Age and Ageing 2003; **32:** 619–625

The predictive validity for mortality of the index of mobility-related limitation – results from the EPESE study

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Abstract

Background: self-reported disability reflects physical, environmental and attitudinal factors. We have previously reported the empirical identification of three simple tests to provide an index of (ambulatory) mobility-related physiological limitations (MOBLI). Evidence of the MOBLI's responsiveness over time has been presented. Evidence of the predictive validity of the index is needed.
Objective: we aimed to measure the predictive validity for future mortality of the MOBLI and of self-reported mobility disability in a longitudinal cohort study.
Methods: data are from the sixth annual interview for two sites in the Established Populations for Epidemiologic Studies of the Elderly study. Included were 3,040 people, with information about self-reported walking difficulties, walking speed, time to complete five chair stands and peak expiratory flow. Age- and sex-adjusted death rates over a 4-year follow-up were computed, and proportional hazards regression models were used in the analysis.
Results: the MOBLI score is associated with subsequent mortality over 4 years, with evidence of a 'dose-response' relationship. The predictive value for mortality of the MOBLI score is similar to that of self-reported mobility disability in the studied population.
Conclusions: the 'objective' MOBLI index has predictive validity as a continuous or dichotomised measure of the physiological component of mobility limitation in older populations. Given its empirical basis and face validity, predictive validity and responsiveness to change, MOBLI should be considered for local validation and use in epidemiological comparisons of older populations across countries or over longer periods of time.

Keywords: *disability, mobility limitation, mortality*

Introduction

Self-reported disability incorporates the effects of many factors, including physiological impairment or limitation, environmental barriers, and attitudes. In practice, all these components of disability are routinely assessed together in typical self-report questionnaires, covering difficulties of mobility and everyday activities. Recent analyses by the World Health Organization have focused on the comparability of responses to non-fatal health questions across countries [1–3], and have shown that different populations display significantly different attitudes (cultural expectations about levels of functioning) when reporting disabilities [4, 5]. In addition, different populations may face different environmental barriers to functioning. Therefore using self-reported disability in epidemiological comparisons across countries or ethnic groups could be biased and difficult to interpret. Employing measurements or tests of physiological impairments or limitations could provide a more 'objective' assessment of the physiological contribution to disability, independent of differences in attitudes, environment or other factors.

Mobility disability (defined as difficulty walking medium distances, typically a quarter or half a mile) is a relatively common, inclusive and well-validated marker of the early stages of the disablement process in older people [6]. In our analysis of the US third National Health and Nutrition Examination Survey (NHANES III) dataset, we showed that established measures such as gait speed, time to complete five chair stands, and peak expiratory flow together could be used in an empirically-based statistical index of (ambulatory) mobility-related limitations [7], which we have named 'MOBLI'. Using multiple logistic regression coefficients, a MOBLI score is computed for each individual, reflecting the probability of having difficulty or being unable to walk a distance of a quarter of a mile, conditional only on three physiological test results.

To further establish the validity of MOBLI, it would be useful to compare it to a 'gold standard' measure of mobility-related impairments. For example, as the MOBLI has been developed as a measure of ability to walk a quarter of a mile, the MOBLI should be compared to the results of a test over that distance. Unfortunately, such a test would face practical difficulties in older populations, and no data from such a test is available for direct validation of the MOBLI score. Therefore, indirect evidence of the validity of MOBLI is needed.

It is well established that self-declared mobility disability [8, 9] is a strong predictor of mortality. In this analysis, we aimed to establish whether the MOBLI has similar predictive validity for subsequent survival compared to self-reported mobility disability. In a further paper [10], we have explored the characteristics and responsiveness to change of the MOBLI index in the Longitudinal Ageing Study of Amsterdam, confirming that the index has a similar relationship to self-reported difficulties in walking medium distances as are observed in the original US population, and that the MOBLI is indeed responsive to changes in reported difficulties over a number of years.

Methods

Study sample

Data for this analysis were from the sixth annual follow-up interview of the Established Populations for Epidemiologic Studies of the Elderly (EPESE), which was conducted between 1988 and 1989. The details of the methods used in the surveys have been described previously [11, 12]. Data from the relevant performance tests were available from only two communities, East Boston and New Haven. Potentially eligible for interview were 2,567 persons in East Boston and 1,853 persons in New Haven. Of these, 1,380 were excluded: 401 had died before the interview; 799 had proxy informants or were interviewed by phone and 180 resided at hospital or a nursing home. Thus, there were a total of 3,040 people included in this analysis. The interviews and performance tests were carried out in respondents' own homes.

Physiological measures

The MOBLI index used here [7] included the 'economical' set of physiological measures associated with self-reported difficulty or inability in walking a quarter of a mile; namely, average gait speed, time to do five chair stands and peak expiratory flow rate. The MOBLI score was created from the calibrated difficulty or inability logistic regression models including these three measures and represented the computed probability (with the range from 0 to 1) of reporting disability. Persons with a higher MOBLI score have a higher risk of impairment or functional limitation. Further details about how to calculate the MOBLI score can be seen online [13].

For the measured walk test, the respondents were instructed to walk an eight-foot long walking course at usual walking pace. Gait speed was calculated from the average time to complete two trials. Time to complete five chair stands was measured from the time to stand up from a straight-backed chair five times, without using the arms. Pulmonary function was assessed by the peak flow rates of respondents using a mini-Wright meter (Armstrong Industries, North Brook, IL, USA). The maximum of three trials was chosen as the peak flow. The details of this measure have been described elsewhere [14, 15].

Self-reported disability and selection of the MOBLI equations

The medium distance mobility disability question in EPESE asked whether respondents were able to walk a half-mile without help, a somewhat different wording from the related NHANES III question, about difficulty walking a quarter of a mile. Not surprisingly, the prevalence of inability to walk half a mile in EPESE (35.5%, 1,062 of 2,990 aged 70 and over) was higher than the prevalence of inability to walk a quarter mile in NHANES III (16.1%, weighted rate calculated from 2,856 aged 70 and over).

Two MOBLI logistic equations (one for 'difficulty' and a second for 'inability' with walking) were derived from the NHANES III datset. In order to decide which would fit the EPESE sample best, Receiver Operating Characteristic (ROC) analyses and logit rank slopes [16] were calculated for the EPESE sample, using AccuROC software (Accumetric Corp., Montreal, Canada) and S-PLUS (MathSoft Inc., Cambridge, MA, USA). ROC area and logit rank slope statistics calculated from the inability equation showed a closer fit, with no evidence of statistical significant differences in sensitivity and specificity characteristics for reported mobility, on independent Z tests [17, 18] for ROC areas and logit rank slopes (details of analysis available on request). Thus, the NHANES 'inability' model was chosen for the analysis set out below.

Mortality outcomes

In East Boston and New Haven, vital status was ascertained through the National Death Index only, but in New Haven information also came from obituaries in local newspapers and contact with proxies. Most respondents (2,296 of 2,335; 98.3%) were traced for over 4 years but only 615 (26.3%) were traced to 5 years, and a 4-year follow-up period was chosen for this analysis.

Table 1. Distribution of study sample by socio-demographics, mortality and test measures

Variable		Number or mean	(Percentage or standard deviation)	Variable		Number or mean	(Percentage or standard deviation)
Sex	Male (%)	1059	(34.8)	Gait speed	Mean (SD)	0.54	(0.22)
	Female (%)	1981	(65.2)	(m/sec)	< 0.57 (%)	1630	(53.6)
Age	Mean (SD)	78.8	(5.3)		0.57–0.71 (%)	590	(19.4)
	70–74 (%)	852	(28.0)		0.72–0.81 (%)	227	(7.5)
	75–79 (%)	1121	(36.9)		0.82–0.94 (%)	172	(5.7)
	80–84 (%)	651	(21.4)		> 0.94 (%)	147	(4.8)
	85 and over (%)	416	(13.7)		Unable to do (%)	189	(6.2)
Site	East Boston (%)	1768	(58.2)		Missing (%)	85	(2.8)
	New Haven (%)	1272	(41.8)	Five stands	Mean (SD)	14.2	(4.8)
Cumulative death	1 year (%)	133	(4.4)	(sec)	< 10.4 (%)	443	(14.6)
	2 years (%)	315	(10.4)		10.4–12.0 (%)	366	(12.0)
	3 years (%)	481	(15.8)		12.1–13.6 (%)	354	(11.6)
	4 years (%)	621	(20.4)		13.7–16.3 (%)	527	(17.3)
Self-reported	Able (%)	1928	(63.4)		> 16.3 (%)	590	(19.4)
walking 1/2 mile	Unable (%)	1062	(34.9)		Unable to do (%)	639	(21.0)
	Missing (%)	50	(1.6)		Missing (%)	121	(4.0)
MOBLI score	Mean (SD)	0.2296	(0.2479)	Peak flow	Mean (SD)	5005	(1972)
	20%	0.0416		(ml/sec)	< 3902 (%)	888	(29.2)
	40%	0.0955			3902–5021 (%)	711	(23.4)
	60%	0.1985			5022–6068 (%)	501	(16.5)
	80%	0.4395			6069–7472 (%)	411	(13.5)
					> 7472 (%)	369	(12.1)
					Missing (%)	160	(5.3)

Statistical analysis

The association between mortality and quintiles of the MOBLI score was examined with the proportional hazards regression models. In the proportional hazards regression models, probabilities of survival as a function of follow-up time for quintiles of the MOBLI score were calculated and survival curves were estimated by the Kaplan-Meier product-limit method. Comparison of self-report and the MOBLI score on mortality prediction used age- and sex-adjusted death rate per 100 person-years of follow-up by the direct method (with 5-year age intervals and the 1990 US resident population as the standard population) and proportional hazards regression models. In the hazard models, results were consistent across the two communities and therefore the data were combined. These were calculated using SPSS-PC version 10 (SPSS Inc., Chicago, IL, USA).

In order to compare the predictive ability for mortality of self-report and the MOBLI score, the proportions of variation explained (PVE) of the dependent variable was calculated. The PVE in the Cox model, analogue to the squared multiple correlation (R^2) in the linear regression models, measures the discrepancy of individual survivals from survival functions and from the Kaplan-Meier estimates [19, 20]. The advantage of using PVE is the direct comparability of groups of prognostic factors. Therefore this measure was applied in this analysis in order to compare the explanatory power of the Cox models from the MOBLI score and self-report.

Results

Basic demography

The socio-demographic characteristics, cumulative deaths in different follow-up years, and both self-report and physical tests of mobility capacity are shown in Table 1. Participants ranged in age from 70 to 104 years. The cumulative death rate over 4 years was 20.4%.

Relationship between the MOBLI score and mortality

In Figure 1, survival curves according to quintiles of the MOBLI score show a progressively worse prognosis for each quintile. With increased MOBLI scores a graded decline in survival is observed throughout the follow-up period.

Survival comparison between the MOBLI and self-report

The mortality predictions from self-report and the MOBLI score were further compared using direct standardisation and the proportional hazards regression models. In our study sample, 35.5% of people reported being 'unable' to walk half a mile. To yield the same proportion of the sample as having 'measured' inability in walking, a cut-point of the MOBLI score of 0.2021 was used to dichotomise respondents as 'able' or 'unable' in measured walking ability. Table 2 shows the two-by-two table

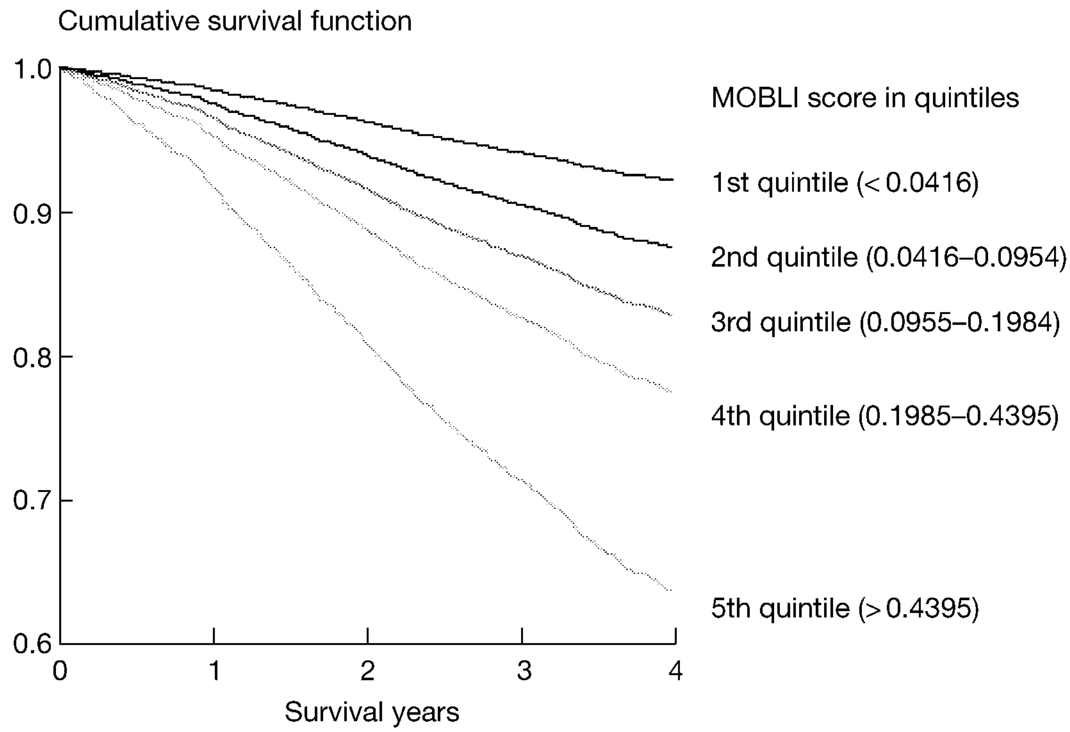

Figure 1. Cumulative probability of survival in different quintiles of the MOBLI score. Curves were from the proportional hazards regression model adjusted for sex and age.

of age- and sex-standardised death rates comparing self-reported and measured mobility inability. The death percentages calculated with two measures were nearly the same (13.6% in 'able to walk half a mile' and 32.4% in 'unable' *versus* 13.9% in 'measured functionally able' and 31.7% in 'functionally unable'). Age- and sex-adjusted person-year deaths for both groups were nearly identical, although all values were smaller (8.0 and 20.1 per 100 person-years in self-report *versus* 8.3 and 19.5 per 100 person-years in functional inability). Again, it showed that death rates associated with index categories are close to those linked to self-report categories.

Proportional hazards models were also used to compare the prediction of survival from self-reported and measured mobility inability. Those who were classified as unable to walk half a mile, either on self-report or on measured MOBLI score had similarly raised hazard ratios in the separate models (Table 3).

In Cox proportional hazards models including age, sex and self-report or dichotomised MOBLI score groups the PVE value for self-reported disability was 9.2%, compared to 8.5% for the dichotomised categories based on the MOBLI score. On using the MOBLI score as a continuous variable, the PVE value was 9.1%, virtually the same as for self-report.

To test if the MOBLI score is also better than other physical tests in mortality prediction, the hazard ratio of one commonly used mobility index – gait speed was calculated and compared to the models in Table 3. Using a cut-off set at 0.4 m/second (the conventional cut-point for walking inability [21]) the hazard ratio for gait speed was 2.07 (95% CI 1.74–2.45), which is somewhat smaller than those of self-report or the MOBLI score and suggests the MOBLI score has greater predictive value for mortality than other mobility indices such as gait speed.

Table 2. Four-year age/sex-crude death rates (%) and age/sex-adjusted death rates per 100 person years of observation, for self-reported and predicted inability to walk half a mile, based on the MOBLI scores

	Measured prediction of functional ability (from MOBLI score)											
	Able to walk 1/2 mile				Unable to walk 1/2 mile				Total			
Self-reported	Deaths	*n*	% dead	Adjusted rate (95% CI)	Deaths	*n*	% dead	Adjusted rate (95% CI)	Deaths	*n*	% dead	Adjusted rate (95% CI)
Able to walk	180	1559	11.6	7.2 (6.3–8.0)	82	369	22.2	13.6 (11.3–15.8)	262	1928	13.6	8.0 (7.3–8.8)
Unable to walk	87	363	24.0	14.8 (12.4–17.2)	257	699	36.8	23.6 (21.1–26.2)	344	1062	32.4	20.1 (18.4–21.9)
Total	267	1922	13.9	8.3 (7.5–9.0)	339	1068	31.7	19.5 (17.8–21.3)	606	2990	20.3	11.6 (10.9–12.3)

Table 3. Hazard ratios[a] (95% confidence intervals) for 4-year mortality, by sex, age, self-reported, and measured mobility inability (based on the MOBLI score)

Variable	HR	(95% CI)	HR	(95% CI)
Sex				
Female	1.00		1.00	
Male	2.45	(2.08–2.90)	2.35	(1.99–2.77)
Age				
70–74	1.00		1.00	
75–79	1.15	(0.92–1.44)	1.15	(0.92–1.44)
80–84	1.28	(1.00–1.63)	1.27	(0.99–1.63)
85 and over	2.18	(1.71–2.79)	2.14	(1.68–2.73)
Self-reported walking 1/2 mile				
Able	1.00			
Unable	2.95	(2.48–3.50)		
Measured mobility inability				
Able			1.00	
Unable			2.71	(2.28–3.21)

[a]Community stratified summary hazard ratios.

Discussion

In this analysis of data from the EPESE community-based prospective study, the measurement-based index of mobility-related limitation (MOBLI) score was shown to have predictive value for subsequent mortality over a 4-year period. Survival rates showed a progressive decrease with increasing MOBLI scores, reflecting greater mobility limitation. Hazard ratios for mortality also revealed similar values in both self-reported and measured (based on the MOBLI) walking ability.

Ideally, evaluation of the MOBLI score should involve a comparison to a 'gold standard' measure of mobility limitation over a medium distance. Unfortunately testing mobility over a half or quarter of a mile would pose great practical difficulties. Establishing the predictive validity of MOBLI for a key outcome like mortality is probably the next best available method for providing evidence of the validity of the index. In this study we have demonstrated that the MOBLI score, especially in its continuous form, does indeed have predictive value for mortality.

A number of methodological issues do need to be considered in evaluating the result. The self-reported medium distance mobility question in the EPESE study was not precisely the same as the question asked in NHANES III. However, we have shown that the test characteristics (ROC and logit rank slopes) of the NHANES-based MOBLI formula for inability walking a quarter of a mile performs well in the EPESE data.

A further issue in this analysis is the rationale for focusing on mortality as the predicted outcome. Of course, some causes of mobility impairments or limitations, such as degenerative arthritis, are not directly linked to mortality, but several other causes are, such as cardiovascular and respiratory disease. Conversely, some causes of mortality are not linked to mobility difficulties. Nevertheless, self-reported mobility disability has been shown to be predictive of mortality [8, 9, 22]. Our finding that the MOBLI index is predictive of mortality is consistent with previous work on the constituent measures. As a part of some validated instruments such as the Summary Performance Score [23] and Physical Performance Test (PPT) [24, 25], gait speed and five chair stands tests were shown to be strong predictors of adverse outcomes such as mortality [23, 26] and nursing home admission [23, 27]. Similarly, peak expiratory flow rate is also a predictor of mortality [28, 29]. In addition, this analysis, based on the availability of the EPESE dataset, only focused on people aged 70 and over. Further work is still needed to test whether the index works as well for people under age 70.

The evidence that the MOBLI is as good, but not better than self-reported mobility disability in the studied population should not be misunderstood as suggesting that the MOBLI offers no advantage. The test-based nature of the MOBLI offers a measure of the physiological component of mobility disability, unbiased by attitudes or environment.

The evidence presented here establishes the 'physiological link' between the MOBLI and subsequent mortality in the EPESE study. Although this needs further testing in different populations, it is likely that the relationship will be robust across different populations. It is perhaps possible that the MOBLI score in a population with, for example, high rates of obstructive airways disease may behave differently, possibly due to the specific effects of airways disease on the lung function test. This suggests two courses of action: firstly to extend the validation of the MOBLI to more diverse populations, and secondly, where differences in the MOBLI scores are obtained in population comparisons, to ensure that the constituent measures and disease prevalences are investigated.

In the development of the MOBLI index, we aimed to identify a feasible battery of brief, physical tests that could be used in large-scale epidemiological studies. The MOBLI was designed to reflect the physiological factors that influence the average reporting of disability experienced in walking medium distances, in a reference population. In this paper, we have shown that the MOBLI has good predictive validity for subsequent mortality in an independent study sample in two geographical areas in the US. In separate analysis [10], we show that this score also has good responsiveness to change in another dataset and country, the Longitudinal Aging Study Amsterdam in the Netherlands. In addition, there is evidence for the repeatability of the constituent measures of the MOBLI, and their previous successful use in a number of large epidemiological studies suggests that respondents are willing to participate in these tests [7].

Validation of a measure like the MOBLI is complex: a measure (i.e., instrument or physical measurement) is not 'validated' once and for all, but an estimation of validity is gauged in particular populations. Together with its demonstrated face validity, predictive validity and responsiveness, use of the MOBLI (if necessary with local validation in the target populations) must be considered seriously in any future epidemiological attempts to compare mobility between differing older populations, or in epidemiological efforts to separate the physical factors from the many other factors (such as attitude or environment) that affect the reporting of disability.

Key points

- In the absence of a gold standard, mortality prediction provides a good validation test for the mobility-related limitations index (MOBLI).
- There is evidence of a clear gradient in survival over 4 years across quintiles of the score.
- Given its applicability, predictive validity and responsiveness to change the MOBLI index should be considered in any epidemiological comparisons across populations or over periods of time.

Acknowledgements

The authors would like to thank Caroline L. Phillips for assistance in data checking and Brian D. M. Tom for statistical advice.

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Received 23 July 2002; accepted in revised form 24 June 2003