Journal of Gerontology: BIOLOGICAL SCIENCES
1998, Vol. 53A, No. 5, B355–B361

Racial Differences in Muscle Strength in Disabled Older Women

Taina Rantanen,[1] Jack M. Guralnik,[1] Suzanne Leveille,[1] Grant Izmirlian,[1] Rosemarie Hirsch,[1] Eleanor Simonsick,[1] Shari Ling,[2] and Linda P. Fried[2]

[1]Epidemiology, Demography and Biometry Program, National Institute on Aging, National Institutes of Health, Bethesda, Maryland.
[2]Johns Hopkins Medical Institutions, Baltimore, Maryland.

This study examines racial differences in muscle strength, and associations of muscle strength to level of physical activity and severity of disability, among a community sample of 254 black and 665 white, moderately to severely disabled women aged 65 and older. Potential confounders that were adjusted for in the models included age, body weight and height, joint pain, number of chronic conditions, and socioeconomic status. Hand grip, hip flexion, and knee extension forces were measured using portable hand-held dynamometers in the participants' homes. Hand grip strength was measured as the maximal isometric force. Hip flexion and knee extension forces were measured as the greatest force the tester had to apply to break the isometric contraction. A declining strength gradient was observed with increasing severity of disability and for decreasing level of physical activity in both races. At equal levels of disability or physical activity, blacks had better hand grip and hip flexion strength, but knee extension strength did not differ by race. The greater hand grip and hip flexion strength found in black women may be related to their greater muscle mass and known racial differences in body dimensions. No consistent racial differences were observed in the relationship between physical activity and muscle strength, or muscle strength and disability, suggesting that the role of muscle strength in the disablement process does not differ between races. Physical activity and exercise programs may be feasible ways to prevent worsening of disability in blacks and whites.

CURRENTLY, little information is available on racial differences in muscle function in older people. The theoretical pathway from disease to disability presents low muscle strength as one of the impairments leading to functional limitations and disability (1–3). Thus it is of great scientific interest to find out whether muscle functions differ between racial groups, particularly as the proportion of blacks in the older population is estimated to increase (4). In earlier cross-sectional studies among whites, poor lower extremity strength has been found to correlate with slow walking speed (5–7), inability to climb stairs (7–8), and self-reported mobility problems (6,9). Moreover, in a prospective study, poor muscle strength was found to predict decline in walking speed (10). No previous information about the role of muscle strength in the disablement process in black women exists.

Cross-sectional and longitudinal studies among whites have shown that although strength decline is the overall trend with advancing age, older people still show considerable variation in strength (11–17). More physically active older people have been found to have greater strength than sedentary people of the same age (13,15). Consequently, the lower level of physical activity found among adult black women compared to white women (18) would imply a disadvantage for the blacks in regard to strength. However, no previous information on the association of physical activity and muscle strength in older black people exists. Low physical activity has been found to be associated with the presence of chronic diseases (19). Chronic diseases in themselves may decrease strength, as healthier women were found to have greater strength to body weight ratio than people with chronic conditions, even though their self-reported level of physical activity did not differ (20). However, independent effects of exercise on strength in older persons with chronic diseases has not been fully evaluated in studies with comprehensive disease ascertainment.

Body size is a very important determinant of muscle strength. Body mass and height, particularly lean body mass and muscle mass, have been found to correlate positively with muscle strength in older persons (21,22). In addition to black women on average having greater body weight than white women (23,24), body composition differs in other ways between races. Black women have been found to have more muscle mass than white women with similar body weights (25). As loss of muscle mass is a major cause of decrease of strength with age (26), older blacks would be hypothesized to have an advantage over whites in strength due to their greater reserve of muscle mass.

The purpose of this article is to compare hand grip, hip flexion, and knee extension strength levels between black and white disabled women, and to study the association of muscle strength to the level of physical activity and severity of disability in black and white women. The analyses take into account the potential confounders of these relationships, which are age, number of chronic conditions, joint pain, and body height and weight. The strength comparison between races is particularly interesting as two factors known to influence strength go in opposite directions—blacks exercise less than whites but have greater muscle mass.

Participants and Methods

The data used in these analyses are from the baseline of the Women's Health and Aging Study (WHAS), a prospective population-based study of the causes and course of disability in older women. The sampling approach, study eligibility criteria, and methods have been described in detail previously (27,28).

Briefly, an age-stratified random sample of 6,521 community-dwelling women aged 65 years and older, with over sampling of those over the age of 85 years, was selected from the residents of the eastern half of Baltimore City and a part of Baltimore county who were listed in the Health Care Financing Administration Medicare eligibility files. Of these, 5,316 were eligible, 4,137 participated in screening, and 3,841 (983 blacks, 2838 whites, 18 other races, 2 missing) were able to finish the interview by themselves. Overall, 1,409 women (367 blacks and 1037 whites, and 5 others) met the criteria for study eligibility, scoring above 17 on the Mini-Mental State Examination (29) and having difficulty in performing tasks in two or more of the following domains: mobility, upper extremity activities, basic self-care, and higher functioning tasks of daily living (30). Of these, 1,002 women (284 blacks, 713 whites, and 5 other races) agreed to participate in the full study. They received an extensive interview and were later visited in their homes by a trained nurse who tested their muscle strength, examined joint pain, and measured body mass and height as part of the examination. For analytic purposes, those 5 women whose ethnic background was either Pacific Islander or Native American were combined with whites.

Disability severity index, ranging from 2 to 4, was calculated on the basis of the number of disability domains. A participant was considered to have *upper extremity disability* if she reported having difficulty in any of the following: carrying 10 pounds, using fingers to grasp or handle, or raising arms up over head. *Mobility disability* was present if the participants had difficulty doing heavy housework, walking a quarter of a mile, walking up 10 steps, or getting in and out of bed or chairs. *Higher functioning disability* was based on having difficulty in shopping for personal items, doing light housework, preparing meals, or using the telephone. *Basic self-care disability* was present if the participant had difficulty in bathing and showering, dressing, using toilet, or eating. The reliability of self-reports of disability has been found to be good (31).

Physical activity was measured by asking about the most common physical activities the women undertook. The categorization was as follows:

1. During the week prior to interview, number of blocks walked; 0 = 0, 1 = 1–5, 2 = ≥6 (approximate tertiles)
2. During the week prior to interview, number of flights of stairs climbed; 0 = 0, 1 = 2–21, 2 = ≥22 (approximate tertiles)
3. During the two weeks prior to interview did heavy household chores; 0 = no, 1 = yes
4. During the two weeks prior to interview did heavy outdoor work chores; 0 = no, 1 = yes
5. During the two weeks prior to interview did regular exercise; 0 = no, 1 = yes
6. During the two weeks prior to interview danced; 0 = no, 1 = yes
7. During the two weeks prior to interview bowled; 0 = no, 1 = yes

A sum total of these responses (range 0–9) was computed and three activity categories created: 0–1, extremely physically inactive (31%); 1–3, minimally physically active (36%); and ≥4, moderately physically active (33%).

Hand grip strength was measured using a JAMAR hand dynamometer (Model No. BK-7498, Fred Sammons, Inc., Burr Ridge, IL) in a sitting position with wrist in a neutral position and elbow flexed 90°. Grip strength was measured three times for each hand. During testing the participant was strongly encouraged to use the greatest possible force. The highest measure in the stronger hand is reported here.

Maximal strength of the hip flexion and knee extensor muscles was measured on both sides using a hand held dynamometer (Nicholas Manual Muscle Tester; Model No. BK-7454, Fred Sammons, Inc., Burr Ridge, IL). For hip flexion strength testing, the participant was seated on a hard chair with her hips and knees flexed at 90°. Knee extension strength testing was also done in a seated position with the knee flexed at 75° down from full extension. The participant was allowed to place her hands on the front edge of the chair but not to lean backwards. In the hip flexion strength test, the dynamometer was placed proximal to the femoral condyles at the distal thigh, and the participant was asked to lift the thigh. In the knee extension strength test, the dynamometer was placed proximal to the ankle joint, and the participant was asked to lift the foot. The participants were strongly encouraged to gradually increase the force to the greatest possible level while the tester was opposing this effort. The strength was measured as peak force, and expressed as kilograms of force the examiner had to apply to break the isometric contraction. After practicing the tests, two formal trials on both sides were done. The best results were used in the analyses. Interrater reliability of strength tests was assessed in a pilot study including 22 women. The intraclass correlation coefficient was .91 for knee extension strength test and .93 for hip flexion strength tests (28).

The hand grip strength test was completed by 247 black women (87%) and 657 white women (92%). The reasons for not doing the test were as follows: systolic blood pressure ≥180 mm Hg or diastolic blood pressure ≥110 mm Hg, n = 57; pain, n = 10; tester or participant felt test was unsafe, n = 11; paralysis or weakness or physically unable, n = 15; participant refused, n = 2; others, n = 3. Hip flexion strength test was undertaken by 239 blacks (84%) and 628 whites (88%). The reasons for not doing the test were as follows: systolic blood pressure ≥180 mm Hg or diastolic blood pressure ≥110 mm Hg, n = 60; pain, n = 10; tester or participant felt test was unsafe, n = 36; participant refused, n = 16; participant unable to lift the knee, n = 3; participant unable to understand instructions, n = 2; others, n = 10. Knee extension strength test was done by 240 blacks (85%) and 642 whites (88%). The reasons for not doing the test were as follows: systolic blood pressure ≥180 mm Hg or diastolic blood pressure ≥110 mm Hg, n = 55; tester or participant felt test was unsafe, n = 33; participant unable to

lift the foot, $n = 10$; participant refused, $n = 8$; pain, $n = 7$; other reasons, $n = 7$. Overall, no systematic differences between races were observed in the reasons for not doing the test.

Prevalence of joint pain was evaluated by clinical examination (pain during passive motion of the joint or tenderness on palpation). Those participants who had tenderness on palpation of any of the finger joints, thumb base joint, or wrist joint in either hand were rated as experiencing hand pain. Knee pain was considered present if the participant had pain during passive motion or tenderness during palpation in either knee. Presence of hip pain was based on presence of pain during passive motion of either hip joint.

Number of chronic conditions was the sum of prevalent conditions ascertained using standardized algorithms established for 17 conditions, which use relevant information from interview and examination findings, x-rays, medications, physicians' reports, and medical records (32). Only definite cases were used for the index.

Race was determined by asking participants about their ethnic background. Body mass was measured in kilograms using a digital scale, with the participant wearing light indoor clothing. Height was marked using a plane with the participant standing in stocking feet with her head positioned against a level doorway, and measured to the nearest centimeter using a stadiometer. Triceps skinfold thickness and upper arm circumference were measured at the midpoint of the upper arm. A Holtain skinfold caliper (Seritex, Carlstadt, NJ) was used for skinfold measurement. Upper arm muscle area was estimated from the triceps skinfold thickness and upper arm circumference using the equation by Heymsfield et al. (33).

The study nurses received extensive training before they were certified. Training and quality control issues are described in detail elsewhere (28).

Statistical Methods

Cross tabulation with chi-square tests and t tests were used to compare the categorical and continuous variables, respectively, between black and white women. Pearson correlation coefficients were computed to study the associations between the strength test results and age, body height and weight, number of chronic conditions, physical activity, and socioeconomic indicators. To study the effects of race and physical activity and race and disability on muscle strength, two-way analysis of variance (ANOVA) was used when observed means were analyzed, and for the adjusted means, analysis of covariance (ANCOVA) was applied.

RESULTS

The characteristics of those who participated in at least one strength test are presented in Table 1. The black participants were on average 2.2 years younger than the whites ($p < .001$) and their average body mass was 5.8 kilograms greater ($p < .001$). The average upper arm muscle area in black women was 5.2 cm^2 greater than in white women ($p < .001$). No differences in body height, number of chronic conditions, prevalence of hand pain, and severity of disability were observed according to race. The socioeconomic indicators, number of school years ($p < .001$) and income ($p < .001$), were lower in the blacks. The median income for blacks was \$6,226 and, for whites, \$11,000 per year. Despite their lower level of physical activity ($p < .001$) and a greater prevalence of hip pain ($p = .005$) and knee pain ($p = .023$), the black women exhibited greater hand grip strength ($p < .001$) and hip flexion strength ($p < .001$) than the white women. No significant differences in the knee extension strength were observed between races.

In both black and white women, age, body mass, body height, and physical activity showed significant but, in some cases, weak correlations with muscle strength (Table 2). Number of chronic conditions showed weak inverse correlations with hand grip in blacks and knee extension strength in whites. Income and number of school years were not significantly associated with strength in either group, with the exception of a weak correlation between education and knee extension strength in black women. Those with knee pain exhibited poorer knee extension strength in both races (blacks: without pain, mean = 13.6 kg, SD = 5.13; with pain, mean = 12.2 kg, SD = 4.85, $p = .03$; whites: without pain, mean = 13.5 kg, SD = 4.84; with pain, mean = 12.0, SD = 4.85, $p < .001$). When the total population was included in the same analysis, those with

Table 1. The Characteristics of the Black and White Women Who Participated in at Least One Strength Test

	Black ($n = 257$)		White ($n = 680$)		t test
	Mean	SD	Mean	SD	p
Grip strength, kg	22.0	6.3	19.8	5.1	<.001
Knee extension strength, kg	13.1	5.1	13.0	4.9	.809
Hip flexion strength, kg	12.5	5.5	11.0	4.8	<.001
Body mass, kg	73.0	19.4	67.2	16.1	<.001
Body height, cm	155.6	6.9	155.2	7.2	.454
Upper arm muscle area, cm^2	47.4	20.0	42.2	17.5	<.001
Age, years	76.6	8.0	78.8	8.0	<.001
Number of chronic conditions	3.0	1.6	2.9	1.6	.242
Income, dollars	8,586	7,230	17,643	22,137	<.001
	Percent		Percent		χ^2 Test, p
Physical activity					
Extremely inactive	38		29		
Minimally active	43		33		
Moderately active	19		38		<.001
Number of disability domains					
Two domains	35		39		
Three domains	32		25		
Four domains	33		36		.143
Education, grades completed					
0–8	56		38		
9–11 years	26		20		
≥12 years	18		42		<.001
Hand pain, either hand	55		52		.336
Knee pain, either knee	42		32		.023
Hip pain, either hip	30		22		.005

hand pain had poorer grip strength than those without hand pain (p = .018). However, when that comparison was repeated for blacks and whites separately, statistically significant differences were not found in either group. Hip flexion strength did not vary according to the presence of hip pain. Estimated upper arm muscle area was significantly correlated with hand grip strength in both races (blacks, r = .289, p < .001; whites, r = .235, p < .001), but not with hip flexion or knee extension strength.

We wanted to study whether the observed racial differences in strength would persist after stratifying according to level of physical activity or severity of disability, and controlling for age, body mass and height, number of chronic conditions, and joint pain. Table 3 shows a two-way ANOVA for observed and ANCOVA for adjusted strength values. In both unadjusted and adjusted models, black women had greater hand grip and hip flexion strength. Physical activity had significant main effects on observed values of all three muscle groups tested, with more active women being stronger. In the adjusted models, the result remained the same except for hip flexion; even though an increasing hip flexion strength gradient was observed for increasing level of physical activity, the association was no longer statistically significant. Race by activity interactions were not significant, indicating that there was no evidence that the relationship of physical activity with muscle strength differs between races.

Table 4 shows the strength gradients according to race and severity of disability. Black race was again associated with greater hand grip and hip flexion strength. Severity of disability had significant main effects on observed and adjusted strength values, with those with more severe disability being weaker. Race by disability interactions were not significant for knee extension and hip flexion strength,

Table 2. Correlation Coefficients Between Strength and Body Weight and Height, Age, Physical Activity, Number of Chronic Conditions, and Socioeconomic Status in Black and White Women

		Weight	Height	Age	Physical Activity	No. of Chronic Conditions	Income	Education
Black (n = 257)								
Hand grip	r	.368	.347	−.298	.200	−.138	.012	.043
	p	<.001	<.001	<.001	<.001	.028	.875	.496
Knee extension	r	.254	.214	−.220	.170	−.064	.026	.132
	p	<.001	.001	.001	.011	.317	.744	.039
Hip reflexion	r	.171	.010	−.139	.140	−.070	.020	.057
	p	.012	.880	.032	.040	.284	.807	.380
White (n = 680)								
Hand grip	r	.378	.444	−.408	.249	−.065	−.043	.059
	p	<.001	<.001	<.001	<.001	.096	402	.127
Knee extension	r	.212	.168	−.239	.252	−.089	.023	.040
	p	<.001	<.001	<.001	<.001	.024	.652	.306
Hip flexion	r	.179	.054	−.210	.170	−.071	.062	.058
	p	<.001	.190	<.001	<.001	.075	.232	.146

Table 3. Observed and Adjusted Means and Standard Deviations of Hand Grip, Knee Extension and Hip Flexion Strength in Groups According to Race and Physical Activity

	Black						White						Main Effects		Race by Activity
	Inactive		Minimally Active		Moderately Active		Inactive		Minimally Active		Moderately Active		Race	Activity	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	p	p	p
Hand grip (kg)															
Observed	20.7	5.53	22.8	6.21	24.1	5.21	18.0	5.10	19.8	4.86	21.3	4.78	<.001	<.001	.938
Adjusted*	21.0	5.60	22.5	6.29	22.6	5.21	19.7	4.91	20.3	4.91	20.5	4.80	<.001	.010	.518
Knee extension (kg)															
Observed	12.4	4.91	13.3	4.89	14.9	5.51	11.6	4.67	12.9	4.78	14.3	4.81	.251	<.001	.859
Adjusted†	12.5	4.73	12.9	4.82	13.9	5.51	12.6	4.63	13.3	4.76	14.1	4.83	.493	.002	.969
Hip flexion (kg)															
Observed	12.3	5.62	12.5	5.27	13.8	5.52	10.0	4.42	11.1	5.16	11.9	4.41	<.001	.006	.572
Adjusted‡	12.1	5.49	12.3	5.11	13.3	5.52	10.7	4.48	11.4	5.20	11.8	4.41	.003	.143	.829

*Adjusted for age, body mass, body height, number of chronic conditions, and hand pain.
†Adjusted for age, body mass, body height, number of chronic conditions, and knee pain.
‡Adjusted for age, body mass, body height, number of chronic conditions, and hip pain.

but for adjusted grip strength a significant race by disability interaction was observed. The mean adjusted grip strength was similar in black and white women with most severe disability, whereas in the other disability groups, blacks were stronger. In blacks, the difference in adjusted grip strength between the moderately and the severely disabled women was greater than in the whites. However, the overall association of muscle strength and disability was parallel in both races, with lower strength consistently associated with more severe disability.

Discussion

We found that black disabled women had greater hand grip and hip flexion strength than white disabled women, even after adjusting for age, body mass and height, number of chronic conditions, and joint pain, and stratifying according to level of physical activity or severity of disability; however, knee extension strength did not differ between races. A declining strength gradient was observed with increasing severity of disability and for decreasing level of physical activity in both races. The correlates of muscle strength were similar in both races. To the best of our knowledge, little other information on muscle strength among older black women is presently available. The positive effect of habitual physical activity on strength has been reported previously in a number of studies among whites (11,14,17). To our knowledge, no previous research has shown a positive association between habitual physical activity and muscle strength in older blacks, although lower levels of physical activity in blacks than in whites have been reported (18). In an earlier prospective study among 413 black and 3428 white self-respondents 70 years of age or older, walking was found to have a greater protective effect against development of lower body disability in blacks than whites (34). Lower body disability was measured in that study as whether or not people reported difficulty in walking a quarter of a mile, walking up 10 steps, standing for two hours, stooping, crouching or kneeling, or lifting or carrying 25 pounds. Walking 4 to 7 days a week reduced the risk of onset of disability by 50% to 80% on all five disability items in the black sample and by 50% on only two items within the white sample. In the current study, however, physical activity was associated with muscle strength the same way in both races, indicated by nonsignificant race by physical activity interactions. The physically active women were stronger than the inactive women.

A certain amount of strength is required for basic motor tasks such as standing up, walking, or climbing stairs or carrying a bag. Below this minimum strength threshold, disability develops as strength is not adequate for the task (2). People whose strength has fallen close to these functionally important thresholds will experience difficulties in doing the task, although they still will be able to do it (6). Also in the current study, people reporting most difficulties were weaker than those reporting difficulties in only two or three domains. No race by disability interactions were found for hip flexion strength and knee extension strength, suggesting that the relationship between muscle strength and disability does not differ according to race. However, in adjusted hand grip strength, a significant race by disability interaction was observed with racial difference being greatest among those with disability in two or three domains, the less disabled in this study population. In the most disabled group, no racial difference was seen. Overall, no consistent evidence was found to support racial difference in the relationship of disability and strength.

One explanation for the greater hand grip and hip flexion strength in blacks may be their greater muscle mass: black women have been reported to have greater appendicular muscle mass and skeletal mass throughout adult life than white women (35). Also in the present study the estimated upper arm muscle area was significantly greater in the blacks than in the whites. In addition, the greater body mass observed here is most probably indicative of greater total body muscle mass, as black women have more muscle mass than white women with similar body weights (25). It has been suggested that racial differences in body composi-

Table 4. Observed and Adjusted Means and Standard Deviations of Hand Grip, Knee Extension and Hip Flexion Strength in Groups According to Race and Severity of Disability

	Black						White						Main Effects		Race by Disability
	2 Domains		3 Domains		4 Domains		2 Domains		3 Domains		4 Domains		Race	Disability	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*p*	*p*	*p*
Hand grip (kg)															
Observed	23.8	5.62	22.6	5.48	19.4	6.93	20.9	4.69	20.3	5.18	18.2	5.17	<.001	<.001	.178
Adjusted*	22.9	4.72	22.7	5.10	19.6	4.92	20.8	5.52	20.6	5.29	19.5	6.97	<.001	<.001	.033
Knee extension (kg)															
Observed	14.7	5.52	12.8	4.73	11.4	4.22	13.9	4.90	13.9	4.51	11.2	4.76	.965	.001	.081
Adjusted†	14.0	5.43	12.8	4.69	11.8	4.15	13.9	4.90	14.1	4.50	12.2	4.78	.143	.001	.254
Hip flexion (kg)															
Observed	13.3	5.97	12.6	5.51	11.5	4,74	11.6	4.71	11.9	4.91	9.7	4.41	<.001	.006	.366
Adjusted‡	12.8	5.88	12.5	5.43	12.0	4.48	11.8	4.69	12.1	4.93	10.1	4.36	.005	.018	.297

*Adjusted for age, body mass, body height, number of chronic conditions, and hand pain.
†Adjusted for age, body mass, body height, number of chronic conditions, and knee pain.
‡Adjusted for age, body mass, body height, number of chronic conditions, and hip pain.

tion may be inherited to a greater extent than they are of environmental origin (36).

In addition to differences in body composition, anthropomorphic differences between black and white women have been reported. Blacks have longer extremities compared to the trunk than whites do, and, particularly, the forearm in relation to the upper arm is longer in blacks (37). Moreover, the width of the radius has been found to be greater in blacks than whites (38). These differences imply that black women may have larger hands, which, in addition to indicating a greater amount of muscle in hands, also points to a biomechanical advantage in grip strength testing compared to whites. Also, differences in lower body structure have been described. Black women have shorter hip axis length than white women (39,40). In addition to reducing the risk of fractures, short hip axis length may provide biomechanical advantage in hip flexion strength testing.

Considering blacks have greater body mass and most probably greater muscle mass, it was surprising that no racial difference was observed for knee extension strength. It has been suggested that knee arthritis is often more severe in black than in white women (41). People aged 65 years and older with knee osteoarthritis have been found to have about 20% lower knee extension to body mass ratio than those without knee osteoarthritis (42). Consequently, we excluded those with adjudicated knee osteoarthritis and reran the analyses. No racial difference was found among this healthier subgroup either. This implies that racial differences in muscle strength in older women vary between muscle groups. Unfortunately, the present study had measurements only in three muscle groups and we cannot explore this suggestion any further.

In summary, greater strength was found in hand grip and hip flexion muscles in black women than white women, but knee extension strength did not differ. A study with strength measurements in multiple muscle groups would be needed to confirm that racial difference in strength varies between muscle groups. The greater muscle mass and differences in body dimensions presumably explain the greater muscle strength found in the black women. The correlates of muscle strength were similar in black and white women. A positive strength gradient was found for increasing level of physical activity and a decreasing gradient for increasing severity of disability in both races. Prospective studies are needed to better understand the role of muscle strength in the disablement process in black and white women. The current results suggest that physical exercise is associated with greater strength, and that greater strength is associated with less severe disability in both black and white older women. Thus, physical activity and exercise may be feasible ways to prevent the worsening of disability in both black and white older women.

ACKNOWLEDGMENTS

Address correspondence to Taina Rantanen, PhD, Epidemiology, Demography and Biometry Program, National Institute on Aging, 7201 Wisconsin Avenue, Gateway Building, Suite 3C-309, Bethesda, MD 20892. E-mail: rantanet@gw.nia.nih.gov

REFERENCES

1. Nagi SZ. An epidemiology of disability among older adults in the United States. *Milbank Mem Fund Q.* 1976;54:439–467.
2. Young A. Exercise physiology in geriatric practice. *Acta Med Scand Suppl.* 1986;711:227–232.
3. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38:1–14.
4. Hazuda HP. Inclusion of ethnic minorities in sarcopenia research: challenges and strategies. *Muscle Nerve.* 1997;Suppl 5:S27–S31.
5. Bassey EJ, Bendall MJ, Pearson M. Muscle strength in the triceps surae and objectively measured customary walking activity in men and women over 65 years of age. *Clin Sci.* 1988;74:85–89.
6. Rantanen T, Era P, Heikkinen E. Maximal isometric strength and mobility among 75-year-old men and women. *Age Ageing.* 1994;23: 132–137.
7. Skelton DA, Greig CA, Davies JM, Young A. Strength, power and related functional ability of healthy people aged 65–89 years. *Age Ageing.* 1994;23:371–377.
8. Rantanen T, Era P, Heikkinen E. Maximal isometric knee extension strength and stair-mounting ability in 75- and 80-year-old men and women. *Scand J Rehab Med.* 1996;28:89–93.
9. Avlund K, Schroll M, Davidsen M, Løvborg B, Rantanen T. Maximal isometric muscle strength and functional ability among 75-year-old men and women. *Scand J Med Sci Sport.* 1994;4:32–40.
10. Gibbs J, Hughes S, Dunlop D, Singer R, Chang RW. Predictors of change in walking velocity. *J Am Geriatr Soc.* 1996;44:126–132.
11. Clement FJ. Longitudinal and cross-sectional assessments of age changes in physical strength as related to sex, social class, and mental ability. *J Gerontol.* 1974;29:423–429.
12. Aniansson A, Sperling, L, Rundgren Å, Lehnberg E. Muscle function in 75-year-old men and women, a longitudinal study. *Scand J Rehab Med.* 1983;12:145–154.
13. Sipilä S, Viitasalo J, Era P, Suominen H. Muscle strength in male athletes aged 70–81 years and a population sample. *Eur J Appl Physiol.* 1991;63:300–403.
14. Bassey EJ, Harries UJ. Normal values for hand grip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clin Sci.* 1993;84:331–337.
15. Rantanen T, Sipilä S, Suominen H. Muscle strength and history of heavy manual work among elderly trained women and randomly chosen sample population. *Eur J Appl Physiol.* 1993;66:514–517.
16. Grimby G. Muscle performance and structure in the elderly as studied cross-sectionally and longitudinally. *J Gerontol.* 1995;50A:17–22.
17. Rantanen T, Era P, Heikkinen E. Physical activity and the changes in maximal isometric strength in men and women from the age of 75 to 80 years. *J Am Geriatr Soc.* 1997;45:1439–1445.
18. Tuten C, Petosa R, Sargent R, Weston A. Biracial differences in physical activity and body composition among women. *Obes Res.* 1995;3: 313–318.
19. Van den Hombergh CE, Schouten EG, Staveren WA, van Amelsvoort LG, Kok FJ. Physical activities in non-institutionalized Dutch elderly and characteristics of inactive elderly. *Med Sci Sport Exerc.* 1995; 27:334–339.
20. Skelton DA, Young A, Greig CA. Muscle function of women aged 65–89 years meeting two sets of health criteria. *Aging Clin Exp Res.* 1997;9:106–111.
21. Kalman DA, Plato CC, Tobin JD. The role of muscle loss in the age-related decline in gripstrength: cross-sectional and longitudinal perspectives. *J Gerontol.* 1990;45:M82–M88.
22. Era P, Rantanen T, Avlund K, Gause-Nilson I, Heikkinen E, Schroll M, Steen B, Suominen H. Maximal isometric muscle strength and anthropometry in 75-year-old men and women in three Nordic localities. *Scand J Med Sci Sports.* 1994;4:26–31.
23. Kleerekoper M, Nelson DA, Peterson EL, Wislon PS, Jacobsen G, Longcope C. Body composition and gonadal steroids in older white and black women. *J Clin Endocrinol Metab.* 1994;79:775–778.
24. Aloia JF, Vaswani A, Ruimei M, Flaster E. Body composition in normal black women: the four compartment model. *J Endocrinol Metab.* 1996;81:2363–2369.
25. Aloia J F, Vaswani A, Ruimei M, Flaster, E. Comparison of body composition in black and white premenopausal women. *J Lab Clin Med.* 1997;129:294–299.
26. Evans W. Functional and metabolic consequences of sarcopenia. *J Nutr.* 1997;127:998S–1003S.
27. Guralnik JM, Fried LP, Simonsick EM, Bandeen-Roche KJ, Kasper JD. Screening the community dwelling population for disability. In:

Guralnik, JM, Fried LP, Simonsick EM, Kasper JD, Lafferty ME, eds. *The Women's Health and Aging Study: Health and Social Characteristics of Older Women with Disability.* Bethesda, MD: National Institute on Aging; 1995:9–18. NIH Pub. No. 95-4009.
28. Simonsick EM, Maffeo CE, Rogers SK, Skinner EA, Davis D, Guralnik JM, Fried LP. Methodology and feasibility of a home-based examination in disabled older women: The Women's Health and Aging Study. *J Gerontol: Med Sci.* 1997;52A:M264–M274.
29. Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: a practicical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res.* 1975;12:189–198.
30. Fried LP, Ettinger WH, Lind B, Newman AB, Gardin J. Physical disability in older adults: a physiological approach. Cardiovascular Health Study Research Group. *J Clin Epidemiol.* 1994;46:747–760.
31. Smith LA, Branch LG, Scherr PA, et al. Short-term variability of measures of physical function in older people. *J Am Geriatr Soc.* 1990;38:992–998.
32. Fried LP, Kasper JD, Williamsson JD, Skinner EA, Morris CD, Hochberg MC. Disease ascertainment algorithms. In: Guralnik JM, Simonsick, EM, Kasper JD, Lafferty ME, eds. *The Women's Health and Aging Study: Health and Social Characters of Older Women with Disability.* Bethesda MD: National Institute on Aging, 1995 Appendix E, 1–17; NIH Pub. No 95-4009.
33. Heymsfield SB, McManus C, Smith J, et al. Anthropometric measurements of muscle mass: revised equations for calculating bone-free arm muscle area. *Am J Clin. Nutr.* 1982;36:680–690.
34. Clark DO. The effect of walking on lower body disability among older blacks and whites. *Am J Public Health.* 1996;86:57–61.
35. Gasperino JA, Wang J, Pierson RN Jr, Heymsfield SB. Age-related changes in musculoskeletal mass between black and white women. *Metabolism.* 1995;44:30–34.
36. Ortiz O, Russell M, Aley TL, et al. Differences in skeletal muscle and bone mineral mass between black and white females and their relevance to estimates of body composition. *Am J Clin Nutr.* 1992;55:8–13.
37. Himes JH. Racial variation in physique and body composition. *Can J Spt Sci.* 1988;13:117–126.
38. Cohn SH, Abesamis C, Yasumura S, Aloia JF, Zanzi I, Ellis KJ. Comparative skeletal mass and radial bone mineral content in black and white women. *Metabolism.* 1977;26:171–178.
39. Cummings SR, Cauley JA, Palermo L, et al. Racial differences in hip axis lengths might explain racial differences in rates of hip fracture. *Osteoporosis Int.* 1994;14:226–229.
40. Mikhail MB, Vaswani AN, Aloia JF. Racial differences in femoral dimensions and their relation to hip fracture. *Osteoporosis Int.* 1996; 6:22–24.
41. Anderson JJ, Felson, DT. Factors associated with osteoarthritis of the knee in the First National Health and Nutrition Survey (HANES I): evidence for the association with overweight, race, and physical demands of work. *Am J Epidemiol.* 1987;128:179–89.
42. Slemenda C, Brandt KD, Heilman DK, et al. Quadriceps weakness and osteoarthritis of the knee. *Ann Intern Med.* 1997;127:97–104.

Received August 22, 1997
Accepted April 14, 1998