Published in final edited form as:

PM R. 2016 August ; 8(8): 738–747. doi:10.1016/j.pmrj.2016.01.007.

The Relationship Between Neuromuscular Impairments, Chronic Back Pain and Mobility in Older Adults

Una E. Makris, MD, MCS,

UT Southwestern Medical Center and Dallas VAMC

Tracy M. Paul, BS,

Case Western Reserve University School of Medicine

Nicole E. Holt, MPH, PhD,

Spaulding Rehabilitation Hospital

Nancy K. Latham, PhD, PT,

Boston University

Pengsheng Ni, MD, MPH,

Boston University

Alan Jette, PhD, MPH,

Boston University

Suzanne G. Leveille, PhD, RN, and

University of Massachusetts Boston

Jonathan F. Bean, MD, MS, MPH

Spaulding Rehabilitation Hospital. New England GRECC, VA Boston Healthcare System.

Department of PM&R, Harvard Medical School

Abstract

Background—For older adults with mobility problems, one focus of rehabilitation is treating the underlying neuromuscular impairment(s) that lead to functional decline and disability. Knowing which neuromuscular impairments contribute to basic mobility tasks among older adults with back pain will fill an important knowledge gap and is a critical step towards developing mechanistically-based rehabilitative interventions.

Objective—To evaluate the relationship of neuromuscular impairments with performance of mobility tasks among older adults with and without back pain.

Corresponding Author and Reprint Contact: Una E. Makris, MD, MCS, UT Southwestern Medical Center and Dallas VAMC, 5323 Harry Hines Blvd, Dallas, TX 75390-9169; una.makris@utsouthwestern.edu.

The results of this study were presented at Gerontological Society of America, New Orleans, LA, Nov 2013 as an oral presentation.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Design—Cross-sectional analysis of baseline data from the Boston Rehabilitative Impairment Study of the Elderly (Boston RISE).

Setting—Primary care based population.

Patients—Participants (N=430) were older primary care patients who completed assessments of neuromuscular impairments and mobility tasks.

Methods—Back pain was assessed using an established comorbidity questionnaire.

Neuromuscular impairments included trunk extensor endurance, kyphosis, leg strength, leg strength asymmetry, leg speed, mean reaction time, leg coordination, knee and ankle range of motion.

Main Outcome Measurements—Mobility tasks included gait speed, standing balance, chair stand and patient-reported functional status. Analysis of covariance was used to generate adjusted means for neuromuscular Impairments that differed significantly by back pain status. Separate multivariable regression models evaluated the association between neuromuscular impairments and mobility based on back pain status after adjusting for socio-demographic factors and physiologic impairments.

Results—Participants had an average age of 77 years, 68% were female, and 31% reported back pain. Trunk extensor muscle endurance, leg strength, and rapid leg coordination were significantly lower among those with back pain compared to those without ($p<.01$, $p=.01$, $p=.04$, respectively). Patterns of neuromuscular impairments that were associated with mobility tasks differed according to back pain status.

Conclusions—The neuromuscular impairment profiles associated with mobility function among older adults with back pain vary as compared to older adults without back pain.

Keywords

Back Pain; Mobility; Aged

Introduction

Back pain is highly prevalent among older adults[1] and the most common musculoskeletal problem in patients over 75 years old[2]. Each year, over \$100 billion is spent in the US on back pain[3], and we anticipate increasing costs as this population ages. Chronic back pain (symptoms lasting greater than three months) leads to disability[4, 5], defined as difficulty or inability to perform functional tasks such as walking and activities of daily living (ADL)[6]. Mobility is critical for maintaining independence in older persons and those who lose mobility have higher rates of morbidity and mortality, and experience poorer quality of life[7–9].

For older adults with mobility problems, one focus of rehabilitation is treating the underlying neuromuscular impairment(s) that lead to functional decline and disability. Focusing on rehabilitation interventions and the *mechanisms* by which older adults have difficulty with mobility is particularly important given the paucity of high quality data guiding care. Five neuromuscular impairments are associated with mobility status in older

primary care patients. These impairments, identified from the Boston Rehabilitative Impairment Study of the Elderly (Boston RISE) [10, 11], are leg strength, leg velocity, knee range of motion, asymmetry of leg strength and trunk extensor muscle endurance. While Boston RISE is designed to focus on risk factors that are responsible for mobility decline, to date, the relevance of coexisting back pain has not been addressed.

It is understood from postural control and balance research [12] that older adults with specific neuromuscular impairments will use different strategies to accomplish the same functional tasks [13, 14]. With regard to back pain, we know from research in younger adults that back pain can lead to use of different strategies to accomplish basic functional tasks [15]. One neuromuscular impairment associated with back pain in *young* adults is trunk extensor muscle endurance. Among young adults, endurance of the trunk extensor muscles is related to both athletic performance and spinal stability-- factors that are linked to back pain symptoms[16]. However, little is known about these relationships among older adults with back pain.

For older adults, who often have multiple chronic conditions[17], optimal rehabilitative care should be directed to neuromuscular impairments that influence mobility most. Knowing which neuromuscular impairments contribute to basic mobility tasks among older adults with back pain will fill an important knowledge gap and is a critical step towards developing mechanistically-based rehabilitative interventions. Therefore, we sought to evaluate the relationship of neuromuscular impairments with mobility among older primary care patients with and without back pain. To address this aim we conducted an analysis of baseline data from Boston RISE.

Boston RISE is a longitudinal cohort study, with two years of follow up, of older primary care patients that evaluates neuromuscular impairments that contribute to functional decline[11]. This study specifically focuses on impairments that can be treated in rehabilitative care. Within Boston RISE, back pain is assessed using an established comorbidity questionnaire[18]. We hypothesized that, among older primary care patients, 1) a subset of neuromuscular impairments, including trunk extensor muscle endurance (TEE), will be lower among patients with back pain compared to those without back pain and, further, that these impairments will be associated with mobility status, and 2) neuromuscular impairments necessary to complete basic mobility tasks will vary depending on whether back pain is present or not.

Patients and Methods

Boston RISE includes 430 primary care patients 65 years old who are at risk for mobility decline as defined by self-reported preclinical disability using criteria defined by Fried et al[19]. The methods of the Boston RISE study are detailed elsewhere[11]. The Institutional Review Boards of Spaulding Rehabilitation Hospital approved this study.

Recruitment of Participants

Potential subjects were identified using a primary care based data registry serving Massachusetts General Hospital and Brigham and Women's Hospital in Boston, MA.

Patients were contacted by mail and then by telephone to undergo initial screening for eligibility, after receiving approval from their primary care physicians. Inclusion and exclusion criteria were reviewed and then potentially eligible participants were invited to undergo an initial visit that included informed consent, completion of screening tests and initial study assessments at Massachusetts General Hospital Clinical Research Center. A second visit was scheduled within two weeks for the baseline assessment.

Recruitment of all 430 Boston RISE participants started in December 2009 and was completed in January 2012. The inclusion criteria for Boston RISE participants were: age 65 years or older, ability to understand and communicate in English, difficulty or task modification while walking half a mile (six blocks) or climbing one flight of stairs. The exclusion criteria were: presence of a terminal disease, major surgery or myocardial infarction in the previous six months, planned major surgery, planned move from Boston area within two years, Mini-Mental Status Exam score less than 18[20], major medical problems interfering with safe and successful testing, and Short Physical Performance Battery (SPPB) score less than four, indicating severe mobility problems[21].

Back Pain Status

Self reported back pain was assessed using the Self-Administered Comorbidity Questionnaire developed by Sangha et al[18], a valid and reliable measure of comorbidities[18]. The questionnaire asks participants if they have any of thirteen common chronic conditions. For each of the chronic conditions, the participant was asked “do you have the problem, do you receive treatment for it, and does it limit your activities.” This study focused on the questions: “do you have the problem of back pain” and “do you receive treatment for it.”[18] Participants who answered yes to both questions were defined as having chronic back pain while participants who answered no to one or both questions were classified as having no back pain for the purposes of this research.

Mobility Tasks (Dependent Variables)

We focused on basic mobility tasks because, in the clinical experience of the investigative team, these are the functional complaints of older adults with back pain that most commonly lead to rehabilitative care referrals. Components of the SPPB and the Physical Function domain of the Late Life Function and Disability Instrument (LLFDI) were used as the primary outcome measures for this study. The SPPB is a well-established physical performance measure of lower extremity mobility function that is predictive of future disability, morbidity, mortality and institutionalization among older adults[21, 22]. Specifically, the SPPB reliably measures three components of lower extremity function: gait speed, standing balance, and the chair stand test. Scores are predictive for the development of disability with both mobility and ADL tasks over 1 to 4 years of follow up[23]. The walking speed test measures the time it takes for participants to walk over four meters at their usual pace. The standing balance test requires participants to stand for ten seconds side-by-side, semi-tandem or in a tandem position. The chair stand test measures the time it takes for participants to rise from a chair with their arms folded over their chest five times.

Gait speed was evaluated as a continuous variable since it has been independently associated with adverse outcomes[23]. According to the standard SPPB scoring[21, 23], standing balance and chair stand performance were scored between 0–4 with higher values representing higher performance. Standing balance and chair stand were used as categorical variables to ensure that those who attempted the task but could not perform it successfully were still included in the analyses (i.e. assigned a score of 0).

The LLFDI assesses patient-reported physical function and disability and has been validated in community dwelling older adults[24–26]. The function component can be divided into 3 subdomains (upper extremity function, and basic and advanced lower extremity function). The domains of the LLFDI are calibrated on a scale from 0–100. Given the focus of this investigation on basic mobility tasks, we only used the basic lower extremity function domain as a patient-reported outcome measure.

Neuromuscular Impairments (Independent Variables)

All neuromuscular impairments assessed are reliable and valid measures that have been linked to mobility outcomes in community dwelling older adults [11].

Trunk extensor muscle endurance measurement has been described in detail in previous reports [27]. Briefly, participants lie prone on a table that is positioned at 45 degrees from the horizontal with their feet secured on an adjustable foot plate with their lower body supported by the apparatus. As shown in figure 1, the table is hinged and participants are positioned so that the trunk and upper body are unsupported. Participants could relax by resting their upper body on the end of the table in a trunk flexion position. During the test, participants crossed their arms over their chest and extended their trunk muscles to keep their entire body in a straight line 45 degrees from the floor for as long as possible. The time the participant could hold himself/herself in this fixed position was defined as trunk extensor endurance (TEE). This test has excellent reliability among mobility limited older adults ($r=.88-.91$)[28]. TEE was normalized for body weight[10, 27].

Leg strength and leg velocity were measured using the Keiser A420 leg press machine as previously described[29]. Leg strength was measured as the one repetition maximum (1RM) separately for each leg—this is a reliable and valid measure of strength[29]. We used the highest value of either leg for analysis. Leg press velocity was measured as the leg velocity generated at peak leg press power, as previously described[10]. Reaction time was measured by asking participants to click a computer mouse as fast as possible when a red light flashes. An electronic timer was used to measure the time it takes for the participant to click the mouse in response to the light stimulus. This is a reliable test of a participant's reaction time[30]. Rapid leg coordination was measured by asking participants to bring the heel of one foot to the outer part of their shin on the opposite leg, four inches below the knee and then return their heel to the floor. The participant was asked to repeat this test ten times as quickly as possible for both feet. The time it takes to perform this test for each foot was measured[31]. Kyphosis was measured using a flexible ruler placed over the participant's spine from C7 to the lumbosacral junction. The curved shape of the ruler was then traced onto a sheet of a paper. The index of kyphosis is defined as the width of this curve divided by its length[32]. A goniometer was used to measure range of motion (ROM) in the knees

which is a reliable measure of knee ROM[33]. Knee flexion ROM was measured by having the participant flex their knee joint as far as they can with active assistance of the examiner. Knee extension ROM was measured by having the participant extend their knee joint as far as they can with active assistance of the examiner. Difference in knee flexion ROM was defined as the highest value from either the left or right leg and this value was subtracted from the value of the other leg. Plantarflexion and dorsiflexion, also referred to as ankle ROM, were categorical variables documenting whether or not the participant could extend both ankles greater than 90 degrees and flex both ankles greater than 110 degrees, respectively.

Covariates

Covariates were assessed at baseline and selected based on the literature and known association with mobility. Demographic data included age, gender, race, and education. Height and weight were used to calculate body mass index (BMI). Overweight was defined as a BMI of 25 to 30 and obese was defined as BMI ≥ 30 . Twelve chronic conditions other than back pain, that affect older primary care patients, were assessed using the questionnaire[18] previously described. Comorbidity was evaluated as a count from 0–12. Sensory loss was measured using 5.07 and 4.17 monofilaments on the dorsum of the right great toe[34]. Depressive symptoms were measured using the 9-item Patient Health Questionnaire (PHQ9) score of ≥ 5 [35]. Cognitive function was measured using the Digit Symbol Substitution Test that asks participants to match numbers to symbols in 90 seconds. A higher score on this test reflects higher cognitive performance[36].

Statistical Analysis

Descriptive statistics, according to back pain status, were calculated for all variables using means and standard deviations for continuous variables and frequency and percentages for categorical variables. T-tests and chi-squared tests were used to calculate differences between groups based upon back pain status. All neuromuscular impairments were evaluated for potential collinearity and were selected for inclusion in the multivariable models if $r < .40$. For variables that were highly correlated, we selected the variable based on strength of association with the outcome and those with the least missing data. Using an analysis of covariance, adjusted means scores were calculated for those impairments that significantly differed between groups (by back pain status), after adjusting for age, gender, race, education, body mass index, chronic conditions, depressive symptoms, and cognitive function. Separate multivariable regression models were constructed to evaluate the [within group] association between neuromuscular impairments and the mobility tasks (outcomes) based on back pain status after adjusting for age, gender, BMI, chronic conditions, and the presence of other neuromuscular impairments. This was done using manual backwards elimination, as previously described[10, 37]. Age, gender, BMI and only those remaining impairments that were significant predictors (p -value $< .05$) were retained in the model. Other covariates were then added to these initial models and evaluated by the same manual backwards elimination process. We retained covariates in the final model if they substantially altered the relationships between individual physiologic impairments (standardized estimate of attribute change by $\geq 20\%$) and the outcomes. Fit of the final model was confirmed using Cook's d .

Statistical tests were two-tailed, and $p < .05$ was considered to indicate statistical significance. All analyses were evaluated using SAS version 9.2 (SAS Institute, Cary, NC).

Results

Among this cohort of older primary care patients, 31.4% reported back pain for which they were receiving treatment. Participants with back pain reported a greater number of chronic conditions than those without back pain (Table 1). Differences were not observed according to sociodemographic characteristics or other health status measures. As shown in Table 2, participants with back pain were more likely to have decreased TEE, leg strength, and leg coordination. Compared to participants without back pain, those with back pain had poorer performance in gait speed ($p = .05$) and chair stands ($p < .01$), and worse basic lower extremity function ($p < .01$).

The adjusted mean scores of TEE, leg strength, and rapid leg coordination, the three neuromuscular impairments that were significantly different between those with and without back pain, are presented in Figure 2. Among those with and without back pain respectively, the adjusted mean for TEE was 1.10 s/kg (CI 0.96, 1.24) and 1.39 s/kg (CI 1.30, 1.48) ($p < .001$); for leg strength was 9.10 N/kg (CI 8.66, 9.47) and 9.61 N/kg (9.35, 9.87) ($p < .001$); and for rapid leg coordination was 11.54 seconds (CI 11.01, 12.06) and 10.97 seconds (CI 10.62, 11.33) ($p < .001$).

Adjusted for demographic and health measures, both TEE and ankle ROM were independently associated with gait speed only among participants without back pain (Table 3). Leg velocity was the only impairment independently associated with gait speed among both participants with and without back pain. Leg strength was associated with standing balance only among those without back pain, whereas TEE and ankle ROM were each independently associated with standing balance among only those *with* back pain. Neuromuscular impairments associated with back pain (TEE, leg strength), coordination and knee ROM were associated with chair stand time in all patients, regardless of whether back pain was present. TEE and coordination were associated with basic lower extremity function for participants without back pain. Leg strength was associated with this LLFDI subscale among all participants, whereas leg velocity was associated with this outcome only among those with back pain.

Discussion

This study among older primary care patients is the first to closely examine a broad array of neuromuscular impairments that can be treated with rehabilitative care among older adults with and without back pain. We evaluated potential neuromuscular impairments associated with mobility tasks in patients with and without back pain. The main findings of this cross-sectional analysis are: 1) TEE, rapid leg coordination, and leg strength are significantly lower among those with back pain as compared to those without; 2) older adults with back pain had slower gait speed, chair stand, and worse basic lower extremity function than those without back pain; and 3) the neuromuscular impairment profiles associated with mobility function vary according to back pain status.

Prior studies among older adults have identified that trunk muscles are uniquely linked to back pain status and to functional decline[2, 38]. Hicks and colleagues[2], using spinal imaging via computed tomography, demonstrated that older adults with poorer trunk muscle composition (represented as increased intramuscular fat within trunk muscles) have lower function and greater functional decline over a 3-year period. This association was greater among older adults with back pain. Hicks did not evaluate TEE or strength, however. The current study found an association between lower TEE and back pain among older patients. Prior research has speculated that TEE is a critical measure in older adults because this population tends to have more problems with kyphosis¹⁴. In our analyses, kyphosis was not significantly different between older adults with and without back pain and was not significantly associated with any of the mobility outcomes.

Studies in older adults have also focused on the importance of leg strength for improving functional and mobility tasks[39, 40]. A study by Suri et al[28], which focused on a more complex measure of balance among older adults, did not find clinically significant associations with leg strength. Back pain status was not evaluated in this study. Our results show that leg strength was associated with standing balance only among older adults *without* back pain. Since we found that leg strength was significantly lower among those *with* back pain, it may be that these individuals rely on other neuromuscular attributes (TEE and ankle range of motion) to perform this task. Despite these different strategies, standing balance did not differ between those with and without back pain in our study. We did not evaluate standing balance for longer than 10 seconds. It is conceivable that if we had evaluated standing balance for a longer period of time, performance on this task may have been worse among those with back pain. This is postulated since TEE was associated with standing balance performance *and* was significantly more impaired among our participants with back pain.

Similarly, differences in TEE may account for the slower gait speed differences among those with back pain. In our study, TEE was not associated with gait speed among participants with back pain. In contrast, those without back pain did not manifest as severe impairments in TEE. For them leg velocity, TEE and ankle ROM were associated with gait speed performance and thus use of these three attributes may account, mechanistically, for the higher gait speeds observed in our participants without back pain. It is worth mentioning that several variables may not have reached statistical significance based on power in our study, however, the magnitude of estimates suggests that there may be differences according to back pain status.

From a function standpoint, other studies have drawn distinctions between self-reported function and performance-based measures of mobility. One study showed that back pain frequency and intensity were associated with *perceived* difficulty in performing functional tasks, but not with observed physical performance[41]. While we did observe differences in mobility performance among those with and without back pain, our definition of back pain did not distinguish between frequency and intensity. This may account for the different findings that we observed.

Another important finding of our study was that the LLFDI was sensitive to differences in basic mobility function among older adults with and without back pain. The LLFDI is a well-established measure of function and disability among community-living older adults who have many comorbidities other than back pain. Identifying that the LLFDI is sensitive to differences based on back pain status further supports its use as a universal outcome measure for community-living older adults.

From a rehabilitative perspective, our findings suggest potential targets for treatment strategies that focus on the neuromuscular impairments most prominent among those with back pain in order to enhance mobility. This may be particularly relevant for enhancing TEE and leg strength. This contention is not only supported by our findings, but also other reports in the literature[2, 42]. For example, Vincent and colleagues[43] conducted a randomized control trial with 49 obese adults (ages 60–85 years) with chronic low back pain to compare the effects of four months of isolated lumbar resistance exercise and total body resistance exercise on walking performance. Both groups exhibited similar, modest improvements in walking endurance compared with the control group. In this study, lumbar extensor strength, but not leg strength, moderately contributed to walking endurance. While focusing on a healthier cohort (these individuals manifested higher levels of physical functioning than our cohort), these findings support the fact that trunk muscle training may be beneficial for improving mobility among older adults with back pain. However, their mode of training involved the use of very expensive back training equipment and simpler modes of training need to be identified for more generalized use among older adults.

Several limitations of this study are worth mentioning. First, some of the older participants did not complete all tests since they found them to be too challenging, resulting in a limited amount of missing data. This is common, particularly in cohort studies that involve older adults and when comprehensive assessments are conducted. Rates of missing data in our study are consistent with other highly regarded cohort studies in older adults[2, 44, 45]. Second, the assessment of back pain did not provide detail about etiology (i.e. differentiating between spinal stenosis or other spine conditions). Third, while prior research has reported on limited trunk extension[46] and repetitive trunk rotation[47] as independent correlates of back pain in older adults, Boston RISE did not assess spine range of motion. Fourth, this study was a cross-sectional analysis and the relationships between back pain, neuromuscular impairments and mobility tasks should be confirmed with longitudinal analyses. Therefore, our findings may suggest potential targets for rehabilitation, but do not provide definitive information regarding causality. Fifth, for estimates that are similar yet not statistically significant for those with back pain as compared to those without (for example, leg strength associated with standing balance) we fully acknowledge that statistical power is a potential concern. Lastly, we evaluated a comprehensive, but not exhaustive list of covariates. For example, Boston RISE did not assess fear avoidance beliefs or catastrophising that are associated with both self-reported and performance-based outcomes in back pain research [48].

Our study has several strengths. The current study included a representative primary care based population that increases the clinical relevance of our findings. Participants in Boston RISE are representative of the Boston MA area where they were recruited (based on gender

and racial composition)[49]. Boston RISE is unique in that it assesses an extensive array of neuromuscular impairments that can be targeted in rehabilitative care, in a large sample of older adults. Importantly, this study highlights that older adults with back pain may have different attributes associated with the performance of basic tasks suggesting that they may use different strategies to complete basic functional tasks. Monitoring these patterns may be a useful means of monitoring the effects of new or existing rehabilitative therapies and may also suggest the need for modifying the design of rehabilitative programs for those with back pain in contrast to those without back pain.

Conclusion

Our findings emphasize how older adults with back pain may differ according to certain neuromuscular impairments from those without back pain. Future studies using longitudinal study designs should confirm different mechanistic strategies used to perform mobility tasks among older adults with back pain. By understanding the neuromuscular impairments that may be linked to mobility among older adults with back pain, these findings are an initial step that can help guide and tailor the development of rehabilitative interventions for older individuals.

Acknowledgments

Funding Source: This work was supported by the National Institute on Aging (5 R01 AG032052-03), the National Center for Research Resources in a grant to the Harvard Clinical and Translational Science Center (1 UL1 RR025758-01) and the National Center for Medical Rehabilitation Research (5R24HD065688-04). Dr. Bean is supported by 1K24HD070966-01 from NIH.

Dr. Makris was supported by the Rheumatology Research Foundation/ASP Junior Career Development Award in Geriatric Medicine, NIA GEMSSTAR (R03AG040653) and the Center for Translational Medicine, NIH/NCATS Grants (KL2TR001103 and UL1TR001105). The content is solely the responsibility of the authors and does not necessarily represent the official views of the Center for Translational Medicine, UT Southwestern Medical Center and its affiliated academic and health care centers, the National Center for Advancing Translational Sciences, or the National Institutes of Health.

References

1. Patel KV, Guralnik JM, Dansie EJ, Turk DC. Prevalence and impact of pain among older adults in the United States: Findings from the 2011 National Health and Aging Trends Study. *Pain*. 2013; 154:2649–57. [PubMed: 24287107]
2. Hicks GE, Simonsick EM, Harris TB, Newman AB, Weiner DK, Nevitt MA, et al. Trunk muscle composition as a predictor of reduced functional capacity in the health, aging and body composition study: the moderating role of back pain. *J Gerontol A Biol Sci Med Sci*. 2005; 60:1420–4. [PubMed: 16339328]
3. Katz JN. Lumbar disc disorders and low-back pain: socioeconomic factors and consequences. *J Bone Joint Surg Am*. 2006; 88:21–4. [PubMed: 16595438]
4. Reid MC, Williams CS, Gill TM. Back pain and decline in lower extremity physical function among community-dwelling older persons. *J Gerontol A Biol Sci Med Sci*. 2005; 60:793–7. [PubMed: 15983185]
5. Leveille SG, Bean J, Ngo L, McMullen W, Guralnik JM. The pathway from musculoskeletal pain to mobility difficulty in older disabled women. *Pain*. 2007; 128:69–77. [PubMed: 17055167]
6. Di Iorio A, Abate M, Guralnik JM, Bandinelli S, Cecchi F, Cherubini A, et al. From chronic low back pain to disability, a multifactorial mediated pathway: the InCHIANTI study. *Spine*. 2007; 32:E809–15. [PubMed: 18091475]

7. Fried LP, Guralnik JM. Disability in older adults: evidence regarding significance, etiology, and risk. *J Am Geriatr Soc.* 1997; 45:92–100. [PubMed: 8994496]
8. Landi F, Liperoti R, Russo A, Capoluongo E, Barillaro C, Pahor M, et al. Disability, more than multimorbidity, was predictive of mortality among older persons aged 80 years and older. *J Clin Epidemiol.* 2010; 63:752–9. [PubMed: 20056387]
9. Hardy SE, Kang Y, Studenski SA, Degenholtz HB. Ability to walk 1/4 mile predicts subsequent disability, mortality, and health care costs. *J Gen Intern Med.* 2011; 26:130–5. [PubMed: 20972641]
10. Bean JF, Latham NK, Holt N, Kurlinski L, Ni P, Leveille S, et al. Which neuromuscular attributes are most associated with mobility among older primary care patients? *Arch Phys Med Rehabil.* 2013; 94:2381–8. [PubMed: 23973445]
11. Holt NE, Percac-Lima S, Kurlinski LA, Thomas JC, Landry PM, Campbell B, et al. The Boston Rehabilitative Impairment Study of the Elderly: A Description of Methods. *Arch Physical Med Rehab.* 2013; 94:347–55.
12. Woollacott MH, Shumway-Cook A, Nashner LM. Aging and posture control: changes in sensory organization and muscular coordination. *Int J Aging Hum Dev.* 1986; 23:97–114. [PubMed: 3557634]
13. Luchies CW, Alexander NB, Schultz AB, Ashton-Miller J. Stepping responses of young and old adults to postural disturbances: kinematics. *J Am Geriatr Soc.* 1994; 42:506–12. [PubMed: 8176145]
14. McIlroy WE, Maki BE. Age-related changes in compensatory stepping in response to unpredictable perturbations. *J Gerontol A Biol Sci Med Sci.* 1996; 51:M289–296. [PubMed: 8914501]
15. McGill, S. Low back disorders: evidence-based prevention and rehabilitation. Champagne (IL): Human Kinetics; 2007.
16. Standaert CJ, Weinstein SM, Rumpeltes J. Evidence-informed management of chronic low back pain with lumbar stabilization exercises. *Spine J.* 2008; 8:114–20. [PubMed: 18164459]
17. Tinetti ME, Fried TR, Boyd CM. Designing health care for the most common chronic condition--multimorbidity. *JAMA.* 2012; 307:2493–4. [PubMed: 22797447]
18. Sangha O, Stucki G, Liang MH, Fossel AH, Katz JN. The self-administered comorbidity questionnaire: A new method to assess comorbidity for clinical and health services research. *Arthritis Care Res.* 2003; 49:156–63.
19. Fried LP, Bandeen-Roche K, Chaves PH, Johnson BA. Preclinical mobility disability predicts incident mobility disability in older women. *J Gerontol A Biol Sci Med Sci.* 2000; 55:M43–52. [PubMed: 10719772]
20. Folstein MF, Folstein SE, McHugh PR. “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res.* 1975; 12:189–98. [PubMed: 1202204]
21. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol.* 1994; 49:M85–M85. [PubMed: 8126356]
22. Studenski S, Perera S, Wallace D, Chandler JM, Duncan PW, Rooney E, et al. Physical performance measures in the clinical setting. *J Am Geriatr Soc.* 2003; 51:314–22. [PubMed: 12588574]
23. Guralnik JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir GV, et al. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci.* 2000; 55:M221–231. [PubMed: 10811152]
24. Jette AM, Haley SM, Coster WJ, Kooyoomjian JT, Levenson S, Heeren T, et al. Late Life Function and Disability Instrument: I. Development and Evaluation of the Disability Component. *J Gerontol A Biol Sci Med Sci.* 2002; 57:M209–M216. [PubMed: 11909885]
25. Sayers SP, Jette AM, Haley SM, Heeren TC, Guralnik JM, Fielding RA. Validation of the Late-Life Function and Disability Instrument. *J Am Geriatr Soc.* 2004; 52:1554–9. [PubMed: 15341561]

26. Beauchamp MK, Schmidt CT, Pedersen MM, Bean JF, Jette AM. Psychometric properties of the Late-Life Function and Disability Instrument: a systematic review. *BMC Geriatr.* 2014; 14:12. [PubMed: 24476510]
27. Suri P, Kiely DK, Leveille SG, Frontera WR, Bean JF. Trunk muscle attributes are associated with balance and mobility in older adults: a pilot study. *PM&R.* 2009; 1:916–24. [PubMed: 19854420]
28. Suri P, Kiely DK, Leveille SG, Frontera WR, Bean JF. Increased trunk extension endurance is associated with meaningful improvement in balance among older adults with mobility problems. *Arch Phys Med Rehab.* 2011; 92:1038–43.
29. Callahan D, Phillips E, Carabello R, Frontera W, Fielding R. Assessment of lower extremity muscle power in functionally-limited elders. *Aging Clin Exp Res.* 2007; 19:194–9. [PubMed: 17607086]
30. Lord SR, Menz HB, Tiedemann A. A physiological profile approach to falls risk assessment and prevention. *Phys Ther.* 2003; 83:237–52. [PubMed: 12620088]
31. Ferrucci L, Bandinell S, Benvenuti E, Di Iorio A, Macchi C, Harris T, 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]
32. Milne JS, Lauder IJ. The relationship of kyphosis to the shape of vertebral bodies. *Ann Human Bio.* 1976; 3:173–9. [PubMed: 1275439]
33. Watkins MA, Riddle DL, Lamb RL, Personius WJ. Reliability of goniometric measurements and visual estimates of knee range of motion obtained in a clinical setting. *Phys Ther.* 1991; 71:90–6. [PubMed: 1989012]
34. Boulton AJM, Armstrong DG, Albert SF, Frykberg RG, Hellman R, Kirkman MS, et al. Comprehensive foot examination and risk assessment: a report of the task force of the foot care interest group of the american diabetes association, with endorsement by the American Association of Clinical Endocrinologists. *Diabetes Care.* 2008; 31:1679–85. [PubMed: 18663232]
35. Zuithoff NP, Vergouwe Y, King M, Nazareth I, van Wezep MJ, Moons KG, et al. The Patient Health Questionnaire-9 for detection of major depressive disorder in primary care: consequences of current thresholds in a crosssectional study. *BMC Fam Pract.* 2010; 11:98. [PubMed: 21144018]
36. Karp JF, Reynolds CF, Butters MA, Dew MA, Mazumdar S, Begley AE, et al. The relationship between pain and mental flexibility in older adult pain clinic patients. *Pain Med.* 2006; 7:444–52. [PubMed: 17014605]
37. Sun G-W, Shook TL, Kay GL. Inappropriate use of bivariable analysis to screen risk factors for use in multivariable analysis. *J Clin Epidemiol.* 1996; 49:907–16. [PubMed: 8699212]
38. Lee J-H, Hoshino Y, Nakamura K, Kariya Y, Saita K, Ito K. Trunk muscle weakness as a risk factor for low back pain: a 5-year prospective study. *Spine.* 1999; 24:54–7. [PubMed: 9921591]
39. Hicks GE, Shardell M, Alley DE, Miller RR, Bandinelli S, Guralnik J, et al. Absolute strength and loss of strength as predictors of mobility decline in older adults: The InCHIANTI Study. *J Gerontol A Biol Sci Med Sci.* 2012; 67A:66–73. [PubMed: 21546582]
40. Ijzerman TH, Schaper NC, Melai T, Meijer K, Willems PJB, Savelberg HHCM. Lower extremity muscle strength is reduced in people with type 2 diabetes, with and without polyneuropathy, and is associated with impaired mobility and reduced quality of life. *Diabetes Res Clin Pract.* 2012; 95:345–51. [PubMed: 22104262]
41. Weiner DK, Haggerty CL, Kritchevsky SB, Harris T, Simonsick EM, Nevitt M, et al. How does low back pain impact physical function in independent, well-functioning older adults? Evidence from the Health ABC Cohort and implications for the future. *Pain Med.* 2003; 4:311–20. [PubMed: 14750907]
42. Vincent HK, Seay AN, Montero C, Conrad BP, Hurley RW, Vincent KR. Functional pain severity and mobility in overweight older men and women with chronic low-back pain—Part I. *Am J Phys Med.* 2013; 92:430–8.
43. Vincent HK, Vincent KR, Seay AN, Conrad BP, Hurley RW, George SZ. Back strength predicts walking improvement in obese, older adults with chronic low back pain. *PMR.* 2013; Epub ahead of print. doi: 10.1016/j.pmrj.2013.11.002

44. Bean JF, Leveille SG, Kiely DK, Bandinelli S, Guralnik JM, Ferrucci L. A comparison of leg power and leg strength within the InCHIANTI Study: which influences mobility more? *J Gerontol A Biol Sci Med Sci*. 2003; 58:M728–M733.
45. Palmer RF, Royall DR. Missing data? plan on it! *J Am Geriatr Soc*. 2010; 58:S343–S348. [PubMed: 21029065]
46. Cecchi F, Debolini P, Lova RM, Macchi C, Bandinelli S, Bartali B, et al. Epidemiology of back pain in a representative cohort of Italian persons 65 years of age and older: the InCHIANTI study. *Spine*. 2006; 31:1149–55. [PubMed: 16648752]
47. Rudy TE, Weiner DK, Lieber SJ, Slaboda J, Boston JR. The impact of chronic low back pain on older adults: a comparative study of patients and controls. *Pain*. 2007; 131:293–301. [PubMed: 17317008]
48. Sions JM, Hicks GE. Fear-avoidance beliefs are associated with disability in older American adults with low back pain. *Physical Ther*. 2011; 91:525–34.
49. United States Census Bureau. [Accessed March 25, 2014] American Factfinder fact sheet: cities and towns, MA. 2000. Available at: <http://factfinder.census.gov>

Figure 1.
Trunk Extensor Endurance Testing

Figure 2.

Analysis of Covariance Evaluating Neuromuscular Impairments vs. Back Pain status

Graph of the adjusted mean scores of trunk extensor endurance (TEE) according to back pain status (n=403; $p<.001$); leg strength according to back pain status (n=385, $p<.001$); and rapid leg coordination according to back pain status (n=412, $p<.001$). Models adjusted for age, gender, race, education, body mass index, chronic conditions, depressive symptoms, and cognitive function. The error bars indicate standard error.

Neuromuscular Impairments	Gait Speed	Standing Balance	Chair Stand	Basic Lower Extremity Function
TEE*				
Leg Strength				
Leg Velocity				
Coordination				
Knee ROM*				
Ankle ROM*				

*Abbreviations: TEE = trunk extensor endurance; Knee ROM refers to knee extension range of motion, described in methods; Ankle ROM refers to loss of ankle dorsiflexion, described in methods.

Impairments associated with performance among those WITHOUT back pain

Impairments associated with performance among those WITH back pain

Impairments associated with performance among BOTH groups

Figure 3.

Four pairs of separate multivariable models evaluating impairments associated with performance on basic mobility tasks

Table 1

Baseline Characteristics of Boston RISE Participants Among Those With and Without Back Pain (N=430)

Characteristic	No Back Pain (N=295, 68.6%) Mean (SD) or N(%)	Back Pain (N=135, 31.4%) Mean (SD) or N(%)	P- value
Age	76.8 (7.0)	76.1 (7.1)	.31
Female	193 (65.4%)	98 (72.6%)	.14
White Race	245 (83.1%)	110 (81.5%)	.69
College Education	166 (56.3%)	65 (48.2%)	.12
Body Mass Index	29.5 (6.4)	29.5 (5.6)	.96
Chronic Conditions	4.0 (1.9)	4.6 (2.1)	<.01 *
Sensory Loss in Feet	83 (28.8%)	40 (29.9%)	.83
Depressed Symptoms	17 (5.8%)	11 (8.2%)	.35
Digit Symbol Substitution Score	36.6 (11.3)	36.0 (10.5)	.48

* denotes p-values that are statistically significant

Table 2

Baseline Values of Neuromuscular Impairments and Mobility Tasks of Boston RISE Participants Among Those With and Without Back Pain

Neuromuscular Attribute	No Back Pain Mean (SD) or N(%)	N	Back Pain Mean (SD) or N(%)	N	P- value
TEE ¹ (s/kg)	1.4 (.85)	278	1.1 (.92)	127	<.01 [*]
Kyphosis	10.7 (3.1)	295	10.2 (3.1)	135	.11
Leg Strength (N/kg)	9.7 (2.5)	272	9.0 (2.5)	115	.01 [*]
Leg Strength Asymmetry	1.19 (.33)	263	1.16 (.20)	109	.28
Leg Velocity (m/s)	1.02 (.23)	268	.96 (.29)	113	.07
Mean Reaction Time (ms)	246.4 (46.7)	295	253.7 (60.6)	135	.21
Rapid Leg Coordination (s)	10.9 (3.0)	282	11.6 (3.3)	132	.04 [*]
Knee Extension ROM ² (°)	9.8 (6.1)	291	8.9 (5.6)	134	.17
Knee Flexion Difference >10°	46 (15.8%)	291	17 (12.7%)	134	.40
Loss of Ankle Dorsiflexion	67 (22.8%)	294	27 (20.0%)	135	.52
Loss of Ankle Plantarflexion	37 (12.6%)	294	17 (12.6%)	135	1.0
Mobility Tasks					
Gait Speed (m/s)	0.92 (.21)	295	0.88 (.22)	135	.05
Standing Balance Quartiles ²		295		135	.49
0	3 (1.0%)		1 (.74%)		
1	34 (11.5%)		16 (11.9%)		
2	62 (21%)		39 (28.9%)		
3	49 (16.6%)		20 (14.8%)		
4	147 (49.8%)		59 (43.7%)		
Chair Stand Quartiles ²		295		135	<.01 [*]
0	18 (6.1%)		17 (12.6%)		
1	58 (19.7%)		35 (25.9%)		
2	76 (25.8%)		40 (29.6%)		
3	84 (28.5%)		28 (20.7%)		
4	59 (20%)		15 (11.1%)		
Basic Lower Extremity Function	68.1 (12.2)	295	61.6 (10.7)	135	<.01 [*]

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

¹ Abbreviations: TEE = trunk extensor endurance; ROM = range of motion.

² Standing balance and chair stand scoring as described in the methods. Quartiles are based on cut-points previously defined in the literature[21, 23].

* denotes p-values that are statistically significant.

Table 3
Multivariable Linear Regression Models / Evaluating Neuromuscular Impairments Associated with Performance on Basic Mobility Tasks

Outcome	Variables	No Back Pain			Back Pain		
		Estimate	SE ²	P-value	Estimate	SE	P-value
Gait Speed		N=251			N=108		
		R ² = .41			R ² = .51		
	TEE ²	0.06	0.01	<.01*	0.03	0.02	.17
	Leg Strength	0.003	0.005	.57	0.01	0.008	.37
	Leg Velocity	0.17	0.05	<.01*	0.24	0.07	<.01*
	Coordination	0.01	0.004	.14	0.01	0.01	.21
	Knee ROM ²	0.003	0.002	.14	0.003	0.003	.28
Standing Balance	Ankle ROM ²	0.08	0.03	<.01*	0.08	0.05	.10
	Variables	Estimate	SE	P	Estimate	SE	P
		N= 248³			N= 108		
		R ² = .27			R ² = .40		
	TEE	0.10	0.08	.22	0.28	0.12	.02*
	Leg Strength	0.07	0.03	.01*	0.06	0.05	.19
	Leg Velocity	0.38	0.31	.22	0.47	0.38	.22
Chair Stand	Coordination	0.01	0.02	.80	0.06	0.03	.051
	Knee ROM	0.01	0.01	.34	0.004	0.02	.82
	Ankle ROM	0.14	0.15	.34	0.62	0.27	.02*
	Variables	Estimate	SE	P	Estimate	SE	P
		N= 251			N= 108		
		R ² = .29			R ² = .37		
	TEE	0.19	0.09	.03*	0.31	0.13	.02*
	Leg Strength	0.09	0.03	<.01*	0.17	0.05	<.01*
	Leg Velocity	0.22	0.34	.52	0.40	0.42	.34
	Coordination	0.11	0.03	<.01*	0.09	0.04	.01*
	Knee ROM	0.03	0.01	.01*	0.04	0.02	.04*

Outcome	Variables	No Back Pain			Back Pain		
		Estimate	SE ²	P-value	Estimate	SE	P-value
Gait Speed	Ankle ROM	0.30	0.16	.07	0.12	0.30	.69
	Variables	Estimate	SE	P	Estimate	SE	P
Basic Lower Extremity Function		N=249 ³			N=108 ³		
		R ² =.22			R ² =.37		
TEE		2.87	0.99	<.01 [*]	0.82	1.17	.43
	Leg Strength	0.90	0.35	.01 [*]	1.25	0.46	.01 [*]
Leg Velocity		1.13	3.69	.76	12.07	3.81	<.01 [*]
	Coordination	0.65	0.29	.03 [*]	0.40	0.33	.22
Knee ROM		0.07	0.12	.55	0.23	0.18	.19
	Ankle ROM	3.28	1.77	.06	3.09	2.73	.26

¹ Multivariable linear regression models were adjusted for age, gender, BMI, chronic conditions, and the presence of other neuromuscular impairments.

² Abbreviations: SE = standard error; TEE = trunk extensor endurance; knee ROM refers to knee extension range of motion, described in methods; ankle ROM refers to loss of ankle dorsiflexion, described in methods.

³ For standing balance and basic lower extremity function outcomes, 3 and 2 observations (respectively) were removed/omitted for optimal fit of the model.

^{*} denotes p-values that are statistically significant