Association of mobility limitations with incident disability among older adults: a population-based study

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Abstract

Background: mobility-related limitations predict future disability; however, the extent to which individual and combined mobility tests may predict disability remains unclear.


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Objectives: to estimate the odds of developing disability in activities of daily living (ADL) according to limitations in walking speed, balance or both; and explore the role of chronic diseases and cognitive function.

Design: a prospective cohort study.

Setting: urban area of Stockholm, Sweden.

Subjects: one thousand nine hundred and seventy-one disability-free persons (age ≥60 years, 63% women) from the Swedish National study on Aging and Care in Kungsholmen (SNAC-K), who underwent baseline examination in 2001–04 and follow-up assessments for 6 years.

Measurements: mobility limitation was defined as a one-leg balance stand <5 s or walking speed <0.8 m/s. ADL disability was defined as the inability to complete one or more ADL: bathing, dressing, using the toilet, transferring and eating.

Results: during a total of 11,404 person-years (mean per person 5.8 years, SD 0.30) of follow-up, 119 (incidence 1.5/100 person-years) participants developed ADL disability. The demographic adjusted odds ratios (OR) (95% confidence intervals, CI) of incident ADL disability related to balance stand and walking speed limitations were 3.8 (2.3–6.3) and 8.4 (5.2–13.3), respectively. The associations remained statistically significant after controlling for number of chronic diseases and cognitive status. People with limitations in both balance and walking speed had an OR of 12.9 (95% CI 7.0–23.7) for incident disability compared with no limitation.

Conclusion: balance and walking speed tests are simple clinical procedures that can indicate hierarchical risk of ADL dependence in older adults.

Keywords: physical performance, disability, activities of daily living, chronic disease, cognitive function, older people

Introduction

Mobility function is a vital component in completing basic activities of daily living (ADL) in older adults and is suggested to deteriorate initially in the pathways to ADL disability [1]. Previous studies have indicated the importance of mobility performance for prognostic disability in old age [2–8], even in high-functioning older adults [9]. Test batteries have often been used to assess mobility function [3, 5, 6], thus overlooking the individual effects of each measure. There is a lack of understanding into the components of test batteries, specifically mobility tests of walking speed and balance, to identify ideal windows of early intervention and the hierarchical ordering inducing different levels of disability risk. Balance has been suggested to decline prior to walking speed, balance or both; and explore the role of chronic diseases and cognitive function.

Performance, with ADL disability. Furthermore, we evaluated the combined effect of balance and walking speed limitations on incident ADL disability and explored the role of chronic diseases and cognitive status in these associations.

Methods

Study population

Data were derived from the Swedish National study on Aging and Care in Kungsholmen (SNAC-K) in central Stockholm [16], where an age-stratified sampling procedure was used to establish 11 age cohorts (60, 66, 72, 78, 81, 84, 87, 90, 93, 96, 99+ years old), after which a random sampling of older adults living in their homes or in institutions was performed according to these age groups. Baseline data were collected from March 2001 to June 2004, and follow-up data were gathered after 6 years for the younger age cohorts (age groups 60–78; 2007–10) and every 3 years for the older age cohorts (age groups 78+; 2004–07 and 2007–10), due to more rapid changes and higher attrition among older adults (Supplementary data, Appendix Figure S1, available in Age and Aging online). Of the 4,590 who were alive and eligible, 3,363 (73.3%) participated in the baseline examination. We excluded persons with missing data on ADL (n=24) and mobility tests (n=279) at baseline, leaving 3,060 participants for the analysis of prevalence of disability, with 5.9% living in institutions. People with missing data at baseline were more likely to be women, older and with a lower education level (P < 0.001).

For the analysis involving incidence of ADL disability, we further excluded 152 persons with dependency in one or more ADL activities at baseline. Prior to the next follow-up examination, 523 persons had died, 405 did not
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participate in further follow-ups due to refusal or loss of contact and 9 had missing follow-up ADL data. Thus, the analytical sample used to determine the incidence of disability included 1,971 participants. Of these, 1.2% were living in institutions and were more likely to be women, older, to have a lower education level and to have a lower Mini-Mental State Examination (MMSE) score, compared with the rest of the sample (P<0.001). In addition, persons who died or dropped out during the follow-up periods were more likely to be older, to have a lower education level and to have a lower MMSE score (P<0.001) at baseline.

All parts of the SNAC-K study were approved by the Regional Ethics Review Board in Stockholm. Written informed consent was provided by all the participants, or by a proxy, if the participant was cognitively impaired. Research within SNAC-K had been conducted according to the principles expressed in the Declaration of Helsinki.

Measures

Mobility function was assessed by two tests that able to differentiate between levels of mobility. The one-leg balance stand was measured by the nurse, asking the participant to stand as long as possible, up to 60 s, first on one leg then the other. This was then repeated, and the best overall score was used. Limitation was defined as a one-leg balance, standing <5 s [17]. This measure was chosen owing to its ability to distinguish performance impairment even in high-functioning older adults [18].

Walking speed was assessed by asking the participants to walk 2.4 or 6 m at a self-selected speed presented in metres per second [19]. Subjects who were unable to walk without personal support received the lowest possible score, i.e. 0 m/s. Limitation was defined as walking speed <0.8 m/s at either distance [20].

Disability in ADL was defined as dependence in one or more ADL: bathing, dressing, toileting, transferring in and out of bed and from bed to chair, and eating, as assessed by nurses [21].

Covariates

Demographic factors (age, sex and education), the number of chronic diseases and cognitive function were included as covariates. Chronic diseases were identified from the clinical examination, medical history and laboratory data, and were assessed according to the number of concurrent chronic diseases or conditions [22]. Diseases were categorised according to The International Classification of Disease (ICD 10). MMSE was used to assess global cognitive function [23].

Statistical analysis

Descriptive analysis was performed by calculating the proportions, means and medians of the covariates according to age group. Statistical differences were tested using $\chi^2$ for categorical variables, the Student’s $t$-test for continuous variables and Mann–Whitney $U$-test for skewed data.

Prevalence of mobility limitation (one-leg balance stand $<$5 s or walking speed $<$0.8 m/s) and ADL disability were estimated and graphed at baseline in six age categories. Follow-up time was calculated from the date of the baseline interview to the date of interview at 3 years or 6 years of follow-ups. We estimated the incidence rates in 100 person-years.

Binary logistic regression was used to estimate odds ratios and 95% confidence intervals of incident ADL disability associated with baseline mobility limitation. To examine the gradient association between levels of mobility performance and the likelihood of ADL disability, we divided subjects into three groups according to tertiles of walking speed ($<$1.0, 0.8–1.0 and $>$1.0 m/s) [20] or one-leg balance stand time ($<$10, 10–59 and 60 s) [24]. We reported results from two models stratifying by age ($<$78 and $\geq$78 years): Model 1 was adjusted for age, sex, follow-up time and education; and in Model 2 an additional adjustment was made for the number of chronic health conditions and cognitive function. Statistical interactions of mobility with chronic diseases and cognition on disability were tested by simultaneously including the independent variables and their cross-product variables in the same model. The combined effect of limitation in balance and walking speed performance on ADL disability was examined by creating four categories: no limitation in either test (reference); limitation only in the balance standing test ($<$5 s); limitation only in walking speed test ($<$0.8 m/s) and limitations in both tests.

Statistical software package Stata version 13 (StataCorp, TX, USA) was used for all analyses.

Results

Of the 3,060 participants examined at baseline, 5.0% were disabled in ADL. Participants aged 78 or older more often had ADL disability than the younger participants (11.0 versus 0.2%, P<0.001). This age difference was also seen for participants with balance or walking speed limitation at baseline, lower cognitive function and having two or more chronic conditions (for all comparisons, P<0.001) (Table 1). The prevalence of multiple ($\geq$2) chronic conditions was 46.7, 95.2, and 82.0% at baseline, 3-year follow-up and 6-year follow-ups, respectively; whereas the mean (standard deviation) MMSE score was 27.9 (4.2), 25.3 (6.4) and 27.5 (5.8), respectively (data not shown).

Figure 1A shows the age-specific prevalence of mobility limitation and ADL disability. Prevalence of limitation defined by the one-leg balance stand test was higher than that by the walking speed test at baseline for all ages. The prevalence of ADL disability had a substantial increase after the age of 84 years.

Of the 1,971 baseline disability-free participants, 119 developed disability in ADL during a total of 11,404 person-years of follow-up (mean per person 5.8, SD 0.3
Discussion

The main findings from this large-scale population-based longitudinal study of older Swedish adults showed, firstly, that limitations in tests of balance stand and walking speed each were associated with an increased likelihood for ADL disability in a dose–response manner, such that an increasing level of limitation was associated with an increased likelihood of developing disability. The association was present, independent of chronic health conditions and cognitive function, and was stronger in people aged <78 than those 78 or older. Secondly, impairment in walking speed (<0.8 m/s) appeared to be more strongly associated with ADL disability than balance limitation (a balance stand <5 s). Finally, there was a joint effect of balance stand and walking speed limitations on the likelihood of functional dependence, such that people having limitations in both mobility tests had substantially increased risk of incident ADL disability compared with those having no limitations in either test.

Table 1. Baseline characteristics of study participants by age group

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total sample</th>
<th>&lt;78 years</th>
<th>≥78 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of subjects</td>
<td>3,060</td>
<td>1,731</td>
<td>1,329</td>
</tr>
<tr>
<td>Age, mean (SD), years</td>
<td>73.7 (10.8)</td>
<td>65.3 (4.8)</td>
<td>84.5 (5.9)</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>1,950 (63.7)</td>
<td>993 (57.4)</td>
<td>957 (72.0)</td>
</tr>
<tr>
<td>Education, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>504 (16.5)</td>
<td>148 (8.6)</td>
<td>356 (27.0)</td>
</tr>
<tr>
<td>High school</td>
<td>1,507 (49.4)</td>
<td>792 (45.8)</td>
<td>715 (54.2)</td>
</tr>
<tr>
<td>University</td>
<td>1,038 (34.0)</td>
<td>790 (45.7)</td>
<td>248 (18.8)</td>
</tr>
<tr>
<td>Balance stand time (s), median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 s</td>
<td>677 (22.1)</td>
<td>71 (4.1)</td>
<td>606 (45.6)</td>
</tr>
<tr>
<td>0.8 m/s</td>
<td>1,790 (58.5)</td>
<td>1,446 (83.5)</td>
<td>344 (25.9)</td>
</tr>
<tr>
<td>Walking speed (m/s), mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;0.8 m/s, WS</td>
<td>468 (15.3)</td>
<td>163 (9.4)</td>
<td>305 (23.0)</td>
</tr>
<tr>
<td>≥0.8 m/s, WS</td>
<td>125 (4.1)</td>
<td>51 (3.0)</td>
<td>74 (5.6)</td>
</tr>
<tr>
<td>Number of chronic conditions, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>710 (23.9)</td>
<td>572 (33.2)</td>
<td>138 (11.0)</td>
</tr>
<tr>
<td>1</td>
<td>876 (29.5)</td>
<td>561 (32.6)</td>
<td>315 (25.2)</td>
</tr>
<tr>
<td>≥2</td>
<td>1,388 (46.7)</td>
<td>389 (24.2)</td>
<td>799 (63.8)</td>
</tr>
</tbody>
</table>

All characteristics were significantly different, P <0.001.
SD, standard deviation; MMSE, Mini-Mental State Examination; IQR, inter-quartile range; WS, walking speed; BL, balance stand time.

years); the overall incidence rate was 1.5 per 100 person-years. Figure 1B displays the age-specific incidence rates according to mobility limitation status at baseline. We observed a gradient difference in the incidence of ADL disability by levels of mobility limitation, with the highest incidence seen for persons with a slow walking speed, followed by those with poor balance. No significant differences between men and women were detected in either the prevalence or incidence of disability according to the baseline mobility limitation.

Baseline balance and walking speed limitations were both significantly associated with an increasing likelihood of subsequent development of ADL disability (Table 2), even after controlling for the baseline number of chronic diseases and cognitive function. The associations were stronger in people <78 years of age compared with those aged ≥78. When examining balance and walking speed in tertiles, there was a linear trend towards decreasing balance stand time or slowed walking speed being associated with an increased likelihood of ADL disability (P for trend <0.001).

We further examined the joint effect of limitations in balance stand and walking speed on incident disability. Compared with people with no limitation in either balance or walking speed, people having either limitation alone had a significantly increased likelihood of ADL disability, and people with limitation in both the one-leg balance stand and walking speed concurrently had a nearly 13-fold increased likelihood for ADL disability. Finally, no statistical interaction was detected for mobility limitation given the number of chronic diseases or cognitive function on ADL disability at baseline (data not shown).
Figure 1. Age-specific (A) prevalence of mobility limitations and ADL disability at baseline ($n=3,060$); and (B) incidence of ADL disability during follow-ups by mobility limitation status ($n=1,971$). Balance and walking speed limitation defined as one-leg balance stand $<$5 s and walking speed $<$0.8 m/s, respectively. ADL, activities of daily living.

Interestingly, the reductions in the odd ratios after controlling for these covariates at baseline was greater in individuals $<$78 years of age than those 78 years or older, which may illustrate the differing effect that chronic conditions and mobility limitation can have with age [19].

The association between mobility and incident ADL disability in old age, independent of chronic health conditions and cognitive function, was similarly exhibited in previous studies [6, 25]. Evidence has shown a strong relationship between structural brain changes (e.g. silent brain lesions) and cognitive decline [29]. Thus, the small reductions in the odds ratios observed after controlling for global cognitive function may reflect, to a certain extent, the link between silent brain lesions and the limitations in mobility, as noted in previous studies [6, 13, 30].

Our study went a step further than prior research in disentangling the contribution of mobility limitation level with disability. People experiencing concurrent limitations in balance and walking speed had the highest likelihood of developing ADL disability. Previous studies have reported a linear trend between the number of limitations in physical performance tests (e.g. balance, chair stand and walking speed) and the likelihood of disability [5, 12, 25, 31]. Few studies have, however, examined the hierarchical ordering of limitations on physical functioning tests, despite the potential in deepening the understanding of the pathways to disability [1] and their possibility to indicate underlying dysfunction in multiple organ systems (i.e. circulatory, neurological and musculoskeletal). Certain degrees of pathological changes may be manifested in the grade of limitation identified through specific physical function tests. To carry out tests of balance and walking speed, similar physiological processes and cognitive networks are used [10, 13, 20]. However, balance is very complex and the requirements are less demanding; therefore, balance may diminish before walking speed when dysfunctions occur. Thus, a combination of these two tests would signify greater reductions in all organ systems, regardless of co-morbidities; and, as our results indicate the one-leg balance stand should be supplementary to walking speed when determining the likelihood of future ADL disability.

This current study was one of the few longitudinal population-based studies to examine the relation between levels of mobility limitation and incident disability. The adoption of objective tests of functional mobility rather than self-reports helped to reduce bias and misinterpretation [18]. The inclusion of participants living in institutions provided a better estimation of the incidence of disability in the general elderly population, increasing the generalisability, which was also supported by the large age range in our sample. However, SNAC-K includes a unique group of older adults of high socioeconomic status and may therefore not be representative of the general older population. Although different distances used for the walking speed test might be considered a potential limitation, walking speed is commonly considered reliable and useful for data collection.
comparison and analysis, disregarding the distance [18]. Furthermore, our estimates may have been diluted due to selective survival as disability is highly related to mortality; however, our supplementary analyses demonstrated a significant and stronger association between mobility limitation with ADL disability than that of mortality or attrition (Supplementary data, Appendix Table S1, available in *Age and Ageing* online).

In conclusion, our findings demonstrate that there is a hierarchical ordering in mobility limitations, and mobility tests can indicate hierarchical risk of disability in older adults; yet, there is substantial higher risk of developing disability in ADL if the limitations are co-occurring. These mobility tests are easy to administer in both clinical and community settings, and are preferable means for developing early interventions to help reduce the risk and burden of ADL disability in older adults.

Key points

- Measures of walking speed and balance should be used together in clinical settings to predict incident disability.

### Table 2. Associations of balance stand and walking speed with incident ADL disability (n= 1,971)

<table>
<thead>
<tr>
<th>Mobility limitation</th>
<th>Model 1*</th>
<th>Model 2*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds ratio (95% confidence interval)</td>
<td>Odds ratio (95% confidence interval)</td>
</tr>
<tr>
<td>Balance stand &lt;5 s</td>
<td>3.8 (2.3–6.3)**</td>
<td>3.4 (2.0–5.6)**</td>
</tr>
<tr>
<td>Balance stand by tertiles (s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper (60)</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>Middle (10–59)</td>
<td>1.0 (1.8–7.9)**</td>
<td>3.7 (1.7–7.8)**</td>
</tr>
<tr>
<td>Lower (&lt;10)</td>
<td>8.3 (2.4–28.5)**</td>
<td>7.1 (2.0–24.6)*</td>
</tr>
<tr>
<td>P for linear trend</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Walking speed &lt;0.8 m/s</td>
<td>8.4 (5.2–13.3)**</td>
<td>7.2 (4.4–11.6)**</td>
</tr>
<tr>
<td>Walking speed by tertiles (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper (&gt;1.0)</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>Middle (0.8–1.0)</td>
<td>3.8 (1.8–7.9)**</td>
<td>3.7 (1.7–7.8)**</td>
</tr>
<tr>
<td>Lower (&lt;0.8)</td>
<td>18.8 (9.2–38.4)**</td>
<td>15.8 (7.7–32.6)**</td>
</tr>
<tr>
<td>P for linear trend</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Combined limitations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WS ≥0.8 m/s, BL ≥5 s</td>
<td>1.0 (reference)</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>WS ≥0.8 m/s, BL &lt;5 s</td>
<td>1.6 (0.8–3.2)</td>
<td>1.5 (0.7–3.0)</td>
</tr>
<tr>
<td>WS &lt;0.8 m/s, BL ≥5 s</td>
<td>4.2 (1.6–10.6)*</td>
<td>3.6 (1.4–9.5)*</td>
</tr>
<tr>
<td>WS &lt;0.8 m/s, BL &lt;5 s</td>
<td>12.9 (7.0–23.7)**</td>
<td>10.4 (5.6–19.5)**</td>
</tr>
<tr>
<td>Age &lt;78 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance stand &lt;5 s</td>
<td>8.4 (3.1–22.5)**</td>
<td>6.5 (2.1–19.6)**</td>
</tr>
<tr>
<td>Walking speed &lt;0.8 m/s</td>
<td>8.4 (3.1–22.5)**</td>
<td>6.5 (2.1–19.6)**</td>
</tr>
<tr>
<td>Age ≥78 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance stand &lt;5 s</td>
<td>2.8 (1.6–4.7)**</td>
<td>2.5 (1.5–4.4)**</td>
</tr>
<tr>
<td>Walking speed &lt;0.8 m/s</td>
<td>6.9 (4.1–11.4)**</td>
<td>6.1 (3.6–10.3)**</td>
</tr>
</tbody>
</table>

WS, walking speed; BL, balance stand time.

*Model 1: adjusted for age, sex, education and follow-up time; Model 2: additionally adjusted for number of chronic diseases and Mini-Mental State Examination score.

*P < 0.05.

**P < 0.001.

### Key points

- Walking speed and balance tests are hierarchical indicators of future disability in personal care activities.
- Mobility limitation can increase the risk of disability regardless of the number of chronic diseases and cognitive status.

### Authors’ contributions


### Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

### Acknowledgements

We thank the SNAC-K participants and the SNAC-K Group for their collaboration in data collection and management.
Conflits of interest

None declared.

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References

Leptin concentration and risk of impaired physical function in older adults: the Seniors-ENRICA cohort

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Abstract

Background: leptin resistance, which may develop during the ageing process, stimulates the production of pro-inflammatory cytokines and insulin resistance that could impair the muscle function. However, the role of leptin on physical functioning among older adults has not yet been elucidated.

Objective: to examine the association between serum leptin levels and physical function impairment in older adults.

Design and setting: prospective study of 1,556 individuals 60 years and older from the Seniors-ENRICA cohort, who were free of physical function limitation at baseline.

Main outcome measure: serum leptin was measured in 2008–10, and incident functional limitation was assessed through 2012. Self-reported limitations in agility and mobility were assessed with the Rosow and Breslau scale, limitation in the lower extremity function was measured with the Short Physical Performance Battery, and impairment in the overall physical performance with the physical component summary of the SF-12.

Results: after adjustment for potential confounders and compared to individuals in the lowest quartile of leptin concentration, those in the highest quartile showed increased risk of impaired physical function; the odds ratio (95% confidence interval) and P-trend was: 1.95 (1.11–3.43), P = 0.006 for self-reported impaired mobility; 1.76 (1.08–2.87), P = 0.02 for self-reported impaired agility; 1.48 (1.02–2.15), P = 0.04 for limitation in the lower extremity function; and 1.97 (1.20–3.22), P = 0.01, for decreased overall physical performance. These associations were only modestly explained by C-reactive protein and insulin resistance. Moreover, the associations held across groups with varying health status and were independent of estimated total body fat.