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Association Between Muscle Strengthening Physical Activities and Mortality among American Adults with Mobility Limitations

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Abstract

Compared to aerobic-based physical activity, less research has evaluated the effects of muscle-strengthening physical activity (MSPA) on mortality. Additionally, limited research has evaluated this among adults with mobility limitations, which was this study’s purpose. Data from the 2003-2006 NHANES, with follow-up through 2011, were used (analyzed in 2016). MSPA was assessed via self-report, with all-cause, CVD-specific, and cancer-specific mortality assessed as the outcome variables. Analyses were limited to adults with mobility limitations (N=1,411), assessed via a validated questionnaire. After adjustments, those meeting MSPA guidelines (vs. not) had a 38% reduced hazard of all-cause death (HR=0.62; 95% CI: 0.41-0.95). Results were similar for CVD-specific mortality (HR=0.46; 95% CI: 0.23-0.97) and cancer-specific mortality (HR=0.27; 95% CI: 0.06-1.20). Meeting MSPA guidelines is associated with reduced all-cause and cause-specific mortality among adults with mobility limitations. This is an encouraging observation as adults with mobility limitations may be unable to engage in sufficient amounts of aerobic-based physical activity. Thus, promotion of MSPA among this population may be of critical importance.

Keywords: Epidemiology; resistance training; survival
Introduction

Physical activity (PA) is encouraged across the lifespan as it is associated with positive health benefits.\textsuperscript{1} Hence, the United States Department of Health and Human Services (USDHHS) recommends regular participation in both aerobic and muscle-strengthening activity across different age ranges, as well as among individuals with disability or chronic disease.\textsuperscript{2} Aerobic activity is typically emphasized due to strong evidence of protective effects on both all-cause and cardiovascular mortality.\textsuperscript{3–5} However, a variety of conditions, such as obesity, joint or muscle pain, amputation, and neurologic impairment can limit an individual’s ability to ambulate, making it difficult for these individuals to participate in many recommended aerobic activities, such as walking, running, playing aerobically-demanding sports, and in some cases even cycling and swimming. Considering that an estimated 17.1 million U.S. adults (7.1\% of the adult population) are unable (or find it very difficult) to walk a quarter mile,\textsuperscript{6} it is important to understand how non-ambulatory-based physical activity may associate with health outcomes in this sizeable subset of the U.S. population.

Muscle-strengthening PA (MSPA) has been shown to associate with an enhancement in physical function,\textsuperscript{7} enhanced glycemic control,\textsuperscript{8} as well as improvement in mental wellbeing.\textsuperscript{9} Despite this range of potential benefits, there is less evidence regarding effects of MSPA on mortality risk. However, there is some evidence that participation in MSPA is associated with reduced risk of all-cause mortality. For example, an analysis of National Health and Nutrition Examination Survey (NHANES) data revealed that participation in any MSPA was associated with a 23\% reduction in risk of death, and there was a 30\% reduction in mortality among those meeting recommendations for MSPA.\textsuperscript{10}
It is reasonable to hypothesize that MSPA may play a greater role in promoting the health of individuals who have difficulty with ambulation. However, the association of MSPA with all-cause mortality among adults with ambulatory limitations is less clear. This is important as adults with ambulatory limitations may differ from the general population in risk of chronic diseases associated with prolonged sedentary time, such as cardiovascular disease and diabetes. The potential independent benefit of MSPA in reducing mortality needs to be better understood in order to appropriately tailor PA programs specific to adults with ambulatory disability. Hence, the purpose of our study was to examine the association between MSPA and mortality among American adults with mobility limitations. We hypothesize that, independent of total PA and other potential confounders, MSPA will have a beneficial effect in reducing the risk of death from all causes, as well as deaths from cancer and cardiovascular disease.

Methods

Design and Participants

The National Health and Nutrition Examination Survey (NHANES) is an ongoing survey conducted by the National Center for Health Statistics which evaluates a representative sample of non-institutionalized U.S. civilians. Participants are selected by a complex, multistage probability design. Participants are interviewed in their home and subsequently evaluated in a mobile examination center within 2 weeks after the household interview.

All procedures for data collection were approved by the National Center for Health Statistics ethics review board, and all participants provided written informed consent prior to data
collection. The authors’ institution provided institutional review board exemption for this study given that the NHANES data is de-identified.

Data from the 2003-2006 NHANES were used, as these are the only NHANES cycles with objectively-measured physical activity data (described below). Data from participants in these cycles were linked to death certificate data from the National Death Index via a probabilistic algorithm. Person-months of follow-up were calculated from the date of the interview until date of death or censoring on December 31, 2011, whichever came first.

Participants were excluded if they died within the first 12-months of the follow-up period or had any of the following conditions at baseline: coronary artery disease, congestive heart failure or stroke. The sample included 1,411 participants with evidence of mobility limitations (described below) between 20 and 85 years of age.

Assessment of Mobility Limitations
Consistent with previous work,12-14 participants were considered to have a mobility limitation if they self-reported difficulty (some, much, or unable to do the activity) in any of the following activities: walking without special equipment use; walking 0.25 miles; walking ten steps without stopping; stooping, crouching, or kneeling; walking from one room to another on the same level; standing up from an armless straight chair; or standing or being on their feet for 2 hours.

Measurement of Muscle Strengthening Physical Activities
Participants were asked two questions related to engagement in muscle strengthening activities: 1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” (response option: yes or no), and 2) among those answering yes to this first question, they were asked, “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” Consistent with the United States Department of Health and Human Services (USDHHS) physical activity guidelines, those self-reporting 8 muscle strengthening activities sessions/month (2/week) were considered to meet muscle strengthening guidelines. These NHANES muscle strengthening items have provided evidence of convergent validity, i.e., the frequency of muscle strengthening engagement from these exact muscle strengthening items have been shown to associate with parameters we would expect muscle strengthening engagement to correlate with. For example, using these exact muscle strengthening items, those with a greater frequency of muscle strengthening engagement have been shown to have a reduced odds of multimorbidity, all-cause mortality, and have more favorable levels of cardiovascular-disease biomarker levels, including red blood cell distribution width. Further, those who have reported greater frequency of muscle strengthening engagement when assessed from these items have been shown to have greater lower extremity muscle strength.

Assessment of Physical Activity

Participants who were not dependent of wheelchair use for ambulation were asked to wear an ActiGraph 7164 (Pensacola, FL) accelerometer on their right hip for 7 days. Accelerometers were affixed to an elastic belt that was worn around the participant’s waist near the mid-axillary line at the level iliac crest. Participants were asked to wear the accelerometer during all
activities, except water-based activities and while sleeping. The accelerometer measured the frequency, intensity, and duration of physical activity by generating an activity count proportional to the measured acceleration. Accelerometry estimates were summarized in 1-minute time intervals. Minutes with activity counts/min ≥ 100 counts/min were classified as total physical activity; counts/min of 100-2019 were classified as light-intensity activity; counts/min of 2020-5998 were classified as moderate-intensity activity; and counts/min of 5999+ were classified as vigorous-intensity activity. The ActiGraph accelerometer has demonstrated evidence of reliability and validity.  

Only those participants with at least 4 days of 10 or more hours/day of accelerometer wear time were included in the analyses in order to ensure that data adequately captured habitual physical activity patterns. To monitor the amount of time the device was worn, nonwear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1-2 minutes of activity counts between 0 and 100.  

Covariates

Covariates included age (yrs; continuous), sex, race-ethnicity (Mexican American, non-Hispanic white, non-Hispanic black, other), accelerometer-assessed aerobic physical activity (min/day; continuous), cotinine-assessed smoking exposure (ng/mL; continuous), C-reactive protein (mg/dL; continuous), cholesterol medication use (yes/no), physician-diagnosed hypertension (yes/no), physician-diagnosed diabetes and measured body mass index (kg/m^2; continuous).

Data Analysis
All statistical analyses (Stata, version 12.0, College Station, TX) accounted for the complex survey design used in NHANES by using survey sample weights, clustering, and primary sampling units (data analyzed in 2016). Weighted multivariable Cox proportional hazard models were used to examine the association between meeting MSPA guidelines and all-cause mortality. Schoenfeld’s residuals were used to verify the proportional hazards assumption. Statistical significance was established as P < 0.05.

**Results**

**Study Variable Characteristics**

In the sample, 233 participants died during the median follow-up period of 81 months (IQR = 66-94). For the entire sample, 111,251 person-months occurred with an all-cause mortality rate of 2.09 per 1,000 person-months. Among the 233 observed deaths, 49 were from cardiovascular disease, 60 from cancer, and the remaining from other causes.

Behavioral and demographic characteristics of the analyzed sample are shown in Table 1. Participants, on average, were 58.9 years, the majority of the sample were women (61%) and non-Hispanic white (79%), and approximately 16% of the sample met muscle strengthening guidelines. On average, these ambulatory-limited adults engaged in 12.4 min/day (86.8 min/week) and 0.2 min/day (1.4 min/week) of moderate and vigorous-intensity physical activity, respectively. These individuals are considerably less active than their able-bodied counterparts in the general population (e.g., 324.5 min/week of moderate-intensity aerobic activity).\(^\text{22}\)

**Association Between MSPA and All-Cause Mortality (Table 2)**
With regard to the main findings, and in an unadjusted Cox proportional hazard model, those meeting muscle strengthening guidelines (vs. not) had a 46% reduced hazard of all-cause death (HR=0.54; 95% CI: 0.34-0.87). After adjusting for aerobic-based physical activity, age, gender, race-ethnicity, smoking, C-reactive protein, cholesterol medication use, hypertension, diabetes and body mass index, those meeting MSPA guidelines (vs. not) had a 38% reduced hazard of all-cause death (HR=0.62; 95% CI: 0.41-0.95; P=0.03). Results were unchanged with restricting the sample to adults 50+ years (HR=0.63; 95% CI: 0.41-0.96; N=1156) or those 65+ years (HR=0.50; 95% CI: 0.30-0.84; N=745).

**Association Between MSPA and Cause-Specific Mortality (Table 2)**

Due to cell size issues, the only cause-specific deaths possible to evaluate were cancer- and CVD-specific deaths. In an unadjusted model, those meeting MSPA guidelines (vs. not) had a 55% reduced hazard of CVD-specific death (HR=0.45; 95% CI: 0.22-0.93). After complete adjustment, results were unchanged (HR=0.46; 95% CI: 0.23-0.97).

With regard to cancer-specific mortality, in an unadjusted model, those meeting MSPA guidelines (vs. not) had a 76% reduced hazard of cancer-specific death (HR=0.24; 95% CI: 0.05-1.05). Results were similar after adjustments (HR=0.27; 95% CI: 0.06-1.20).

**Sensitivity Results**

Additional analyses evaluated whether there were any multiplicative interaction effects of the covariates and MSPA on all-cause mortality. There was no evidence of such an interaction effect, as, for example, age (HR=0.97; 95% CI: 0.93-1.02), gender (HR=1.81; 95% CI: 0.41-
7.85) and aerobic-based physical activity (HR=0.99; 95% CI: 0.98-1.01) did not interact with MSPA to influence all-cause mortality risk.

Additional analyses were computed that did not consider accelerometer-assessed physical activity, but instead, included self-reported physical activity as a covariate. This was evaluated because those using a wheelchair were not eligible for the accelerometer monitoring. This analysis consisted of 2,031 adults with mobility limitations, some of which may have been using a wheelchair, but this determination could not be confirmed as there is no NHANES variable indicating if they were using a wheelchair. Among this sample of 2,031 adults with mobility limitations, and after adjusting for age, gender, smoking, CRP, cholesterol medication, hypertension, BMI, diabetes and self-reported physical activity\(^3\), those meeting MSPA guidelines (vs. not) had a 34% reduced hazard of cancer-specific death (HR=0.66; 95% CI: 0.47-0.92). Results were unchanged when restricting the sample to adults 50+ years (HR=0.63; 95% CI: 0.42-0.93) or those 65+ years (HR=0.56; 95% CI: 0.37-0.85). Although there was no specific NHANES variable indicating if participants were using a wheelchair or not, participants were asked, “Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?” For the entire sample, and when adding in this variable as a covariate, those meeting MSPA guidelines (vs. not) had a 33% reduced hazard of all-cause death (HR=0.67; 95% CI: 0.47-0.93). Results were unchanged when restricting the sample to adults 50+ years (HR=0.63; 95% CI: 0.43-0.92) or those 65+ years (HR=0.57; 95% CI: 0.38-0.85).

**Discussion**
Previous research demonstrates that aerobic-based physical activity is inversely associated with mortality risk. Emerging research has also demonstrated that MSPA is inversely associated with mortality risk. Limited research, however, has evaluated whether MSPA is associated with reduced mortality risk among those with mobility limitations, which, notably, are less likely to engage in sufficient amounts of aerobic-based physical activity. Thus, the purpose of our study was to specifically evaluate the association between MSPA and mortality risk (all-cause and cause-specific) among a national sample of adults with mobility limitations. Our main finding was that, independent of aerobic-based physical activity, adults with mobility limitations who met MSPA guidelines had a 38-46% reduced risk of all-cause mortality; results were similar for cancer- and CVD-specific mortality. This degree of risk reduction is at least comparable to the 30% mortality reduction previously noted in the general population. The inverse association between MSPA and mortality is especially important for this cohort with mobility limitations, given that levels of moderate to vigorous (aerobic) physical activity were very low compared to the general population.

As we have discussed in detail previously, a key component of physical activity promotion among those with mobility limitations is to emphasize safe forms of physical activity that minimize fall and injury risk. Thus, physical activity interventions among those with mobility limitations may require modifications to an individual’s indoor and outdoor space in order to create an environment which minimizes fall/injury risk and promotes activity. As described previously, Rimmer and Schiller developed the RAMP (Restoring Activity, Mobility and Participation) framework to promote physical activity among those with mobility-related disorders. This framework consists of four main components, including Access, Participation,
Adherence, and Health and Function. The RAMP model emphasizes that it is important that environments are accessible and known to those with mobility impairments; are usable and allow for participation by those with mobility impairments; enhance adherence to physical activity programs by varying the types of activities, varying the location, and developing social support networks; and enhance health and function by preventing overuse injuries and developing effective methods for measuring and monitoring physical activity among disabled populations.

One potential modality, which aligns with this RAMP framework, is MSPA. Thus, the present findings of an inverse association between MSPA and mortality risk among those with mobility limitations, is a very encouraging observation. Of course, safe and progressive forms of MSPA would need to be a key part of an exercise prescription program among those with mobility limitations, whom naturally may be less likely to engage in aerobic-based physical activity. Although limited in evaluation, and similar to our findings, other work also demonstrates that physical activity may have beneficial health effects among those with mobility limitations. For example, among those with mobility limitations, physical activity has been shown to positively affect cardiovascular disease and type 2 diabetes risk factors.

In conclusion, our findings demonstrated that adults with mobility limitations who met MSPA guidelines had a 38-46% reduced risk of all-cause mortality, with similar results observed for cancer- and CVD-specific mortality. Thus, if confirmed by additional work, then clinicians should not only promote MSPA among the general population, but targeted efforts should be made to promote MSPA among those with ambulatory-related limitation. Limitations of this study include the subjective assessment of muscle MSPA and mobility limitations, as well as the
inability to determine the duration of MSPA engagement and duration of mobility limitations. Another limitation is our inability to evaluate the association between MSPA and mortality specifically among those using a wheelchair. Notable strengths, however, include the study’s novelty, objective-measure of free-living aerobic-based physical activity, prospective study design, and national sample. Future experimental and prospective work, overcoming our study’s limitations, is warranted. Further, intervention-based work identifying the most effective strategies for getting mobility-impaired adults to initiate and maintain a muscle strengthening program, is needed.

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References


Table 1. Characteristics of the analyzed sample, NHANES 2003-2006 ($N = 1,411$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Point Estimate</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean yr</td>
<td>58.9</td>
<td>0.6</td>
</tr>
<tr>
<td>% Female</td>
<td>60.9</td>
<td></td>
</tr>
<tr>
<td>Race-Ethnicity, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mexican American</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>79.1</td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>Body Mass Index, mean kg/m$^2$</td>
<td>29.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Total physical activity, mean min/day</td>
<td>327.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Light-intensity physical activity, mean min/day</td>
<td>315.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Moderate-intensity physical activity, mean min/day</td>
<td>12.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Vigorous-intensity physical activity, mean min/day</td>
<td>0.2</td>
<td>0.03</td>
</tr>
<tr>
<td>% Meeting muscle strengthening guidelines</td>
<td>15.8</td>
<td></td>
</tr>
<tr>
<td>Mean sessions/month engaging in muscle strengthening activities</td>
<td>3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>C-reactive protein, mean mg/dL</td>
<td>0.52</td>
<td>0.03</td>
</tr>
<tr>
<td>Cotinine, mean ng/mL</td>
<td>59.5</td>
<td>4.5</td>
</tr>
<tr>
<td>% Cholesterol medication</td>
<td>20.8</td>
<td></td>
</tr>
<tr>
<td>% Diabetes</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>% Hypertensive</td>
<td>46.8</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Association between meeting muscle strengthening physical activity (MSPA) guidelines and all-cause and cause-specific mortality, NHANES 2003-2006 (N = 1,411).

<table>
<thead>
<tr>
<th></th>
<th>All-Cause Mortality</th>
<th>CVD-Mortality</th>
<th>Cancer-Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td><strong>Unadjusted</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meeting MSPA Guidelines (vs. not)</td>
<td>0.54 (.34-.87)</td>
<td>0.45 (.22-.93)</td>
<td>0.24 (.05-1.05)</td>
</tr>
<tr>
<td><strong>Adjusted †</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meeting MSPA Guidelines (vs. not)</td>
<td>0.62 (.41-.95)</td>
<td>0.46 (.23-.97)</td>
<td>0.27 (.06-1.20)</td>
</tr>
</tbody>
</table>

† Adjusted for aerobic-based physical activity, age, gender, race-ethnicity, smoking, C-reactive protein, cholesterol medication use, hypertension, diabetes and body mass index.
Highlights

- A national sample was employed
- Muscle strengthening physical activities (MSPA) was linked with survival
- Limited research has evaluated this among those with mobility limitations
- MSPA was protective against early mortality among this population