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Clinical Implications for Muscle Strength Differences in Women of Different Age and Racial Groups: The WIN Study

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Abstract

Background—Reduction in muscle strength is strongly associated with functional decline in women, and women with lower quadriceps strength adjusted for body weight are more likely to develop knee osteoarthritis.

Objective—To compare body weight--adjusted strength among women of different age/racial groups.

Study Design—Cross-sectional study of muscle strength in 918 women aged 20--83 ($M \pm SD = 52 \pm 13$).

Methods—An orthopedic examination was conducted including measurement of handgrip and lower extremity strength (hip abductors/external rotators, knee flexors/extensors). Data were grouped into young (20--39 years, n = 139), middle (40--54 years, n = 300), and older (55+ years, n = 424) ages for white (n = 699) and African American (AA) (n = 164) women. Means and standard deviations for strength adjusted for body weight were calculated for each age and racial group and compared using 2-way multivariate analysis of variance and post hoc tests.

Results—No significant age-by-race interaction ($P = .092$) but significant main effects for age and race ($P < .001$). Pairwise comparisons revealed significant differences in knee extensor and flexor strength between all age groups. For grip and hip external rotator strength, significant differences were found between the middle and older groups. Differences in hip abductor strength were found between the young and middle-aged groups. AA women had lower strength than white women in all muscle groups ($P < .05$) except hip external rotators.

Conclusions—Strength decreased with age in all muscle groups but magnitude of decrease varied by muscle. Strengthening programs should target different muscles, depending on a woman's age and race.

Keywords

African American; osteoarthritis; physical activity guidelines

Introduction

Muscle strength is needed to generate forces that produce or stabilize joint movement. Skeletal muscle mass and strength decline with age[1--3] and these declines are associated with increased risk of falls and fractures,[4] decreased ability to perform self-care activities,[5]

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and increased disability.[6--8] Sarcopenia, the loss of muscle mass, is more prevalent in women and tends to be more severe.[7] Data from the Third National Health and Nutrition Examination Survey reveal that 45% of men and 59% of women older than 60 years have class I (moderate) sarcopenia and that 7% and 10% of men and women, respectively, have class II (severe) sarcopenia.[7] Although the relationship between muscle mass and muscle strength is not fully understood, several studies show a steady decline in muscle strength beginning around the age of 30 years, and accelerating in women around the age of 55 years.[1,2] Furthermore, reduction in muscle strength is more strongly associated with functional decline in women than in men.[2]

There is agreement about the steady decline in muscle strength with age, but magnitude of the decline may vary by muscle group. Samson et al[2] showed that in women between 20 and 55 years, knee extensor strength and handgrip strength decreased by 10.3% and 8.2%, respectively. However, between 55 and 80 years, quadriceps strength decreased by 40.2% while grip strength decreased only by 28%.[2] Most studies of muscle strength and aging use handgrip or knee extensors because these are thought to represent the behavior of upper and lower extremity strength, respectively.

Evidence suggests that other factors including gender, race/ethnicity, and body mass index (BMI) may influence changes in muscle strength associated with disease such as the development of osteoarthritis (OA).[9--11] Slemenda et al[9] showed that knee OA was associated with increased body weight in women but not in men. In addition, these authors found that knee extensor strength adjusted for body weight was 18% lower in women who subsequently developed knee OA than in women who did not develop OA over the next 2 to 3.5 years. On the basis of this finding, Slemenda et al[9] concluded that decreased knee extensor strength relative to body weight may be a risk factor for development of knee OA.[9] Hootman et al[12] also studied lower extremity muscle strength in 3081 community-dwelling men and women and found that women with higher values of quadriceps peak torque to body weight ratios had a 55% to 64% lower risk of having hip or knee OA.[12]

Differences in body composition and weight,[13,14] varying levels of physical activity,[15] and anthropometric differences have been reported between races.[14,16] Thus it is reasonable to believe that racial differences in muscle strength may exist and could contribute to the higher incidence of OA observed in black women than in white women. Data from the First National Health and Nutrition Examination Survey demonstrated racial differences associated with incidence of knee OA in black women, but not in men. Black women were found to be at an increased risk of disease (odds ratio = 2.12; 95% confidence interval = 1.39--3.23) compared with white women, even after controlling for age and body weight.[10] A greater understanding of muscle strength differences in racial groups could be important to prevention and treatment of OA as both body weight and muscle strength have been implicated as important factors for development of OA.

Few studies have directly investigated differences in muscle strength between racial groups across a wide age range. Taaffe et al[17] compared baseline measures of handgrip and knee extensor strength in white and African American (AA) women aged 70 to 79 years from the Health, Aging, and Body Composition (Health ABC) study and found both strength measures to be significantly greater in the AA women ($P < .001$).[17] Goodpaster et al[18] examined the same participants from the Health ABC study but examined declines in baseline strength measure over a 3-year period and reported that knee extensor strength declined at a higher annual rate ($P < .05$) in AA men and women than in white men and women.[18] Both of these studies investigating racial differences in muscle strength were limited in the range of ages (70--79 years), thereby limiting conclusions about muscle strength for younger and middle-aged women. The purposes of this study were as follows:

(1) to compare handgrip and lower extremity muscle strength values among apparently healthy women of different racial groups across 3 age groups (young, middle, older) and (2) to determine whether differences in strength across racial and age groups are consistent for different muscles. We hypothesized that handgrip and lower extremity muscle strength would differ for age and racial groups. We also hypothesized that strength differences in age and/or racial groups would not be consistent in all muscles.

Methods and Measures

Participants

This was a cross-sectional study of muscle strength in community-living women between the ages of 20 and 83 years. Data for the study were obtained from a larger study of women's injuries (WIN). Women's injuries is a surveillance study of physical activity behaviors and musculoskeletal injuries in adult women. Details of WIN are presented elsewhere.[19] Participants were recruited for the WIN study between 2007 and 2008 from a listing of more than 6000 women who had visited, contacted, or completed health and/or fitness assessments at The Cooper Institute in Dallas, Texas. Additional recruitment methods included advertisements, health fairs, and community meetings. Attempts were made to have a sample reflective of the greater Dallas-Fort Worth Metroplex. Recruitment methods resulted in 23% race/ethnic minority at study onset. Women were excluded if they had a disease or condition that limited their mobility or they needed an assistive device to ambulate or if the condition limited or interfered with their usual daily or recreational activities. During an orientation session, eligible women gave informed consent for participation in the WIN study. The WIN study was approved by The Cooper Institute institutional review board. After consenting to participate, women completed a questionnaire requesting demographic and medical history information. The current study obtained data from a baseline orthopedic examination conducted by a physical therapist that included anthropometric, joint range of motion, flexibility, muscle strength, ligamentous laxity, and postural measures. For this article, however, only procedures and data specific to anthropometrics and muscle strength are presented.

Measurements

Anthropometric measurements—Height and weight were measured using a stadiometer and digital scale, respectively. Skinfold measurements were taken at 3 sites (triceps, suprailiac, thigh), using a Lange caliper, and percent body fat was estimated using the Jackson-Pollock equation.[20] Skinfold measurements taken at these 3 sites have been shown to provide a valid estimation of percent body fat in women[20] and have been shown to be reliable.[21]

Muscle strength measurements—Grip strength was measured using a Jamar (Sammons Preston, Inc, Bolingbrook, Illinois) grip dynamometer. Hand grip strength measurements were performed according to standardized testing procedures developed by the American Society for Hand Therapists.[22,23] Participants sat with their arm close to their side with elbow flexed to 90°. They were then instructed to squeeze the dynamometer as hard as possible. The test was performed twice for each hand and the average of two measurements was recorded to the nearest kilogram. Intra- and interrater reliability of the Jamar dynamometer for measuring grip strength in healthy individuals have previously been demonstrated (ICC = 0.87--0.97).[24]

Lower extremity muscle strength was assessed using the Human Performance Measurement (HPM) system (Human Performance Measurement, Inc., Arlington, Texas). The HPM is a computer-automated system used to assess a selection of sensorimotor functions called basic elements of performance (BEP). The BEP IIIa is a hand-held dynamometer (HHD) and a component of the HPM system used to run the BEP modules and record and store data. The software automatically calculates torque in Newton·meters (Nm) using estimated moment arm lengths based on the subject's height.

Lower extremity muscle strength testing was performed bilaterally on the following muscle groups: hip abductors, hip external rotators, knee extensors, and knee flexors. For each muscle group, participants practiced once prior to performance of 2 maximum effort trials. The mean of the 2 maximum effort trials was recorded and used for data analysis. For each muscle test trial, the participant was instructed to gradually start pushing against the dynamometer at the sound of an electronic beep and then to push as hard as she could against the dynamometer until a second electronic beep was heard. A second contraction was measured in the same manner after a 4- to 5-second pause. A visual assessment of the results of 2 test trials was made by the examiner to ensure that the values for each trial were similar to each other and therefore likely to represent maximal effort by the subject. When difference between 2 test trials was excessive (>5 Nm), the test trials were repeated after a 1- to 2-minute rest. 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 rather than having the tester manually hold the dynamometer. Reliability of muscle strength testing of the hip abductors and external rotators using an HHD stabilized with a strap has been demonstrated ($ICC_{3,3}$ = 0.97 and 0.85).[25] Reliability of strength testing of the knee extensors and flexors using an HHD stabilized with a strap has been demonstrated using identical muscle testing procedures in a group of 30 women ($ICC_{3,2}$ = 0.93 and 0.84, respectively).[26]

Hip abductor muscle strength was tested with the participant positioned supine, legs extended, and ankles 6 inches apart. The HHD was stabilized against the lateral aspect of the distal femur. The strap was affixed around the treatment table and secured over the leg being tested without interfering with the opposite leg. The examiner stabilized the participant's opposite leg with one hand, while ensuring that the HHD remained secure in its position under the stabilizing strap with the other hand. Hip external rotator strength was measured with the participant sitting on the edge of the treatment table with the hips and knees flexed to 90°. The HHD was placed against the medial aspect of the lower leg, proximal to the medial malleoli, and held in place by a strap secured to an immovable part of the treatment table. The examiner used one hand to stabilize the thigh, while maintaining the position of the HHD with the other hand, as the participant attempted to externally rotate the hip with as much force as possible.

Knee flexor and extensor strength were measured in the seated position with the participant grasping the edge of the treatment table for stability, and with a towel roll placed under the distal femur to attain a 90° angle of knee flexion. The HHD was secured to the lower leg just proximal to the medial and lateral malleoli on the anterior aspect for knee extensors and posterior aspect for knee flexors using a strap. For the purposes of data analysis, only measurements from the right side were utilized for all muscle groups tested.

Statistical Analysis

Data were analyzed using the 15.0 version of SPSS for Windows (SPSS, Inc, Chicago, Illinois). Handgrip and lower extremity muscle strength results were divided into the following age groups for data analysis: young (20--39 years), middle (40--54 years), and older (55+ years). These age groups are meant to broadly represent the age group exhibiting near peak muscle strength (20--39), the effects of slow decline (40--54), and accelerated decline (55+). Means and standard deviations were used to describe the demographic characteristics of the participants. Multivariate analysis of variance (MANOVA) was used to test for differences in muscle strength values of handgrip, hip abductors/external rotators, and knee flexors/extensors across age and racial groups. Univariate ANOVAs were performed when the MANOVA was significant and significant ANOVAs were followed with Bonferroni post hoc tests. An alpha level of 0.05 was used for statistical tests.

Results

Thirteen of the 918 participants who underwent the orthopedic examination had missing data or were excluded because of pain with muscle strength testing. Only data for the white and AA women were included for analysis as there were insufficient numbers of women in any of the other racial or ethnic groups. A total of 42 women who were in racial/ethnic groups other than white or AA were removed for all data analyses (12 Asian, 6 American Indian, 1 native Hawaiian, and 23 who selected “other”). Table 1 presents a summary of characteristics for the remaining 863 participants (white, n = 699; AA, n = 164). Muscle strength means and standard deviations (SD) were calculated for each of the two racial groups in each of the age groups and are presented in Table 2.

A 3 × 2 MANOVA of body weight--adjusted handgrip and lower extremity strength values revealed no significant age-by-race interaction ($P = .092$) but significant main effects for age ($P < .001$) and race ($P < .001$). Subsequent ANOVAs showed significant main effects of age for all muscle groups ($P < .001$) (Table 3) and significant main effects of race for all muscles ($P \leq .002$) except for hip external rotators ($P = .481$) (Table 4). That is, AA women had significantly lower values of body weight--adjusted strength than white women in all muscle groups except hip external rotators. Subsequent post hoc tests revealed significantly less muscle strength in knee extensors and flexors with each advancing age group ($P \leq .05$) (Table 3). Significant differences in hand grip and hip external rotator strength were found between each age group ($P \leq .006$) *except* for the young- to middle-age group comparison. That is, the mean strength values for the young- and middle-age groups were similar but both had significantly higher mean strength values than the older group (Table 3). Hip abductor strength was significantly lower in the middle- and older-age groups than in the young-age group ($P \leq .001$), but there was no significant difference between the middle- and older-age groups ($P = .110$). Thus, there was little change in hip abductor strength after middle age (Table 3). Muscle strength was less with each advancing age group in all muscles, but the total average difference from the young group to the older group ranged from 13.9% for handgrip to 23.6% for hip abductors. The difference in lower extremity strength from the young to older group ranged from 19.1% to 23.6%.

Comment

In observational descriptive studies such as ours, one of the main caveats to proper interpretation of results is that the sample of individuals who participated in the study is, in fact, representative of the population at large. We feel that our study fulfills this requirement.

Almost 37% of our participants had a normal BMI classification (BMI = 18.5--24.9) while 61% were overweight or obese (BMI ≥ 25). This is very similar to the BMI classifications for women in the United States as reported by the Centers for Disease Control and Prevention via the Behavioral Risk Factor Surveillance System (www.cdc.gov/brfss). Nationally, 36.6% of women are reported to have a normal BMI while 63.2% are overweight or obese. Self-reported levels of physical activity by the women in our study also indicate that they participated in similar levels of physical activity as women in the United States. Sixty-six percent of our participants reported that they were performing 150 or more minutes of moderate or 75 or more minutes of vigorous physical activity per week (or combinations thereof) at the time that they entered into our study. The Centers for Disease

Control and Prevention recently assessed how well people in the United States are meeting the new *Physical Activity Guidelines* using self-report data from the Behavioral Risk Factor Surveillance System and reported that 64.5% of adults (68.9% of men and 60.4% of women) were classified as meeting the 2008 guidelines using the same criteria that we used in our study.[27]

The results of our study revealed that handgrip and lower extremity muscle strength values differ across age and race in women, as hypothesized. In a study of handgrip and knee extensor strength in 738 white women and 599 black women between the ages of 70 and 79 years, Taaffe et al[17] found muscle strength to be significantly greater ($P < .001$) in the black women for both muscle groups.[17] However, muscle strength was not adjusted for body weight in the study by Taaffe et al.[17] Our results also showed AA women having significantly higher values of observed (ie, unadjusted) muscle strength than white women ($P < .001$). However, when muscle strength values were adjusted for body weight, white women had higher weight-adjusted muscle strength for handgrip, hip abductors, knee extensors, and knee flexors than AA women. We chose to report on weight-adjusted muscle strength because the AA women in our study were significantly heavier than the white women ($P < .001$), and because a lower proportion of muscle strength relative to body weight has been associated with increased risk for developing OA in women.[9,12]

Our study shows that older women are weaker overall than younger women with some variations for each muscle group. Because our data analyses revealed no interaction effect for age group and race, we did not conduct analyses of muscle strength by age group for each race separately. Our results show that when all participants' data are looked at collectively, handgrip strength appears least affected by age with only a 13.9% difference from the youngest age group to the oldest. Lower extremity strength showed larger differences with age. Total difference in muscle strength from the youngest group to the oldest group ranged from 19.1% for hip external rotators to 23.6% for the hip abductors. Strength differences between age groups, however, varied between muscle groups. The hip abductors, for example, had the largest difference in strength from the young-age group to the middle-age group. Although not examined statistically, some interesting observations are made when strength in individual muscle groups is looked at separately in white and AA women. In AA women, large differences in strength are observed between the young- and middle-age groups for the hip abductors (22.0%) and knee extensors (17.0%), with relatively small differences between the middle- and older-age groups (7.5% and 6.0%). White women had more modest differences in strength between the young- and middle-age groups for hip abductors (10.4%) and knee extensors (7.0%) followed by differences between the middle- and older-age groups of 10.3% and 14.9% for hip abductors and knee extensors, respectively.

There are several implications for our findings. First, previous research shows that women are at greater risk for developing knee OA when they have lower weight-adjusted muscle strength in the knee extensors[9] and when they have increased body weight,[9,28] BMI,[28,29] or fat mass.[30] Our results show that AA women have higher body weight, BMI, body fat, and lower weight-adjusted knee extensor muscle strength than white women, potentially placing them at greater risk for knee OA. In a study of the prevalence of radiographically defined OA, Sowers et al[31] found that in women aged 40 years or older, prevalence of knee OA is 23.1% in black women compared with 8.5% in white women. Weight loss programs are frequently advocated for the treatment and prevention of knee OA, but weight loss programs have been shown to reduce muscle mass as well as fat mass in older obese adults.[32] The optimal program would be a weight loss program that reduces fat mass, while maintaining or increasing muscle mass. This likely would include a resistance training component in addition to the aerobic training that is traditionally advocated with dietary modification for weight loss. This recommendation would be consistent with the recently published *Physical Activity Guidelines for Americans* that advocate resistance training on 2 or more days of the week along with the recommended 150 minutes of moderate-intensity aerobic exercise for general health benefits.[33] After reviewing the evidence for the role of physical activity in joint health, the Physical Activity Guidelines Advisory Committee concluded that there is no evidence to indicate that the recommended levels of physical activity for general health benefits increase the risk of developing OA. The Advisory Committee further concluded that there is strong evidence for the benefits of both endurance and resistance types of exercise in persons who already have OA "without exacerbating symptoms or worsening disease progression."[34]

Another implication for our results is that strengthening exercises for hip abductors and knee extensors should begin at an early age, especially in AA women whose adjusted muscle strength values in these muscle groups were considerably lower than those of their white counterparts especially in the young- and middle-age groups. Clinicians should discuss and incorporate muscle strengthening recommendations from the *Physical Activity Guidelines for Americans* but should also provide specific exercises that address the hip abductors and knee extensors since weakness in these muscle groups may have implications for the development of hip and knee OA. Women who are overweight or obese should especially be targeted.

Our study has several limitations. The first limitation is that our age group comparisons are cross-sectional. We must be cautious about looking at differences in muscle strength between age groups as "declines" since these differences were not observed longitudinally. Another limitation is that there were fewer AA women than white women in our study. Although we tested 164 AA women, once they were dispersed into the 3 age groups, sample sizes were smaller. The young-age group, for example, had only 40 AA women and the middle- and older-age groups had 60 and 64, respectively. These smaller sample sizes increase the potential for cohort effects. Finally, we recognize that comorbidities become more prevalent with age and could affect muscle strength. We chose to address the factor of comorbidities in a similar fashion as Goodpaster et al[18] and Taaffe et al[17] did in their studies of muscle strength changes with age and race.[17,18] Both of these authors utilized data from the Health, Aging, and Body Composition (Health ABC) Study and excluded participants if they reported difficulty walking a quarter of a mile, climbing 10 steps, or if they had difficulty with any activities of daily living. Similarly, potential subjects did not qualify for our study if they had a disease or condition that limited their mobility or if they needed an assistive device to ambulate or if the condition limited or interfered with their usual daily or recreational activities. In addition, we excluded participants from muscle strength testing if they experienced pain with the testing. Therefore, the results of this study can be generalized to community-living women who are able to carry out usual daily or recreational activities but may not apply to women who use an assistive device to ambulate.

Conclusion

This study found differences in handgrip and lower extremity muscle strength values among apparently healthy women of different ages and racial groups. Once muscle strength was adjusted for body weight, white women were found to be stronger than AA women in all muscle groups tested except for hip external rotators. Strength decreased with age in all muscle groups but magnitude of decrease varied by muscle. The hip abductors experienced the largest decline between the young- and middle-age groups whereas all other muscle groups experienced their largest decline after the age of 55 years. Strengthening programs should target different muscles, depending on a woman's age and race to promote and maintain musculoskeletal health.

Women with low body weight--adjusted muscle strength in the hips or knees may be at increased risk for developing hip and knee OA and therefore should be encouraged to include a resistance training component in addition to the aerobic training that is traditionally advocated for weight loss.

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Table 1

Descriptive Characteristics of the Participants

Characteristic	All (*n* = 863)	White (*n* = 699)	African American (*n* = 164)
Age, mean (SD)	53 (12.3)	53 (12.4)	49 (11.0)
Age group, n (%)			
20- 39	139 (16.1)	99 (14.2)	40 (24.4)
40-54	300 (34.8)	240(34.3)	60 (36.6)
55+	424 (49.1)	360(51.5)	64 (39.0)
Height, cm, mean (SD)	163.7 (6.1)	163.9 (6.1)	163.0 (6.3)
Weight, kg, mean (SD)	74.0 (17.0)	71.8 (15.8)	83.4 (18.5)
% body fat, mean (SD)	32.1 (7.6)	31.3 (7.4)	35.5 (6.8)
BMI, kg/m^2, mean (SD)	27.6 (6.1)	26.7 (5.6)	31.4 (11.0)
BMI Category, n (%)			
Underweight (<18.5)	15 (1.7)	15 (2.1)	-------
Normal (18.5-24.9)	318 (36.8)	293 (42.0)	25 (15.2)
Overweight (25-29.9)	283 (32.8)	231 (33.0)	52 (31.7)
Obese (≥30)	247 (28.6)	160 (22.9)	87 (53.0)
Self-reported PA, n (%)			
MPA (≥150 min/wk)	385 (44.6)	320 (45.8)	65 (39.6)
VPA (≥75 min/wk)	341 (39.5)	270 (38.6)	71 (43.3)
MVPA[b]	547 (63.4)	449 (64.2)	98 (59.8)

[a]Abbreviations: BMI, body mass index; MPA, moderate physical activity; PA, physical activity; VPA, vigorous physical activity.

[b]The number of participants who met the 2008 *Physical Activity Guidelines for Americans*[33] for moderate physical activity (≥150 min/week) **or** vigorous activity (≥75 min/wk).

Table 2

Muscle Strength Values Unadjusted and Adjusted for Body Mass by Race and Age Group

Mean (SD) for observed muscle strength values by race and age group						
Race	**Age Groups**	**Hand Grip, (kg)**	**Hip Abductors, (Nm)**	**Hip Ext. Rot. (Nm)**	**Knee Ext. (Nm)**	**Knee Flex. (Nm)**
Caucasian	20-39 (n = 99)	28.9 (4.5)	51.1 (15.0)	27.2 (9.6)	90.9 (25.9)	44.3 (13.9)
	40-54 (n = 240)	28.6 (5.2)	47.8 (16.1)	27.2 (9.9)	88.7 (25.0)	43.1 (13.2)
	55+ (n = 360)	24.3 (5.6)	42.1 (16.5)	22.1 (8.0)	73.5 (21.9)	36.0 (12.1)
	20-39 (n = 40)	29.7 (6.0)	53.4 (22.3)	30.7 (9.7)	99.5 (25.9)	45.4 (13.4)
	40-54 (n = 60)	29.7 (7.5)	43.0 (15.3)	28.7 (10.6)	85.6 (26.9)	42.3 (15.3)
African-American	55+ (n = 64)	28.8 (5.6)	39.9 (15.4)	27.0 (11.1)	81.7 (29.3)	36.4 (12.0)
Means (SD) for muscle strength values adjusted for body weight by race and age group[a]						
Caucasian	20-39 (n = 99)	0.43 (0.10)	0.77 (0.27)	0.40 (0.15)	1.34 (0.42)	0.66 (0.25)
	40-54 (n = 240)	0.40 (0.09)	0.69 (0.28)	0.38 (0.14)	1.25 (0.38)	0.61 (0.21)
	55+ (n = 360)	0.35 (0.09)	0.61 (0.27)	0.32 (0.13)	1.06 (0.36)	0.52 (0.21)
African-American	20-39 (n = 40)	0.39 (0.11)	0.68 (0.28)	0.40 (0.14)	1.28 (0.38)	0.59 (0.19)
	40-54 (n = 60)	0.36 (0.11)	0.53 (0.23)	0.35 (0.14)	1.06 (0.42)	0.52 (0.22)
	55+ (n = 64)	0.36 (0.10)	0.49 (0.20)	0.33 (0.13)	1.00 (0.38)	0.44 (0.16)

[a]Values are mean (SD) Nm/kg of body mass except for handgrip, which is just proportion of body weight (no unit).

Table 3

Analysis of Variance for Body Weight-Adjusted Strength (Races Combined)

	Age Groups			Statistics			Multiple Comparisons[a]		
Muscle Groups	**20-39 years (Group 1) n = 139**	**40-54 years (Group 2) (n = 300)**	**55+ years (Group 3) (n = 424)**	**F**	***P***	**Effect Size**	**1/2**	**1/3**	**2/3**
Hand grip	0.42 (0.10)[b]	0.39 (0.09)	0.35 (0.09)	13.7	<.001	0.031		*	*
Hip abductors	0.74 (0.27)	0.65 (0.27)	0.59 (0.26)	15.1	<.001	0.034	*	*	
Hip external rotators	0.40 (0.14)	0.37 (0.14)	0.32 (0.13)	12.3	<.001	0.028		*	*
Knee extensors	1.32 (0.40)	1.21 (0.39)	1.05 (0.36)	20.8	<.001	0.046	*	*	*
Knee flexors	0.64 (0.23)	0.59 (0.21)	0.51 (0.20)	19.0	<.001	0.042	*	*	*

[a] Bonferroni post hoc comparisons were conducted.

[b] Values are mean (SD) for body weight adjusted strength.

[*] A significant difference between the means of the indicated age groups at an alpha level of .05.

Table 4

Analysis of Variance for Body Weight Adjusted Strength (Ages Combined)

Muscle Groups	White n = 699	African American n = 164	F	*P*	Effect Size
Hand grip	0.38 (0.10)[b]	0.36 (0.10)	9.52	.002*	0.011
Hip abductors	0.66 (0.28)	0.55 (0.24)	24.09	<.001 *	0.027
Hip external rotators	0.35 (0.14)	0.35 (0.13)	0.49	.481	0.001
Knee extensors	1.16 (0.39)	1.09 (0.41)	9.27	.002 *	0.011
Knee flexors	0.57 (0.22)	0.50 (0.19)	17.93	<.001 *	0.020

* A significant difference at an alpha level of .05.

[b] Values are mean (SD) for body weight adjusted strength.