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Can Failure on Adaptive Locomotor Tasks Independently Predict Incident Mobility Disability?

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Abstract

This study examined if inability to perform adaptive locomotor tests predicts self-reported incident mobility disability. InCHIANTI study participants (n=611, age: 50–85 years) who could walk 7 m at self-selected speed and had no self-reported mobility disability at baseline were included. Ability to complete 4 adaptive locomotor tests was assessed: fast walking, walking on a narrow path, crossing obstacles while walking and talking while walking. Mobility disability was recorded again at 3-year follow-up. Failure in fast walking and narrow-path walking tests predicted ~2.5 times likelihood of reporting incident mobility disability (p=0.009 and 0.011, respectively). Failure in obstacle crossing test predicted ~2 times likelihood of reporting incident mobility disability, however, this result did not reach statistical significance (p=0.077). Failure in talking while walking did not predict incident mobility disability. Those who failed both fast walking and narrow-path walking tests were almost 9 times as likely to report incident mobility disability.

Keywords

Mobility; Disability; Aging

In older persons, disability usually occurs first in mobility and sets a downward spiral of progressive disablement¹. The incidence of mobility disability increases with increasing age even when not accompanied by overt co-morbid conditions². It is generally accepted that detecting mobility disability during an early or preclinical stage is likely an important opportunity for implementing preventative measures³.

Mobility is defined as the ability to walk safely and independently in one's natural environment⁴. Although the ability to walk provides the basis of mobility, 'the ability to

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walk' and 'mobility' are not synonymous⁵. The natural environment commonly imposes varied challenges while walking; for example, increasing walking speed when necessary, avoiding or stepping over obstacles, accommodating different kinds of surfaces performing postural transitions etc.⁶. The newer models of disability suggest that it is the inability to accommodate these environmental demands on mobility that leads to mobility disability^{4,7}.

Commonly encountered environmental challenges necessitate precise adaptations of relevant gait parameters to accommodate the challenge and to maintain equilibrium and navigation, thus imposing significantly higher demands on dynamic postural control mechanisms compared to walking at a self-selected comfortable speed on a straight and uncluttered path⁸. Traditionally, however, mobility disability is ascertained as self-reported inability to walk a quarter mile without resting or inability to walk up a flight of stairs unsupported^{9,10}. The relationship between self-reported mobility disability and the actual ability to accommodate challenges while walking has not been examined. The objective of this study was to identify baseline differences in the ability to complete adaptive locomotor tasks in middle-aged and older individuals with and without 3-year incident mobility disability (IMD) and get an insight if inability to perform a specific adaptive locomotor task is associated with self-reported IMD over 3 years.

METHODS

Participants

The InChianti study is a population-based epidemiological study conducted in the Chianti region of Italy to investigate age-related decline in mobility. The study design and data collection have been described previously elsewhere¹¹. The study protocol was approved by the ethical committee of the Italian National Institute of Research and Care of Aging and complies with the Declaration of Helsinki and all participants signed an informed consent. The present study used 2001–02 data of the middle aged and older participants (age 50–85 years) as the baseline data because adaptive locomotor performance was systematically recorded in this wave. The participants who did not report mobility disability and completed 7 m walk at a self-selected normal speed at baseline were included in the final analysis. Those with Mini Mental Examination¹² score <18 were excluded to ensure that the participants followed the instructions appropriately.

Outcome Measures

Mobility Disability—Mobility disability was defined as self-reported inability to walk a quarter mile without resting or inability to walk up a flight of stairs unsupported^{9,10} and was ascertained at the baseline and at the 3-year follow-up.

Adaptive Locomotor Tests—The starting location of the 7 m walking path was marked with a colored tape. The end of the path was not marked, to prevent slowing in anticipation. The time to complete the walking test was recorded and then converted into walking speed (m/s). Initially, participants were asked to walk at their self-selected usual speed (normal speed).

For increasing demands while walking participants were asked to walk in the following four challenging conditions. 1. Fast walking: participants walked as fast as possible. They failed the test if they could not increase the speed by at least 0.1 m/s compared to their normal walking speed¹³. 2. Obstacle crossing: Participants crossed over two obstacles placed in the path while walking as fast as possible. The obstacles were 6-cm and 30-cm tall and were positioned at 2m and 4m, respectively, from the starting line. They failed the test if they tripped on or touched the first obstacle or needed manual assistance for any reason. 3.

Narrow path walking: participants walked at their usual pace, but stayed between lines of colored tape placed 25 cm apart. If they stepped on or outside the tape lines two or more times, a failure was recorded. 4. Walk-and-talk: participants walked while simultaneously performing a verbal cognitive task (recite names of animals starting with a specific given letter). They were instructed to focus equally on the verbal and the locomotor task. A failure was recorded if the participant could not verbalize even one name.

Overall, the participant also failed the test if he/she could not successfully complete the trial, if it was perceived unsafe by the tester for the participant to perform or if the participant refused to perform the walking trial. The participants performed each task only once to maintain novelty of each task and to simulate natural circumstances. Demographic variables included age, sex and body mass index (BMI, kg/m²).

Statistical Analysis

The baseline differences in the demographics between the participants who reported 3-year IMD and those who did not report it was determined using a general linear model (for age and BMI) and chi square analysis (for gender distribution). The baseline differences in the ability to complete each adaptive locomotor test between the participants who reported 3-year IMD and those who did not report it was determined using a chi-square test. Therefore, the dependent variable for these comparisons was presence/absence of IMD.

If the frequency distribution of inability to perform the adaptive locomotor task was different ($p < 0.1$) in these two groups after adjusting for age and sex, a binary logistic regression analysis was performed to examine the likelihood of reporting 3-year IMD for those who could not perform the task. These regression analyses were adjusted for age, sex, BMI and normal walking speed. Finally, the cumulative risk of the inability to perform multiple adaptive locomotor tasks for future mobility disability was examined for those tasks that were significantly associated with IMD in individual regression analyses. Data were analyzed using IBM SPSS version 19. A $p < 0.05$ was considered statistically significant.

RESULTS

A total of 611 participants were included in the final analysis (age: 71.5 ± 7.1 years, women: 53.6%). Four hundred thirty-seven participants successfully performed all four adaptive locomotor tasks, 131 participants could not perform one, 42 could not perform two and seven participants could not perform three adaptive locomotor tasks. None of the participants failed all four tasks. Seventy-nine participants reported 3-year IMD. Those who reported IMD were significantly older ($p < 0.001$) and had a higher proportion of women ($p = 0.001$) compared to those who did not report IMD. IMD group also had a significantly higher proportion of participants who failed fast walking, narrow-based walking and obstacle crossing tasks even after adjusting for age and sex. There was no difference in the proportion of participants who failed the walk-and-talk test (Table 1).

The failure in fast walking and narrow-based walking tests were each associated with ~2.5 times likelihood of reporting IMD ($p = 0.009$ and 0.011 , respectively). Failure in obstacle crossing test was associated with ~2 times likelihood of reporting IMD, however, this result did not reach statistical significance ($p = 0.077$). Those who failed both fast walking and narrow-based walking tests were almost 9 times as likely to report IMD compared to those without these (Table 2)

DISCUSSION

The finding demonstrated that inability to accommodate certain challenges while walking is predictive of future self-reported mobility disability. In particular, inability to increase walking speed on demand and inability to accommodate constraints for maintaining stability in the mediolateral direction while walking significantly increased the possibility of reporting mobility disability in future.

Our previous work has demonstrated that the ability to increase walking speed is associated with lower limb strength¹⁴ in order to generate higher push off forces¹⁵. One of the questions for ascertaining mobility disability enquired ability to walk up stairs without using support which also demands generation of higher lower limb muscle forces in order to lift the body against the gravity¹⁶. The other question for ascertaining mobility disability inquired about quarter mile walking ability for which the participants most likely visualized walking in their community. The ability to increase walking speed when needed is critical for safely and efficiently traversing in community environment (e.g. to cross streets, to avoid collisions with other individuals etc.). Thus, inability to increase walking speed on demand could significantly predict self-reported mobility disability in this study. Previous work has shown that fast walking speed is also able to predict cognitive decline in future¹⁷ and is able to extract important differences in postural control by stressing the postural control mechanisms¹⁸. In addition to generating higher forces the ability to increase walking speed also depends on the ability to build forces at higher rate in a precise sequentially alternating pattern inducing a neuromuscular challenge. It is known that the ability to manipulate muscle forces is reduced with increasing age¹⁹ possibly due to decline in the precision of motor unit discharge²⁰. Overall, the findings suggest that fast walking speed may be a critical performance parameter that should be recorded during geriatric assessment.

The ability to perform narrow base walking is particularly associated with lower limb coordination¹⁴, possibly, because the task demands precise foot placement. Older individuals are known to adopt conservative strategy of wider step width while walking²¹ possibly, to compensate for worsening postural control in the frontal plane. It is known that the stability in the frontal plane while walking is under active neural control²² and depends on the ability to maintain the line of center of gravity medial to the supporting foot²³ for which active adjustment of lateral foot placement is pertinent. Limiting the possibilities for foot placement in the lateral direction may impose significant challenge. Therefore, it is not surprising that the ability to perform this task was able to predict mobility disability that was ascertained by ability to walk upstairs without help and to walk in possibly complex community environment. Narrow-based walking has been previously suggested as a possible clinical tool for measuring physical function in high functioning older adults as it imposes higher challenges for maintaining stability^{24,25}. Our findings provide the evidence for its utility as a tool that can be used to identify older persons who are highly likely to report mobility disability in near future.

There was a multiplicative cumulative effect on the likelihood of reporting mobility disability at 3 years for those who failed in the fast walking as well as narrow base walking tasks. Since mobility disability is the most initial stage in the downward spiral of disability¹, identifying older persons in the pre-clinical stage of mobility disability could be vital. Inability to perform adaptive locomotor tasks in non-disabled may indicate impairments that have only a mild impact on functional ability that individuals may not recognize as frank disability²⁶ and may provide an opportunity for implementing preventative measures.

The failure in obstacle crossing task was only marginally associated with the risk of future mobility disability. When included in the cumulative risk analysis, it did not significantly

change the outcome (data not shown). These findings suggest that although safely stepping over smaller obstacles without tripping may be important for safe mobility, the performance on this task did not provide additional information for predicting IMD. Surprisingly, failure in walk and talk test which is associated with increased fall risk²⁷, was not associated with IMD for this population. However, it is possible that inability to simultaneously attend to a cognitive task while walking can be predictive of mobility disability for individuals living in busier metro city environments.

The first limitation of this study is that the study population was homogenously Caucasian and lived in relatively smaller cities. It may not represent multiracial elderly population living in highly busy metropolitan areas. Additionally, only one challenge was imposed at a time while walking. In reality, particularly in busy environments, individuals may need to accommodate more than one challenge while walking. It is also acknowledged that subjective measures assess individual's perceived ability rather than the actual ability. However, it is suggested that they reflect actual performance and also correlate well with underlying physiological measures such as strength, lower limb somatosensory functions etc. and are the key measures in many clinical trials of various populations. Further, disability is commonly identified using a self-report (e.g. ADL, IADL or advance ADL disability). In order to feel confident about participants' responses and minimize errors we used the MMSE cut off point as an exclusion criterion. When we raised the MMSE cut off point to 24 to confirm our results, the overall results did not change. Nonetheless, lack of availability of objective measures of mobility disability strongly warrants development of objective measures. In conclusion, inability to perform certain adaptive locomotor tasks can predict mobility disability in near future. Failure on more than one such task may significantly increase the likelihood of mobility disability. Recording fast walking speed may be helpful in monitoring physical and cognitive health particularly, in older persons.

References

1. Fried LP, Bandeen-Roche K, Chaves PH, et al. Preclinical mobility disability predicts incident mobility disability in older women. *J Gerontol A Biol Sci Med Sci*. 2000; 55(1):M43–52. [PubMed: 10719772]
2. Daley MJ, Spinks WL. Exercise, mobility and aging. *Sports Med*. 2000; 29(1):1–12. [PubMed: 10688279]
3. Rivera JA, Fried LP, Weiss CO, et al. At the tipping point: predicting severe mobility difficulty in vulnerable older women. *J Am Geriatr Soc*. 2008; 56(8):1417–1423. [PubMed: 18808598]
4. Patla A, Shumway-Cook A. Dimensions of mobility: defining the complexity and difficulty associated with community mobility. *J Aging Phys Act*. 1999; 7:7–19.
5. Frank JS, Patla AE. Balance and mobility challenges in older adults: implications for preserving community mobility. *Am J Prev Med*. 2003; 25(3 Suppl 2):157–163. [PubMed: 14552940]
6. Patla, AE. Adaptive human locomotion: influence of neural, biological and mechanical factors on control mechanism. In: Bronstien, AM.; Brandt, T.; Woollacott, MH.; Nutt, JG., editors. *Clinical disorders of balance, posture and gait*. Arnold Publishers; London, UK: 2004. p. 20-38.
7. National Advisory Board for Medical Rehabilitation Research. Research Plan for the National Center for Medical Rehabilitation Research. Washington, DC: National Institutes of Child Health and Human;
8. Huxham FE, Goldie PA, Patla AE. Theoretical considerations in balance assessment. *Aust J Physiother*. 2001; 47:89–100. [PubMed: 11552864]
9. Gill TM, Allore HG, Hardy SE, et al. The dynamic nature of mobility disability in older persons. *J Am Geriatr Soc*. 2006; 54(2):248–54. [PubMed: 16460375]
10. LaCroix AZ, Guralnik JM, Berkman, et al. Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. *Am J Epidemiol*. 1993; 137(8):858–869. [PubMed: 8484377]

11. Ferrucci L, Bandinelli S, Benvenuti E, et al. Subsystems contributing to the decline in ability to walk: bridging the gap between epidemiology and geriatric practice in the InCHIANTI study. *J Am Geriatr Soc.* 2000; 48:1618–25. [PubMed: 11129752]
12. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: A practical method for grading the state of patients for the clinician. *J Psychiatr Res.* 1975; 12:189–198. [PubMed: 1202204]
13. Studenski, S. Exercise. In: Landefeld, CS.; Palmer, R.; Johnson, MA., et al., editors. *Current Geriatric Diagnosis and Treatment.* New York: McGraw-Hill; 2004. p. 436-446.
14. Deshpande N, Metter EJ, Ferrucci L. Sensorimotor and psychosocial correlates of adaptive locomotor performance in older adults. *Arch Phys Med Rehabil.* 2011; 92(7):1074–9. [PubMed: 21704787]
15. Winter DA, Patla AE, Frank JS, Walt SE. Biomechanical walking pattern changes in the fit and healthy elderly. *Phys Ther.* 1990; 70:340–7. [PubMed: 2345777]
16. Mian OS, Thom JM, Narici MV, Baltzopoulos V. Kinematics of stair descent in young and older adults and the impact of exercise training. *Gait Posture.* 2007; 25(1):9–17. [PubMed: 16481170]
17. Deshpande N, Metter EJ, Bandinelli S, et al. Gait speed under varied challenges and cognitive decline in older persons: a prospective study. *Age Ageing.* 2009; 38(5):509–14. [PubMed: 19549981]
18. Ko SU, Stenholm S, Chia CW, et al. Gait pattern alterations in older adults associated with type 2 diabetes in the absence of peripheral neuropathy--results from the Baltimore Longitudinal Study of Aging. *Gait Posture.* 2011; 34(4):548–52. [PubMed: 21873064]
19. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People *Age Ageing.* 2010; 39:412–23.
20. Kallio J, Sogaard K, Avela J, et al. Age-related decreases in motor unit discharge rate and force control during isometric plantar flexion. *J Electromyogr Kinesiol.* 2012 Jun 28. [Epub ahead of print].
21. Hollman JH, McDade EM, Petersen RC. Normative spatiotemporal gait parameters in older adults. *Gait Posture.* 2011; 34(1):111–8. [PubMed: 21531139]
22. Kuo AD. Stabilization of lateral motion in passive dynamic walking. *Int J Robot Res.* 1999; 18:917–30.
23. MacKinnon CD, Winter DA. Control of whole body balance in the frontal plane during human walking. *J Biomech.* 1993; 26 (6):633–44. [PubMed: 8514809]
24. Bandinelli S, Pozzi M, Lauretani F, et al. Adding challenge to performance-based tests of walking: The Walking InCHIANTI Toolkit (WIT). *Am J Phys Med Rehabil.* 2006; 85:986–91. [PubMed: 17033595]
25. Simonsick EM, Newman AB, Nevitt MC, et al. Health ABC Study Group. Measuring higher level physical function in well-functioning older adults: expanding familiar approaches in the Health ABC study. *J Gerontol A Biol Sci Med Sci.* 2001; 56:M644–9. [PubMed: 11584038]
26. Fried LP, Herdman SJ, Kuhn KE, et al. Preclinical disability: hypotheses about the bottom of the iceberg. *J Aging Health.* 1991; 3:285–300.
27. Beauchet O, Annweiler C, Dubost V, et al. Stops walking when talking: a predictor of falls in older adults? *Eur J Neurol.* 2009; 16(7):786–95. [PubMed: 19473368]

Table 1

The baseline differences in the ability to complete the adaptive locomotor tests and demographics between the participants who reported 3-year incident mobility disability and those who did not report it.

Variable	No incident mobility disability N= 532	Incident mobility disability N= 79	F or χ^2 , p
age	70.7(7.0)	76.4(5.1)	49.519, <0.001
Sex (% women)	51.1%	69.9%	10.162, 0.001
BMI	26.3(3.5)	26.8(4.2)	1.486, 0.223
Inability to successfully complete the adaptive locomotor task adjusting for age, sex and BMI (%)			
Fast walking	8.3%	21.5%	5.699, 0.017
Narrow-based walking	6.8%	26.6%	13.746, <0.001
Obstacle crossing	5.5%	26.6%	15.036, <0.001
Walking-while-talking	10.7%	13.9%	0.031, 0.860

Table 2

The results of binary logistic regression analysis performed to examine the likelihood of reporting 3-year incident mobility disability for those who could not perform the adaptive locomotor test and the cumulative risk of the inability to perform multiple adaptive locomotor tests. These regression analyses were adjusted for age, sex, BMI and normal walking speed.

variable	B(SE)	p	OR(CI)
Fast walking inability	0.997(0.379)	0.009	2.710 (1.291–5.693)
Narrow base walking inability	0.914(0.359)	0.011	2.494 (1.233–5.044)
Obstacle crossing inability	0.636(0.375)	0.077	1.955 (0.930–4.110)
Cumulative likelihood of reporting IMD			
No fast or narrow base walking inability	Comparison group	0.002	
Fast or Narrow base walking inability	0.824 (0.311)	0.008	2.280 (1.240–4.193)
Fast and Narrow base walking inability	2179(0.830)	0.009	8.833 (1.731–44.919)