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**Associations between physical and executive functions among community-dwelling  
older men and women**

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**ABSTRACT**

Walking is a complex task requiring interplay of neuromuscular, sensory, and cognitive functions. Owing to the age-related decline in cognitive and physical functions, walking may be compromised in older adults. For cognitive functions, especially poor performance in executive functions, is associated with slow walking speed. Hence, the aim of this study was to investigate the associations between different sub-domains of executive functions and physical functions and whether the associations found differ between men and women. Multiple linear regression analysis was performed on data collected from 314 community-dwelling, older adults who did not meet physical activity guidelines but had intact cognition. Our results showed that while executive functions were associated with gait and lower extremity functioning, the associations depended partly on the executive process measured and the nature of the physical task. Moreover, the associations did not differ between the sexes.

**Key words:** cognition, gait, dual-task cost, aging, sex differences

## Background

Walking is a complex task which is based on interplay of neuromuscular, sensory and cognitive functions (Holtzer et al., 2006; Yogev-Seligmann et al., 2008). As physical and cognitive functions decline with aging, walking, especially in more challenging conditions, may be compromised in older adults (Shumway-Cook et al., 2007). Reduced gait speed and cognitive functioning are both important determinants of health that are associated with poor health outcomes, disability, and mortality. A recent study suggests that the relationship between these determinants is bidirectional and that they are mutually capable of accelerating each other's development (Basile & Sardella, 2020). It has also been indicated that the presence of both reduced gait speed and cognitive impairment is more predictive of future disability and mortality than either of these determinants alone (Grande et al., 2020).

Poor cognition, especially poor performance in executive functions, i.e., higher-level functions that allow flexible goal-directed action and problem solving, has been found to be associated with slow gait speed (Morris et al., 2016). According to Miyake et al. (2000) executive functions include cognitive processes such as the ability to update and monitor working memory representation (updating), the ability to shift attention between tasks (set shifting) and the ability to inhibit over-learned stimulus response (inhibition).

Several brain regions are involved in regulating gait and executive functions. According to Grande et al. (2019), gait relies on interplay between prefrontal, motor and posterior parietal cortices, sub-cortical areas and more peripheral structures. From the executive functions, updating, set-shifting and inhibition have been shown to increase activation in the frontoparietal network (including e.g. dorsolateral prefrontal cortex), the cingulo-opercular network and the Striatum (Wu et al., 2020). It has been hypothesized that

1 the partially overlapping anatomical locations and neuronal networks, mainly in the  
2 prefrontal (Morris et al., 2016) and parietal areas, may be underlying causes of the  
3 association between executive function and gait parameters (Poole et al., 2019).

4 Previous research investigating the associations between different subdomains of  
5 executive functions and gait have reported partially conflicting results. Associations between  
6 better performance in updating, set shifting or inhibition and faster gait speed or better lower  
7 extremity functioning have been reported in some (Berryman et al., 2013; Coppin et al.,  
8 2006; Demnitz et al., 2018; Herman et al., 2011; Morris et al., 2016; Soumare et al., 2009)  
9 but not all studies (Hausdorff et al., 2005; Valkanova et al., 2018). Thus, there is no  
10 consistent knowledge, if some subdomain of executive function is more strongly associated  
11 with different types of walking or physical performance than others.

12 To perform a cognitive task simultaneously with a physical task, such as walking,  
13 requires the allocation of limited cognitive processing resources. Walking-related dual-  
14 tasking thus affects walking parameters, slows down gait speed, and negatively impacts  
15 cognition (Menant et al., 2014). Due to the anatomical overlap regulating gait speed and  
16 executive functions, decrements in dual-task performance may be due to competition for the  
17 same resources.

18 Earlier studies that have investigated sex differences in executive functions have  
19 shown mixed results. One study found sex differences to be sub-domain specific: women  
20 outperformed men in fluent language production and in a task requiring working memory  
21 updating, whereas no sex differences were observed in set-shifting (McCarrey et al., 2016).  
22 Grissom & Reyes (2019), in turn, suggest that sex is not the primary factor influencing  
23 performance in executive functions, and that the differences between the sexes may be more

dependent on differences in the strategies used to complete a task than in the ability to perform it. In physical functions, men have higher performance compared to women in tasks requiring maximal performance such as muscle strength and power (Sialino et al., 2019). Despite these differences, sex differences in the associations between cognitive and physical functions have been little studied. Best et al. (2016) found no differences between women and men in the longitudinal association between habitual gait speed and executive functions. Thibeau et al. (2019), in turn, found a moderating effect of sex on the longitudinal association between mobility (including habitual gait speed and dynamic balance) and executive functions. As performance in physical and executive tasks between the sexes differs depending on the nature of the task, we suggest that the potential sex-differences in associations between executive functions and physical functions may also depend on the executive function assessed or the nature of the physical task.

The aim of this study was to investigate if better performance in executive functions is associated with better performance in physical functions, especially walking-related functions, in community-dwelling older people and whether the associations differ between men and women. We applied the model of (Miyake et al. (2000), which “categorizes” executive functions into three subdomains – mental set shifting, updating and inhibition – and included tests for each. We assessed physical functioning with tests that have been extensively used in studies among older people, have predictive value for physical limitation and disabilities, and require cognitive demand from low to high.

## Methods

### Participants

This cross-sectional study utilized baseline data gathered for a randomized controlled trial (The PASSWORD study, ISRCTN52388040). A detailed description of the study design and recruitment has been published earlier (Sipilä et al., 2018). Participants were randomly selected from the Finnish National Registry. They were 70- to 85-year-old community-dwelling men and women living in the city of Jyväskylä, Finland, who did not meet physical activity guidelines (less than 150 min of moderate physical activity/week and no regular resistance training) (Nelson et al., 2007) but were able to walk 500 meters without assistance. Participants suffering from severe chronic or progressive diseases, severe musculoskeletal problems, depressive mood (GDS-15>5 points and who, according to the participants themselves and assessments by physicians and primary investigators, would not have the resources to commit to the study), excessive (risk level) use of alcohol (more than 7 units per week for women and 14 for men) or any other contraindications for physical training, or a Mini Mental State Examination (MMSE) score below 24 points were excluded.

Finally, 314 individuals were recruited for the study. The study was implemented according to the Declaration of Helsinki and approved by the Ethical Committee of the Central Finland Health Care District (K-S shp Dnro 11U/2016). All participants signed an informed consent before the baseline measurements.

## Measurements

Physical functions: In the *10-meter maximal gait speed* test (maximal gait speed), participants were asked to walk as fast as possible over the 10-meter course, with 2 to 3 meters allowed for acceleration. The time taken (s) to complete the walk was measured by photocells and gait speed (m/s) calculated. This test requires additional physical effort and is more sensitive to different levels of cognition than habitual gait speed (Fitzpatrick et al.,



2007). In the *20-meter habitual gait speed test* (habitual gait speed), participants were asked to walk 20 meters at their habitual speed. The time (s) taken to complete the walk was measured by photocells and gait speed (m/s) calculated. Reduced habitual gait speed is associated with risk for disability and cognitive impairment (Abellan van Kan et al., 2009). After the habitual gait speed test, participants were asked to repeat the walk again while performing a visuospatial cognitive task (Menant et al., 2014). The visuospatial task involved a display with three boxes set side by side and labelled A, B and C. Participants were asked to visualize a star that randomly moved to the left or right from one box to another. After three imagined movements, participants were asked to name the box containing the star. Participants were informed about the random starting position of the star and the direction of its movements through headphones continuously throughout the walking trial. Each new set of three movements was announced within one second of the participant answering the previous question. The difference between the two trials, *i.e.*, *dual-task cost*, was calculated. Dual-task cost shows how the need to divide attention affects gait speed (Yogev-Seligmann et al., 2008). In the *six-minute walking distance test* (6-min walking distance), participants were asked to walk around a 20-meter indoor track for 6 minutes, their aim being to walk the longest possible distance without risking their health. This test serves as a measure for community walking and walking endurance (Manttari et al., 2018). Lower extremity function, which is essential for walking, was measured with the *Short Physical Performance Battery* (SPPB), which comprises three subtests: standing balance test, habitual gait speed test and repeated chair-rise test (Guralnik et al., 1994). A sum score (0-12) was calculated, with higher scores indicating better performance.

Executive functions: In the *Color-Word Stroop test* (Stroop), participants were asked to name colors under different conditions (Graf et al., 1995). First, they were asked to name a set of red, blue, or green colored letter x's as quickly as possible. They were then asked to

1 read words naming colors (e.g., red, blue) printed in black. Finally, they were required to  
2 state the color named by a word printed in an incongruent color, e.g., the word “blue” printed  
3 in red ink. The inhibition cost, i.e., the difference between the time taken to name the colors  
4 and the time taken to complete the incongruent word-color trial was calculated. The Stroop  
5 test assesses the ability to inhibit a practiced and over-learned stimulus response (word-  
6 reading), and to react to the less trained task of color naming. In the *Trail Making Test* (TMT)  
7 A, which assesses psychomotor speed, participants were instructed to draw a line from  
8 number one to number two and so on up to number 25 (Reitan, 1958). In TMT B, which  
9 assess mental flexibility and set shifting, participants were instructed to draw a line from  
10 number one to the letter A and then from number two to the letter B and so on. The difference  
11 in the time taken to complete the two tests (TMT B-A) was calculated and used as an  
12 outcome. Updating and lexical access speed was assessed with the *Verbal Fluency test* (VF)  
13 (Koivisto et al., 1992). In this test participants were asked to name as many words beginning  
14 with P, A and S as possible in one minute and the number of words was summed.

15 Background variables: Information on *age and sex* were drawn from the Finnish  
16 National Population register. Body height and weight were measured, and body mass index  
17 was calculated. *Chronic diseases and medication* were self-reported and verified by the study  
18 physician through Finland’s integrated patient information system. *Cognitive status* was  
19 assessed with the MMSE, which is a tool commonly used for screening cognitive functions  
20 among older adults (Folstein et al., 1975). The MMSE provides information about  
21 registration, attention, calculation, recall and language. The maximum MMSE test score is 30  
22 and scores above 24 indicate normal cognitive function. Information on falls during the  
23 previous year, physical activity, education and smoking were self-reported and assessed by  
24 validated questions. *Indoor and outdoor falls* during previous year were reported separately  
25 as follows: 1=none, 2=once, 3=2-4 times, 4=5-7 times 5=8 times or more. On the basis of the

information received on these questions, participants were characterized as fallers (categories 2 to 5) and non-fallers (category 1). Self-reported physical activity was assessed on a seven-point scale. Response options were: 1= I do not move more than is necessary in my daily routines/chores; 2=I go for casual walks and engage in light outdoor recreation 1–2 times a week; 3= I go for casual walks and engage in light outdoor recreation several times a week; 4= I engage 1–2 times a week in brisk physical activity (e.g. yard work, walking, cycling) to the point of perspiring and some degree of breathlessness; 5 = Several times a week (3–5) I engage in brisk physical activity (e.g. yard work, walking, cycling) to the point of perspiring and some degree of breathlessness; 6= I do keep-fit exercises several times a week in a way that causes rather strong shortness of breath and sweating during the activity; and 7= I participate in competitive sports and maintain my fitness through regular training (Hirvensalo et al., 2000). For the regression analysis, physical activity was re-categorized as high (categories 5 to 7) medium (categories 3 and 4) and low (categories 1 and 2). Except for one participant who had reported category 6, all the participants in the high physical activity category (n=40) had reported category 5. No participant had reported category 7. Education was categorized as low (primary school or less) medium (middle school, folk high school, vocational school, or secondary school) or high (high school diploma or university degree). Smoking categories were, never, former, and current. For the analysis, smoking status was re-coded as smokers (former and current) and non-smokers.

## **Statistical analyses**

The sample size of this study, calculated for the primary outcome of the RCT design, i.e., 10-meter maximal gait speed, was 314. Participants' characteristics were expressed as means and standard deviations (SD) for continuous variables and as frequencies (n) and percentages (%) for categorical variables. Differences between men and women were tested

with the Mann-Whitney U-test for non-normally distributed continuous variables, with chi-square test for categorical variables and independent samples t-test for normally distributed continuous variables. To correct for the abnormal distribution of the dual-task cost we added a constant of 1 + the absolute value of minimum of the variable (-1.724) before using the BoxCox transformation with lambda equal to -0.39.

Associations between executive and physical functions and their interaction with sex were assessed with multiple linear regression analyses. For the analysis, three model sets were constructed to explain each physical function measurement. In the executive functions main-effect models, the main predictors were executive function and sex. In the executive functions-sex-interaction models, the main predictors were executive function, sex and executive function-sex-interaction. In the sex-stratified models, the analyses were carried out separately for women and men and the main predictor was executive function. Finally, we adjusted the main-effect models and sex-interaction models for multiple testing using the Bonferroni correction. When the sex-interaction p-value was non-significant, the parameters of the main effects model produced the most parsimonious description of the associations between executive functions and physical functions, and the results were interpreted from the main-effects model (see parameters for main effects in Table 3).

Theoretically meaningful and available control variables education, age, MMSE scores, level of physical activity and smoking were included in the models. Relationships between physical and executive functions and the control variables were tested with the Pearson correlation coefficient and Spearman's rank correlation coefficient (Table 2).

For regression models, two dummy variables were created from education and physical activity. Normality of residuals was checked using quantile-quantile plots and

skewness and kurtosis statistics. Heteroskedasticity of residuals was assessed by regressing squared residuals on the predictor variables. The degree of multicollinearity was assessed using variance inflating factors (VIFs). Residual diagnostics suggested two outliers remained for the outcome, dual-task cost, even after Box-Cox transformation. However, the sensitivity analysis indicated that removing these subjects from the analysis would not lead to substantial modification of the results, and hence we decided to retain the subjects in the analysis. Analyses were performed using IBM SPSS statistics (version 26). The descriptive and bivariate correlation analyses were considered explorative, and we set alpha to the nominal 0.05 level. For the model-based tests of effects, we used the Bonferroni-corrected alpha level set at 0.05

## Results

Participant characteristics are shown in Table 1. Mean age was 75 years and 60% of the subjects were women. Significant anthropometric differences were observed between men and women. Women were more likely to have higher education status and slightly higher MMSE scores than men. Men were likely to smoke more than women and perform better in the physical function and dual-task tests, except for habitual gait speed. No significant differences between men and women were found in Stroop or TMT B-A. Women significantly outperformed men in VF (Table 1).

Of the selected control variables, age and education correlated with the physical function measurements with the exception of dual-task cost, which did not correlate with age or education. Age correlated with all executive functions except verbal fluency. Education and MMSE scores correlated with all executive functions. Physical activity correlated with all the physical function measurements except maximal gait speed and dual-task cost.

Physical activity showed no significant association with executive functions and MMSE showed no significant association with physical functions. Smoking did not show a statistically significant association with physical or executive functions. However, as smoking is a known risk factor for poor physical and cognitive functioning, we decided to retain it in the models (Table 2).

In the multiple linear regression analysis (Table 3), we first examined only associations involving the main effects of executive function (significant main effect and non-significant sex interaction). After adjusting the models for multiple comparisons, we found that VF was associated with higher maximal and habitual gait speed ( $\beta=0.273$   $p<0.001$ ,  $\beta=0.184$   $p=0.009$ , respectively), longer 6-min walking distance ( $\beta=0.242$ ,  $p<0.001$ ) and higher SPPB scores ( $\beta=0.234$ ,  $p<0.001$ ). TMT B-A was associated with higher SPPB scores ( $\beta=-0.236$ ,  $p=p<0.001$ ). Stroop was not associated with any of the physical function tests. In addition, all sex interactions were non-significant. Sex-stratified models are shown in supplementary table 1.

## Discussion

In this study conducted among community-dwelling older adults who did not meet physical activity guidelines, we found that better performance in executive functions related to updating and set shifting was associated with better walking performance and lower extremity functioning. However, the ability to inhibit an over-learned stimulus response was not associated with any of the physical function tests. In addition, we found non-significant sex-interactions in the associations between physical and executive functions.

Earlier studies that have investigated the associations between executive functioning and walking performance have reported partially conflicting results. Associations between

1 better performance in set shifting, updating and inhibition and faster gait speed or better  
2 lower extremity functioning have been reported in some studies (Berryman et al., 2013;  
3 Coppin et al., 2006; Demnitz et al., 2018; Herman et al., 2011; Soumare et al., 2009) while  
4 other studies did not find these associations (Hausdorff et al., 2005; Kaye et al., 2012;  
5 Valkanova et al., 2018). Our results suggest that among community-dwelling and relatively  
6 healthy older people, executive functions related in particular to updating, but also to set-  
7 shifting are associated with physical functions.

8         We found that updating and set shifting were associated with faster maximal and  
9 habitual gait speed, longer distance travelled (updating) and better lower extremity  
10 functioning (updating and set shifting), whereas no significant association was observed  
11 between executive functions and dual-task cost in gait speed. These results suggest that safe  
12 and stable walking and lower extremity functions requiring dynamic, reciprocal, rhythmic  
13 and fluent sensorimotor performance may depend more on updating/lexical access speed and  
14 mental flexibility than the ability to inhibit an over-learned stimulus response. As indicated  
15 above, our findings highlight the dependency of the associations between physical and  
16 executive functions on the type of executive processes and physical tasks measured and thus  
17 may partly explain the conflicting results of prior studies (Berryman et al., 2013; Coppin et  
18 al., 2006; Demnitz et al., 2018; Hausdorff et al., 2005; Herman et al., 2011; Kaye et al., 2012;  
19 Valkanova et al., 2018)

20         Surprisingly, unlike previous studies that have reported associations between  
21 executive functions and dual-task gait performance, at least when the concurrent cognitive  
22 task is demanding (Liu-Ambrose et al., 2009; Menant et al., 2014), we found no association  
23 between executive functions and smaller dual-task cost in gait speed. We assessed the dual-  
24 task condition with a cognitively challenging visuospatial-motor task that has been found to

1 induce greater interference while walking than non-spatial tasks (Menant et al., 2014) and  
2 were therefore surprised to find that the association between executive functions and dual-  
3 task cost in gait speed was non-significant. However, a systematic review showed that the  
4 visuo-spatial cognitive domain is associated with the postural control domain of gait rather  
5 than pace, i.e., speed of gait (Morris et al., 2016). Moreover, Coppin et al. (2006) have  
6 suggested that the cost associated with increased executive load during basic walking differs  
7 by the nature of the dual task. We assessed dual-task gait performance in habitual gait speed,  
8 which is not a physically challenging task, and this may have affected our results. It may be  
9 that among well-functioning, relatively healthy older adults the association between  
10 executive functions and dual-task performance is more prominent when both the cognitive  
11 and physical task are simultaneously demanding.

12         The associations of sex differences with executive and physical functions were non-  
13 significant. Prior research on this topic is limited. Best et al. (2016) found no sex differences  
14 in the longitudinal associations between executive functions and habitual gait speed, whereas  
15 Thibeaudeau et al. (2019) reported that sex moderated the longitudinal associations of executive  
16 functions with walking and balance. They suggest that the sex-dependent association of  
17 physical activity and walking or balance, with executive functions is multifactorial, due to,  
18 for example, age-related changes in neural networks and brain structure in the frontal cortex  
19 that differ between the sexes (Crivello et al., 2014; Scheinost et al., 2015). In addition,  
20 muscle and metabolic biomarkers affecting gait speed and cognition differ between men and  
21 women. For example, sex-specific muscle and metabolic biomarkers have been shown to be  
22 associated with changes in gait speed in both sexes whereas metabolic biomarkers were  
23 shown to be associated with changes in cognitive functions only among men (Waters et al.,  
24 2020). It should be noted that the earlier studies only measured habitual gait speed, which  
25 does not necessarily reveal the known sex differences underlying gait speed, such as body



1 height and lower body muscle strength. Our results showing no sex differences in the  
2 associations between gait speed and executive functions extend those reported by Best et al.  
3 (2016) by showing no sex differences in the associations of gait speed tests differing in  
4 difficulty and length with executive functioning among a sample of older adults who did not  
5 meet physical activity guidelines. However, further studies are needed to confirm this result.

6 To further knowledge on the associations between cognitive and physical functions  
7 among relatively healthy older people, we designed a measurement protocol with a  
8 comprehensive array of executive and physical function measures. We included tests for  
9 three subdomains of executive functioning that have been extensively used in studies among  
10 older people. The measures of physical function traits used here are commonly used in  
11 clinical settings and in aging research and known to predict adverse outcomes, e.g., disability,  
12 cognitive impairment, falls and even mortality in older populations (Abellan van Kan et al.,  
13 2009). These included a relatively simple measure, habitual gait speed over a short distance,  
14 along with more physically and cognitively challenging tests, such as walking over a longer  
15 distance either at maximal gait speed or under dual-task conditions, and a more complex  
16 measure (SPPB) in which walking, balance and lower body muscle power scores are merged  
17 into a composite score.

18 In addition to assessing gait and executive function with an extensive measurement  
19 protocol, the strengths of this study include a representative sample of community-dwelling  
20 older people who did not meet the physical activity guidelines and the measurements that are  
21 widely used and considered to be suitable for assessing older adults. Moreover, the fact that  
22 the measurements were conducted by the same investigators is likely to enhance the  
23 reliability of the results.

The main limitation of this study is the cross-sectional design, which does not allow conclusions to be drawn on causality. We only used a single task to target each executive function, instead of multiple tasks, which makes the measurement of each executive function suboptimal. Hence, caution in interpreting the results is warranted. In addition, our results cannot be generalized to groups who do not meet our eligibility criteria. However, the sample were drawn from the Finnish National Register and as few potential participants as possible were excluded from the study. Our participants were relatively healthy with intact cognition. This characteristic may even have attenuated the results and could explain why, among the control variables, the MMSE did not correlate with physical functions and physical activity did not correlate with executive functions.

## Conclusions

We found that while executive functions are associated with walking and lower extremity functioning among older adults, the associations were partly dependent on the specific executive process measured and the nature of the physical task. Longitudinal studies are needed to confirm the associations found and ascertain possible causality.

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**Table 1**

Participants Characteristics (Means and standard deviations or frequencies and percentages)

	All (n=314)	Women (n=188)	Men (n=126)	p
Age	74.5 ± 3.8	74.5 ± 3.8	74.4 ± 3.9	0.568 <sup>a</sup>
Height (m)	1.66 ± 0.09	1.61 ± 0.06	1.74 ± 0.06	<0.001 <sup>c</sup>
Weight (kg)	76.9 ± 14.2	71.9 ± 13.1	84.3 ± 12.5	<0.001 <sup>a</sup>
BMI	27.9 ± 4.7	28.0 ± 5.3	27.9 ± 3.6	0.394 <sup>a</sup>
Education (%):				0.027 <sup>b</sup>
Low	48 (15)	21 (11)	27 (21)	
Medium	200 (64)	122 (65)	78 (62)	
High	66 (21)	45 (24)	21 (17)	
Current physical activity (%)				0.227 <sup>b</sup>

Low	126 (40)	73 (39)	53 (42)	
Medium	148 (47)	95 (51)	53 (42)	
High	40 (13)	20 (11)	20 (16)	
Fall in the previous year (%)				0.231 <sup>b</sup>
Yes	164 (52)	93 (50)	71 (56)	
No	150 (48)	95 (51)	55 (44)	
Smoking status (%)				<0.001 <sup>b</sup>
Never smoker	191 (61)	135 (72)	56 (44)	
Former smoker	109 (35)	48 (26)	61 (48)	
Current smoker	14 (4)	5 (3)	9 (7)	
Number of the chronic diseases	2.4±1.5	2.4±1.6	2.6±1.5	0.344 <sup>a</sup>

MMSE (score)	27.6±1.5	27.8±1.5	27.5±1.4	0.049 <sup>a</sup>
SPPB (score)	10.1±1.5	9.8 ± 1.5	10.6 ± 1.4	<0.001 <sup>a</sup>
10m gait speed (m/s)	2.0± 0.4	1.9± 0.3	2.1 ± 0.4	<0.001 <sup>c</sup>
20m gait speed (m/s)	1.3 ± 0.2	1.3 ± 0.2	1.3 ± 0.2	0.148 <sup>c</sup>
6min walking distance (m)	475.4± 81.7	457.3 ± 70.3	502.4 ± 89.9	<0.001 <sup>c</sup>
Dual-task cost (s) <sup>d</sup>	1.25 ± 0.25	1.29 ± 0.24	1.20 ± 0.25	0.004 <sup>a</sup>
Stroop difference (s)	46.7 ± 25.0	46.5 ± 22.4	46.9 ± 28.6	0.770 <sup>a</sup>
TMT B-A (s)	88.0 ± 52.2 (n=313)	83.8 ± 50.8 (n=187)	94.4 ± 53.8	0.051 <sup>a</sup>
Verbal fluency test (words)	41.6 ± 13.0	44.4 ± 12.1	37.5 ± 13.2	<0.001 <sup>c</sup>

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Note. BMI= body mass index, MMSE= Minimental State Examination, SPPB= Short Physical Performance Battery, TMT= the Trail Making Test. One participant was unable to perform TMT test due to hand pain.

<sup>a</sup>Mann-Whitney U-test, <sup>b</sup>Chi-square, <sup>c</sup>Independent samples t-test, <sup>d</sup> Distribution shifted by adding a constant of 2.724 and Box-Cox transformed with  $\lambda = -0.39$ .

**Table 2.**

Bivariate correlations between physical and executive function variables (columns) and background variables (rows).

		<b>Maximal gait speed</b>	<b>Dual-task cost</b>	<b>Habitual gait speed</b>	<b>Walking distance</b>	<b>SPPB</b>	<b>Verbal fluency</b>	<b>TMT B-A</b>	<b>Stroop</b>
<b>Age<sup>a</sup></b>	<b>r</b>	-0.29	0.07	-0.26	-0.33	-0.18	-0.05	0.28	0.15
	<b>p</b>	<0.001	0.222	<0.001	<0.001	0.002	0.427	<0.001	0.010
<b>Education<sup>b</sup></b>	<b>rs</b>	0.14	-0.07	0.12	0.14	0.17	0.33	-0.35	-0.15
	<b>p</b>	0.011	0.188	0.036	0.013	0.016	<0.001	<0.001	0.008
<b>Physical activity<sup>b</sup></b>	<b>rs</b>	0.07	0.05	0.18	0.20	0.18	-0.05	-0.03	0.03
	<b>p</b>	0.204	0.368	0.002	<0.001	0.002	0.394	0.576	0.647
<b>MMSE<sup>a</sup></b>	<b>r</b>	0.05	-0.05	0.05	0.04	0.05	0.19	-0.25	-0.11
	<b>p</b>	0.378	0.407	0.421	0.502	0.341	0.001	<0.001	0.043
<b>Smoking<sup>b</sup></b>	<b>rs</b>	-0.02	-0.06	-0.07	-0.10	<0.01	-0.01	<0.01	0.02
	<b>p</b>	0.693	0.336	0.194	0.102	0.951	0.836	0.997	0.768

*Note*, Correlation coefficients and p-values presented. <sup>a</sup>Pearson correlation coefficient <sup>b</sup>Spearman's rank correlation coefficient

**Table 3**

*Association between physical functions and executive functions among 70-85 years old men and women. Main effect coefficients are from main effects models for each executive function and sex-interaction p-values are from the sex-executive function interaction models.*

	Maximal gait			Habitual gait			Dual-task cost <sup>a</sup>			6min walking			SPPB		
	speed			speed						distance					
	$\beta$	R <sup>2</sup>	p	$\beta$	R <sup>2</sup>	p	$\beta$	R <sup>2</sup>	p	$\beta$	R <sup>2</sup>	p	$\beta$	R <sup>2</sup>	p
Main effects models															
VF	0.273	0.272	<0.001	0.184	0.127	0.009	-0.050	0.032	1.000	0.242	0.291	<0.001	0.234	0.184	<0.001
TMT B-A	-0.100	0.214	0.409	-0.111	0.108	0.360	0.144	0.046	0.121	-0.130	0.253	0.107	-0.236	0.178	<0.001
STROOP	-0.063	0.213	1.000	-0.052	0.101	1.000	0.110	0.042	0.267	-0.057	0.245	1.000	-0.058	0.142	1.000
Interaction effect models															
VF*sex			0.120			0.799			0.357			0.110			1.000
TMT B-A*sex			1.000			1.000			0.109			1.000			1.000
STROOP*sex			0.788			1.000			1.000			0.544			1.000

*Note.* Bonferroni-corrected p-value for five outcome variables. TMT=Trail making test, VF=verbal fluency test. In sex-interaction models reference was male. Control variables in models were age, education, level of physical activity, smoking and MMSE scores. <sup>a</sup>Distribution shifted by adding a constant of 2.724 and Box-Cox transformed with  $\lambda = -0.39$ .



