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The combined effect of lower extremity function and cognitive performance on perceived walking ability among older people: A two-year follow-up study.

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ABSTRACT

Background: We studied the combined effects of cognitive performance and lower extremity function on self-reported walking modifications and walking difficulty, and on self-reported walking difficulty incidence over a two-year follow-up.

Methods: A total of 848 community-dwelling older people aged 75–90 years participated at baseline, 816 at the one-year follow-up, and 761 at the two-year follow-up. Baseline lower extremity function was measured with the Short Physical Performance Battery (<10 vs. ≥10) and cognitive performance with the Mini Mental State Examination (<24 vs. ≥24). Difficulty in walking 2km was self-reported and categorized into no difficulties, no difficulties but walking modifications, and prevalent difficulties. Data were analyzed with multinomial and Cox regressions and a mediation analysis.

Results: At baseline, 33% reported no walking difficulties, 25% walking modifications and 42% walking difficulty. Poorer lower extremity function and lower cognition increased the odds for walking difficulty. For those with both, the odds were almost eight-fold higher for walking difficulty and three-fold higher for walking modifications compared to having neither. Poorer lower extremity function mediated the association between low cognition and poorer perceived walking ability. Of those with no walking difficulty at baseline, 31% developed walking difficulty during the follow-up, the risk being almost two-fold higher among those with poorer lower extremity function at baseline (HR 1.82, 95%CI 1.28-2.59).

Conclusion: Older people with poorer lower extremity function and cognitive performance are likely to have walking difficulties, rendering them especially vulnerable to further disability.

Cognitive performance should be considered in interventions aimed at preventing mobility disability.

Keywords: cognition, physical function, physical performance, mobility limitation

INTRODUCTION

Walking ability is important for accessing community amenities¹ and for maintaining independence in old age². Self-report measures of walking provide information about one's mobility in the everyday environment and usually express the degree of difficulty perceived when walking a specific distance¹. Perceived walking ability relates closely to actual walking behavior^{1,3}. Self-report measures may also identify people who modify their walking, i.e. change their way of walking⁴. Modifications in walking, such as slowing down or pausing for rest during performance may indicate declining functional capacity even in the absence of frank walking difficulty⁴. People with walking modifications represent an intermediate level of functional capacity when compared to those reporting walking difficulty and to those reporting no walking difficulty and no modifications^{4,5}. However, modifications also denote adaptive compensatory practices, as these may help older people to maintain their life-space mobility and participation in out-of-home activities regardless of their physical decline⁶.

Pathology or aging may cause impairments in physical and cognitive capacity⁷. Moreover, it has been pointed out that decline in physical capacity often co-occurs with decline in cognition⁸. Three recent systematic reviews and meta-analyses reported on the associations of indicators of mobility

with measures of cognition⁹⁻¹¹. Older people with poorer physical performance do worse in cognitive tests⁹, and vice versa¹⁰, and are at risk for developing dementia¹¹. This may stem from a common biologic aging process, which manifests as deficits in both physical and cognitive performance⁹. Further, it has been suggested that deficits may manifest first in physical performance as, at least in part, they are easier to observe than cognitive changes^{12,13}.

The combined deterioration of physical and cognitive performance may underlie perceived walking modifications and walking difficulties in old age. Two international workshop reports have suggested that research on mobility should incorporate cognitive measures, and that cognition and mobility should be regarded as a combined research entity^{14,15}. Nevertheless, to our knowledge, the cognitive and physical domains have not hitherto been studied together as predictors of perceived walking difficulties. The purpose of this study, therefore, was to investigate the combined associations of cognitive performance and lower extremity function with self-reported walking modifications and walking difficulty cross-sectionally and with incidence of perceived walking difficulty over a two-year follow up. In addition, we studied whether lower extremity function mediates the association between cognition and perceived walking ability.

METHODS

Study design

This study forms part of the *Life-Space Mobility in Old Age* (LISPE), which was a 2-year (2012–2014) prospective cohort study targeting community-dwelling older people conducted at the University of Jyväskylä, Finland. Participants were recruited from a random sample of 2550 people aged 75 to 90 years drawn from the national population register and living in the municipalities of Jyväskylä and Muurame in Central Finland. Of this number, 848 persons were eligible (living independently and able to communicate) and willing to participate in the at-home personal interview¹⁶. Of these, 816 participated in the one-year and 761 in the two-year follow-up implemented by phone. Reasons for dropout over the two-year period were death (n=41), institutionalization (n=15), impaired ability to communicate (n=12), moving outside the study area (n=6), declined health (n=5), unwillingness to continue (n=6), and not being reached (n=2)¹⁷.

The Ethical Committee of the University of Jyväskylä approved the LISPE study. The study protocol followed the guidelines of the Declaration of Helsinki. Participants were informed about the study and each signed an informed consent before the assessments.

Variables

Perceived walking difficulty and walking modifications

Participants were asked if they perceived difficulties in walking 2km²⁻⁴ at baseline and at the one- and two-year follow-ups. The response options were “able without difficulty”, “able with some difficulty”, “able with a great deal of difficulty”, “unable without the help of another person” and “unable to manage even with help”. Those who reported being able to manage without any difficulty were asked whether they have modified their way of walking⁴. The question was “Have

you noticed any of the following changes in walking 2 km?" The response options were yes/no and the items were decreased walking frequency, given up walking the distance, use of an assistive device, slower walking pace, and pausing for rest during the performance. Participants were categorized as follows: 1) no walking difficulties (reporting neither difficulty nor modifications), 2) walking modifications (reporting no walking difficulty but at least one modification), and 3) walking difficulties (reporting some or a great deal of difficulties or being unable to perform).

Lower extremity function

Lower extremity function was assessed at baseline with the Short Physical Performance Battery (SPPB)¹⁸. The battery includes tests for standing balance (feet together, semi-tandem, full tandem), walking (normal gait speed for 2,44m) and chair rise (5 times). Each task was scored from 0 to 4, yielding a sum score of between 0 and 12 points⁴, with higher scores indicating better performance. The sum score was calculated and scaled if at least two of the three tests were completed¹⁹. In total, nine participants (1.0%) did not complete the tests due to refusal (n=4), being in a wheelchair (n=4), or a proscriptio from a doctor (n=1). The sum scores were not normally distributed, and thus were categorized. Participants with a SPPB score of ten or higher (n=529) were considered as having good physical performance and formed the reference group. Because only few participants had very low scores (<4 points n=28), no further categorization was possible, and hence those with a score below ten were assigned to the category of poorer lower extremity function (n=310)²⁰.

Cognitive performance

Cognitive performance was assessed at baseline with the Mini Mental State Examination (MMSE), which is a brief screening test for cognitive impairment²¹. It consists of 11 items measuring orientation, registration, attention, calculation, recall and language. The maximum sum score is 30, higher scores indicating better performance. The sum score was scaled if the respondent was not able to perform all the test tasks, e.g. due to visual impairment. Since the MMSE scores were not normally distributed in this study, we used the established cut-point of 24²² to identify the participants with cognitive decline (MMSE <24, n=150). The remainder formed the reference category (MMSE ≥24, n=698).

Covariates

Age and sex were drawn from the national population register and years of education was self-reported. Morbidity was evaluated as the number of physician-diagnosed self-reported chronic conditions. A list of 22 diseases was presented, followed by an open-ended question asking about other conditions¹⁹. Depressive symptoms were assessed with the 20-item Centre for Epidemiologic Studies Depression Scale (CES-D)²³. Vision was assessed subjectively with the question: “How well can you see from a distance?” The response options were dichotomized into 1) good (those who answered “well” and “reasonably well”) and 2) declined (those who answered “poorly”)²⁴.

Statistical analyses

Means, standard deviations, and percentages were used to describe the participants’ baseline characteristics, and crude differences were tested with the chi square test and one-way analysis of variance. The cross-sectional odds for walking modifications or walking difficulties vs. no

difficulty were calculated with multinomial regression analyses. The preliminary regression analyses revealed an interaction between the MMSE and SPPB scores and walking modifications and difficulties ($p < .001$). Therefore, we first added the SPPB and MMSE into the models separately and thereafter together to assess the combined influences of poorer lower extremity function and low cognitive performance. All models were first adjusted for age and sex, and then additionally for years of education, number of chronic conditions, depressive symptoms, and vision. The model including only cognition was adjusted for lower extremity performance, and vice versa. In addition, a latent factor mediator analysis was conducted to assess whether SPPB mediated the association between MMSE and walking ability at baseline. The mediation analysis was adjusted for age and sex.

The incidence of walking modifications was too low for meaningful analysis. Thus, we used Cox regression to analyze the relative risk for incident walking difficulties among those who did not report walking difficulties at baseline ($n=492$). People were censored at the time they reported walking difficulty or at the end of the follow-up, whichever happened first. Those who had missing data on walking ability in one or the other of the assessments were categorized and censored according to the answer that was available. Additionally, the Cox regression analysis was stratified according to baseline modifications. Finally, Little's MCAR test (MCAR) was used to analyze study attrition.

All analyses were performed with SPSS Statistics 24 for Windows except for the mediation analysis, where MPlus version 5.21 was used.

RESULTS

Mean baseline age was 80.6 (standard deviation, SD=4.3) and 62% of the participants were women. At baseline, 33% (n=280) reported no walking difficulties, 25% (n=212) reported walking modifications and 42% (n=356) walking difficulties. Those without walking difficulties had the best cognitive performance and lower extremity function, whereas those with walking difficulties had the poorest. Those reporting walking modifications had intermediate scores (Table 1). In addition, those with walking difficulties were older, less educated, more often women and had more chronic conditions, depressive symptoms, and more often poor vision ($p \leq .005$ for all) than those reporting no walking difficulties. These variables were chosen as covariates. The baseline characteristics according to lower extremity function and cognitive performance categories are presented under Supplementary Material.

Table 2 shows that poor cognitive performance was not associated with walking modifications but increased the odds for walking difficulties at baseline. Poorer lower extremity function increased the odds for both walking modifications and walking difficulties. The highest odds for walking difficulties were observed among those with concurrent poorer lower extremity function and poor cognition. A parallel, but less pronounced association was seen for walking modifications. In addition, those with good lower extremity function but poor cognition were likely to have walking difficulties, but only when the model was adjusted for all the covariates. The mediation analysis showed that the association of higher cognitive capacity with better perceived walking ability was mediated through better lower extremity function. The direct association between MMSE and perceived walking ability was not significant (see Figure 1).

Of the 492 participants who did not report walking difficulties at baseline, 153 (31%) developed walking difficulty during the two-year follow-up. Table 3 shows that poorer lower extremity function both alone and together with good cognition increased the risk for incident walking difficulty. When the analysis was stratified according to baseline walking modifications, those without walking modifications but with poorer lower extremity function and poor cognition were at risk of incident walking difficulty (Hazard Ratio, HR 2.75, 95% Confidence Interval, CI 1.01-4.17). Among those reporting walking modifications, the results remained nearly unchanged (data not shown). Study attrition was analyzed with Little's MCAR test, which showed that missing data were not missing completely at random ($\chi^2=9.756$, $df=1$, $p=0.002$). Thus, it was assumed that the mobility of those who reported no walking difficulties at baseline but dropped out during the follow-up due to death or institutionalization ($n=22$) would have declined. Therefore, we categorized them as having developed walking difficulty to determine whether that would alter the results. The results supported our main findings (data not shown).

DISCUSSION

The findings of this study suggest that older people with both poorer lower extremity function and low cognitive performance are more likely to have walking difficulties than those with neither or only the other, making them especially vulnerable to further disability. Poor lower extremity function as a risk factor for mobility modifications and disability has been reported earlier^{4,7,18}. Our results expand those findings by showing that the odds for reporting walking modifications or

difficulties were highest among those with poorer lower extremity function and poor cognitive performance. The results are in line with previous findings on the association between mobility limitations and cognitive decline^{9,10} but extend them by showing that the association is evident already in the early phase of mobility decline.

Recently, reports have shown that cognitive decline together with slowed gait in older people without dementia or mobility disability²⁵ increase the risk for dementia^{25,26}, mortality²⁷ and falls²⁸ when compared to people without this combination. In addition, the combination of objectively measured cognitive decline and mobility limitations has been found to increase the risk for institutionalization²⁹. Our cross-sectional results are in line with these studies but extend them for walking difficulties and support the view that studying mobility and cognition together improves the accuracy of risk prediction^{9,14,15,26,30}.

Our longitudinal results, however, were only partially parallel to those obtained in cross-sectional analyses, and most of the differences centered on cognitive capacity. Neither poor cognitive functioning nor poorer lower extremity function in the presence of low cognitive capacity was associated with increased risk for new walking difficulties. Previous studies have found that persons with more severe cognitive decline may under-report difficulties in everyday functioning³¹. Our results indirectly supported this by showing an increased risk for walking difficulty solely among those with poorer lower extremity function and high MMSE score at baseline. Unfortunately, data were not available to examine if those who initially had lower

cognitive capacity exhibited further decline, which might underlie the absence of self-reported walking difficulties among them. Another explanation is the high prevalence of walking difficulties at baseline among those with poorer lower extremity function and low cognitive capacity. Of the 73 people in this category, fifty already had walking difficulties at baseline and were excluded from the prospective analyses. Consequently, we cannot rule out the possibility that the risk of incident walking difficulty is an underestimation in this group.

We found that the association between cognition and walking difficulties was attenuated when the model was adjusted for lower extremity function. Furthermore, the mediation analysis showed that the association of lower cognition with poorer walking ability was mediated by poorer lower extremity function. Thus, our findings suggest that poorer lower extremity function partially explains the association between cognitive decline and walking difficulties. A recent study indicated that lower extremity function also partially explains the association between executive function, a higher order cognitive function, and life-space mobility, a correlate of self-reported 2km walking ability^{32,33}. The strong associations of lower extremity function with walking difficulties and walking modifications may be explained by age-related losses in muscle strength and postural balance, which are biomechanical prerequisites for walking^{1,34,35}.

We chose to study older people aged 75-90 years at baseline, since that is usually the time of life when people start to experience decline in mobility and cognition. In addition to investigating the cross-sectional associations of cognition and lower extremity function with perceived walking

modifications and difficulties, we conducted longitudinal analyses, since the deterioration of walking ability is a process^{2,4,36}. The combined effects have been studied previously by comparing people with the combination of poor physical and poor cognitive performance to people without this combination (e.g.^{25,27}). We were also interested in those with deficits in only one or other of the predictors. Thus, we categorized the participants based on clinical thresholds for lower extremity function and cognition and used the different combinations of these in our analyses. This enabled us to consider different profiles of functioning; however, it also prevented subgroup analyses since the groups were small and statistical power low. Finally, we chose MMSE and SPPB as indicators of cognitive and physical performance, as they are well-established measures of overall cognitive and physical performance. However, in the future, it might be beneficial to study executive function (EF) in addition to overall cognition, since EF is a more sensitive measure for detecting early cognitive decline than MMSE³⁷. In addition, EF is closely related to walking¹², since it is controlled by prefrontal brain areas, which are important for motor control especially in old age³⁸.

Strengths and limitations

The strengths of this study concern the study design and the measures used. First, we had a rather large population-based sample with little missing data. To our knowledge this was the first study to examine the combined associations of lower extremity function and cognitive performance with perceived walking ability. Moreover, we used both well-established subjective and objective measures, the validity and reliability of which have been tested^{4,18,20,21}. Earlier research has tended to study walking objectively, whereas, given the stated need for assessment of real-world

mobility³⁹, subjective measures may provide more comprehensive information about older people's mobility in their everyday environment¹. Furthermore, self-reports are an economical way to assess mobility in large samples⁴. Using self-reported walking difficulties as an outcome also allowed us to study mobility modifications. Modifications precede walking difficulties but are signs of declining function and health⁴. They have not yet been studied thoroughly and may not have been detected in traditional walking assessments.

This study has its limitations. First, we might not have covered the whole phenomenon of mobility modification. We used a structured question, which may not have included all possible changes in walking, to measure walking modifications. However, the measure has been validated⁴. Further, SPPB and MMSE were dichotomized in the analyses. Dichotomization reduces variability in data, rules out detection of dose-response relationships, and may lead to underestimation of associations. However, using established cut-off criteria makes the results more understandable, and in the present study, made it possible to examine the combined influences of lower extremity function and cognitive performance on walking ability. The MMSE cut-point of 24 is commonly used to identify risk for dementia²², but some people with impaired cognition may have scored above that cut-point. It has been discovered that highly educated persons, especially, would need a higher cut-point to represent their normal level of cognition⁴⁰. Another limitation is that we only used baseline characteristics as predictors of incident walking difficulties. Therefore, the analysis does not take into account competing risks of new comorbidities, or subsequent cognitive decline or lower extremity impairments. However, the level of attrition was low, which may support the validity of the findings.

Conclusion

The findings of this study indicate that older people who concurrently manifest poorer lower extremity function and cognitive performance have the highest odds for walking difficulty. Thus, they are especially vulnerable to further disability. However, future studies should establish whether current methods to assess mobility among older people with cognitive impairment are adequate. Moreover, our results suggest that in addition to lower extremity function, cognitive performance should be taken into account when developing interventions aiming at preventing mobility disability. Furthermore, studying cognition and mobility as a combined research entity may improve the accuracy of risk prediction for mobility disability.

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TABLE 1. Baseline characteristics of the participants according to walking ability category (N=848).

Characteristics	No walking difficulties n=280	Walking modifications n=212	Walking difficulties n=356	P-value
	Mean (SD)	Mean (SD)	Mean (SD)	
Age	78.4 (3.7)	79.8 (4.3)	81.7 (4.1)	<.001 ^a
Years of education	10.3 (4.5)	9.9 (3.7)	8.8 (4.0)	<.001 ^a
Number of chronic conditions	3.2 (2.0)	4.2 (2.3)	5.4 (2.4)	<.001 ^a
CES-D score	7.3 (5.7)	9.5 (6.0)	11.6 (7.5)	<.001 ^a
MMSE score	26.6 (2.5)	26.1 (2.8)	25.8 (3.0)	.003 ^a
SPPB score	10.8 (1.4)	10.1 (1.9)	8.4 (3.0)	<.001 ^a
Sex (female %)	53.9	58.5	70.5	<.001 ^b
Vision (poor %)	1.4	2.8	6.2	.005 ^b

Note. CES-D, Centre for Epidemiologic Studies Depression Scale; MMSE, Mini Mental state Examination; SPPB, Short Physical Performance Battery.

^a: tested with one-way analysis of variance (ANOVA)

^b: tested with chi square test

TABLE 2. Cross-sectional analyses of lower extremity function and cognitive performance separately and combined with self-reported walking modifications and walking difficulties among community-dwelling older people aged 75–90 years at baseline (n=827).

	Walking modifications			Walking difficulties		
	model 1	model 2	model 3	model 1	model 2	model 3
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
MMSE (<24 vs. ≥24)	1.62 (.97-2.73)	1.73 (1.00-2.99)	1.57 (.90-2.75) ^a	1.97 (1.22-3.17)	2.11 (1.25-3.57)	1.81 (1.05-3.14) ^a
SPPB (<10 vs. ≥10)	2.39 (1.55-3.71)	2.07 (1.32-3.26)	2.02 (1.28-3.18) ^b	7.07 (4.71-10.62)	5.24 (3.39-8.10)	5.06 (3.26-7.84) ^b
SPPB ≥10 & MMSE <24 ^c	1.50 (.79-2.82)	1.71 (.88-3.33)	-	1.78 (.95-3.35)	2.04 (1.03-4.05)	-
SPPB <10 & MMSE ≥24 ^c	2.39 (1.47-3.87)	2.13 (1.29-3.51)	-	7.18 (4.58-11.25)	5.38 (3.32-8.73)	-
SPPB <10 & MMSE <24 ^c	3.08 (1.26-7.53)	2.65 (1.05-6.69)	-	9.70 (4.30-21.86)	7.67 (3.27-18.04)	-

Reference category: no walking difficulties

Note. SPPB, Short Physical Performance Battery; MMSE, Mini Mental State Examination.

Multinomial regression model 1: adjusted for age and sex

Model 2: adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, and vision

Model 3: adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, vision, ^aSPPB, and ^bMMSE.

^c: vs. SPPB ≥10 & MMSE ≥24

TABLE 3. Baseline lower extremity function and cognitive performance as separate and combined predictors of walking difficulty incidence over a two-year follow-up among community-dwelling older people with no walking difficulties regardless of walking modifications at baseline (n=492).

	Developing walking difficulty in 2 years		
	model 1	model 2	model 3
	HR (95% CI)	HR (95% CI)	HR (CI 95%)
MMSE (<24 vs. ≥24)	1.28 (.84-1.95)	1.28 (.83-1.98)	1.06 (.68-1.67) ^a
SPPB (<10 vs. ≥10)	1.85 (1.32-2.60)	1.84 (1.30-2.60)	1.82 (1.28-2.59) ^b
SPPB ≥10 & MMSE <24 ^c	1.47 (.86-2.52)	1.59 (.92-2.76)	-
SPPB <10 & MMSE ≥24 ^c	2.10 (1.45-3.06)	2.20 (1.50-3.22)	-
SPPB <10 & MMSE <24 ^c	1.50 (.77-2.92)	1.38 (.70-2.71)	-

Reference category: no walking difficulties

Note. SPPB, Short Physical Performance Battery; MMSE, Mini Mental State Examination.

Cox regression model 1: adjusted for age and sex

Model 2: adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, and vision

Model 3: adjusted for age, sex, years of education, number of chronic conditions, depressive symptoms, vision, and ^aSPPB, and ^bMMSE

^c: vs. SPPB ≥10 & MMSE ≥24

FIGURE 1. Unstandardized path coefficients with 95% confidence intervals of a cross-sectional, age- and sex-adjusted, latent factor mediator model for Mini Mental State Examination (MMSE), Short Physical Performance Battery (SPPB), and perceived walking ability (Walking ability) among community dwelling older participants (N=848).

