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ABSTRACT
Magyari, PM and Churilla, JR. Association between lifting weights and metabolic syndrome among U.S. adults: 1999–2004 National Health and Nutrition Examination Survey. J Strength Cond Res 26(11): 3113–3117, 2012—The purpose of this cross-sectional study was to determine the proportion of U.S. adults who participate in the resistance exercise modality of lifting weights (LWs) by demographic characteristics and to investigate the impact of LWs on the prevalence and risk of metabolic syndrome (MetS) in a national representative sample of U.S. adults. The sample (n = 5,618) in this cross-sectional study included adults aged ≥20 years who participated in the 1999–2004 National Health and Nutrition Examination Survey. Approximately twice as many men (11.2%; 95% confidence interval [CI] 9.5, 13.1) reported LWs as women did (6.3%; 95% CI 5.2, 7.6) with non-Hispanic Whites (9.6%; 95% CI 8.1, 11.4) reporting the highest levels and Mexican Americans reporting the lowest levels (5.6%; 95% CI 4.4, 7.2) of engaging in LWs. Additionally, higher levels of socioeconomic status were associated with greater levels of self-reported LWs. MetS prevalence was found to be significantly lower among U.S. adults reporting LWs (24.6%; 95% CI 19.3, 30.9) compared with adults not reporting LWs (37.3%; 95% CI 35.5, 39.2) with associated risk reductions of 58% (p < 0.001) and 37% (p < 0.01) in the unadjusted model and model adjusted for demographic variables, respectively. These findings suggest that LWs may play a role in reducing the prevalence and risk of MetS among U.S. adults. Therefore, exercise professionals should strongly encourage the activity of LWs among the subgroups who report the lowest levels of LWs.

KEY WORDS resistance exercise, resistance training, epidemiology, metabolic risk, physical activity

INTRODUCTION
Metabolic syndrome (MetS) is a clustering of 5 cardiovascular (CV) disease risk factors that include poor glucose control or frank diabetes, overweight and obesity, hypertriglyceridemia, low high-density lipoprotein cholesterol (HDL-C), and hypertension (HTN) (9). An individual who possesses ≥3 of these CV risk factors would be classified as having MetS.

Recent published reviews outlining the impact of exercise in the prevention and treatment of MetS highlight the importance of resistance exercise (RE), either as a component in a comprehensive exercise program or as an effective intervention independent of additional exercise modalities (4,5,10,12,18,25). These reviews focus on the impact RE can have on each individual component of the metabolic health. There is a paucity of studies with strong external validity illustrating (a) how many people actually engage in RE and (b) describe the effects of RE in those identified by the comprehensive diagnosis of MetS. Furthermore, little data exist from nationally representative samples examining various types of REs, particularly lifting weights (LWs).

Several cross-sectional studies have identified an inverse relationship between muscular strength and the prevalence of MetS (2,8,16,17,20,23,26). It has been proposed that the participation in RE activities may be responsible for both the increased strength and reduced metabolic risk (16,26) identified in these studies. Unfortunately, the demographic scope of the 6 previously published cross-sectional studies is limited to the following characterizations: Caucasian men (16,17), Caucasian men and women (26), older English men and women (23), Australian men (2), and Japanese men (20).

There is an absence of literature that investigates either the impact of muscular strength or RE on the prevalence of
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MetS in a demographically diverse population representative of U.S. adults. Using an epidemiological approach in the analysis of large nationally representative data sets may be the initial step in elucidating the relationship between the most popular RE modality, LWs, and the prevalence risk of MetS.

There have been a few reports describing the proportion of U.S. adults who regularly engage in RE with study averages ranging from 8.7 to 21% (7,13,24). The higher percentages were reported among studies in which a more comprehensive definition of RE was used (RE or resistance training was defined as muscular strengthening activities such as LWs or doing calisthenics) (7,24). The only report that investigated the percentage of U.S. adults regularly participating in the specific RE modality of LWs used data collected between 1988 and 1994 and found 13.4% of U.S. adults reported LWs in the previous month, with 8.7% reporting LWs an average of 2 d wk⁻¹ (13).

The purpose of this cross-sectional study was to (a) determine the proportion of U.S. adults who participate in the RE modality of LWs by demographic characteristics; (b) examine the association between LWs and prevalence and risk estimates of MetS in a national representative sample of U.S. adults.

METHODS

Experimental Approach to the Problem

This cross-sectional study used 6 years of data from the 1999–2004 National Health and Nutrition Examination Survey (NHANES), a continuous survey conducted by the National Center for Health Statistics (6). The NHANES was designed to provide national estimates of the health and nutritional status of noninstitutionalized U.S. civilians over the age of 2 months.

Subjects

For this study, the final sample consisted of 5,618 participants >20 years of age who met the following criteria: (a) adult men and women who gave informed consent; (b) attended a morning examination center examination after an overnight fast of at least 8 hours; (c) nonpregnant women; and (d) had complete data on all the variables of interest. The NHANES uses trained staff to conduct in home interview administered questionnaires and standardized medical examinations conducted by physicians and other health care professionals. The questionnaires collected demographic information and information regarding varying types of physical activity, diet, and current medical conditions. A physician conducted examinations and obtained information on anthropometrics, blood pressure, and complete blood profiles. Measurements of lipid values were conducted under the direction of the Lipoprotein Analytical Laboratory at John Hopkins University in Baltimore, MD, and plasma glucose was measured using the hexokinase enzyme reaction at the Diabetes Diagnostic Laboratory at the University of Missouri in Columbia Missouri (6,11).

Blood pressure readings were obtained after the participant was seated quietly for 5 minutes, with 3–4 consecutive measurements being taken on the same arm (right arm if possible). Abdominal obesity was assessed by measuring waist circumference (WC) using a steel tape at the level of the uppermost lateral borders of the right and left ilium, wrapping the tape around the trunk horizontally. Informed consent was obtained from all the subjects, and the Institutional Review Board of the University of North Florida approved the use of the 1999–2004 NHANES data.

The American Heart Association/National Heart, Lung, Blood Institute Metabolic Syndrome Definition

The dependent variable in this study was a positive diagnosis of MetS based on the American Heart Association/National Heart, Lung, Blood Institute (AHA/NHLBI) definition (14). The AHA/NHLBI definition requires that 3 of the following 5 CV risk factors be present for a diagnosis of MetS: (a) impaired fasting glucose (IFG) >100 mg dl⁻¹ or undergoing pharmacological treatment for IFG; (b) low HDL-C (<40 mg dl⁻¹ in men or <50 mg dl⁻¹ in women) or undergoing pharmacological treatment for an abnormal HDL-C level; (c) triglycerides >150 mg dl⁻¹ or undergoing pharmacological treatment for hypertriglyceridemia; (d) a WC >102 cm in men or >88 cm in women; and (e) blood pressure >130/85 mm Hg or undergoing pharmacological treatment for HTN. The AHA/NHLBI definition is unique in that an individual can have any combination of 3 of the 5 MetS criteria and does not require a requisite condition found in all other medical society definitions of MetS (9).

Lifting weights

This study examined the associations between the self-reporting of LWs and MetS in U.S. adults. Data used to measure LWs participation was derived from 1 of the 2 distinct NHANES physical activities questionnaire data files—the ‘physical activities individual activities file’ (PAQIAF) (6). The first file included the question “Over the past 30 days, did you do any physical activity specifically designed to strengthen your muscles such as LW, push-ups or sit-ups?” The second PAQIAF file includes detailed information regarding several specific types of moderate and vigorous leisure-time physical activities whereby the specific activity of LWs is coded separately from other muscle strengthening activities of push-ups and sit-ups. In this study, self-reported participation in the specific muscle strengthening activity of LWs was analyzed dichotomously (yes or no).

Statistical Analyses

The data in this study were initially managed using SAS 9.1 (22). The SAS was used to conduct both complex variable recodes and data coding validation. The SAS-callable SUDAAN (21) was then used to conduct the analysis, incorporating sampling weights within the context of the correlated multistage complex sampling design inherent to NHANES. Age-adjusted prevalence estimates were calculated using PROC DESCRIPT. For prevalence estimates, nonoverlapping 95% confidence intervals (CIs) indicate
significance. Logistic regression (PROC RLOGIST) analysis was used to estimate odds ratios (ORs) and 95% CI for MetS. Data were analyzed to estimate if there was a difference in the prevalence of MetS among U.S. adults who reported L Ws compared with those who did not and if risk estimates varied among those reporting L Ws compared with their counterparts who did not report L Ws.

**RESULTS**

**Prevalence of Lifting Weights by Demographics**

Approximately, 8.8% (95% CI 7.6, 10.1) of this subpopulation of the NHANES reported L Ws. Differences in reported L Ws were observed based on age, gender, race, education, and income.

**Age and Gender**

Table 1 illustrates an inverse relationship between the prevalence of L Ws and age across all the age groups. Among the participants who reported L Ws, there were significant differences in participation rates found between the younger men and women (third, fourth, and fifth decades of life) and older adults (seventh and eighth decades and older) ($p < 0.05$). When examining gender, significantly fewer women reported L Ws compared with men ($p < 0.001$) (Table 1).

**Race**

When examining race, the self-reported prevalence of L Ws was found to be similar among non-Hispanic Whites and non-Hispanic Blacks. The prevalence of L Ws was also found to be similar between non-Hispanic Blacks and Mexican Americans. However, significantly fewer Mexican Americans (5.6%; 95% CI 4.4, 7.2) reported engaging in L Ws compared with non-Hispanic Whites (9.6%; 95% CI 8.1, 11.4) ($p < 0.05$) (Table 1).

**Education and Income (Socioeconomic Status)**

The participants reporting less than a high school education (3.5%; 95% CI 2.2, 5.6) were found to report L Ws at a significantly lower rate than the participants who reported greater than a high school education (11.3%; 95% CI 9.8, 13.0) ($p < 0.05$) (Table 1).

**Metabolic Syndrome Prevalence**

According to the NHANES, between 1999 and 2004, the prevalence of MetS was found to be significantly lower (24.6%; 95% CI 19.3, 30.9) among adults reporting L Ws compared with that among adults not reporting L Ws (37.3%; 95% CI 35.5, 39.2). In the unadjusted model, U.S. adults were found to be 58% less likely (OR 0.42, 95% CI 0.29, 0.59) to have MetS compared with their counterparts not reporting L Ws (Table 2). After adjustment for age and other demographic variables, the adults reporting L Ws were found to be 37% less likely (OR 0.63, 95% CI 0.43, 0.92) to have MetS. Further adjustment for leisure-time physical activity (LTPA) slightly attenuated this association ($p = 0.08$).

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**Table 1. Age-adjusted prevalence of U.S. adults >20 years reporting lifting weights: 1999–2004 NHANES.**

<table>
<thead>
<tr>
<th>Sample N</th>
<th>Lifting weights % (SE)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>5,618</td>
<td>8.8 (0.82)</td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>871</td>
<td>14.5 (1.39)</td>
</tr>
<tr>
<td>30–39</td>
<td>917</td>
<td>10.5 (1.26)</td>
</tr>
<tr>
<td>40–49</td>
<td>1,007</td>
<td>10.2 (1.25)</td>
</tr>
<tr>
<td>50–59</td>
<td>763</td>
<td>5.7 (1.06)</td>
</tr>
<tr>
<td>60–69</td>
<td>949</td>
<td>3.9 (0.77)</td>
</tr>
<tr>
<td>70–79</td>
<td>645</td>
<td>3.5 (0.81)</td>
</tr>
<tr>
<td>&gt;80</td>
<td>466</td>
<td>2.0 (0.66)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2,836</td>
<td>11.2 (0.90)</td>
</tr>
<tr>
<td>Female</td>
<td>2,782</td>
<td>6.3 (0.59)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nh-White</td>
<td>2,908</td>
<td>9.6 (0.81)</td>
</tr>
<tr>
<td>nh-Black</td>
<td>1,022</td>
<td>7.3 (0.89)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>1,290</td>
<td>5.6 (0.68)</td>
</tr>
<tr>
<td>Other</td>
<td>418</td>
<td>6.8 (1.28)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;High school</td>
<td>1,793</td>
<td>3.5 (0.83)</td>
</tr>
<tr>
<td>High school/GED</td>
<td>1,302</td>
<td>7.2 (1.10)</td>
</tr>
<tr>
<td>&gt;High school</td>
<td>2,515</td>
<td>11.3 (0.81)</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20 K</td>
<td>1,199</td>
<td>5.5 (0.95)</td>
</tr>
<tr>
<td>20–45 K</td>
<td>1,690</td>
<td>5.7 (0.73)</td>
</tr>
<tr>
<td>&gt;45&lt;75K</td>
<td>1,138</td>
<td>9.2 (1.00)</td>
</tr>
<tr>
<td>&gt;75 K</td>
<td>991</td>
<td>13.8 (1.20)</td>
</tr>
</tbody>
</table>

*SE = standard error; nh = non-Hispanic; CI = confidence interval (nonoverlapping 95% CI indicate significant differences between groups within category); NHANES = National Health and Nutrition Examination Survey; GED = General Education Development (High School equivalency test).
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**TABLE 2.** Odds ratios of metabolic syndrome diagnosis according to lifting weights status: 1999–2004 NHANES.*

<table>
<thead>
<tr>
<th>Lifting weights</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes†</td>
<td>0.42</td>
<td>0.29, 0.59</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes‡</td>
<td>0.63</td>
<td>0.43, 0.92</td>
<td>0.01</td>
</tr>
<tr>
<td>No</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes§</td>
<td>0.72</td>
<td>0.50, 1.04</td>
<td>0.08</td>
</tr>
<tr>
<td>No</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*CI = confidence interval; NHANES = National Health and Nutrition Examination Survey; SES = socioeconomic status.
†Unadjusted model.
‡Adjusted for age, gender, race, SES, smoking status, family history of diabetes, family history of cardiovascular disease, and alcohol intake.
§Model b plus adjustment for leisure-time physical activity.

**DISCUSSION**

This study is novel in that it investigated the influence of the self-reported activity of LWs on the estimated prevalence and risk of MetS. The findings of this cross-sectional study are representative of U.S. adult men and women between 1999 and 2004, with specific regard to the associations of LWs and MetS. These data suggest that U.S. men and women who report LWs have a significantly lower prevalence of MetS (24.6%; 95% CI 19.3, 30.9) than those not reporting LWs (37.3%; 95% CI 35.5, 39.2). Additionally, U.S. adults who reported LWs were found to be significantly less likely to have MetS; however, when considering LTPA, this association was slightly attenuated (p = 0.08). These findings substantiate those of previous studies of muscular strength and mass, which inferred that LWs may play a role in reducing the incidence of MetS among U.S. adults.

Both muscle strength and muscle mass are highly influenced by RE activities (1). Several epidemiological studies have examined the relationship between measured muscular strength and muscle mass and the prevalence of MetS (2,16,17,20,23,26). Invariably, these studies have demonstrated an inverse relationship between measured muscular strength and muscle mass and the prevalence of MetS alluding to the possible preventative effect of RE.

Cross-sectional studies that have assessed the associations of both upper body (hand grip dynamometer) (2,20,23) and lower body (leg extension dynamometer) (20,26) isometric strength have consistently demonstrated an inverse relationship with the prevalence of MetS. In an analysis of 1,216 Japanese men aged 20–79 years, Miyatake et al. (20) found significantly lower levels of both upper and lower body isometric strengths (relative to body weight) among men diagnosed with MetS compared with those who did not meet MetS criteria. In a study of 1,579 English men and 1,418 English women aged 59–73 years, Sayer et al. (23) found that lower isometric grip strength was significantly associated with increased odds of having MetS using the National Cholesterol Education Program Adult Treatment Panel III (p < 0.001) (3) and the International Diabetes Federation MetS definitions (p = 0.03) (15).

Atlantis et al. (2) studied a cohort of 1,195 Australian men aged 35–80 years from the northwest regions of Adelaide. They found low muscle strength to be a significant factor associated with an increased risk of MetS. Additionally, they hypothesized that MetS prevalence would have been significantly attenuated (14% reduction) if the participants increased their strength scores from the second to the fourth quartile of muscle strength. In a study of 571 male and 448 female Flemish subjects, Wijndaele et al. (26) found lower body muscular strength to be inversely associated with MetS in women, even after extensive adjustment for potential confounding factors including aerobic fitness. The inverse association found between muscular strength and MetS in men was weaker and not independent of aerobic fitness.

In another cross-sectional study of 8,570 predominantly non-Hispanic white U.S. men, Jurca et al. (16) found a strong inverse gradient of MetS incidence across quartiles of dynamic muscular strength (p < 0.0001). They also found a strong direct association (p < 0.001) between maximal muscular strength and the frequency of self-reported RE activity. This led to the hypothesis that the preventative effects of increased strength may be largely related to participation in RE activities (17). This is in agreement with the findings of this study where the self-reported activity of LWs was inversely associated with the prevalence of MetS.

Prospective data describing the impact of RE on MetS are just beginning to emerge. Levinger et al. (19) implemented a 10-week progressive total body RE intervention among subjects with a high number of metabolic risk factors (HiMFs) and found significant increases in both muscle strength and muscle mass. Additionally, HiMF participants who completed the RE intervention experienced significant improvements in their self-reported quality of life and their demonstrated capacity to perform activities of daily living. As long-term prospective RE studies continue to manifest, an important focus should be to examine whether increases in muscle mass and strength translate into reductions in the comprehensive diagnosis of MetS.

It is important to note that although the percentage of U.S. adults reporting LWs was lower in this study than in previous reports, trends found among the subjects reporting LWs in this study were similar to trends found in previous studies of RE activities (7,13,24). Reported LWs was higher among young vs. older adults, men vs. women, non-Hispanic White vs. Mexican American, high school graduates vs. non–high school graduates, and higher vs. lower income groups.
This study is not without limitations. The determination of whether study subjects participated in the RE activity of LWs was based on self-report. Additionally, LWs is 1 form of RE used to improve muscle strength and size, but study subjects may have participated in other forms of muscle strengthening activities (resistance bands, calisthenics, manual labor) not captured by the LWs designation. Therefore, although this study suggests that participating in the RE activity of LWs may play a role in the protective effect observed in other cross-sectional studies of increased muscle mass and strength on the risk and prevalence of MetS, this warrants further study.

In summary, this study illustrated that U.S. adults who report participating in the activity of LWs have significantly lower prevalence and risk estimates of MetS compared with those who do not report LWs. This is in line with the previously reported associations attributed to increases in either muscular strength or muscle mass and the reduced risk and prevalence of MetS.

**Practical Applications**

This study is meant to raise the awareness of strength and conditioning professionals about the benefits of LWs beyond the athletic and fitness populations. Adults living in the U.S.A. who report participating in the activity of LWs have a significantly lower prevalence and risk estimates of MetS compared with those who do not report LWs. This information provides support to justify funding of prospective studies designed to better understand the relationship between MetS and LWs. This study also highlights the importance of promoting the adoption of RE and RWs among subgroups of U.S. adults who undergo this valuable health-promoting activity such as women, older adults, Mexican Americans, and those of lower SES.

**Acknowledgments**

Disclosure: Investigators received no funding for this work.

**References**