Relations of Meeting National Public Health Recommendations for Muscular Strengthening Activities With Strength, Body Composition, and Obesity: The Women's Injury Study

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Objectives. We examined the relations of meeting or not meeting the *2008 Physical Activity Guidelines for Americans* recommendations for muscular strengthening activities with percentage of body fat, body mass index (BMI; defined as weight in kilograms divided by height in meters, squared), muscular strength, and obesity classification in women.

Methods. We analyzed data on 918 women aged 20 to 83 years in the Women's Injury Study from 2007 to 2009. A baseline orthopedic examination included measurement of height, body weight, skinfolds, and muscle strength.

Results. Women who met muscle strengthening activity recommendations had significantly lower BMI and percentage of body fat and higher muscle strength. Women not meeting those recommendations were more likely to be obese (BMI≥30) compared with women who met the recommendations after we adjusted for age, race, and aerobic physical activity (odds ratio = 2.28; 95% confidence interval = 1.61, 3.23).

Conclusions. There was a small but significant positive association between meeting muscle strengthening activity recommendations and muscular strength, a moderate inverse association with body fat percentage, and a strong inverse association with obesity classification, providing preliminary support for the muscle strengthening activity recommendation for women. (*Am J Public Health.* 2011;101: 1930–1935. doi:10.2105/AJPH.2011.300175)

The benefits of increased muscle mass and muscle strength have become well recognized and documented.[1] Higher levels of muscular strength, independent of aerobic fitness level, are associated with lower all-cause mortality in men and women,[2,3] and lower incidence of metabolic syndrome in healthy men.[4] Muscular strength has been shown to be inversely related to excessive body fat and abdominal fat,[5] both of which are associated with increased risk for chronic diseases and adverse events that include heart disease,[6,7] type 2 diabetes,[8–10] cancer,[11] and stroke.[7,12] Muscle strength becomes especially important for preventing falls[13,14] and ability to function independently in the later years of life.[15] Among older adults, lower extremity muscle strength and power have a positive association with walking speed[16,17] and walking distance in everyday walking behavior.[17]

With the known benefits of muscular strength, public health physical activity guidelines have included muscle strengthening activities.[1,18] Resistance exercise increases muscle mass and improves muscle strength and endurance.[1] Jurca et al. demonstrated that men who reported participating in higher levels of resistance training had higher levels of muscular strength,[19] but this relationship has not been demonstrated in women. The *2008 Physical Activity Guidelines for Americans* recommend muscle strengthening activities on 2 or more days per week in addition to aerobic activity for adults.[18] Specifically, the guidelines state:

> adults should also do muscle-strengthening activities that are moderate or high intensity and involve all major muscle groups on 2 or more days a week.[18(p22)]

Women meet the overall physical activity guidelines at a lower rate than do men, and even fewer women report participating in muscle strengthening activities. The prevalence of self-reported strength training 2 or more days per week by women from 1998 to 2004 was 14.4% to 17.5%.[20] Even when women meet the recommended muscle strengthening activity guidelines, it has not been established that meeting the recommendation results in improved muscular strength or improved health benefits in women.

We examined the relations of meeting or not meeting the recommended frequency of 2 or more days per week of muscle strengthening activities with objective measures of muscular strength, percentage of body fat, and obesity classification in women. This information provides preliminary validation of the muscle strengthening activity recommendation presented in the 2008 guidelines.

METHODS

The Women's Injury Study is a surveillance of physical activity behaviors and musculoskeletal injuries in adult community–living women aged 20 to 83 years. We recruited participants from a listing of more than 6000 women who had visited, contacted, or completed health or fitness assessments at the Cooper Institute in Dallas, Texas. Additional recruitment methods included advertisements, health fairs, and community meetings. We excluded from study women who needed an assistive device to ambulate or those who had a disease or condition that limited their mobility, or limited or interfered with their usual daily or recreational activities. Participants reported physical activity behavior including frequency of muscle strengthening activities weekly via the Internet for up to 3 years from 2007 to 2009. Details of the Women's Injury Study are presented elsewhere.[21] A baseline orthopedic examination was conducted by a physical therapist and included anthropometric measures, flexibility, muscle strength, ligamentous laxity, and postural measures. The anthropometric and muscle strength measures were the focus of this study; therefore, only the procedures related to those measures are presented.

Measurements

Anthropometric measurements. We measured height and weight with a stadiometer (Meyer Distributing, Twinsburg, OH) and digital scale (Tanita Corporation, Arlington Heights, IL), respectively, and took skinfold measurements at 3 sites (triceps, suprailiac, and thigh) with a Lange caliper (Beta Technology, Santa Cruz, CA). We then estimated percentage of body fat by using the Jackson–Pollock equation.[22] Skinfold measurements taken at these 3 sites have been shown to provide a valid and reliable estimation of percentage of body fat in women.[22]

Muscle strength measurements. We measured grip strength with a Jamar (Sammons Preston Inc, Bolingbrook, IL) grip dynamometer according to standardized testing procedures developed by the American Society for Hand Therapists.[23,24] We tested participants as they sat in a chair with arms close to their sides and elbow flexed 90°. The examiner instructed the participant to squeeze the dynamometer as hard as possible. Testing was performed twice for each hand and the average of 2 measurements recorded to the nearest kilogram. Intra- and interrater reliability of the Jamar dynamometer for measuring grip strength in healthy individuals have been demonstrated previously (intraclass correlation [ICC]=0.87–0.97).[25]

We assessed lower extremity muscle strength with the Human Performance Measurement system (Human Performance Measurement Inc, Arlington, TX). The Human Performance Measurement system is a computer-automated system that assesses a selection of sensorimotor functions called basic elements of performance (BEP). The BEP IIIa is a handheld dynamometer (HHD) and a component of the Human Performance Measurement system that measures isometric muscle strength. The BEP Windows software was used to run the BEP modules and record data. The software automatically calculates torque in newton-meters (Nm) by using estimated moment arm lengths based on the participant's height.

We performed lower extremity muscle strength testing bilaterally on the following muscle groups: hip abductors, hip external rotators, knee extensors, and knee flexors. For each muscle group, participants practiced once before performance of 2 maximum effort trials with the mean used for data analysis. For each muscle test trial, the examiner instructed the participant to gradually start pushing against the dynamometer, and then to push as hard as possible. A second contraction was measured in the same manner after a 4- to 5-second pause. The examiner made a visual assessment of the results of 2 test trials to ensure that the values for each trial were similar to each other and therefore likely to represent maximal effort. When differences between 2 test trials were excessive (>5 Nm), the test trials were repeated after a 1- to 2-minute rest. Previous studies have shown that strength of the tester can be a major factor in the reliability of forces measured with a HHD.[26,27] To remove tester strength as a variable and improve reliability, straps were used to stabilize the dynamometer during testing of all lower extremity muscle groups. Reliability of muscle strength testing of the hip abductors and external rotators ($ICC_{3,3}$=0.97 and 0.85)[28] and strength testing of knee extensors and flexors ($ICC_{3,2}$=0.93 and 0.84, respectively)[29] using an HHD stabilized with a strap have been demonstrated. For all lower extremity muscle tests, the examiner used one hand to stabilize the body part tested while maintaining the position of the HHD under the stabilization strap with the other hand. For the purposes of data analysis, we used only measurements from the right side because strength measurements on the right and left side were highly correlated (r=0.83) and 94% of participants were right-hand dominant.

Assessment of physical activity. As part of the baseline assessment, participants self-reported their muscle strengthening activity by answering "yes" or "no" to a question asking if they had performed "resistance exercises (using free weights or weight machines, calisthenics, power yoga, pilates, etc.)" during the past month. If participants answered yes, they were asked to indicate the average number of days per week they performed muscle strengthening activities. Consistent with the *2008 Physical Activity Guidelines for Americans*, they were categorized as meeting the strengthening guidelines if they reported 2 or more days per week of strengthening activities.

To control for aerobic physical activity as a confounder in assessment of the relations of muscle strengthening activity with strength and body mass variables, we obtained moderate and vigorous physical activity minutes per week from the online self-report of weekly physical activity behaviors. We used the following questions based on the Behavioral Risk Factor Surveillance System (http://www.cdc.gov/brfss) to assess moderate and vigorous physical activity: "During the past 7 days, did you do moderate activities for at least 10 minutes at a time, such as brisk walking, bicycling, vacuuming, gardening, or anything else that causes small increases in breathing or heart rate and would not make you strain?" and "During the past 7 days, did you do vigorous activities for at least 10 minutes at a time, such as running, aerobics, heavy yard work, or anything else that causes large increases in breathing or heart rate and would eventually make you strain?" Answering yes to either of these questions resulted in a follow-up question requesting the days per week and minutes per day the activity was performed that week.

For the present study, we used data from week 1 of the online self-report responses to the moderate and vigorous questions. Consistent with the *2008 Physical Activity Guidelines for Americans*, we obtained the accumulated total minutes of moderate and vigorous physical activity for each individual. As suggested by the guidelines, we multiplied vigorous minutes by 2 and added them to moderate minutes.[18] We designated individuals accumulating 150 or more minutes of moderate and vigorous physical activity as sufficiently active for health benefits. Using data for week 1 allowed moderate and vigorous physical activity to be closely linked in time to the baseline assessment of strength and muscle strengthening activity. In a separate study of the measurements obtained for moderate and vigorous physical activity, reliability estimates exceeded 0.90.[30]

Data Analysis

We categorized participants as meeting or not meeting the *2008 Physical Activity*

Guidelines for Americans for aerobic and strengthening activities. We calculated and reported descriptive statistics separately for those who met or did not meet the guidelines for muscle strengthening activities. We conducted 2 analyses of covariance (ANCOVA) to contrast the muscle strengthening activity groups. Body mass index (BMI; defined as weight in kg divided by height in m^2) and percentage of body fat were the dependent variables and age was the covariate in the analyses. We also performed a multivariate analysis of covariance (MANCOVA) to contrast the muscle strengthening activity groups with the 5 measures of strength as dependent variables and age and body weight as covariates. To determine the relation between obesity status (BMI≥30) and muscle strengthening activities, we used logistic regression and calculated odds ratios (ORs) with 95% confidence intervals (CIs). Confounders controlled in the logistic regression were age, race, and meeting or not meeting MVPA recommendations.

RESULTS

Of the 918 participants who underwent the orthopedic examination 13 had missing data or were excluded from study because of pain with muscle strength testing. Of the remaining 905 women (age=53 ±13 years), 77% were White and 23% were non-White (Black, Hispanic/Latina, other). Table 1 provides descriptive statistics. Contrasted with women who did not meet muscle strengthening activity recommendations (n=522; 58%), those who met the muscle strengthening activity recommendations (n=383; 42%) were younger, lower in body weight, higher in moderate and vigorous physical activity, lower on BMI, lower on percentage of body fat, stronger on all strength measures, and lower in the percentage classified as obese. Almost an equal percentage of participants met (51%) or did not meet (49%) the moderate and vigorous physical activity recommendations. Although age, height, and weight were meant mainly to be descriptive, each can have an effect on muscle strength measures, so we conducted an independent *t*-test to establish equality between the groups (met or did not meet muscle strengthening activity recommendations) on these 3 variables. We found significant differences between the groups in body weight ($P<.001$) and age ($P<.05$), with women who did not meet muscle strengthening activity recommendations being significantly older and heavier than were women who did meet muscle strengthening activity recommendations. For this reason, we controlled for age and body weight when appropriate for subsequent analyses.

The ANCOVA with BMI as the dependent variable and with control for age indicated a significant difference ($P<.001$) between the muscle strengthening activity groups with a moderate effect size (ES) of 0.45. The ANCOVA for percentage of body fat as the dependent variable and control for age also indicated a significant difference ($P<.001$) with a moderate ES of 0.53. Women who met muscle strengthening activity recommendations were significantly leaner based on both measures of body composition.

The MANCOVA with the 5 strength measures as dependent variables and age and body weight as covariates indicated a significant ($P<.034$) multivariate difference between the muscle strengthening activity groups. As a follow-up to the multivariate effect, univariate ANCOVA indicated significant differences for knee extension ($P<.001$; ES=0.22), knee flexion ($P<.028$; ES=0.17), and hip abduction ($P<.029$; ES=0.22).

The prevalence of obesity is provided in Table 2 based on participants meeting or not meeting recommendations for muscle strengthening activities, moderate and vigorous physical activity, and combinations of muscle strengthening activities and moderate and vigorous physical activity classifications. The prevalence of obesity for the total sample was 28%. In almost all cases, participants meeting muscle strengthening activity or moderate and vigorous physical activity recommendations had a lower prevalence of obesity than did the total sample. The exception was participants who did not meet the muscle strengthening activity recommendations but did meet the moderate and vigorous physical activity recommendations. Participants who met neither recommendation had the highest prevalence of obesity at 40%.

The results of logistic regression are also presented in Table 2. The Hosmer–Lemeshow test indicated an adequate fit of the logistic regression models to the data ($P>.195$). The model indicated a significantly increased odds (OR=2.28; 95% CI=1.61, 3.23) of being classified as obese (BMI≥30) for those participants who did not meet the muscle

TABLE 1—Descriptive Statistics: Women's Injury Study, Dallas, TX, 2007-2009

	Met MSA Recommendations, No. (%) or Mean ±SD	Did Not Meet MSA Recommendations, No. (%) or Mean ±SD
Participants	383 (42)	522 (58)
Age, y	50.5 ±13.0	54.0 ±12.0
Weight, kg	69.3 ±14.8	77.1 ±18.1
Height, cm	163.7 ±5.8	163.5 ±6.6
MVPA, min[a]	352.0 ±426.8	169.7 ±253.7
BMI, kg/m^2	25.9 ±5.3	28.8 ±6.5
Percentage of body fat	29.7 ±7.2	33.7 ±7.5
Grip strength, kg	27.2 ±5.3	26.9 ±6.4
Knee extension, Nm	85.6 ±24.8	80.0 ±26.0
Knee flexion, Nm	41.1 ±12.7	38.7 ±13.8
Hip abduction, Nm	47.2 ±16.7	43.5 ±16.8
Hip external rotation, Nm	25.8 ±9.5	24.8 ±9.8
Obese (BMI≥30)	62 (17)	179 (36)

Notes. BMI = body mass index (weight in kilograms divided by height in meters squared); MSA = muscle strengthening activities; MVPA = moderate and vigorous physical activity. Meeting MSA recommendations was defined as performing strengthening activities on ≥2 d/wk.
[a]Missing data for 35 participants.

TABLE 2—Prevalence of Obesity and Results of Logistic Regression Analyses: Women's Injury Study, Dallas, TX, 2007–2009

	Obesity Prevalence (BMI ≥ 30)		
	Overall,[a] No.	Obese, No. (%)	OR (95% CI)
MSA recommendations			
Did not meet	502	179 (36)	2.28[b] (1.61, 3.23)
Met (Ref)	368	62 (17)	1.00
MVPA recommendations			
Did not meet	435	152 (35)	1.56[c] (1.12, 2.16)
Met (Ref)	435	89 (20)	1.00
MSA and MVPA recommendations			
Met MSA and not MVPA	123	27 (22)	1.73[d] (0.97, 3.08)
Met MVPA and not MSA	190	54 (28)	2.35[d] (1.44, 3.82)
Did not meet both	312	125 (40)	3.45[d] (2.23, 5.35)
Met both (Ref)	245	35 (14)	1.00

Note. BMI = body mass index (weight in kilograms divided by height in meters squared); CI = confidence interval MSA = muscle strengthening activities; MVPA = moderate and vigorous physical activity; OR = odds ratio. Meeting MSA recommendations was defined as performing strengthening activities on ≥ 2 d/wk. Meeting MVPA recommendations was defined as ≥ 150 min/wk of accumulated moderate and vigorous aerobic activity, where vigorous minutes were multiplied by 2 and added to moderate.
[a]Missing MVPA data for 35 participants, n = 870.
[b]Controlled for age, race (White or non-White), and MVPA.
[c]Controlled for age, race (White or non-White), and MSA.
[d]Controlled for age and race (White or non-White).

strengthening activity recommendations after controlling for age, race, and moderate and vigorous physical activity. The odds of being classified as obese were 128% greater for participants who did not meet the muscle strengthening activity recommendations. Not meeting the recommendations for moderate and vigorous physical activity increased the odds of being classified as obese by 56%. Not meeting either or both of the recommendations produced increased ORs when we used the participants who met both recommendations as the referent group.

DISCUSSION

With the 1996 Surgeon General's report on physical activity and health and the *2008 Physical Activity Guidelines for Americans*, the US Department of Health and Human Services established specific recommendations for physical activity participation for public health.[18,31] These recommendations were based on a large body of scientific evidence relating higher levels of physical activity and fitness with lower risks for a variety of chronic diseases.[32] In the guidelines, a specific recommendation of 2 or more days per week of muscle strengthening activities for adults was presented. We studied the association of meeting or not meeting the muscle strengthening activity recommendations with muscular strength, body composition, and obesity classification in adult women. After we controlled for relevant confounders, the findings demonstrated a small but significant positive association between meeting the recommendations and muscular strength, a moderate inverse association with body composition as measured by percentage of body fat and BMI, and a strong inverse association with the classification of obesity. The associations observed in the present study provide preliminary support for the muscle strengthening activity recommendation of the guidelines for adult women. Randomized controlled studies should be undertaken to determine if increasing muscle strengthening activity results in reduced obesity.

Results of our study are in agreement with findings from a study by Jackson et al. showing that the prevalence and incidence of obesity decreased systematically with increasing quintiles of muscular strength in adult men, after the authors corrected for age, body weight, and fitness level.[5] Jackson et al. concluded that their study provides support for the current public health recommendations for resistance exercise but that similar studies should be conducted on women. We examined the relationship between current public health recommendations for resistance training and prevalence of obesity in women, but we investigated this relationship by examining prevalence of obesity in women who met or did not meet recommendations for muscle strengthening activities 2 or more days per week rather than in relation to quintiles of muscular strength. Therefore, our study concurs with the study by Jackson et al. but more directly supports the *2008 Physical Activity Guidelines for Americans* recommendation for muscle strengthening activities.

The national prevalence of obesity in 2007 to 2008 for adult women was 35.5%,[33] whereas prevalence for the total participant sample in the current study was 28%. Therefore, participants in our study had a lower level of obesity than did the national average for women. However, 36% of the women who did not meet the muscle strengthening activity recommendation were classified as obese, which is similar to the national percentage. Only 17% of the women who met the muscle strengthening activity recommendation were classified as obese. Flegal et al. investigated obesity prevalence and trends among US adults from 1999 to 2008 and concluded that the prevalence of obesity for women showed no statistically significant change (increase of 2.1%) for the 10-year period from 1999 to 2008.[33] This finding represents an important change from the striking increases seen in similar studies in the 1980s and 1990s leading Flegal et al. to comment that the prevalence in obesity "may have entered another period of relative stability."[33(p240)] Still, it remains that 35.5% of women in the United States have a BMI of 30 or higher.

Given that only 14.4% to 17.5% of women report participating in muscle strengthening activities 2 or more days per week,[20] increasing participation in muscle strengthening activities remains a potential intervention for lowering the current obesity prevalence. Obesity is a result of energy imbalance over a prolonged period of time that can be altered by decreasing energy intake or increasing energy expenditure. Total energy expenditure is largely comprised of resting energy expenditure and activity-related expenditure, with resting expenditure normally making up the largest portion of total energy expenditure.[34] Resting energy expenditure can be altered by increasing muscle metabolism and can vary substantially depending on muscle mass.[35] The results of our study demonstrate that women who meet the guidelines for muscle strengthening activities have a lower prevalence of obesity and, therefore, support the positive energy balance effects of muscle strengthening activities. However, the current study was observational, and therefore we cannot make definitive statements regarding the effect of muscle strengthening activities on obesity.

The women in the Women's Injury Study reported participating in muscle strengthening activities at a higher rate than the national average. Nationally, only 14.4% to 17.5% of women report participating in muscle strengthening activities 2 or more days per week[20] compared with 42% of participants in the present study. Part of the reason for this discrepancy may be that the question used to assess muscle strengthening activity in the national study stated "How often do you do physical activities designed to strengthen your muscles, such as lifting weights or doing calisthenics?" The question in the Women's Injury Study asked how often women performed resistance exercises (using free weights or weight machines, calisthenics, power yoga, pilates, etc.). Adding power yoga and pilates as examples likely added to the prevalence of women who met the guidelines for muscle strengthening activities.

Performing muscle strengthening activities 2 or more days per week appears to be effective for strengthening the major lower extremity muscle groups (hip abductors, knee flexors, and extensors). However, women in our study who met the guidelines for muscle strengthening activities were not stronger in measures of hip external rotation and hand grip compared with women who did not meet muscle strengthening guidelines. There are several possible explanations for this finding. Hip external rotators were selected to meet the overall objective of the Women's Injury Study to investigate musculoskeletal risk factors for injury. Because hip external rotator muscle strength is generally not considered to be of vital importance to functional independence, muscle strengthening activities for improving hip external rotator strength may not have been performed as part of an overall strengthening program. Hip external rotator exercises are not commonly included in a lower extremity strengthening program, but hip abductor and knee flexor and extensor exercises generally are included. Because gripping is used in many forms of muscle strengthening activities, it was somewhat unexpected that grip strength was essentially equal for women meeting and not meeting muscle strengthening activity recommendations. Grip strength is considered a surrogate measure of upper body strength as well as overall muscular strength, and lower values of grip strength have been associated with all-cause mortality[36–38] and disability.[36] Therefore, the finding of equal grip strength in women meeting or not meeting muscle strengthening activity guidelines in our study is particularly important. Further studies examining the muscle strengthening practices of women (i.e., types of exercises performed, repetitions, sets) should be undertaken to help clarify these findings.

In cross-sectional studies such as ours, recruited in a localized geographic region, it is useful to judge the participants' basic representativeness of the population. Our participants were similar to national reported population data on 2 important variables to the present study. Of our participants, 39% had a normal BMI classification (BMI = 18.5–24.9) whereas 61% were overweight or obese (BMI ≥ 25). *Health, United States, 2009*, from the National Center for Health Statistics indicates that 35% of women have a normal BMI whereas 63% are overweight or obese.[39] National statistics on the prevalence of meeting the *2008 Physical Activity Guidelines for Americans* vary from 40%[40] to 60%[41] for women depending on the source. The Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (http://www.cdc.gov/brfss) indicates that 49% of adult women are moderately or vigorously active. In the present study, 50% of the participants were moderately or vigorously active according to criteria established from the 2008 guidelines.

A limitation of the study is that women self-reported how many days per week they performed muscle strengthening activities, but we do not know anything about the types of activities performed, intensity of exercises, or sets and repetitions performed.

The results of this study provide a unique contribution to the preventive medicine and public health literature by specifically relating public health recommendations for muscle strengthening activities to relevant health and fitness variables in a sample (i.e., adult women) representing a population in need of adequate participation in muscle strengthening activities. Further studies should be conducted to determine the types, intensities, and amounts of muscle strengthening activities performed by women to further clarify the health benefits of these activities. ■

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E. Trudelle-Jackson and J. R. Morrow Jr were responsible for the conceptualization of the study, and contributed to writing and reviewing all sections of the article. A. W. Jackson assisted with data analysis and interpretation, and contributed to writing the Methods section.

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Human Participant Protection

Informed consent was obtained from all participants upon entry into the study and before participation in the orthopedic examination. Consent forms and study protocols were reviewed annually by the institutional review board at the Cooper Institute.

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