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Dysmobility syndrome and mortality risk in US men and women age 50 years and older[1]

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Abstract

Purpose—Dysmobility syndrome was recently proposed as an approach to evaluate the musculoskeletal health of older persons, but data linking this syndrome to adverse outcomes are currently lacking. The present study used data from the National Health and Nutrition Examination Survey (NHANES)1999–2002 to assess the relationship between dysmobility and mortality in adults age 50 and older by age, sex, and race or ethnicity.

Methods—Dysmobility was defined as three or more of the following: high body fat, osteoporosis, low muscle mass, low muscle strength, slow gait speed, or falling risk. Body composition and bone density were assessed with dual energy x-ray absorptiometry. Gait speed was measured via a timed walk, muscle strength via isokinetic knee extension, and fall risk via self-reported balance problems in the past year. Hazards ratios (HR) for mortality were calculated with Cox proportional hazards models.

Results—Twenty-two percent of adults age 50+ years had dysmobility in 1999–2002. Mortality risk by dysmobility varied significantly by age ($p_{interaction}$=0.001). HRs for those aged 50–69 years were 3.63 (95% CI 2.69, 4.90) and 2.59 (95% CI 1.82, 3.69), respectively, before and after adjusting for all confounders, compared with 1.46 (95% CI 1.07, 1.99) and 1.23 (95% CI 0.89, 1.69) for those aged 70+ years. The relationship was significant when examined by sex or race/ethnicity within age group for most subgroups.

Conclusions—Dysmobility was associated with increased mortality risk in adults age 50 years and older, with risk being higher in those age 50–69 years than in those age 70+ years.

Keywords

Dysmobility; mortality; longitudinal study; NHANES

Introduction

Interest in considering more than bone density when assessing skeletal health has grown considerably in the past decade. Recently Binkley et al [1] proposed to expand the adverse

[1]The findings and conclusions in this report are those of the author and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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musculoskeletal outcomes considered beyond fracture when evaluating older adults to include risk of disability, falls and mortality. They suggested evaluating a combination of conditions, which they named dysmobility syndrome, that share pathogenesis and may act together to increase risk of this wider range of adverse events. These authors noted that this combination is similar in concept to the metabolic syndrome that is now clinically used to assess cardiovascular risk [1]. They proposed a score-based approach to define dysmobility as having at least three of the following six conditions: osteoporosis, low muscle mass, low muscle strength, slow gait speed, history of falls and high body fat [1].

Binkley et al [1] noted that more work is needed to refine and evaluate the dysmobility concept, including assessing its link with adverse outcomes. The present study uses data from the National Health and Nutrition Examination Survey (NHANES) conducted in 1999–2002 to examine the relationship between dysmobility and all-cause mortality in adults age 50 years and older by age, sex, and race/ethnicity. The relationship between the individual conditions that compose dysmobility and all-cause mortality is also examined. Assessing these relationships may help to evaluate the utility of this new proposed syndrome, and also may provide insight on ways to further refine it.

Methods

Sample

The present study used data from the NHANES 1999–2002 because these survey cycles included measurements of the six conditions needed to define dysmobility as proposed by Binkley et al [1]. The NHANES is conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention, to assess the health and nutritional status of a large representative cross-sectional sample of the non-institutionalized, civilian US population. All procedures in NHANES 1999–2002 were approved by the NCHS Institutional Review Board, and written informed consent was obtained from all subjects [2].

Data were collected in NHANES 1999–2002 via household interviews and direct standardized physical examinations that were conducted in specially equipped mobile examination centers [2]. NHANES 1999–2002 was designed to provide reliable estimates for three race/ethnic groups: non-Hispanic whites (NHW), non-Hispanic blacks (NHB), and Mexican Americans (MA). Race and ethnicity were self-reported by the participants.

The analytic sample in this study consisted of persons ages 50 years and older at the time of their baseline interview. There were 2975 respondents age 50 years and older in the final analytic sample, which represents 60% of those who were interviewed, and 67% of those who were examined in NHANES 1999–2002. Descriptive characteristics and risk factors were compared between retained versus excluded respondents to assess potential nonresponse bias in study results. The excluded respondents were older, female, and had higher body fat and slower gait speed. They were also more likely to have died by 2011, and to be non-Hispanic black or other race. Finally, they were more likely to self-report fair or poor health, chronic conditions, previous fracture, and less activity than others of the same age or sex. Respondents and non-respondents did not differ in lumbar spine subregion bone mineral density (BMD), appendicular lean mass/height^2, isokinetic knee extensor muscle

strength, smoking, or alcohol use, however. Analyses performed to assess the impact of potential nonresponse bias on results are described in more detail in the Statistical Analysis section.

Variables

Mortality—Vital status was determined through December 31, 2011 using the restricted access Linked Mortality File for NHANES 1999–2002. This file uses a probabilistic match between the eligible NHANES 1999–2002 sample and the National Death Index (NDI) to determine vital status [3].

Dysmobility conditions—Dysmobility was defined as having at least 3 of the following 6 conditions: high body fat, osteoporosis, low muscle mass, low muscle strength, slow gait speed, and risk of falling. The measurements used to define each condition are described in detail below. Cutoffs for each condition are summarized in Table 1. The same methods and cutoffs as those used by Binkley et al [1] were applied in the present study for high body fat, low muscle mass and slow gait. However, different cutoffs for low muscle strength, osteoporosis and falling risk were used because different measurement methods were used in NHANES 1999–2002.

Total body DXA scans: Body fat, lean mass and bone density were measured using total body DXA scans. Total body scans were performed with Hologic QDR 4500A fan-beam densitometers (Hologic, Inc., Bedford, Massachusetts) using DOS software version 8.26:a3*. Scanning was done in the fast mode. Details of the DXA examination protocol have been published elsewhere[4]. Each scan was reviewed and analyzed by the Department of Radiology of the University of California, San Francisco. Hologic Discovery software version 12.1 was used to analyze all total body scans.

Osteoporosis status was based on BMD from the lumbar spine subregion of the total body DXA scan because dedicated femur and lumbar spine scans were not performed in NHANES 1999–2002. Previous research indicates that BMD from the lumbar spine subregion of a total body scan correlates closely with BMD from a dedicated anterior-posterior (AP) lumbar spine scan and results in similar estimates of osteoporosis prevalence and similar odds ratios for predicting fracture [7]. The diagnostic criteria for osteoporosis from the World Health Organization (WHO) were used to define lumbar spine osteoporosis. Specifically, respondents were defined as having osteoporosis if their lumbar spine BMD value fell more than −2.5 SD's below the mean BMD of a young reference group [8]. The young reference group consisted of 30 year-old white females from the Hologic lumbar spine reference database, in accordance with recent recommendations from the International Society for Clinical Densitometry (ISCD) [9]. Reference values for the AP spine were used because reference data for the lumbar spine subregion from total body scans have not been published by the DXA manufacturer. Preliminary analyses showed that application of the Hologic AP thresholds to the lumbar spine subregion data from NHANES 1999–2002 resulted in a similar prevalence of osteoporosis among adults age 50 years and older (6.3%) as that seen in this age group when based on dedicated AP spine scans from NHANES 2005–2008 (6%) [10].

Timed walk: A 20-foot (6.15 meter) timed walk performed at the respondent's usual pace was used to assess gait speed [11]. Walk time was measured with a stop watch from the time the examinee's foot first touched the floor across the start line until their foot touched the floor across the finish line. Respondents who needed the assistance of another person to walk were excluded from testing, but respondents who needed to use a walking device such as a walker or cane were permitted to use them during the test. Slow gait was defined as gait speed < 1.0 meters/second (Table 1).

Isokinetic knee extensor muscle strength: A Kinetic Communicator isokinetic dynamometer (Kin Com MP, Chattanooga Group, Inc., Chattanooga, TN) was used to evaluate knee extensor strength of the right quadriceps [11, 12]. Respondents were excluded from the muscle strength test if they had a recent history of myocardial infarction or chest or abdominal surgery, any history of aneurysm/stroke or current severe right knee pain, right knee or hip replacement, or severe neck or back pain. Peak force (PF, in Newton/meters (Nm)) of the quadriceps was measured at one speed (60 degrees/second). Only concentric movements were tested due to safety concerns. Each respondent was asked to perform three practice trials for warm-up and three trials for maximal voluntary effort. Peak force was defined as the highest value obtained from the maximum effort trials for those who completed at least 5 trials (approximately 98% of respondents). If four or fewer trials were completed, the highest PF from the completed trials was selected. Peak torque (PT) was calculated as: (PF x mechanical arm length in cm)/100. The mechanical arm length was defined as the distance from ankle to knee joint. Gravity corrections to torque were based on a measured leg weight at 2.62 radians (rad) (150 degrees; 3.14 rads being equivalent to a straight leg position).

Criteria to define low muscle strength on the basis of isokinetic knee extensor muscle strength have not been included in consensus definitions of sarcopenia published to date [13–15]. In the absence of such criteria, the present study used two approaches to define thresholds for low muscle strength. First, a healthy reference group of respondents age 50–59 years from NHANES 1999–2002 was created by excluding individuals in that age range who suffered from any of the six conditions used to define dysmobility. Sex-specific thresholds for low muscle strength were defined as the peak torque value that fell more than 2 SDs below the sex-specific mean peak torque of this healthy 50–59 year old reference group (Table 1). The mean minus 2 SD's of this middle-aged reference group was used to be consistent with the ISCD definition of bone density that is below the expected range for age [9]. The second approach used sex-specific means and SDs from a sample of 28 healthy, 20–29 year old Danish men and women [16]. The sex-specific thresholds to define low muscle strength using these Danish data (< 118.25 Nm for men and < 67.25 Nm for women) were defined as the peak torque value that fell more than 2.5 SDs below the sex-specific mean peak torque of this healthy 20–29 year-old Danish reference group. The mean minus 2.5 SD's of these young adults was used to be consistent with the WHO definition of osteoporosis [8]. Preliminary analyses indicated that the risk of mortality by dysmobility status was similar regardless of the thresholds used to define low muscle strength, so results presented below are based on thresholds derived from the 50–59 year old healthy reference group from NHANES 1999–2002.

Balance problems: Risk of falling was defined as having problems with balance based on a single questionnaire item that asked respondents if they had dizziness, difficulties with balance, or difficulties with falling during the past 12 months. Those who responded "yes" were defined as having balance problems.

Confounding variables—Selected variables were evaluated for inclusion as possible confounders in multivariate models of mortality risk by dysmobility status. These were limited to variables that were not already encompassed by the dysmobility conditions, and included the following:

Smoking and alcohol intake: Cigarette use was categorized as ever smoked versus never smoked based on responses to questionnaire item asking "Have you ever smoked at least 100 cigarettes in your lifetime?" Alcohol users were defined as respondents who self-reported that they usually consumed three or more drinks per day when they drank alcohol.

Self-reported health status, physical activity and chronic conditions: Respondents were asked to rate their general health status as poor, fair, good, very good or excellent. Respondents were also asked to rate their current physical activity level as more active, less active, or about the same when compared to others of their same age and sex. Respondents who self-reported that a doctor had ever told them that they had angina, arthritis, cancer, chronic bronchitis, congestive heart failure, coronary heart disease, diabetes, emphysema, heart attack, any liver condition, stroke, or thyroid disease were considered to have chronic conditions.

Statistical analysis

All analyses were performed using SAS 9.3 (SAS Institute, Cary NC) and SUDAAN software [17] for analysis of data from complex survey samples. Descriptive characteristics and risk factors at baseline were compared by dysmobility status and mortality status using linear regression models and chi-square analyses. Risk factors that were significantly related to dysmobility or to mortality were used in subsequent multivariable models.

Risk of all-cause mortality by dysmobility status was analyzed using Cox proportional hazards models in order to control for all risk factors simultaneously and to account for unequal length of follow-up. Length of follow-up was calculated as the time from date of examination to date of death for decedents or end of follow-up on December 31, 2011 for non-decedents. A test of the proportional hazard assumption indicated no significant trend in hazards ratio (HR) with time ($p=0.80$), which suggests the assumption was not violated. Cox models were also used to obtain the HR for the individual conditions used to define dysmobility when tested in separate models, as well as in a single model to assess the contribution of each condition after adjusting for the other five conditions.

Secondary analyses were performed to assess the impact of possible nonresponse bias on results given the differences in several important characteristics related to health status described earlier between survey respondents and non-respondents in the analytic sample. Specifically, PROC WTADJUST was used to adjust the original sample weights using an approach described by Mirel et al [18]. Differences in results based on the adjusted weights

versus original sample weights were minor: estimates of dysmobility prevalence by demographic characteristics differed by 0–1.6 percentage units and estimates of HR for mortality by dysmobility differed by 0.03 units. As a result, all estimates presented are based on the original sample weights for the survey.

Secondary analyses were also performed to assess the influence of respondents with pre-existing illness on mortality risk by comparing the results from the main analyses with those performed after excluding respondents with ≤ 2 years of follow-up after baseline.

Finally, secondary analyses were performed to assess the impact of using different thresholds for selected dysmobility conditions when assessing the risk of mortality by dysmobility status. Specifically, recent thresholds for gait speed and muscle mass proposed by the Foundation of the National Institutes of Health (FNIH) [15] were used in place of the thresholds for these two conditions shown in Table 1. The HR for mortality by dysmobility using the new cutoffs was compared with the HR for mortality by dysmobility obtained in the main analysis. In addition, Harrell's R^2 was calculated to compare the ability of the two models to predict mortality [19]. Harrell's R^2 is an estimate of the proportion of explained variance, and is calculated as: $R^2_H = (\log L_R - \log L_U)/\log L_R$, where $\log L_R$ is the log-likelihood ratio statistic for the Cox model without covariates and $\log L_U$ is the log-likelihood ratio statistics for the Cox model with covariates [19].

Results

Approximately 22 percent of adults age 50 years and older had dysmobility at baseline in 1999–2002 (Table 2). The prevalence of dysmobility was significantly higher among respondents age 70 years and older at baseline than in those age 50–69 years. Respondents ages 70 years and older were also more likely to suffer from a greater concurrent number of the individual conditions that compose dysmobility than respondents ages 50–69 years (figure 1). In addition to being significantly related to age, dysmobility at baseline was also significantly related to sex (women > men) and to race or ethnicity (Mexican Americans and persons of other races > non-Hispanic whites or non-Hispanic blacks) (Table 2).

Respondents were followed for an average of 9.9 years after baseline. Twenty one percent of adults age 50 years and older at baseline were deceased by 2011 (Table 2). Mortality was significantly higher in the older age group compared to the younger group, and was also higher in non-Hispanic whites and non-Hispanic blacks than in Mexican Americans or other races (Table 2). Mortality also differed significantly by dysmobility status at baseline: 45% of respondents with dysmobility at baseline died by 2011, compared to 15% of respondents without dysmobility ($p < 0.001$).

Potential confounding health or lifestyle variables that were significantly related to both dysmobility and mortality included physical activity, self-reported health status, and self-reported diagnosis of chronic conditions at baseline (Table 2). Those with dysmobility at baseline or who were deceased by 2011 were more likely to report less physical activity, being in fair or poor health, and having chronic conditions than those without dysmobility at baseline or who were alive in 2011. As a result, these three variables were included in

subsequent multivariate analyses. Two additional variables were related to either dysmobility or mortality, so were also included in subsequent multivariate analyses. Specifically, smoking status was significantly related to mortality status but not to dysmobility, while alcohol consumption was related to dysmobility but not mortality.

Table 3 summarizes risk of mortality by dysmobility status using the base model (adjusted for demographic variables) and full multivariate model (adjusted for significant health and lifestyle variables as well as demographic variables). These analyses were stratified by age because preliminary analyses revealed that a significant age X dysmobility status interaction existed for risk of mortality. Although mortality risk was significantly higher in those with dysmobility compared to those without dysmobility in both age groups after adjusting for demographic variables, the HR was roughly 2.5 times higher in those age 50–69 years (HR=3.63) than in those age 70 years and older (HR=1.46). The base model HR was also significantly elevated when examined by the other demographic characteristics in all groups except Mexican Americans among 50–69 year olds, but among those age 70 years and older, the base model HR was significant only for men and non-Hispanic whites. Adjusting for lifestyle and health-related variables in the full model attenuated the HR somewhat among 50–69 year olds, but risk remained significantly elevated in all groups except Mexican Americans. In contrast, after adjusting for the additional variables in the 70+ year group, only the HR for men remained significantly elevated.

Results of the secondary analyses to assess the impact of pre-existing disease on results by limiting respondents to those with more than 2 years of follow-up indicated little effect of these conditions on conclusions. Specifically, the base model HR before and after excluding those with ≤ 2 years of follow up were almost identical in both age groups (HR=3.63 and 3.65, respectively, for age 50–69 years; HR=1.46 and 1.40, respectively, for age 70+ years). Comparable results for the full model HR were also observed (HR=2.59 and 2.71, respectively, for age 50–69 years; HR=1.23 and 1.19, respectively, for age 70+ years).

HR adjusted for demographic variables by number of dysmobility conditions are shown by age group in Figure 2. There was a significant linear trend in the HR in both age groups ($p<0.0001$). Among 50–69 year olds, the HRs were statistically significant for those with 3 or 4–6 conditions, but not for those with 1 or 2 conditions (figure 2A). Among those 70 and older, the HR for those with 4–6 conditions was significant, whereas the HR for fewer conditions was not (figure 2B). Of note, the lower limit of the 95% CI for the HR in those 70 and older with 3 conditions just overlapped 1.00 (HR=2.16, 95% CI 0.98-XX). It is also important to note that several of the HR's in both age groups had wide CI's, possibly due to the low number of deaths in some of the categories.

Estimates of the prevalence of the individual conditions that compose dysmobility by age group are shown in Table 4. High body fat was very common in both age groups, affecting 57% and 60% of the younger and older age groups, respectively. The other five conditions were 1.6–5 times more common in the older age group (in whom prevalence estimates ranged from 10–62%), than in the younger age group (in whom prevalence estimates ranged from 5–28%). Among the younger respondents, high body fat was most the common condition, followed by slow gait speed and balance problems in the past year. In the older

group, slow gait was the most common condition, followed by high body fat and low muscle strength.

Table 4 also provides two set of HR for these conditions after adjusting for age, sex, and race or ethnicity. The first set of HR pertains to each condition when tested in separate Cox models, while the second set of HR pertains to each condition when tested together in a single Cox model. When tested separately, differences in the relationship between these conditions and mortality risk by age are evident. For example, among 50–69 year olds, each condition was significantly associated with increased mortality risk when tested separately except lumbar spine osteoporosis. In contrast, among those age 70 years and older, high body fat, lumbar spine osteoporosis and low muscle mass were not significantly associated with increased mortality risk when tested separately, and the HR point estimate for high body fat suggested a protective effect. Deleting high fat from the dysmobility definition in this age group increased the HR for dysmobility to 1.80 (95% CI 1.44–2.26), but it remained significantly lower than the HR among 50–69 year olds.

Age differences were also evident when each condition was tested in a single model that included the other five conditions in addition to the demographic variables (Table 4). Balance problems, low muscle strength, and high percent body fat remained significantly associated with mortality risk among 50–69 year olds when all six conditions were tested together, while balance problems and slow gait speed remained significantly associated with mortality risk among those age 70 years and older.

Results of secondary analyses performed to assess the impact of using FNIH thresholds for gait speed and low muscle mass instead of the cutpoints used in the main analyses for these conditions revealed little impact on HR for mortality by dysmobility status. Specifically, after adjusting for age, sex, and race or ethnicity, the HR for mortality by dysmobility status in the total sample was 1.94 (95% confidence interval (CI) 1.45, 2.59) when the original cutpoints were used to define dysmobility, compared to 2.08 (95% CI 1.65, 2.64) when the FNIH cutpoints were used. Harrell's R^2 was 0.029 for both approaches.

Discussion

Dysmobility syndrome was significantly associated with increased mortality risk in adults age 50 and older from NHANES 1999–2002 when examined by age, sex, and race/ethnicity. Dysmobility was also a relatively common condition, affecting roughly 22% of adults age 50 years and older in 1999–2002. This relatively common prevalence coupled with its link to increased mortality risk lend support to the proposal from Binkley et al [1] to use this constellation of musculoskeletal and mobility conditions to identify older adults at risk of adverse outcomes.

Although dysmobility was significantly related to mortality risk in both age groups examined in the present study, the magnitude of risk differed significantly by age. Specifically, the HR for mortality was roughly 2.5 times greater in 50–59-year-old respondents with dysmobility (HR=3.63) than in respondents age 70 years and older with this condition (HR=1.46) (p for age X dysmobility interaction = 0.001). This pattern

occurred even though older respondents were more likely to have more than three individual dysmobility conditions concurrently than younger respondents. The pattern of higher HR point estimates for dysmobility in the younger age group seen in the total sample was also apparent when the HR for dysmobility was examined separately by sex and race/ethnicity. Finally, the same age pattern emerged for HR associated with most of the individual conditions that compose dysmobility when they were examined in separate models.

Attenuation of mortality risk with age has been seen for other risk factors, such as body fat or body mass index and smoking [20, 21]. One possible explanation for this phenomenon is the steep rise of absolute mortality above age 70 in all respondents, which acts to attenuate the magnitude of relative effect estimates that compare mortality in those with a risk factor to those without it. Another explanation might be presence of pre-existing illness or disease that was not captured by adjusting for confounders in present study. Excluding respondents with ≤ 2 years of follow-up did not alter the HR for dysmobility, which suggests pre-existing illness did not play a major role in the present study However, there is some disagreement as to whether deleting individuals with short amounts of follow-up time can adequately decrease confounding due to pre-existing disease [22, 23].

Another possible explanation for the age pattern in HR for mortality by dysmobility status might be related to age differences in the occurrence of the individual conditions that were used to define dysmobility. For example, there was some variability in the prevalence of the individual conditions by age, which suggests that dysmobility status might be based on presence of a somewhat different set of conditions in the two age groups. The two most prevalent conditions in both age groups were high body fat and slow gait speed. However, the third most common condition in the younger age group was balance problems, compared to low muscle strength in the older age group.

Differences in mortality risk associated with the individual conditions by age could also play a role in the observed age patterns. When examined separately, the six individual conditions generally had HR point estimates that suggested an increased risk of mortality in the younger age group, although not all the HR were statistically significant. In contrast, the HR point estimate for high body fat in the older age group, while not statistically significant, suggested that body fat might be protective against mortality risk in that age range. Some, but not all, studies have also found mortality risk to be unrelated to obesity or to be attenuated among those in the oldest age groups [21, 24]. Finally, a somewhat different set of conditions remained significant predictors of mortality in the two age groups when considered together in a single model. Specifically, balance problems remained a significant predictor of mortality after adjusting for the other five dysmobility conditions in both age groups. However, high body fat and low muscle strength also remained significant predictors in the younger age group, while slow gait speed was the only other predictor that remained significant in the older age group.

Mortality risk was significantly related to the number of dysmobility conditions in a linear fashion in both age groups. The increased risk in those with at least 3 conditions was statistically significant in 50–69 year-olds and just missed significance in those aged 70 and older, which suggests that use of 3 conditions to define dysmobility syndrome is reasonable.

However, power was not optimal to address this issue in the present study, as indicated by the wide 95% CI's for several of the HRs.

The present study used the same measurement methods and thresholds to define the individual dysmobility conditions as Binkley et al [1] whenever possible. However the definition of osteoporosis, falling risk, and muscle strength differed because NHANES 1999–2002 employed different methods to measure the relevant variables for these conditions. Specifically, osteoporosis was based on lumbar spine BMD only, and BMD data from the lumbar spine subregion from total body DXA scans were used instead of BMD from a dedicated AP spine. Previous research found that lumbar spine BMD measured by these two approaches were highly correlated, produced similar estimates of osteoporosis prevalence and had a similar association with fracture [7]. However, some misclassification of osteoporosis status of individual respondent was observed [7]. In addition, total body subregion measurements are not as accurate or precise as those from dedicated scans [7]. Finally, history of balance problems in past year was used to assess falling risk rather than number of falls, and isokinetic knee extensor muscle strength was used in place of grip strength to estimate muscle strength

Binkley et al [1] noted that their proposed cutpoints to define abnormality for the six conditions, while based on expert consensus to the extent possible, might require revision as more evaluation of the dysmobility concept occurs. Results from the present study in which two different sets of thresholds were evaluated when defining some of the individual conditions may provide some insight into this possibility. Specifically, two sets of thresholds to define low muscle strength were tested because thresholds to define low muscle strength based on isokinetic knee extensor muscle strength have not been provided in consensus statements [13–15]. In addition, new thresholds for gait speed and muscle mass developed by the FNIH that were released subsequent to the study by Binkley et al [1] were tested in the present study. In the present study, the HR's for dysmobility were similar regardless of the thresholds used to define these three conditions. Whether this lack of impact extends to the other conditions or to use of different thresholds for more than three of the dysmobility conditions is not clear, however. It is also not clear whether HR for other adverse outcomes like fracture would be unaffected by changes in thresholds.

Study limitations include potential misclassification of osteoporosis status because it was based on lumbar spine BMD only. This misclassification can occur when either AP or total body DXA scans are used due to presence of artifacts such as aortic calcification or osteophytes that may falsely elevate these BMD measurements. In addition, exclusions for missing data resulted in creation of an analytic sample with respondents who differed from excluded respondents in a number of ways that could affect the generalizability of results. Specifically, excluded respondents were more likely to be older, have several indications of poor health and to have high body fat and slow gait speed, which are two of the conditions used to define dysmobility. Secondary analyses were performed to address this potential non-response bias by adjust the sampling weights via re-weighting. Results based on the adjusted sampling weights were similar to those obtained when the original sampling weights were used, which suggests that the exclusions from the analytic sample did not introduce serious biases. However, these analyses cannot completely rule out nonresponse

bias because the sample size was not large enough to permit reweighting by all the characteristics that varied between respondents and nonrespondents.

In conclusion, mortality risk was significantly increased in respondents with dysmobility in this sample derived from a nationally representative survey. The relationship was stronger in those age 50–69 years than in those age 70 years and older, which supports the utility of evaluating persons in this younger age range for dysmobility despite their lower prevalence of the condition. The present study supports the predictive utility of dysmobility for mortality, but additional work is needed to evaluate its relationship with other adverse outcomes like mobility disability, falls and fractures.

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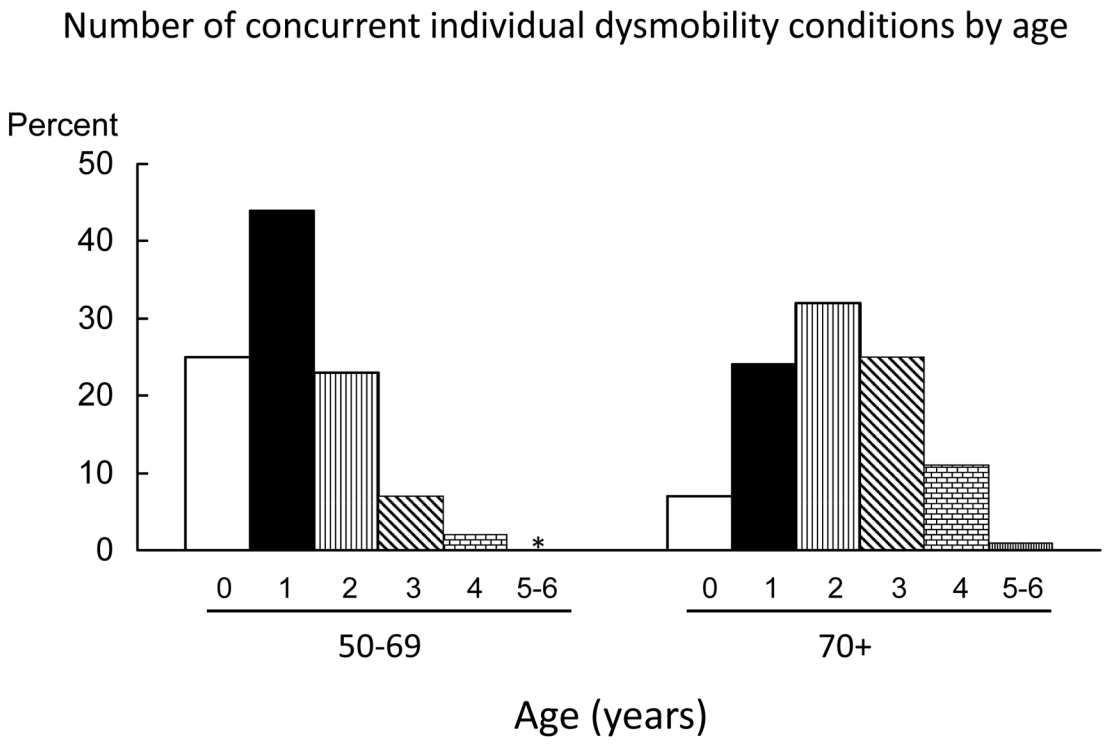
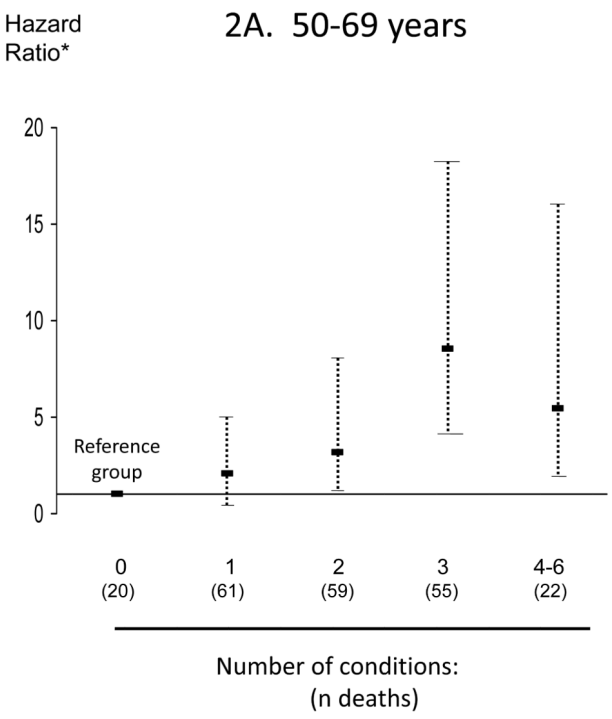
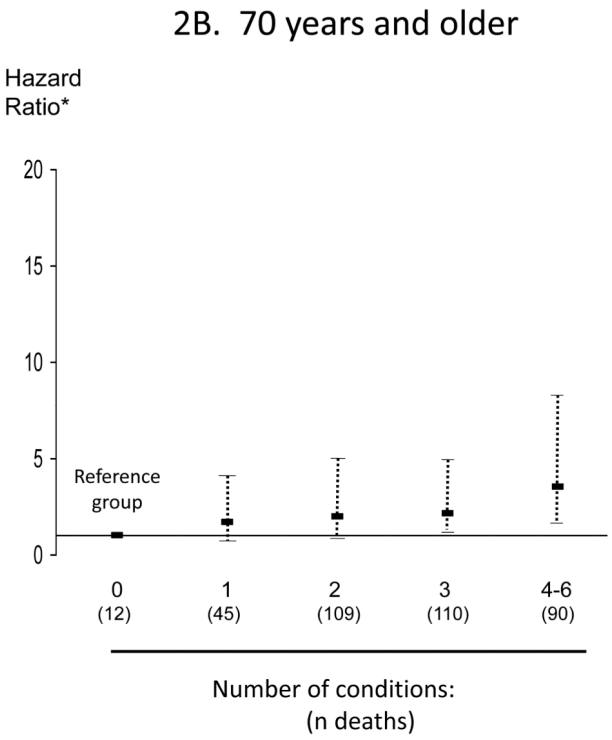


* Statistically unreliable estimate; SE/percent >40%

Figure 1.
Number of concurrent individual dysmobility conditions by age



p linear trend < 0.0001



p linear trend < 0.0001

Figure 2.
HR for mortality by number of dysmobility conditions and age group

Table 1

Criteria for individual conditions composing dysmobility syndrome

Condition	Threshold source	Cutpoints	
		Men	Women
High body fat	Framingham [25]	Percent body fat > 30	Percent body fat >40
Low muscle mass	European Working Group on Sarcopenia in Older People [26] [13]	ALM/ht^2 < 7.26	ALM/ht^2< 5.45
Slow gait	International Working Group on Sarcopenia [14]	< 1.0 meters/sec	< 1.0 meters/sec
Low strength	Peak knee extensor torque < − 2 SD's below mean of NHANES 50–59 healthy reference group*	Peak knee extensor torque <104.4 Nm	Peak knee extensor torque <62.6 Nm
Osteoporosis	International Society for Clinical Densitometry 2013 Adult Position Paper [9]	< − 2.5 SD below mean lumbar spine BMD of 30 year old white women in DXA manufacturer reference database	< − 2.5 SD below mean lumbar spine BMD of 30 year old white women in DXA manufacturer reference database
Balance problems (balance, dizziness, falls) in past year	Not applicable	Yes for any problem	Yes for any problem

*do not have any of the individual conditions composing dysmobility syndrome

Table 2

Selected baseline characteristics by baseline dysmobility syndrome and vital status in 2011 Adults age 50years and older, NHANES 1999–2002

		Had dysmobility at baseline		Deceased by 2011	
Characteristic	**Total n**	**%**	**p***	**%**	**p****
Total	2975	21.7		21.4	
Age (years)			<0.001		<0.001
50–69	1951	13.9		12.3	
50–59	920	9.8		8.2	
60–69	1030	20.4		18.7	
70+	1024	44.2		47.7	
70–79	672	38.8		38.1	
80+	352	58.8		74.0	
Sex			<0.001		0.05
Men	1500	17.7		23.2	
Women	1475	25.3		19.9	
Race or Hispanic origin			0.05		0.03
Non-Hispanic white	1716	20.3		22.2	
Non-Hispanic black	502	20.8		23.2	
Mexican American	560	27.4		18.5	
Other	197	34.3		13.4	
Hip, wrist, or spine fracture after age 20			0.11		0.23
Yes	249	25.9		25.0	
No	2726	21.3		21.0	
Ever smoked			0.71		0.002
Yes	1607	21.9		24.3	
No	1361	21.4		18.1	
Drink 3+ units alcohol/drinking occasion			<0.001		0.53
Yes	388	11.4		17.9	
No	2151	22.1		20.2	
Physical activity compared to others of same age and sex			<0.001		0.002
More	1453	18.7		20.8	

Characteristic	Total n	Had dysmobility at baseline %	Had dysmobility at baseline p*	Deceased by 2011 %	Deceased by 2011 p**
Less	359	35.3		29.5	
Same	1111	20.5		19.1	
Self-reported health status			<0.001		<0.001
Good/very good/excellent	2245	16.1		17.9	
Fair/poor	729	46.1		36.7	
Chronic conditions			<0.001		<0.001
Yes	1815	26.5		25.5	
No	1081	13.3		13.9	

* compared to those without dysmobility syndrome at baseline

** compared to those who were alive in 2011

Osteoporos Int. Author manuscript; available in PMC 2016 February 18.

Table 3

Risk of mortality by age and dysmobility status in adults age 50 years and older, NHANES 1999–2002

	50–69 years (n=1617)							70 years and older (n=808)						
		Base model*			Full model**				Base model*			Full model**		
Characteristic			95% CI			95% CI				95% CI			95% CI	
Dysmobility status	n deaths	HR	LL	UL	HR	LL	UL	n deaths	HR	LL	UL	HR	LL	UL
Total sample														
Yes	77	3.63	2.69	4.90	2.59	1.82	3.69	200	1.46	1.07	1.99	1.23	0.89	1.69
No	140	1.00	--	--	1.00	--	--	166	1.00	--	--	1.00	--	--
Men														
Yes	37	3.36	2.05	5.49	2.23	1.29	3.88	102	1.63	1.16	2.31	1.50	1.03	2.19
No	96	1.00	--	--	1.00	--	--	88	1.00	--	--	1.00	--	--
Women														
Yes	40	3.97	2.55	6.19	3.04	1.73	5.32	98	1.33	0.90	1.97	1.11	0.74	1.65
No	44	1.00	--	--	1.00	--	--	78	1.00	--	--	1.00	--	--
Non-Hispanic whites														
Yes	35	4.06	2.74	6.02	2.70	1.59	4.61	146	1.67	1.09	2.57	1.29	0.91	1.83
No	67	1.00	--	--	1.00	--	--	122	1.00	--	--	1.00	--	--
Non-Hispanic blacks														
Yes	18	2.95	1.31	6.63	2.84	1.25	6.49	26	1.45	0.72	2.93	0.93	0.46	1.89
No	35	1.00	--	--	1.00	--	--	24	1.00	--	--	1.00	--	--
Mexican Americans														
Yes	18	1.33	0.54	3.27	1.24	0.53	2.91	24	1.61	0.84	3.10	1.80	0.85	3.82
No	34	1.00	--	--	1.00	--	--	13	1.00	--	--	1.00	--	--

*Adjusted for age, sex, and race/ethnicity (results for total sample); adjusted for age and race/ethnicity (results for men and women); adjusted for age and sex (results for non-Hispanic whites, non-Hispanic blacks, Mexican Americans)

**Base model adjusted for smoking, alcohol consumption, self-rated health status, chronic conditions and physical activity compared to others of same age and sex.

Table 4

Prevalence and risk of mortality of dysmobility component conditions by age Adults age 50 years and older, NHANES 1999–2002

			Conditions tested separately*	95% CI		Conditions tested together**	95% CI	
Characteristic	**% with condition**	**Rank of prevalence within age group**	**HR**	**LL**	**UL**	**HR**	**LL**	**UL**
Age 50–69								
Balance problem in past year	18.2	3	1.96	1.25	3.08	1.72	1.05	2.80
Low muscle strength	8.0	5	3.31	2.17	5.03	2.54	1.50	4.29
Slow gait speed	28.0	2	1.60	1.07	2.39	1.26	0.82	1.93
Low muscle mass	14.9	4	1.91	1.23	2.96	1.57	0.97	2.54
Lumbar spine osteoporosis	4.7	6	1.38	0.73	2.64	1.18	0.59	2.36
High percent body fat	56.8	1	1.71	1.21	2.42	1.77	1.29	2.42
Age 70+								
Balance problem in past year	29.0	5	1.49	1.18	1.88	1.41	1.12	1.78
Low muscle strength	39.9	3	1.52	1.18	1.96	1.29	1.00	1.68
Slow gait speed	61.8	1	1.95	1.44	2.66	1.86	1.37	2.54
Low muscle mass	30.3	4	1.26	1.00	1.59	1.18	0.91	1.52
Lumbar spine osteoporosis	9.9	6	1.17	0.82	1.68	1.11	0.78	1.59
High percent body fat	59.8	2	0.81	0.66	1.00	0.82	0.65	1.03

*Hazard ratio for respondents with the individual dysmobility condition compared to respondents without the condition after adjusting for age, sex, race/ethnicity

**Hazard ratio for respondents with the individual dysmobility condition compared to respondents without the condition after adjusting for age, sex, race/ethnicity, and the other five dysmobility conditions