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Dynapenic-Obesity and Physical Function in Older Adults

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Background. Dynapenia (low muscle strength) and obesity are associated with an impaired physical function. It was hypothesized that older individuals with both conditions (dynapenic-obesity) would have a more impaired physical function than individuals with dynapenia or obesity alone.

Methods. This cross-sectional study included 2,039 men and women aged 55 years and older from the 1999–2002 National Health and Nutrition Examination Survey. Fat mass was measured by dual-energy x-ray absorptiometry and leg strength by dynamometer. Based on fat mass and leg strength tertiles, four independent groups were identified: non-dynapenic and non-obese, obese alone, dynapenic alone, and dynapenic-obese. An objective physical function measure was obtained from a 20-foot walking speed test, whereas subjective physical function measures were obtained from five self-reported questions.

Results. Within both sexes, the dynapenic-obese group had a slower walking speed than the non-dynapenic and non-obese and obese-alone groups ($p \leq .01$) but not the dynapenic-alone group. Similarly, with the exception of the dynapenic-alone group in men, the global subjective score was lower in the dynapenic-obese group than in the non-dynapenic and non-obese and obese-alone groups ($p \leq .01$). By comparison to the dynapenic-obese group, the adjusted odds ratios (95% confidence interval) for walking disability were 0.21 (0.12–0.35) in the non-dynapenic and non-obese, 0.34 (0.20–0.56) in the obese-alone, and 0.54 (0.33–0.89) in the dynapenic-obese groups. The corresponding odds ratios for a disability based on the global subjective score were 0.20 (0.09–0.42), 0.60 (0.30–1.21), and 0.41 (0.19–0.87).

Conclusion. Dynapenic-obesity was associated with a poorer physical function than obesity alone and in most cases with dynapenia alone.

Key Words: Fat mass—Muscle strength—Physical performance.

ALTHOUGH life expectancy has continued to increase in almost countries, the number of years the average person lives prior to developing physical disability has remained stable (1). In fact, the average person will spend approximately 15% of his or her life span in a disabled state (2). The increased length of time that individuals are living with disability is concerning given that disability is associated with frequent and prolonged hospitalizations (3), higher nursing home admission rates (4), and a poorer quality of life (5). Understanding the causes of disability among older persons would contribute to the development of optimal prevention and treatment strategies. Because an impaired physical function typically precedes the development of disability (6), research studies often focus on this early warning sign of disability.

An impaired physical function can be caused by several factors (7,8), including a high fat mass (9–11) and low muscle strength (12–14). The term *dynapenia* has recently been coined to define the loss of strength associated with aging (15). Because obesity and dynapenia are each associated with physical function, it would be rational to hypothesize that older individuals with both a high fat mass and a low muscle strength (dynapenic-obese) would have greater impairments in their physical function than older individuals

with obesity or dynapenia alone. To our knowledge, two studies reported the effect of the combination of these two conditions. First, a 6-year follow-up study of 930 adults aged 65 years or older used the body mass index (BMI) as a proxy measure of obesity and knee extensor strength as a measure of muscle strength (16). The authors concluded that obese individuals ($\text{BMI} > 30 \text{ kg/m}^2$) in the lowest leg strength tertile had a greater decline in physical function than the other participants. Second, in a cross-sectional study, the same research team reported that the prevalence of walking limitation was higher in older adults who had a high body fat percentage and low handgrip strength (61%) than in those with a low body fat percentage and high handgrip strength (7%) (17). This research team proposed that larger studies that obtain direct measures of body fat are needed to confirm these findings.

The main objective of this study was to determine if individuals with dynapenic-obesity had a poorer physical function in comparison to those with dynapenia alone and obesity alone. A large and representative sample of adults aged 55 years and older was studied. Validated measures of fat mass and muscle strength were obtained to determine dynapenic-obesity status.

METHODS

Study Population

The study sample consisted of men and women aged 55 years and older (56–85 years) who participated in the 1999–2000 and 2001–2002 cycles of the U.S. National Health and Nutrition Examination Survey (NHANES). These representative cross-sectional surveys were completed in the noninstitutionalized population. Participants were identified using a complex, stratified, multistage probability sampling design. Detailed survey operation manuals and consent forms are available on the NHANES website (18). Briefly, the NHANES consisted of a home interview and a thorough health examination. During the home interview, participants were asked questions about their health status, disease history, and lifestyle behaviors, including alcohol and smoking. The health examination was performed in a mobile exam center.

All participants provided written and informed consent. The protocol was approved by the National Center for Health Statistics. The study sample was limited to 2,295 men and women aged 55 years or older who completed both the home exam and the mobile exam center portion of the survey. Two hundred fifty-six of these individuals were missing data for at least one of the study variables and were excluded from the analyses. Thus, the final sample size was limited to 2,039 individuals. However, these individuals were not different from the 219 excluded participants for age (70.1 ± 7.7 vs 70.7 ± 8.9 years) and sex (50.4% vs 51.5% male).

Measurement of Obesity

Dual-energy x-ray absorptiometry (DXA) scans were taken with a Hologic QDR-4500A fan-beam densitometer using software version 8.26 (Hologic, Inc., Bedford, MA). DXA provides validated total and regional measures of fat mass, bone mass, and lean mass in all age groups (19). Total fat mass (kilograms) was selected as the obesity measure for the analyses. In this study, total fat mass was highly correlated with percent body fat ($r = .75$; $p \leq .01$). To take into account body size, we adjusted the total fat mass for height as explained in more detail later.

Measurement of Dynapenia

Leg extension strength (kilograms) was measured by a dynamometer (A Kin Com MP; Chattanooga Group, Chattanooga, TN). A number of studies have reported excellent test–retest reliability of leg extension strength measures using the Kin–Com dynamometer (20). Six attempts were performed at a fixed angular velocity of 60 degrees per second (isokinetic). The highest score was used for the analyses. Although leg strength was the only strength measure included in the NHANES study, it is known to be well correlated with other strength measures, including maximal handgrip ($r = .59$), leg press ($r = .86$), and triceps extension strength ($r = .77$) (21).

Classification of Dynapenia, Obesity, and Dynapenic-Obesity

Because sex, age, and height differences in fat mass and muscle strength are well documented (22), age- and height-adjusted values were created within sex. Fat mass and leg strength values were each regressed to a full cubic polynomial in age (age, age², and age³) and height (height, height², and height³) within-sex subgroups using forward stepwise regressions. The standardized residuals were retained to represent age- and height-adjusted values. Participants were divided into four groups based on their sex-specific age- and height-adjusted fat mass and leg strength residual values. Those in the lowest fat mass tertile and lowest leg strength tertiles were classified as “dynapenic alone.” Participants in the highest fat mass tertile and in one of the highest two leg strength tertiles were classified as “obese alone.” Participants in the highest fat mass tertile and the lowest leg strength tertile were classified as “dynapenic-obese.” Participants in one of the lowest two fat mass tertiles and one of the highest two leg strength tertiles were classified as “non-dynapenic and non-obese.”

Measurement of Physical Function

Physical function was measured using both objective and subjective measures. First, walking speed was objectively measured by asking the participant to walk 20 feet at his or her usual pace in a flat corridor. Speed was calculated in meters per second. A walking speed slower than 0.8 m/s was considered as having walking disability (23).

Self-reported physical function was collected using five questions that asked participants to rate their difficulty walking for one quarter of a mile; walking up 10 steps without resting; stooping, crouching, or kneeling; lifting or carrying 10 pounds; and standing on their feet for 2 hours. The response options for each question were as follows: no difficulty (3 points), some difficulty (2 points), much difficulty (1 point), and unable to do (0 point). A factor analysis was performed to confirm that all self-reported physical function measures could be used to create an aggregated factor score. The factor analysis revealed that each of the five measures was highly related ($r \geq .82$) to the factor score. The response from all five self-reported physical function measures was summed to create a global subjective score, with values ranging from 0 to 15. Individuals with a global score of 5 or less or individuals who were unable to do one or more tasks (e.g., score of 0 on any measure) were considered as being disabled. A global score of 5 corresponds to an average rating of “much difficulty” or worse on the five measures.

Covariates

Covariates included in the analyses were age (continuous variable), race or ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), smoking status (never-smoker, former smoker, and current smoker), and alcohol consumption

(average number of drinks per day). The following five chronic conditions known to be related to physical function, strength, and fat mass were also considered based on a medical questionnaire: visual problems, arthritis, diabetes, lung disease (emphysema, asthma, or chronic bronchitis), and cardiovascular disease (angina, heart failure, stroke, or myocardial infarction). Physical activity was assessed by self-report. Participants were asked whether they were engaged in the previous month in 48 different leisure-time activities of at least a moderate intensity. Information regarding frequency and duration was used to calculate a daily mean time devoted to these activities, and participants were placed into one of four groups (none, <30, 30–59, and ≥ 60 min/d). Because of the similarity of the physical activity covariate and the physical function outcomes (e.g., if an individual is unable to achieve basic physical functions, such as walking a one quarter of mile, he or she will be unable to participate in physical activity), separate regression models were run that excluded and included the physical activity covariate.

Statistical Analysis

Data management and statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC). Statistics accounted for the sample weights and complex survey design (strata, probability sampling units). Generalized linear models (GLMs) were used to identify differences in walking speed and the global subjective score among the four groups. Bonferroni post hoc analyses were used to identify any group difference. Logistic regression models were used to predict impaired walking speed (<0.8 m/s) and impaired global subjective score (≤ 5 of 15 or a score of 0 on any of the five tasks). The GLM analyses were adjusted for age, race or ethnicity, alcohol, smoking, and the five chronic conditions (visual problems, arthritis, diabetes, lung disease, and cardiovascular disease). The patterns of results were similar in men and women, and because of the relatively small sample size in each sex group, men and women were combined for the logistic regression analyses.

To determine whether obesity and dynapenia status had additive or multiplicative effects on the physical function measures, all the GLM and logistic regression analyses were repeated. These additional analyses included dichotomous variable for obesity status (yes = obese alone or dynapenic-obese; no = non-dynapenic and non-obese or dynapenic alone), a dichotomous variable for dynapenia status (yes = dynapenia alone or dynapenic-obese; no = non-dynapenic and non-obese and obese alone), an interaction term for these two variables (Obese \times Dynapenia), and the covariates. Significance of the interaction terms was used to denote whether the effects of obesity and dynapenia were additive (nonsignificant interaction) or multiplicative (significant interaction). Significance was accepted at $p \leq .05$.

Table 1. Descriptive Characteristics of the 2,039 Study Participants

Characteristic	Value
General characteristics	
Age (y)	70.1 (7.7)
Men (%)	50.4
Race or ethnicity	
Non-Hispanic white	82.8
Non-Hispanic black	7.1
Hispanic	7.3
Other	2.8
Alcohol intake	
Nondrinker	42.5
Light drinker (<1 drink/d)	43.5
Moderate drinker (1–2 drinks/d)	10.6
Heavy drinker (>2 drinks/d)	3.3
Smoking status	
Never smoked	46.6
Former smoker (>100 cigarettes in life)	40.9
Current smoker	12.5
Physical activity level	
None	51.2
<30 min/d	25.9
30–59 min/d	10.8
>60 min/d	12.1
Chronic conditions	
Visual problems	19.6
Arthritis	44.9
Diabetes	11.9
Lung disease	16.5
Cardiovascular disease	13.1

Note: Data presented as unadjusted mean (SD) for age and prevalence (%) for categorical variables.

RESULTS

Descriptive Characteristics

As reported in Table 1, the mean age of the participants was 70.1 ± 7.7 years. The sample was mostly non-Hispanic white and was composed equally of men and women. Most of the participants drank less than one alcoholic beverage per day and were nonsmokers.

Table 2 shows the characteristics of men and women according to their obesity and dynapenia status. There were no differences in age or the sum of chronic conditions across groups in men or women. Because of the study design, the obese-alone and dynapenic-obese groups had a greater fat mass than the other two groups. Similarly, the dynapenic-alone and dynapenic-obese groups had lower leg strength values than the other groups. There was no difference in fat mass between the obese-alone and the dynapenic-obese groups in both sexes. Finally, leg strength values were not different in the dynapenic-obese and dynapenic-alone groups.

Differences in Physical Function

As illustrated in Table 3, once adjusted for covariates, within both sexes, the non-dynapenic and non-obese group had a faster walking speed than the remaining three groups ($p \leq .01$ in both sexes). No difference was observed between obese-alone and dynapenic-alone groups ($p = .99$ in both

Table 2. Characteristics of Men and Women According to Obesity and Dynapenia Status

	Non-dynapenic and Non-obese	Obese Alone	Dynapenic Alone	Dynapenic and Obese
Men (<i>N</i> = 1,025)	<i>n</i> = 437	<i>n</i> = 247	<i>n</i> = 246	<i>n</i> = 95
Age (y)	68.9 (68.1–69.6)	68.6 (67.5–69.6)	68.3 (67.2–69.4)	69.4 (67.3–71.4)
Fat mass (kg)	22.5 (21.9–23.0) ^{b,c,d}	34.9 (33.9–35.8) ^{a,c}	21.2 (20.4–22.0) ^{a,b,d}	35.9 (34.6–37.2) ^{a,c}
Leg strength (kg)	45.2 (44.3–46.2) ^{c,d}	46.2 (45.0–47.3) ^{c,d}	30.4 (29.3–31.6) ^{a,b}	30.3 (28.4–32.3) ^{a,b}
Total lean mass (kg)	54.4 (53.7–55.3) ^{b,c,d}	62.7 (61.6–63.8) ^{a,c}	49.8 (48.8–50.8) ^{a,b,d}	58.8 (56.8–60.8) ^{a,c}
Race (% non-Hispanic white)	84.8 (84.6–85.0) ^b	91.3 (91.2–91.5) ^{a,c}	73.6 (73.2–74.0) ^b	90.2 (91.1–91.7)
>1 alcohol drink/d (%)	25.3 (21.6–29.0)	17.5 (13.2–21.8)	21.4 (19.7–26.1)	8.8 (5.1–12.5)
Current smokers (%)	13.9 (9.9–17.8)	7.8 (3.7–11.9)	22.5 (15.8–29.2)	8.8 (3.1–14.5)
Physical activity ≥30 min/d (%)	40.3 (34.8–45.8) ^{b,c,d}	24.2 (17.6–30.9) ^a	29.0 (21.5–32.5) ^a	27.8 (16.5–33.1) ^a
Sum of chronic conditions (0–5)	0.9 (0.8–1.1)	1.1 (0.9–1.3)	1.0 (0.9–1.2)	1.4 (1.1–1.8)
Women (<i>N</i> = 1,014)	<i>n</i> = 427	<i>n</i> = 249	<i>n</i> = 249	<i>n</i> = 89
Age (y)	70.0 (69.1–71.9)	68.9 (67.7–70.0)	69.8 (68.8–70.8)	70.7 (69.4–72.1)
Fat mass (kg)	26.2 (25.6–26.9) ^{b,c,d}	41.3 (40.1–42.4) ^{a,c}	24.2 (23.3–25.1) ^{a,b,d}	40.5 (38.9–42.1) ^{a,c}
Leg strength (kg)	30.1 (29.4–30.7) ^{b,c,d}	31.9 (31.0–32.8) ^{a,c,d}	20.1 (19.6–20.7) ^{a,b}	19.8 (18.5–21.1) ^{a,b}
Total lean mass (kg)	38.0 (37.5–38.6) ^{b,c,d}	44.2 (43.3–45.1) ^{a,c}	35.4 (34.8–35.9) ^{a,b,d}	43.7 (42.3–45.0) ^{a,c}
Race (% non-Hispanic white)	80.1 (76.6–83.6)	81.5 (77.8–85.4)	84.0 (80.1–87.9)	79.6 (72.1–87.1)
>1 alcohol drink/d (%)	7.8 (6.0–9.6)	6.4 (4.0–8.7)	5.4 (2.7–8.1)	4.5 (0.2–9.2)
Current smokers (%)	10.2 (6.5–13.9)	9.9 (5.2–14.6)	16.2 (10.7–21.7)	6.7 (0.6–12.8)
Physical activity ≥30 min/d (%)	25.6 (20.7–30.6) ^{b,d}	12.4 (7.4–17.3) ^a	17.7 (12.6–22.7)	10.3 (2.9–17.5) ^a
Sum of chronic conditions (0–5)	1.1 (0.9–1.3)	1.3 (1.1–1.5)	1.4 (1.2–1.6)	1.5 (1.2–1.8)

Notes: Data presented as unadjusted mean or prevalence (95% confidence interval). Significantly different ($p \leq .05$) from the: ^anon-dynapenic and non-obese group, ^bobese-alone group, ^cdynapenic-alone group, and ^ddynapenic-obese group. Generalized linear models were used to identify among the four groups. Bonferroni post hoc analyses were used to identify any group difference.

sexes). Furthermore, within both sexes, the dynapenic-obese group had a slower walking speed than the obese-alone group ($p \leq .01$ in both sexes) but not the dynapenic-alone group ($p = .08$ in men, $p = .12$ in women). When further adjusted for physical activity, the mean walking speed increased slightly in each group without any change of significant differences among groups.

For the global subjective score (Table 3) within both sexes, the non-dynapenic and non-obese group had a greater

score than the remaining three groups ($p \leq .01$ in both sexes) once adjusted for covariates. Again, there was no difference in the global subjective score in the obese-alone and dynapenic-alone groups in both sexes. With the exception of dynapenic-alone group in men, the global subjective scores in the dynapenic-obese groups were lower than the scores in the other three groups ($p \leq .01$ in both sexes). Similarly to what was observed for the walking speed results, the mean score increased slightly when further adjusted for physical

Table 3. Physical Function According to Obesity and Dynapenia Status

	Non-dynapenic and Non-obese	Obese Alone	Dynapenic Alone	Dynapenic-Obese
Men	<i>n</i> = 437	<i>n</i> = 247	<i>n</i> = 246	<i>n</i> = 95
Walking speed (m/s)				
Nonadjusted	1.09 ± 0.20	1.03 ± 0.18	0.99 ± 0.22	0.93 ± 0.21
Adjusted*	0.94 ± 0.38 ^{b,c,d}	0.89 ± 0.32 ^{a,d}	0.87 ± 0.30 ^{a,d}	0.81 ± 0.24 ^{a,b,c}
Adjusted**	0.96 ± 0.42 ^{b,c,d}	0.91 ± 0.31 ^{a,d}	0.89 ± 0.31 ^{a,d}	0.82 ± 0.29 ^{a,b,c}
Global subjective score (0–15)				
Nonadjusted	14.34 ± 3.19	13.80 ± 2.15	13.02 ± 2.54	12.42 ± 1.29
Adjusted*	12.95 ± 4.50 ^{b,c,d}	12.32 ± 3.78 ^{a,d}	11.90 ± 2.54 ^a	11.33 ± 1.29 ^{a,b,c}
Adjusted**	13.08 ± 4.60 ^{b,c,d}	12.52 ± 3.93 ^{a,d}	12.17 ± 3.61 ^a	11.55 ± 2.92 ^{a,b,c}
Women	<i>n</i> = 427	<i>n</i> = 249	<i>n</i> = 249	<i>n</i> = 89
Walking speed (m/s)				
Nonadjusted	1.03 ± 0.23	0.97 ± 0.28	0.95 ± 0.24	0.84 ± 0.20
Adjusted*	0.95 ± 0.63 ^{b,c,d}	0.88 ± 0.52 ^{a,d}	0.86 ± 0.50 ^{a,d}	0.80 ± 0.35 ^{a,b,c}
Adjusted**	0.98 ± 0.62 ^{b,c,d}	0.92 ± 0.47 ^{a,d}	0.90 ± 0.47 ^{a,d}	0.82 ± 0.28 ^{a,b,c}
Global subjective score (0–15)				
Nonadjusted	13.61 ± 3.87	12.01 ± 3.29	12.32 ± 3.29	10.53 ± 2.33
Adjusted*	12.10 ± 7.58 ^{b,c,d}	10.86 ± 6.26 ^{a,d}	11.22 ± 6.07 ^{a,d}	9.57 ± 4.23 ^{a,b,c}
Adjusted**	12.46 ± 9.09 ^{b,c,d}	11.43 ± 6.31 ^{a,d}	11.64 ± 6.00 ^{a,d}	10.14 ± 4.15 ^{a,b,c}

Notes: Data are presented as mean ± SD. Significantly different ($p \leq .05$) from the: ^anon-dynapenic and non-obese group, ^bobese-alone group, ^cdynapenic-alone group, and ^ddynapenic-obese group. Generalized linear models were used to identify differences among the four groups. Bonferroni post hoc analyses were used to identify any group difference.

*Adjusted for age, gender, race or ethnicity, alcohol intake, smoking status, and the five chronic conditions (visual problems, arthritis, diabetes, lung disease, and cardiovascular disease).

**Further adjusted for physical activity.

Table 4. Risk of Physical Disability According to Obesity and Dynapenia Status

	Non-dynapenic and Non-obese, <i>n</i> = 864	Obese Alone, <i>n</i> = 496	Dynapenic Alone, <i>n</i> = 495	Dynapenic-Obese, <i>n</i> = 184
Walking disability				
Prevalence	12.2	18.0	24.1	36.1
Model 1	0.21 (0.13–0.35)	0.38 (0.23–0.64)	0.53 (0.32–0.88)	1
Model 2	0.21 (0.12–0.37)	0.38 (0.22–0.66)	0.56 (0.32–0.97)	1
Model 3	0.21 (0.13–0.35)	0.34 (0.20–0.56)	0.54 (0.33–0.89)	1
Global subjective score				
Prevalence	2.2	7.3	5.3	13.2
Model 1	0.14 (0.07–0.30)	0.52 (0.27–0.75)	0.36 (0.17–0.75)	1
Model 2	0.17 (0.08–0.36)	0.56 (0.28–1.14)	0.37 (0.17–0.80)	1
Model 3	0.20 (0.09–0.42)	0.60 (0.30–1.21)	0.41 (0.19–0.87)	1
Climbing stairs*				
Prevalence	1.2	5.5	6.1	14.6
Model 1	0.07 (0.03–0.17)	0.32 (0.26–0.66)	0.35 (0.17–0.70)	1
Model 2	0.08 (0.03–0.20)	0.32 (0.5–0.17)	0.35 (0.16–0.76)	1
Model 3	0.09 (0.04–0.21)	0.29 (0.14–0.61)	0.36 (0.17–0.77)	1
Stooping-kneeling-bending*				
Prevalence	4.8	14.2	12.7	31.5
Model 1	0.11 (0.06–0.19)	0.35 (0.22–0.58)	0.30 (0.18–0.51)	1
Model 2	0.11 (0.06–0.19)	0.29 (0.16–0.51)	0.34 (0.21–0.58)	1
Model 3	0.13 (0.07–0.23)	0.37 (0.22–0.60)	0.33 (0.19–0.56)	1
Walking one quarter of mile*				
Prevalence	3.3	12.3	10.9	12.9
Model 1	0.23 (0.11–0.46)	0.97 (0.50–1.90)	0.79 (0.40–1.56)	1
Model 2	0.24 (0.11–0.49)	1.02 (0.51–2.02)	0.77 (0.38–1.56)	1
Model 3	0.29 (0.14–0.58)	1.07 (0.54–2.10)	0.86 (0.44–1.68)	1
Lifting 10 lbs*				
Prevalence	2.9	5.6	9.8	9.7
Model 1	0.27 (0.13–0.61)	0.54 (0.25–1.19)	0.96 (0.45–2.03)	1
Model 2	0.29 (0.12–0.66)	0.55 (0.24–1.26)	0.94 (0.43–2.07)	1
Model 3	0.37 (0.16–0.88)	0.68 (0.29–1.57)	1.19 (0.54–2.70)	1
Standing for 2 h*				
Prevalence	4.9	13.6	14.4	24.8
Model 1	0.15 (0.08–0.29)	0.48 (0.28–0.81)	0.49 (0.29–0.84)	1
Model 2	0.15 (0.08–0.28)	0.46 (0.26–0.81)	0.46 (0.26–0.83)	1
Model 3	0.17 (0.10–0.31)	0.46 (0.27–0.79)	0.50 (0.29–0.87)	1

Notes: Data are presented as % and odds ratio (95% confidence interval). Model 1: adjusted for age and gender. Model 2: adjusted for age, gender, race/ethnicity, alcohol intake, smoking status, and the five chronic conditions (visual problems, arthritis, diabetes, lung disease, and cardiovascular disease). Model 3: further adjusted for physical activity level.

*Disability defined as reporting “much difficulty” or “unable to do.”

activity, but the significant differences among groups did not change.

Additional analyses considered whether there were differences between groups in the proportion of those considered as disabled based on walking speeds, global subjective score, as well as the five self-reported physical function measures. These results (Table 4) were comparable to those presented for the continuous outcomes in the preceding two paragraphs such that the non-dynapenic and non-obese group had the lowest proportion of disability and the dynapenic-obese group had the highest proportion of disability (exception: lifting disability). By comparison to the dynapenic-obese group, the adjusted odds ratios (95% confidence interval) for walking disability were 0.21 (0.12–0.35) in the non-dynapenic and non-obese group, 0.34 (0.20–0.56) in the obese-alone group, and 0.54 (0.33–0.89) in the dynapenic-obese group. The corresponding odds ratios for a disability based on the global subjective score were 0.20 (0.09–0.42), 0.60 (0.30–1.21), and 0.41 (0.19–0.87).

Additional analyses testing the possible interaction of obesity and dynapenia status on all the relations presented in Tables 3 and 4 were performed. In all cases, obesity and dynapenia status were significant ($p \leq .01$) predictors of the physical function measures; however, the interaction term (Obesity \times Dynapenia) was not significant ($p > .05$). This implies that obesity and dynapenia had additive but not multiplicative effects on the physical function measures.

DISCUSSION

Older individuals with obesity alone or dynapenia alone had an impaired physical function in comparison with individuals without either of these two conditions (e.g., non-dynapenic and non-obese). For most of the measures examined, older individuals with dynapenic-obesity had a poorer physical function than individuals with obesity alone or dynapenia alone. The analyses suggest that dynapenia and obesity

had independent effects on the physical function measures and that these effects were additive and not multiplicative.

Our findings are consistent with the only group of researchers to date that has considered the combined effect of obesity and muscle strength on physical function in older adults. In one of their two studies, Stenholm and colleagues (16) examined 930 adults aged 65 years and older over a 6-year follow-up period. Obese individuals (classified with BMI) with low muscle strength (measured with knee extensor strength) had a 17% reduction in walking speed over the follow-up period compared with 8% in obese individuals with a normal strength and 4% in individuals with low strength and a normal BMI. In their other cross-sectional study of 2,208 adults aged 55 years and older, they reported that the prevalence of walking limitation was much higher when a person simultaneously had a high body fat percentage and low handgrip strength (17).

Until now, most of the literature examining the independent and interactive effects of fat and muscle on physical function has employed measures of muscle mass (sarcopenia) instead of muscle strength (dynapenia). In contrast to the findings reported here and by Stenholm and colleagues (16,17) for dynapenic-obesity, all but one (24) of the sarcopenic-obesity studies concluded that sarcopenic-obesity is not associated with a greater risk of physical impairment than obesity alone (25–27). The discrepancy between the dynapenic-obesity and the sarcopenic-obesity studies may be explained by the fact that muscle mass is only a modest correlate of muscle strength within older adults (28,29).

Our finding that obesity alone and dynapenia alone were associated with an impaired physical function is supported by a large body of evidence (9–12,30). When comparing the two conditions, dynapenic men had a slower walking speed than obese men. Furthermore, in comparison to the dynapenic-obese group, walking speed was slower in the obese men and women but not slower in the dynapenic men and women. Thus, on the whole, physical function was impaired to a greater extent in individuals with dynapenia alone than in those with obesity alone. This finding is supported by Stenholm and colleagues (16) who indicated that the decline in muscle strength over a 6-year follow-up period explained the largest portion of the decline in walking speed in dynapenic-obese older adults.

The difference in walking speed observed between the different groups in this study may, at first glance, appear to be small and of little relevance. For example, the difference between the non-dynapenic and non-obese and the dynapenic-obese groups was approximately 0.14 m/s (or 14.9%). This difference is not trivial, and it would translate into a difference of 2.8 seconds over a 20-m distance, which would have obvious implications for tasks of daily living, such as crossing the street in the time allowed (25). Because walking speed and difficulty are independent determinants of self-rated health (26) and mobility difficulty, this added

time could have a large impact on autonomy and endurance during activities of daily living.

Although a decline in physical function is an inevitable part of aging, there is tremendous interindividual variability in the rate at which this process occurs (27). Poor leg strength (28) and a high fat mass (29) are modifiable risk factors that may contribute to an accelerated decline in physical function with aging. Therefore, as supported by this study, prevention and treatment approaches to enhance physical function in older adults may want to incorporate strategies that will address both the muscle strength and the fat mass components. Although it is an often overlooked strategy, strength training may be particularly relevant, particularly given the controversy in the literature regarding the effects of weight loss (especially when induced by caloric restriction alone) on overall health in older adults (30). Recent findings from a 6-month intervention study conducted in obese older adults indicate that a 20- to 30-minute resistance training session, consisting of a single set of 10 different exercises targeting the major muscle groups, performed 3 days per week, is enough to significantly improve physical function (31).

As with any study, this study was not without its limitations. Because we used tertiles to categorize dynapenic-obesity status, the muscle strength and fat mass thresholds were arbitrary in nature. Furthermore, the self-reported physical function scale and thresholds employed have not been previously validated. Additional studies are needed to identify if there is specific muscle strength to fat mass ratio associated with a reduced risk of functional impairment in older adults. Finally, the cross-sectional design did not allow us to ascertain the temporal sequence of the variables studied.

In summary, dynapenia in the absence of obesity and obesity in the absence of dynapenia were each associated with an impaired physical function. Moreover, dynapenic-obesity was associated with a more impaired physical function than dynapenia alone or obesity alone.

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