Form A Part 1 and Part 2.

The study was approved by the Research Ethics Committee of the Maria Grzegorzewska University. Participants were recruited through online advertisements and flyers. Prior to the assessment, they received written information about the purpose of the study, a description of the procedure, how to get feedback on the group results of the study, information that participation in the study was voluntary and confidential, and that they could withdraw at any time. All participants gave written informed consent. At the end of the study, the participants were given a leaflet with the WHO recommendations for healthy PA, a gift card and a pedometer.

DATA ANALYSIS

In order to provide an overview of all the methods used in this study, the results for men and women on all the cognitive tasks and activity data, as well as demographic characteristics, are first presented using means and standard deviations. These were compared using Student's *t*-tests and Mann-Whitney *U*-tests. Next, to obtain more general measures of cognitive function, two cognitive factors were extracted using principal component analysis (PCA). Continuous test variables with a near-normal distribution were included in the PCA: Link's Cube completion times, WAIS-R(PL) Block Design and Digit Symbol subtest scores, total reaction times for correct responses on the Mental Rotation task, and total reaction times for correct responses on the n-back task. PCA involved standardising the input variables before calculating the factors. Parametric and non-parametric correlation analyses and a general linear model were used to determine whether participants' cognitive function was associated with the amount of walking during the study and with home and leisure activities, controlling for age. The variables age and home and leisure activities were normally distributed.

RESULTS

The study included data from 104 participants (50 men and 54 women) aged 50-81 years. The age distribution was as follows: there were 18 women and 18 men in the 50-59 age group (34.6% of the total sample), 27 women and 19 men in the 60-69 age group (44.2% of the sample), and nine women and 13 men in the 70-81 age group (21.2% of the sample). The employment rate was 43.3%. Sixty-two percent of the study group were in a relationship. Some people reported health conditions being treated, such as hypertension (41%), cardiovascular disease (17%), type II diabetes (7%), thyroid disease (6.7%), asthma, COPD, arrhythmia, obesity, migraine, sciatica, and osteoporosis. Twelve percent of the study group were current or former cigarette smokers. Men were taller ($t(95) = 11.10$, $p < .001$, $d = 6.24$), heavier ($t(95) = 5.49$, $p < .001$, $d = 13.04$) and had a longer stride than women ($t(95) = 11.99$, $p < .001$, $d = 2.59$). Mean diastolic blood pressure was higher in men than in women ($t(99) = 2.55$, $p = .012$, $d = 11.07$). The study was carried out in two parts – first with both women and men (Gawron et al., 2024). In the following autumn and winter, men were matched so that the total number of men was equal to the total number of women. Average day length during the study was longer for women ($M_{\text{day length}} = 923.2$ minutes; $SD_{\text{day length}} = 110.5$) than for men ($M_{\text{day length}} = 770.4$ minutes; $SD_{\text{day length}} = 208$; $U = 748$; $p < .001$). Table 1 shows demographic and health information.

Women outperformed men on the Digit Symbol subtest of the WAIS-R (PL) ($M_{\text{Digit Symbol}} = 47.8$, $SD_{\text{Digit Symbol}} = 10$ for women vs. $M_{\text{Digit Symbol}} = 42.9$, $SD_{\text{Digit Symbol}} = 9.8$ for men, $U = 1607.50$, $p = .021$). On the Mental Rotation task, men scored more hits on

Table 1

Demographic and health information in the study sample

Variable	Male *n* = 50		Female *n* = 54		*t*	*p*
	M	*SD*	*M*	*SD*		
Age	64.0	8.1	63.1	7.3	0.62	.267
Height (cm)	177.3	6.0	163.3	6.4	11.10	< .001
Weight (kg)	84.3	13.0	69.7	13.1	5.49	< .001
BMI	26.7	3.6	26.1	4.6	0.69	.245
Step length (cm)	73.6	2.4	67.2	2.8	11.99	< .001
Years of education	16.9	3.9	15.4	3.6	1.95	.055
Diastolic blood pressure (mmHg)	84.1	11.5	78.4	10.6	2.55	.012
Systolic blood pressure (mmHg)	128.4	12.9	124.5	13.4	1.49	.139
Pulse	72.5	12.7	74.2	11.8	−0.66	.514

Note. BMI – body mass index.

identical figures turned by 0° ($M_{0^\circ\ \text{identical}} = 5.2$, $SD_{0^\circ\ \text{identical}} = 3$ for men vs. $M_{0^\circ\ \text{identical}} = 3.7$, $SD_{0^\circ\ \text{identical}} = 2.8$ for women, $U = 860$, $p = .004$), and on mirror figures rotated by 150° ($M_{150^\circ\ \text{mirror}} = 4.1$, $SD_{150^\circ\ \text{mirror}} = 2.7$ for men vs. $M_{150^\circ\ \text{mirror}} = 3.1$, $SD_{150^\circ\ \text{mirror}} = 1.8$ for women, $U = 967.50$, $p = .034$). They also responded faster than women to mirror figures rotated by 150° ($M_{150^\circ\ \text{mirror}} = 2948.6$ ms, $SD_{150^\circ\ \text{mirror}} = 1418.5$ ms for men vs. $M_{150^\circ\ \text{mirror}} = 3713.4$ ms, $SD_{150^\circ\ \text{mirror}} = 1713.2$ ms for women, $U = 932$, $p = .020$). Men made more hits and correct rejections than women in the 1-back condition of the n-back task ($M_{\text{1-back}} = 13.6$, $SD_{\text{1-back}} = 5.4$ for men vs. $M_{\text{1-back}} = 11.2$, $SD_{\text{1-back}} = 8.5$ for women, $U = 1005$, $p = .049$). There were no other differences between men and women for the computer tasks, other cognitive tests, walking and reported home and leisure activities. Table 2 shows the cognitive and PA scores.

Table 2

Neuropsychological outcomes and physical activity results in the studied male and female participants

Variable	Male *n* = 50		Female *n* = 54		*U/t*	*p*
	M	*SD*	*M*	*SD*		
WAIS-R(PL)						
Digit Span	11.9	4.0	10.9	2.8	1220	.394
Digit Symbol	42.9	9.8	47.8	10.0	1607.5	.021
Block Design	27.0	9.5	24.7	7.3	1080.5	.144
Link's Cube time (s)	613.1	320.7	677.2	359.1	1391	.406
Link's Cube errors	5.9	5.8	6.1	5.2	1237	.691
Link's Cube memory	3.1	1.3	2.7	1.3	1003.5	.060
Color Trails Test						
Part 1 (s)	52.4	28	46.9	12.6	1347	.874
Part 2 (s)	101.5	47.3	102.2	38.2	1392	.520
Error rate	1.1	0.6	1.2	0.8	1356	.687
Choice Reaction Task						
Total hits	85.5	2.6	86.1	1.7	1228.5	.632
Total RTs for hits (ms)	1137.3	190.7	1192.7	187.5	1177.5	.418
Mental Rotation						
Total mirror and identical hits	41.2	15.0	37.3	8.9	1088	.206
Total RTs for hits (ms)	26270.5	5882.5	28087.3	8439.9	1115.0	.280
N-back						
Total hits and correct rejections	45.1	12.9	45.1	18.3	1218.0	.590
Total RTs for hits and correct rejections (ms)	5900.4	922.5	5915.4	1124.1	1260.0	.797
Physical activity						
Walking steps	53232.3	19692.4	60538.4	24648.6	−1.65	.102
Walking distance (km)	39.8	17.5	40.5	17.0	−0.20	.422
Walking calories	4209.4	1769.7	4086.3	1567.0	0.37	.709
Walking time (min)	475.57	173.45	499.63	171.94	−0.71	.482
Walking average speed (km/h)	4.5	0.7	4.4	0.8	0.57	.286
Home and leisure activities total score	72.6	14.7	74.1	13.9	−0.53	.298

Note. WAIS-R(PL) – Wechsler Adult Intelligence Scale Revised, Polish adaptation; RT – mean reaction time; Total RTs – total response times for correct trials.

In order to obtain more general measures of cognitive function, two independent components were derived from the PCA, accounting for 61.2% of the total variance in the results. The analysis was performed on the values of five test variables with normal distribution (Eigenvalue – greater than one, extraction method – principal axis factoring, rotation method – varimax with Kaiser normalisation, Kaiser measure of sampling adequacy = .547; Bartlett's test of sphericity approximately = 60.79, $df = 10$, $p < .001$). The first component was Visuospatial/Executive Function. It accounted for 36.5% of the variance in the scores. This component included the performance time on the Link's Cube task, the total reaction time for correct responses on the Mental Rotation task, and the Block Design subtest score (Table 3). Higher scores on the first two variables indicated slower completion of the task or slower reaction times. In the Block Design subtest, more points were awarded if the person arranged the geometric patterns quickly and within the time limit. For this reason, in the Visuospatial/Executive functioning component, the Block Design variable had a negative loading and the other two variables had positive loadings. Slower Mental Rotation performance (i.e. longer reaction times for correct answers) and slower Link's Cube placement (i.e. longer completion times) correlated with lower (worse) Block Design scores. The second component, Working Memory/Executive Function, accounted for 26.3% of the variance in scores. This component included reaction times for correct responses on the n-back task and scores on the Digit Symbol subtest of the WAIS-R(PL). Higher results on the Digit Symbol test correlated with slower performance on the n-back task. We believe that the latter may indicate a need to suppress fast, impulsive responses in order to succeed on the n-back task (Zarantonello et al., 2019). The pattern matrix of variable loadings in the cognitive components is shown in Table 3.

Preliminary correlational analyses were conducted to determine whether participants' cognitive function was associated with PA, reported home and leisure activities, and age, as well as other variables that could potentially be associated with outcomes – education and day length at the time of the study. These showed that among the studied individuals, older age correlated with higher scores on the Visuospatial/Executive Function component ($r = .41$, $p < .001$). In our view, this indicates that the older people were, the slower they were in performing the tasks included in the Visuospatial/Executive Function factor. Also, older participants were tested in months with shorter days ($rho = -.30$, $p = .002$). More educated participants were more active at home and in their leisure time ($r = .23$, $p = .023$). More activity at home and in leisure time correlated with faster performance on the Visuospatial/Executive Function factor ($r = -.24$, $p = .019$) and better and slower performance on the Working Memory/Executive Function factor ($r = .25$, $p = .015$). Non-parametric correlations also showed that more home and leisure activities correlated with more steps taken during the study period ($rho = .28$, $p = .005$) and longer time spent walking ($rho = .23$, $p = .023$). However, there was no correlation between the amount of walking and age or cognitive performance.

Finally, a general linear model was used to examine the relationship between cognitive performance and activity. Cognitive factors were entered as dependent variables, home and leisure activities as independent variables, and age as a covariate (Table 4). The results showed that home and leisure activities and age accounted for 19% of the variance in the Visuospatial/Executive Function factor (adj. $R^2 = .19$, $F(2, 9.938) = 12.11$, $p < .001$, $\eta p^2 = .212$) and

Table 3

Pattern matrix of the variables' loadings in the cognitive components

PCA variables	Component loadings	
	1	2
Component 1. Visuospatial/Executive functioning		
WAIS-R(PL) Block Design	**–.783**	.378
Link's Cube time of performance	**.825**	–.006
Mental Rotation task hit reaction times	**.526**	.190
Component 2. Working Memory/Executive functioning		
N-back task hit reaction times	.306	**.726**
WAIS-R(PL) Digit Symbol	–.285	**.780**

Note. $N = 95$. The extraction method was principal axis factoring with Varimax rotation with Kaiser normalization. Factor loadings above .40 are in bold.; PCA – principal components analysis; WAIS-R(PL) – Wechsler Adult Intelligence Scale Revised, Polish adaptation and normalization.

Table 4

The associations between cognitive components and home and leisure activities when controlling for age

Component	*B*	*SE*	*t*	*p*	95% CI		ηp^2
					LL	UL	
Visuospatial/Executive functioning							
Intercept	−2.21	.97	−2.28	.025	−4.133	−.283	.055
Home and leisure activities	−.02	.01	−2.22	.029	−.028	−.002	.052
Age	.05	.01	4.18	< .001	.027	.077	.162
Working Memory/Executive functioning							
Intercept	−.19	1.05	−0.18	.859	−2.270	1.895	.000
Home and leisure activities	.02	.01	2.38	.020	.003	.031	.059
Age	−.02	.01	−1.25	.215	−.044	.010	.017

Note. $N = 93$; CI – confidence interval; LL – lower limit; UL – upper limit; B – estimate; SE – standard error; ηp^2 – partial eta squared.

Cognitive function in middle-aged and older adults and physical activities

6% of the variance in the Working Memory/Executive Function factor (adj. $R^2 = .59$, $F(2, 3.748) = 3.90$, $p = .024$, $\eta p^2 = .080$). Home and leisure activities accounted for 5% of the variance in the Visuospatial/Executive Function factor ($\beta 1 = -.02$, $p = .029$, $\eta p^2 = .052$) and 6% of the variance in Working Memory/Executive Function factor ($\beta 2 = .02$, $p = .020$, $\eta p^2 = .059$). A negative association of home and leisure activities with the Visuospatial/Executive Function factor seems to indicate that more active people performed faster and better on the tasks included in this factor. A positive association of home and leisure activities with the Working Memory/Executive Function factor seems to indicate that more active people performed better on the tasks in this factor. Age as a covariate accounted for 16.2% of the variance only in the Visuospatial/Executive Function factor ($\beta 1 = .05$, $p < .001$, $\eta p^2 = .162$), Thus, older age was associated with slower performance on the visuospatial tasks and not related to the Working Memory/Executive Function factor ($\beta 2 = -.02$, $p = .215$, $\eta p^2 = .017$).

DISCUSSION AND CONCLUSIONS

The aim of this study was to investigate the relationship between cognitive function and PA in community-dwelling people aged 50-81 years in a cross-sectional design. In particular, we evaluated whether people who were more active performed better on visuospatial tasks such as mental rotation, assembling a wooden cube, mapping coloured geometric patterns with blocks, copying geometric symbols, and reacting to arrows pointing to the left or right. The tasks also involved attention, processing speed, working memory and executive functions. Physical activity was measured by walking. Volunteers also reported on activities and occupations at home and in leisure time. A key finding is that participants' performance on the Visuospatial/Executive Function and Working Memory/Executive Function factors was associated, albeit modestly, with engagement in home and leisure activities. More home and leisure activity was linked to better cognitive performance. This may be in line with the cognitive reserve (CR) theory (Stern, 2007). According to the CR theory, exposure to cognitively stimulating experiences enhances the acquisition of cognitive strategies that may protect against age-related decline. Having a rich cognitive and physical lifestyle can be beneficial to cognitive function in middle and older adulthood. Cognitive reserve is developed primarily through long-term experiences such as education, professional activities and positions held, exposure to complex environments with multiple stimuli, having hobbies and interests, and engaging in intellectual, social or physical activities (Opdebeeck et al., 2016; Stern, 2007). The study also found a negative correlation between performance on tasks involving visuospatial and executive functions and older age. This is consistent with previous studies showing age-related declines in mental rotation speed (Palermo et al., 2016; Zhao et al., 2020), visuospatial perception, and construction abilities (Borella et al., 2014; Brzezinski et al., 1996). The current study also indicates that home and leisure activities, even when assessed over shorter periods such as months, may be related to cognitive performance. Similar results have been found in other work (Bernstein et al., 2022; Ishioka et al., 2023).

It should be noted, however, that domestic and leisure activities, and age, only partly explained the cognitive results in the middle-aged and older adults in the current study. This is similar to the results of a cross-sectional study conducted by Szepietowska and Dąbal (2023), who examined the associations between older people's lifetime PA and their current cognitive function. They assessed attention (Trail Making Test), verbal fluency, executive function, and short-term and working memory (WAIS-R(PL) Digit Span). They found positive correlations between self-reported lifetime PA and neuropsychological outcomes, but these were smaller than the associations of neuropsychological outcomes with age, which is in line with the results of the current study. The results of the research by Szepietowska and Dąbal (2023) and our own study may be consistent with the hypothesis that PA and/or cognitive function may be influenced by factors not included in the assessments. For PA, many global investigations have identified related factors, including: demographic (age, occupation, education, gender, socioeconomic status, overweight/obesity, heart disease), biological (age, occupation, education, gender, socioeconomic status, overweight/obesity, heart disease), psychological (e.g. attitudes toward activity, intention to exercise, self-motivation, health knowledge, self-image as an exerciser, perceived lack of time), behavioural (history of activity in childhood, adolescence and adulthood, eating habits, smoking), social status, social support, and environmental (dog ownership, access to sports facilities, climate/season, pleasant environment, lighting, safe neighbourhood) (Buckworth et al., 2023).

The current study, having a naturalistic/laboratory design, adds information on walking/leisure activities to improve understanding of functioning in middle-aged and older adults (Marcotte et al., 2022). Walking is a highly individualised form of daily activity. It is also the most common form of PA (World Health Organization, 2020). Studies combining walking and traditional in-depth laboratory neuropsychological assessments are rare, but their number is increasing due to the growing popularity of activity trackers. In the present study, weekly walking volume measured by pedometers was not correlated with cognitive performance. This contrasts with other studies that found associations between PA, as collected by monitoring devices, and executive function (Johnson et al., 2016), attention and working memory (Gothe, 2021; Umegaki et al., 2018), visual memory and learning (Hayes et al., 2015). These findings, however, are consistent with evidence from small groups. In a study of 51 healthy older people, Phillips and colleagues (2016) found that performance on a routine cognitive assessment questionnaire, a letter series task with inductive reasoning, and a WAIS-R digit-symbol substitution task was not associated with accelerometer-measured walking over a 5-day period. Bernstein and colleagues (2022) also reported no association between outcomes on a battery of cognitive tasks and PA. In their study, a subset of participants (n = 30, M_{age} = 73.7, SD_{age} = 5.7) wore smartwatches to assess sleep and PA patterns over a 1-month period. In this study group, cognitive performance was associated with gait speed and variability rather than step count. On the other hand, clinical studies involving at least a few hundred individuals have demonstrated significant associations between step count and cognitive performance (Fazeli et al., 2023; Mc Ardle et al., 2024). Clinical studies have also shown that mobility problems, slow walking, physical weakness and low grip strength may be a sign of general health decline, including cognitive decline in older adults (Nader et al., 2023; Peel et al., 2019). Gait speed and grip strength have been found to correlate with visuospatial ability, information processing speed and verbal memory (Killane et al., 2014; Okely & Deary, 2020). Future work should therefore include larger groups of middle-aged and older healthy people to clarify the relationship between cognitive functions (particularly mental rotation, construction, perceptual speed, attention, working memory and executive functions) and PA (particularly walking).

The current study also has some limitations. As mentioned, a larger sample size might have helped to highlight associations between cognitive function and different types of activity. Future studies should include measurements with an accelerometer (a smartwatch, waistband or wearable patches), a device that can separately record moderate and vigorous PA as well as time spent resting, provide precise measurements of walking speed, and even physiological parameters such as pulse or blood saturation over a 24-hour period. Increasing research shows that low-intensity activity and rest represent a relatively large proportion of daily activity and merit extensive study (Erlenbach et al., 2021). Moreover, to fully assess the effects of leisure, hobbies, interests and travel on cognitive function in middle and later adulthood, it is worth conducting longitudinal studies with a large sample of middle-aged and older adults at baseline (de Paula Couto et al., 2022; Kujawski et al., 2021), including all types of physical activity (including sexual activity) and adding aspects of life satisfaction to the questions under study (Olszewski et al., 2024).

This study found limited associations between visuospatial/executive and working memory/executive function outcomes, age, and home and leisure activities in volunteers aged 50-81. The participants' walking was measured during normal activities, which is an important strength of the study. The results help to understand age-related differences in cognitive ability, activity and leisure. They are also in line with cognitive reserve theory, which suggests that exposure to stimulating experiences and activities may be beneficial for cognition. More research is needed to clarify the relationships between neuropsychological function, PA and leisure activities in middle-aged and older adults.

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Disclosures

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The authors declare no conflict of interest.

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