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A Stiff Price to Pay: Does Joint Stiffness Predict Disability in an Older Population?

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Abstract

Objectives—To describe the prevalence of joint stiffness and associated comorbidities in community-living older adults; and to determine whether joint stiffness, independent of pain, contributes to new and worsening disability.

Design—Population-based cohort

Setting—Urban and suburban communities in the Boston, Massachusetts area.

Participants—765 adults aged 70 years underwent a baseline home interview and clinic exam, 680 participants completed the 18-month follow up.

Measurements—Morning joint stiffness on most days in the past month was assessed in the arms, back, hips and knees. Mobility limitations were measured using self-reported difficulty and the Short Physical Performance Battery (SPPB). The home interview and clinic exam included extensive health measures.

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Results—About half of the sample reported morning joint stiffness (n=401), 26% with one site of stiffness and 26% with multisite stiffness. Twenty percent of participants with multisite stiffness and 50% with single site stiffness did not have a major stiffness-associated condition. After adjustment for pain severity and other covariates, multisite stiffness was associated with a 64% increased risk for developing new or worsening mobility difficulty (RR 1.64, 95% CI 1.05-2.79). Those with multisite stiffness exhibited an accelerated decline in physical performance over the 18 month follow up.

Conclusion—Older adults with multisite stiffness are more likely to be at risk for disability than those without joint stiffness after accounting for pain severity and the presence of stiffness-associated conditions. Better assessment, along with strategies to prevent and treat multisite joint stiffness is needed to prevent or slow the progression of disability in elders.

Keywords

Joint stiffness; pain; arthritis; elderly; disability

Introduction

Joint stiffness is a highly prevalent symptom commonly associated with pain and arthritis, the leading causes of disability in the older population (1, 2). Approximately 30% of adults in the U.S. report joint stiffness, aching or pain in the preceding 30 days, and 50% of these adults are over the age of 75(3). However, the ramifications of chronic joint stiffness in older adults are poorly understood because information is limited on the impact of this condition on health, activity limitations, and health-related quality of life in the older population (4, 5). Joint stiffness and pain can be caused by a number of highly prevalent chronic musculoskeletal conditions associated with aging, including osteoarthritis (OA), rheumatoid arthritis (RA), spinal stenosis/disc disease and past injuries (6).

Most research addressing the problem of joint stiffness has focused on the combined impact of pain and stiffness (7). At times, joint stiffness has been described as a precursor to pain in the progression of arthritis, yet few studies have considered stiffness as a distinct health problem or determined its unique risks in relation to disability (8, 9). Pain contributes to functional decline and is associated with mobility limitations but whether or how much stiffness may contribute to the overall burden of musculoskeletal conditions has yet to be determined. In fact, persons who do not report pain may suffer disabling consequences related to unassessed stiffness. Insights in this area could lead to better recognition and management of symptoms of stiffness and perhaps improve mobility as people confront the challenges of age-associated musculoskeletal conditions and risk for disability. The Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly (MOBILIZE) Boston Study (MBS) is among the first longitudinal population-based studies of community residing older adults to separately assess both chronic pain and joint stiffness in addition to mobility difficulty and mobility performance(10). For this study, we explored the relationship between joint stiffness and mobility limitations and the progression of disability in the older adult population.

Methods

Participants

The MOBILIZE Boston Study is a prospective cohort study of 765 older adults recruited door-to-door within a 5-mile radius of the Institute for Aging Research at the Hebrew Rehabilitation Center (HRC) in Boston from September, 2005 to January, 2008. Participants were randomly selected from town lists in this geographic area that comprised most of Boston and sections of 5 surrounding suburban communities. To be included in the study, eligible participants were aged ≥70 years (or aged ≥65 years if living with a study participant), able to walk 20 feet without help from another person, able to communicate in English and expecting to stay in the area for at least 2 years. Potential participants were excluded if they had moderate or severe cognitive impairment determined by Mini-Mental State Examination (MMSE score <18)(11), or a diagnosis of terminal disease. Ineligibility was most commonly related to language, poor health, or residing in a nursing home.

Baseline and 18-month follow-up assessments were conducted in 2 parts: a home visit and subsequent clinic examination conducted within 2 weeks at the HRC. At the start of the baseline home visit, participants provided written informed consent. All protocols for the study and consent procedures were approved by the institutional review boards of the HRC and collaborating institutions. Details of the study methods and recruitment were published previously (10, 12).

Joint Stiffness

Joint stiffness was defined as a positive response to the question, “Have you had stiffness in your <site> when you first get up in the morning on most days in the past month?” Sites assessed were the arms, back, hips, and knees. Morning joint stiffness, regardless of laterality, was measured as the count of the number of stiffness sites and categorized as no sites, 1 site, and 2 or more sites. To request that participants draw a distinction between pain and stiffness, in the introduction to the question, participants were instructed by the interviewer as follows: “Now I am going to ask you some questions about stiffness in your back and joints. Later, I will also ask you about pain in your back and joints, but for these questions, as much as possible, think about stiffness and not pain.” Further, during the interviewer training, study staff was taught about the importance of distinguishing between pain and stiffness in the interviews. The wording of the stiffness questions was based on a set of joint pain questions developed for the Women's Health and Aging Study(13) and also used in the current MBS (10). The joint pain measure has been found to be associated with incident or worsening disability, mobility limitations, and falls(14-16).

Chronic Pain

Chronic pain was assessed as global pain severity using the 4-item Pain Severity Subscale of the Brief Pain Inventory (BPI)(17). Pain referred to as “pain in the past week that has lasted more than a week or two”, was rated according to four conditions: worst pain, least pain, pain on average, and pain now, referring to an 11-point numeric rating scale, with 0 indicating no pain and 10 indicating “severe or excruciating pain as bad as you can imagine.” The BPI severity score, an average of the four-item ratings, was categorized into

tertiles (<1; 1-3.25; 3.25-10) with the 3rd tertile indicating moderate to severe pain. The BPI has been validated for use in chronic nonmalignant pain(18, 19). Reliability has been demonstrated over short intervals using test retest item correlations ($r = 0.59-0.93$)(18).

Mobility Limitation

Mobility performance was assessed using the well-validated Short Physical Performance Battery (SPPB), which includes measures of standing balance, 4-meter usual-paced walking speed, and ability and time to rise from a chair 5 times(20, 21). Standing balance was scored using 3 timed tests of side-by-side, semi-tandem, and tandem stands. In order to measure time to rise from a chair, participants were asked to fold their arms across their chest and stand up and down from a chair 5 times as quickly as possible. Gait speed was based on the shortest time of 2 trials of a usual paced 4-meter walk. The SPPB score (range 0-12) was calculated from the sum of the scores on the three tests each scored 0–4. Low scores on the SPPB (<10) has been shown to predict disability and hospitalizations(21-24). Self-reported mobility difficulty was defined as any difficulty walking ¼ mile or climbing stairs without personal assistance. Participants reporting any mobility difficulty were asked to rate their difficulty as a little, some, a lot of difficulty, or unable to do the task(25). Self-reported mobility difficulty is predictive of subsequent hospitalizations, health care costs, and mortality(26).

Sociodemographics and Health Measures

Demographic characteristics collected at the baseline home visit included: age, sex, race, years of education, and income. MMSE scored 0-30 was used to assess cognitive function(11). Body mass index (weight in kilograms divided by height in meters squared) was calculated from measured height and weight. Physical activity in the previous week was measured using the Physical Activity Scale for the Elderly (PASE), categorized into tertiles (0-66; 66.01-124; 124.04-559) (27). Self-reported physician-diagnosed chronic conditions included asthma/lung disease, stroke, Parkinson's disease, RA, and spinal stenosis or disc disease. Presence of heart disease was based on report of heart attack, congestive heart failure, angina, pacemaker, or cardiac arrhythmia. Peripheral neuropathy was assessed using Semmes-Weinstein monofilament testing(28). Peripheral arterial disease (PAD) was defined based on an ankle-brachial blood pressure index of less than 0.90 and the Rose Intermittent Claudication questionnaire(29). Diabetes mellitus was assessed using an algorithm based on laboratory measures from the baseline clinic visit including random glucose (> 200 mg/dL) and hemoglobin A1c ($\geq 7\%$) use of anti-diabetic medications, and self-reported diabetes. Research nurses were trained to assess the clinical criteria for the diagnosis of OA of the knees and hands defined by the American College of Rheumatology (30, 31). Depression was assessed using a modified version of the 20-item Centers for Epidemiologic Studies Depression scale (32, 33).

Statistical Analysis

Descriptive statistics were used to examine sociodemographic and health measures according to number of sites of stiffness. Mantel -Haenszel chi-square tests were used to determine linear trend (1 df), except for the categorical race comparisons, which used chi-square test for overall differences (4 df). In order to assess potential underlying causes of the

number of stiff joints, we considered combinations of stiffness-associated conditions according to the number of sites of stiffness. To do this, we set up mutually exclusive groupings of conditions according to the following hierarchy: RA, spinal stenosis/disc disease with OA (hand and/or knee), both knee and hand OA, spinal stenosis/disc disease, knee OA only, and hand OA only. We chose this set of definitions of musculoskeletal disease in order to assess the presence of underlying conditions that potentially could explain the participants' self-reported single site or multisite stiffness.

Generalized linear models were performed to estimate marginal means for each measure of mobility performance including SPPB score, gait speed, standing balance score, and time for chair stands, each adjusted for age and sex according to categories of stiffness. The relationships between stiffness groups and outcomes of mobility disability and physical performance at baseline and follow-up were determined by relative risks (RR) and 95% confidence intervals derived from Poisson regression modeling with robust error variances and adjusted for potential confounders (Proc GENMOD)(34, 35). We performed two sets of longitudinal models. In the first, we used a repeated measures approach to examine the cross-sectional association between stiffness count and mobility difficulty at baseline and follow-up. In the second set of longitudinal models, using a cohort of participants without severe mobility difficulty at baseline (n=524), we used a similar modeling approach to estimate relative risks for developing new or worsening mobility difficulty at follow-up related to baseline stiffness. New mobility difficulty was defined as report of any difficulty in either walking ¼ mile or climbing stairs at the 18-month follow-up among those reporting no difficulty at baseline. Worsening disability was defined as increased difficulty comparing the 18-month follow-up to baseline, defined as report of a little or some difficulty at baseline, and a lot of mobility difficulty or inability to walk ¼ mile or climb stairs at follow up. Models were adjusted for baseline mobility difficulty to adjust for differences in rate of worsening between those with incident mobility difficulty and those worsening from a little or some difficulty to a lot of mobility difficulty. We conceptualized function on a continuum in our population and thus combined the outcomes of new and worsening mobility difficulty, both capturing functional decline over time. Participants with a lot of difficulty or inability to walk ¼ mile or climb stairs without personal assistance at baseline were excluded from the incidence/worsening models (n=157). Models were constructed by adding covariates sequentially, beginning with adjustment for age, sex, race and education (Model 1), subsequently adding chronic conditions and health measures (Model 2), and finally adding pain severity (tertiles of the BPI pain severity subscale) (Model 3). No major outliers were detected in any of the models and there was no evidence of collinearity among variables included in the models. Less than 2% of data were missing for poor mobility performance at follow up and <1% of data were missing for all other key and adjustment variables. Analyses were conducted by using SAS software version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

Of the 765 participants enrolled, 680 participants completed the follow up assessment. Among the participants who didn't continue in the study, 21 were deceased (2.7% of total) and 63 (8%) dropped out of the study for the following reasons: 11 were withdrawn by

investigator, 22 withdrew due to advancing illness, 13 were lost to follow up, and 17 didn't continue due to personal or family difficulties and length of study. Those who died were somewhat older, with lower BMI, fewer stiff joints, and more mobility difficulty than the participants in the 18-month follow-up. Participants who withdrew or were lost to follow-up were older, had less education, lower BMI and more mobility difficulty than those who completed the follow-up assessment.

Participants in the MOBILIZE Boston cohort were largely representative of older adults in the Boston area according to age (average age, 78 years), sex (63% female), and race (19% nonwhite), based on comparisons with data from the U.S. Census 2000. Among the 765 participants who completed the baseline assessment, about half reported morning joint stiffness (n=401), with 26% reporting one site of stiffness and another 26% reporting 2 sites of stiffness. Characteristics and health measures of participants according to number of stiffness sites are presented in Table 1. Women and persons with less education reported more sites of stiffness. However, older age was not associated with stiffness count in this elderly cohort. Health factors associated with more sites of stiffness included higher body mass index, poorer cognitive function (MMSE score <24) and presence of medical conditions including OA, spinal stenosis/disc disease, depression, RA, and PAD. Global pain severity was also associated with number of stiff sites, with 57% of those with multisite stiffness reporting moderate to severe pain, compared to 24% of those without stiffness.

Persons who reported more sites of stiffness had the greatest prevalence of stiffness-associated musculoskeletal conditions, with 80% having one or more conditions, compared to 30% of those with no stiffness (Figure 1). Among those with multisite stiffness, the most prevalent condition was clinically assessed OA (knee only, hand only, or both), present in 46% of participants. However, 40% had single site OA or spine/disc disease that did not explain their multisite report of stiffness. Notably, 20% of people with multisite stiffness and 50% of those with single site stiffness did not have a major stiffness-associated condition.

When we examined the cross-sectional relationship between stiffness and self-reported mobility difficulty, there was a 37% increased risk for mobility difficulty among those with multisite stiffness compared to their peers who reported no stiffness, adjusted for sociodemographic and health factors (adj. RR 1.37, 95%CI 1.19-1.60). Further adjustment for pain severity weakened the association though it remained statistically significant (adj. RR 1.23, 95% CI 1.05-1.44). Participants who reported single site stiffness were not more likely to report mobility difficulty than their counterparts who did not have joint stiffness (adj. RR, 1.01, 0.86-1.18). The association of stiffness and limited mobility performance (SPPB <10) was not significant after adjusting for pain severity.

At baseline, physical performance was lowest among those who had more stiffness. For example, SPPB score was 9.0 among those with multisite stiffness, compared to 9.8 in persons with no stiffness (trend $p<0.0001$) after adjusting for age and sex (Table 2). Similar trends were observed for poorer mobility performance with more sites of stiffness related to timed chair stands (trend $p<0.0001$) and usual-paced gait speed (trend $p=0.007$), but not for standing balance ($p=0.11$). Prospectively, participants with 2 sites of stiffness at baseline experienced the greatest decline in SPPB score after 18 months of follow-up but the trend

was not statistically significant ($p<0.09$) after adjusting for age and sex. Similar trends were observed for worsening performance over time in standing balance ($p<0.01$) and usual-paced gait speed ($p<0.05$), but not for repeated chair stands ($p<0.51$).

The incidence of new or worsening mobility difficulty over 18 months (excluding persons with severe disability at baseline) increased as number of stiffness sites increased; 17% of those with no stiffness versus one-third of persons with 2 sites of stiffness developed new or worsening mobility difficulty at follow-up. After adjusting for sociodemographics, older adults who reported multisite stiffness at baseline had a 70% increased risk for developing new or worsening mobility difficulty over 18 months (Table 3). After further adjustment for pain severity and other health factors, 2 sites of stiffness was associated with a 64% increased risk for developing new or worsening mobility difficulty (RR 1.64, 95% CI 1.05-2.79). Although the risk estimates were suggestive of an increase in risk, having only one site of stiffness was not significantly associated with an increased risk for subsequent mobility difficulty. In the presence of both pain and stiffness, step wise comparisons of each possible grouping according to BPI pain severity tertiles and number of sites of stiffness showed that the prevalence of new and worsening mobility difficulty increased as a function of both increasing pain severity and number of sites of stiffness in this sample (Figure 2). The prevalence of new and worsening mobility difficulty in those with no pain or stiffness was 18% compared to 43% of those with 2 sites of stiffness and moderate to severe pain (defined as 3.25-10 on the BPI pain severity scale). The test for interaction between multisite stiffness and pain severity was of borderline statistical significance (p -value of the interaction term, 0.056), providing further evidence that there was an added risk for new or worsening mobility difficulty in the presence of both conditions.

Discussion

As hypothesized, we found that stiffness was an independent risk factor for mobility disability over 18 months in this population of community living older adults. The findings took into consideration the presence and severity of chronic pain along with the presence of underlying musculoskeletal conditions such as OA. The findings were consistent in both the concurrent (cross-sectional) and longitudinal relationships of mobility disability and stiffness. In addition, we observed a more rapid rate of decline in mobility performance over time among persons who reported stiffness in multiple joint areas compared to those with no reported stiffness. Thus individuals with multisite stiffness were not only at higher risk for mobility disability over time, but that multisite stiffness appears to hasten functional decline in this elderly population.

To our knowledge, this is the first population-based study to examine joint stiffness as a contributor to mobility disability in older adults, independent of pain and musculoskeletal disease. Osteoarthritis is the most prevalent chronic condition associated with joint stiffness in this population. The pathophysiology of chronic stiffness remains unclear. Studies have shown that OA is influenced by systemic biochemical and local biomechanical factors that may contribute to the symptom profile predominated by pain and stiffness (9). In addition to arthritis, older adults may experience joint stiffness as a result of ligament injury, fibrotic changes to the joint capsule, loss of viscoelasticity of joint cartilage fibers, and lack of

movement(36). It is possible that muscle stiffness which might be described as joint stiffness could be related to subclinical or clinical neuromuscular disorders, such as Parkinson's disease (37). Biomechanists have suggested that stiffness in the human body manifests from a number of effects involving muscles, tendons, ligaments, cartilage, and bone(38). Obesity, mild cognitive impairment, spinal stenosis, depression, RA and PAD were all associated with greater number of stiff joints in this population. Problems with stiffness related to periods of immobility such as overnight in this older population could be related to OA pathology or other less well understood age-related changes affecting joints and muscles.

We found that a substantial portion of stiffness in this population was unexplained by common stiffness-associated chronic conditions. For example, 1 in 5 people who reported multisite stiffness had no chronic musculoskeletal condition identified to explain this symptom, and another 40% had single-joint disease that did not account for their report of multisite stiffness. This finding suggests that either other previously unknown etiologies or pathological mechanisms could be responsible for joint stiffness. In studies of pain and arthritis, considerable discrepancy exists between reported symptoms, function and power and observed radiographic disease severity (39, 40). If stiffness is a precursor to pain in the progression of arthritis, as some propose, it could be one reason for unexplained joint stiffness in our cohort (8).

Maly et al., (2006) measured functional self efficacy (FSE), the confidence an individual has to perform a task, in relation to personal, pathophysiologic, and impairment factors of knee OA in older adults (41). Greater than 30% of the variance in FSE was attributed to joint stiffness. The greater stiffness, the poorer the individual rated their self efficacy for physical tasks. They concluded that joint stiffness likely provides negative feedback to individuals with knee OA during physical activity and therefore influences self efficacy providing evidence that increasing joint stiffness has a multi-dimensional impact on the lives of older adults.

Gignac et al. (2006) conducted a focus group study to compare the health experiences of adults with moderate OA symptoms to those without (8). Participants reported that OA symptoms such as joint stiffness have a significant impact on their general health, work, leisure, social activities, and relationships. They were also frustrated when their complaints to healthcare providers were met with no recommendations to manage symptoms other than acceptance of the symptoms as part of the "normal" aging process. Most importantly, participants expressed concerns about their stiffness and other symptoms such as swelling and cracking, believing these to be early indicators of a progressive arthritic condition requiring additional assessment and management.

As an approximation for severity of stiffness, the number of sites of stiffness (arm, knee, hip, or back) was measured as a count variable. In this study the main effects were noted for 2 sites of stiffness, and 1 site of stiffness was not a significant predictor of self-reported mobility difficulty. Categories were collapsed for 2, 3, 4 sites of stiffness, because ultimately the report of multiple sites of stiffness may be more clinically relevant. Age was not associated with more sites of stiffness. This could represent a plateau effect related to aging, since our cohort was limited to persons aged ≥ 70 years.

One key assumption in this study was that participants would be able to differentiate between pain and stiffness. The evidence presented for the relationship between stiffness and mobility disability maybe misleading if both constructs (pain and stiffness) are being measured simultaneously; therefore instructing participants and interviewers to make this distinction was essential to the research questions posed in this study. Stiffness was measured as “morning stiffness” and was highly associated with presence of OA. The results are also evidence of construct validity. There was no evidence of collinearity among the variables included in the models. We found that increasing prevalence of new and worsening mobility disability was a function of both more sites of stiffness and greater pain severity, which providing further evidence that increasing joint stiffness was a contributor to this effect.

As a prospective population-based cohort study, MBS employed rigorous methods to enroll elderly Boston area residents. The study employed self report, objective measures, and clinical assessments conducted by trained staff. The MBS has a well characterized sample, with extensive baseline and follow-up measures of pain, medication use, chronic conditions, falls, and other risk factors, not available in other epidemiologic studies. The enrolled MOBILIZE sample of 765 adults, aged 70 years, represents a diverse population of urban and suburban elders. The high participant retention has contributed to an excellent data resource, providing an exceptional and unique opportunity for studying stiffness, pain and disability, and their consequences in older adults using a variety measures.

Limitations

Comparisons of our cohort demographics with US Census population data for the Boston metropolitan area supports the representativeness of our cohort, however it is likely that persons with more education are more likely to participate in research even in the context of population based recruitment. The MBS was originally designed to measure novel risk factors for falls in seniors in the Boston area (10). Thus the questionnaires and clinical assessments were targeted to measure those risk factors. Data from prospective observational studies are often used to answer different research questions that may not be part of the original specific aims. This analysis was designed with the existing dataset which has a limited measure for stiffness, specifically one interview question assessing morning stiffness at 4 specific sites, especially when stiffness can also occur after periods of inactivity throughout the day. Further questions about the severity of joint stiffness at each site, or at varying time points during the day could shed more light on the role of stiffness in the progression of disability in older adults.

We observed modest changes in physical performance scores in part related to the relatively short follow-up time of 18 months. However, our results showed a clinically meaningful change of almost a full point of the SPPB (24). Our assessment of chronic conditions was largely based on self-report. However, OA, the most prevalent cause of stiffness and pain in the older population, was assessed using a validated assessment of clinical criteria with substantial staff training by an experienced rheumatologist. While we assessed hip stiffness we did not have a measure of hip OA, which could also have been an underlying condition contributing to stiffness.

Conclusion

Joint stiffness is a major symptom of arthritis, the primary disabling chronic condition in the older population. Older adults with multi-site stiffness are more likely to be at risk for mobility disability and accelerated decline in mobility performance than those without joint stiffness after accounting for the presence of chronic pain and a number of chronic diseases including arthritis.

Up to now, joint stiffness has rarely been addressed for its unique contribution to mobility disability; in fact elders and their providers often attribute stiffness to normal aging thus missing its potentially deleterious effects on function and quality of life(7, 8). The results from this study suggest that multisite joint stiffness is a clinically relevant symptom, and isn't always explained by common stiffness-associated conditions. Better assessment techniques, along with strategies to prevent and treat multisite joint stiffness could prevent or slow the progression of disability in the elder population. Further studies are needed to better understand the problem of multisite stiffness, its possible etiologies, and its impact on physical function and disability in older adults.

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Figure 1. Prevalence of Stiffness-associated Chronic Conditions According to Number of Sites of Stiffness. Mutually exclusive groupings according to the following hierarchy: Rheumatoid Arthritis, Spinal stenosis/disc disease with osteoarthritis, Both knee and hand osteoarthritis, Hand osteoarthritis only, Knee osteoarthritis only, Spinal stenosis/disc disease.

Figure 2.

Prevalence of New and Worsening Mobility Difficulty by Joint Stiffness and BPI Pain Severity. Participants who were severely disabled at baseline were excluded. BPI pain severity (0-10) presented in tertiles, no pain rated as 0, mild to moderate pain as 1-3.25, moderate to severe pain as 3.25-10.

Table 1

Baseline Characteristics According to Stiffness Categories^a, 765 participants aged 70 and older, MOBILIZE Boston, 2005-2007.

Characteristics	Total Sample (n=765)	No Stiffness (n=363)	1 site stiffness (n=201)	2 sites stiffness (n=200)	p-value (trend) ^b
Percent					
Age in years:					
70-74	30.6	28.1	26.9	30.9	
75-79	31.9	32.0	31.3	32.3	0.52
80-84	23.7	20.9	28.4	23.9	
85	13.8	16.3	11.9	11.4	
Women	63.9	58.1	65.7	72.6	0.0005
Education:					
< high school	11.1	8.6	10.0	16.9	
high school graduate	23.3	26.5	13.9	26.9	0.02
college graduate	65.6	64.9	76.1	56.2	
Race:					
White	77.6	78.8	81.6	71.5	
Black	16.1	15.4	13.4	20.0	0.09
Other	6.3	5.8	5.0	8.5	
Body Mass Index ^c					
<25	29.7	33.2	33.8	19.0	
25-29.9	42.8	42.8	39.4	46.4	
>= 30	27.4	24.0	26.8	34.5	0.0005
Physical activity score ^d					
0-66	33.2	33.9	31.3	33.7	
66.01-124	33.6	32.8	34.9	33.7	0.99
124.01-559	33.3	33.3	33.8	32.7	
Use of cane, walker or other mobility aid	15.7	12.7	15.4	21.4	0.008
Any mobility difficulty ^e	35.0	28.4	33.0	51.2	<0.0001
MMSE < 24 ^f	12.0	9.9	11.4	16.4	0.03
Pain severity ^g					

Characteristics	Total Sample (n=765)	No Stiffness (n=363)	1 site stiffness (n=201)	2 sites stiffness (n=200)	p-value (trend) ^b
No pain	31.5	47.1	25.4	9.5	
1-3.25	33.6	29.1	41.8	33.5	
3.25-10	34.9	23.8	32.8	57.0	<0.0001
Spinal stenosis or disc disease	18.3	12.4	18.9	28.4	<0.0001
Arthritis ^h					
Neither site	63.4	82.6	59.2	32.5	
Hand only	11.5	6.6	13.4	18.5	
Knee only	17.5	8.8	23.4	27.5	<0.0001
Both	7.6	1.9	4.0	21.5	
Depression ⁱ	7.3	5.8	5.5	11.9	0.01
Heart disease ^j	41.7	43.0	39.3	41.8	0.70
Diabetes ^k	20.0	18.7	20.9	21.4	0.42
Asthma/lung disease	16.3	15.2	12.6	21.9	0.08
Stroke	9.9	12.4	4.5	9.2	0.64
Rheumatoid Arthritis	5.0	2.5	5.0	9.5	0.0003
Peripheral neuropathy ^l	12.2	10.9	14.6	12.2	0.53
Peripheral arterial disease ^m	9.5	8.0	6.5	15.4	0.01

^aStiffness defined as positive response to: "Have you had stiffness in your <site> when you first get up in the morning on most days in the past month?" Sites assessed: arm, back, hip, and or knee. Categories are the sum of reported stiffness in the aforementioned sites.

^bMantel-Haenszel chi-square test for trend across the 3 stiffness categories, except for race comparisons, which used chi-square test for overall differences..

^cBody Mass Index is calculated as weight in kilograms divided by height in meters squared.

^dPhysical activity tertiles measured using the Physical Activity Scale for the Elderly.

^eAny mobility difficulty defined as self-reported difficulty climbing stairs or walking 1/4 mile.

^fMini-Mental State Examination (MMSE) cut point for cognitive impairment.

^gPain severity measured using the Brief Pain Inventory.

^hAs defined by American College of Rheumatology, widespread pain includes all of the following: pain in left side, right side, above waist, below waist; and axial skeletal pain in back or chest.

ⁱDepression assessed with Eaton method, modification of Centers for Epidemiologic Studies Depression scale.

- ^jHeart disease included self report of: heart attack, congestive heart failure, angina, pacemaker, or cardiac arrhythmia.
- ^kDiabetes defined from algorithm of: self-report, use of anti-diabetic medications, random glucose, and hemoglobin A1c.
- ^lPeripheral neuropathy was assessed with Semmes-Weinstein monofilament testing.
- ^mPeripheral arterial disease defined from algorithm of: ankle-arm index and Rose Intermittent Claudication questionnaire.

Table 2
Changes in Physical Performance over 18 Months According to Number of Sites of Stiffness (n=622)

Number of Sites of stiffness	No stiffness		1 site of stiffness		2 or more sites of stiffness	
	Baseline Mean $\pm$ SE	Mean difference from BS to FU	Baseline Mean $\pm$ SE	Mean difference from BS to FU	Baseline Mean $\pm$ SE	Mean difference from BS to FU
Performance Test						
SPPB ^b	9.84 $\pm$ 0.13	-0.21 $\pm$ 0.09	9.85 $\pm$ 0.17	-0.39 $\pm$ 0.12	8.96 $\pm$ 0.17	-0.46 $\pm$ 0.12
Gait speed (m/s)	1.0 $\pm$ 0.01	-0.02 $\pm$ 0.01	0.99 $\pm$ 0.02	-0.02 $\pm$ 0.01	0.93 $\pm$ 0.02	-0.05 $\pm$ 0.01
Balance test	4.46 $\pm$ 0.08	-0.05 $\pm$ 0.07	4.58 $\pm$ 0.11	-0.27 $\pm$ 0.09	4.20 $\pm$ 0.12	-0.33 $\pm$ 0.09
Chair stands (s)	14.08 $\pm$ 0.43	0.66 $\pm$ 0.32	14.88 $\pm$ 0.59	0.79 $\pm$ 0.44	17.39 $\pm$ 0.59	1.03 $\pm$ 0.45

^a Chi-square test for mean differences from baseline to follow up for composite score for Short Physical Performance Battery and each performance test.

^b Estimated marginal means and standard errors (SE) from general linear models adjusted for age and sex.

Table 3
Longitudinal Association of Stiffness with New and Worsening Mobility Difficulty over 18 months (n=524)

	Model 1 +demographics RR (95% CI)	Model 2 +health characteristics RR (95% CI)	Model 3 +pain severity RR (95% CI)
No stiffness	1.0	1.0	1.0
1 site stiffness	1.25 (0.78-2.00)	1.33 (0.82-2.70)	1.29 (0.78-2.11)
2 or more sites	2.00 (1.29-3.01)	1.70 (1.08-2.70)	1.64 (1.01-2.67)

Multivariate Poisson regression Model 1: adjusted for age, sex; education and race; Model 2 added: mobility difficulty at baseline, Physical Activity Score (PASE), BMI, MMSE, lung disease, heart disease, diabetes, peripheral arterial disease; Model 3 added: Brief Pain Inventory (BPI) severity. Model 4 included covariates from Models 1, 2, and added pain distribution measured by Models excluded participants who were severely disabled at baseline.