

Relative Contributions of Adiposity and Muscularity to Physical Function in Community-dwelling Older Adults

Catherine M. Jankowski¹, Wendolyn S. Gozansky¹, Rachael E. Van Pelt¹, Margaret L. Schenkman², Pamela Wolfe³, Robert S. Schwartz¹ and Wendy M. Kohrt¹

Objective: To determine the relative contributions of adiposity and muscularity to multi-dimensional performance-based and perceived physical function in older adults living independently.

Methods and Procedures: Data from 109 women and men, aged 60 or older, with low serum dehydroepiandrosterone (DHEA) sulfate levels were included in this cross-sectional analysis of baseline measures from a single-site, randomized, controlled trial of DHEA replacement therapy. Physical function was determined by means of performance on the 100-point Continuous Scale-Physical Functional Performance (CS-PFP) test and by self-reporting using the physical function subscale of the Medical Outcomes Short Form-36 (SF36_{PF}). Body composition was measured by dual-energy X-ray absorptiometry (DXA). Linear regression analyses were used to determine the contributions of body mass index (BMI; kg body mass/m²), fat index (FI; kg fat/m²), and appendicular skeletal muscle index (ASMI; kg muscle/m²) to the CS-PFP and SF36_{PF} scores, adjusted for age and sex.

Results: Age-adjusted regression analyses indicated that FI, but not ASMI, was a significant ($P < 0.001$) determinant of CS-PFP ($R^2 = 0.54$) and SF36_{PF} ($R^2 = 0.37$). When adjusted for age and sex, BMI was nearly as good a predictor of CS-PFP ($R^2 = 0.50$) and SF36_{PF} ($R^2 = 0.34$) as FI.

Discussion: Adiposity was a stronger predictor of measured and self-reported physical function than was muscularity in older adults living independently. BMI, adjusted for sex, is a reasonable substitute for adiposity in the prediction of physical function.

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INTRODUCTION

With advancing age, many adults will have relative degrees of both obesity and sarcopenia as a result of the inevitable increase in fat mass (FM) and decrease in muscle mass (1,2). High BMI (3,4), low muscle mass (5), and the combination of excess FM with low muscle mass (6) have been associated with increased risk for physical disability in older adults. Sarcopenic obesity describes a body type that is over-fat and under-muscle relative to body size (6,7). Although an accepted definition of sarcopenic obesity is lacking, it has been suggested that it is present in <10% of the elderly population (8,9), whereas the prevalence of sarcopenia is 13–36% (10) and ~33% of older Americans are obese (11).

Several studies (3,8,12–16) support the notion that the impairment of physical function in the elderly is more strongly associated with excess body mass and/or relative FM than inadequate fat-free mass (FFM). However, these studies were limited by the use of only self-reported physical function (8,12,14)

or the evaluation of only one dimension of performance-based function (e.g., lower extremity function) (13,15,16). In studies that included multi-dimensional performance-based measures of physical function, high BMI (17–19) and low relative FFM (18) were each significant determinants of functional limitations, but the relative contributions of FM and FFM to function were not evaluated. Therefore, the aim of this study was to determine the relative contributions of adiposity and muscularity to multi-dimensional performance-based (i.e., measured) and perceived (i.e., self-reported) physical function in community-dwelling older women and men.

METHODS AND PROCEDURES

Study population

Women and men aged 60 years or older were recruited to participate in a randomized, double-blinded, placebo-controlled trial of dehydroepiandrosterone (DHEA) replacement therapy conducted at a university medical center. The study cohort included 109 participants (55 women) for whom complete body composition and physical function testing

¹Department of Medicine, Division of Geriatric Medicine, University of Colorado Denver, Aurora, Colorado, USA; ²School of Medicine, Physical Therapy Program, University of Colorado Denver, Aurora, Colorado, USA; ³Department of Preventive Medicine and Biometrics, University of Colorado Denver, Aurora, Colorado, USA. Correspondence: Catherine M. Jankowski (catherine.jankowski@uchsc.edu)

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were obtained at study entry. All participants provided written informed consent to participate in the study, which was approved by the local Institutional Review Board.

A medical history was taken and screening tests were performed to determine eligibility for participation in the randomized trial. Participants met the following eligibility criteria: serum DHEA sulfate $<3.8 \mu\text{mol/l}$; fasted serum triglycerides $<4.52 \text{ mmol/l}$; blood pressure $<180/95 \text{ mm Hg}$; normal thyroid function; normal liver enzymes; Geriatric Depression Scale (20) score <20 ; Mini-mental State Exam (21) score >24 ; and no contraindications for DHEA replacement therapy. Individuals were also excluded for the following reasons: unstable health, poorly controlled diabetes mellitus or use of insulin, and use of hormone therapies or oral glucocorticoids in the previous 6 months. Thirteen (eleven of whom were men) of the 261 volunteers screened for participation had serum DHEAS levels that exceeded the inclusion criterion (22).

Physical function performance

Measured physical function performance was determined using the total score on the Continuous Scale-Physical Functional Performance (CS-PFP) test (23). The CS-PFP comprises 16 tasks of varying difficulty that represent activities of daily living and instrumental activities of daily living, such as dressing and carrying a bag of groceries. Performance is quantified using combinations of time to complete a task, amount of weight carried, and/or distance walked, then scored on a scale from 0 to 100 with higher scores reflecting better function. The CS-PFP total score is the average score of all tasks. The CS-PFP tests were administered by three testers (inter-rater reliability = 0.94–0.99), in a standardized laboratory setting using scripted instructions. Additional information regarding the CS-PFP is available at <http://www.coe.uga.edu/cs-pfp>.

Perceived physical function was determined using the physical function subscale of the Medical Outcomes Short Form-36 (SF36_{PF}) with higher scores indicating better perceived function (24,25). Eight of the ten questions within the SF36_{PF} are similar to tasks performed in the CS-PFP (e.g., climbing one flight of stairs). The SF36 and CS-PFP were completed ~2 weeks apart.

Body composition

Dual-energy X-ray absorptiometry. Body composition was measured via dual-energy X-ray absorptiometry (DXA) with either a Lunar DPXIQ (Software v4.38, GE Healthcare Technologies, Waukesha, WI) ($n = 79$; 34 women, 45 men) or a Hologic Delphi W (software v11.2, Hologic, Bedford, MA) ($n = 30$; 21 women, 9 men) instrument. Because the use of two DXA instruments could not be avoided, we did a separate study of 34 subjects (not in the present trial) measured on both instruments. The between-instrument bias was assessed using Bland-Altman plots and an orthogonal regression (26) of the measures from Lunar regressed on Hologic. The mean \pm s.d. of the bias for body mass, FM, FFM, and appendicular skeletal muscle mass were $0.21 \pm 0.69 \text{ kg}$, $0.71 \pm 1.12 \text{ kg}$, $-0.92 \pm 1.06 \text{ kg}$, and $-0.10 \pm 0.70 \text{ kg}$, respectively. The estimated regression coefficients from the orthogonal regression were used to transform data for the 30 subjects measured using a Hologic instrument in this study. Body mass, FM, and appendicular skeletal muscle mass were normalized to height² to control for skeletal size (10). Each variable was expressed categorically and continuously, as described below.

BMI. BMI, an index of obesity, was derived from body mass measured by DXA to the nearest gram and height measured to the nearest 0.1 cm. We used the World Health Organization cutoff points for BMI (27) to classify participants by obesity because of the widespread clinical use of this index and for comparison with previous studies (3,8,14,18). Participants were categorized as obese (BMI ≥ 30), overweight ($25 \leq \text{BMI} < 30$), or normal weight (BMI < 25).

Fat index. Fat index (FI), a measure of adiposity, was calculated as FM normalized to height (kg/m²). Unlike BMI, FI reflects sex differences

in adiposity. The distribution of FI was divided into tertiles for the categorical analyses.

Appendicular skeletal muscle index. Appendicular skeletal muscle index (ASMI), a measure of muscularity, was the sum of bone-free, fat-free tissue mass in the arms and legs normalized to height (kg/m²). Unlike obesity, there is no single accepted clinical parameter of muscularity. For the categorical analyses, cutoff points for muscularity were selected using the method of Baumgartner *et al.* (9) whereby women and men with ASMI <5.45 and <7.26 , respectively, were classified as sarcopenic (6,10). Because of the lack of consensus on the definition of sarcopenia (9), a second approach for the categorical analyses utilized tertiles of ASMI.

Statistical analysis

The primary dependent variables were CS-PFP and SF36_{PF}. Sex differences in body composition, CS-PFP, and SF36_{PF} were determined by independent *t*-tests. The association of CS-PFP with SF36_{PF} was assessed using Spearman's rank correlation coefficient (*r*). Differences in the primary outcomes among categories of BMI, tertiles of FI, categories of sarcopenia, and tertiles of ASMI were tested using one-way ANOVA with Tukey post-hoc tests. Linear regression models were used to determine the relative contributions of age, sex, FI, ASMI, and BMI, expressed as continuous variables, to CS-PFP and SF36_{PF}. Because tests of assumptions revealed a skewed distribution of SF36_{PF} (i.e., a ceiling effect) and no single transformation was appropriate for both SF36_{PF} and CS-PFP, confidence intervals (CI) for the model parameters were estimated using bootstrapping methods. We re-sampled cases with replacement 5,000 times, estimating the regression parameters for each model on each iteration, and used the percentile method for estimating the 95% CIs (28) for the population parameters. Resampling of cases is preferred to resampling the errors because the former is more robust to misspecification of the model. For the 30 cases with transformed Hologic DXA data, errors saved from the orthogonal regressions were sampled and attached to the transformed body mass, FM, and appendicular skeletal muscle values before entering the bootstrap analysis. Analyses were performed using SAS statistical software version 9.1 (SAS Institute, Cary, NC); significance was defined as $\alpha \leq 0.05$ except in the bootstrap estimates, where the null hypothesis ($H_0: \beta = 0$) was rejected when the 95% CI excluded 0. Data are presented as the mean \pm s.d.

RESULTS

Subject characteristics

The participants were aged 69 ± 7 years (range: 60–84 years), ambulatory, and living independently; 94% were white and non-Hispanic (Table 1). Twenty-five participants were obese based on BMI, 19 were sarcopenic based on ASMI, and one was sarcopenic obese. Significant cognitive impairment and major depression were absent. Medication use has been previously described (22). Men scored significantly ($P < 0.01$) better than women on the CS-PFP, but not on the SF36_{PF}. CS-PFP was significantly correlated with SF36_{PF} ($r = 0.53$, $P < 0.001$). The sex differences in body composition were as expected, with women having similar BMI but significantly greater adiposity and less muscularity than men.

Effects of body mass, adiposity, and muscularity on physical function: categorical analyses

There were significant differences across BMI categories and FI tertiles in CS-PFP (both $P < 0.05$) and SF36_{PF} (both $P < 0.001$) (Table 2). In the post-hoc analyses, CS-PFP was significantly

Table 1 Subject characteristics (mean ± s.d.)

	Women (n = 55)	Men (n = 54)
Age (years)	69 ± 7	69 ± 7
CS-PFP	56.5 ± 13.4	64.8 ± 16.9*
SF36 _{PF}	79.0 ± 17.1	84.0 ± 19.8
Body mass (kg)	70.8 ± 16.3	84.6 ± 13.4**
BMI (kg/m ²)	27.0 ± 5.2	27.5 ± 4.3
Fat mass (kg)	30.0 ± 11.7	25.6 ± 9.7***
Fat index (kg fat/m ²)	11.4 ± 4.1	8.4 ± 3.2**
Fat-free mass (kg)	41.1 ± 6.0	59.0 ± 5.7**
Appendicular skeletal muscle mass (kg)	16.4 ± 2.9	24.8 ± 3.2**
Appendicular skeletal muscle index (kg/m ²)	6.3 ± 0.9	8.1 ± 0.9**

All body composition variables include Lunar and transformed Hologic data. Range of CS-PFP and SF36_{PF} is 0–100.

CS-PFP, total score on the Continuous Scale-Physical Functional Performance test; SF36_{PF}, physical function subscale of the 36-Item Medical Outcomes Survey.

* $P < 0.01$; ** $P < 0.001$; *** $P \leq 0.05$; women vs. men.

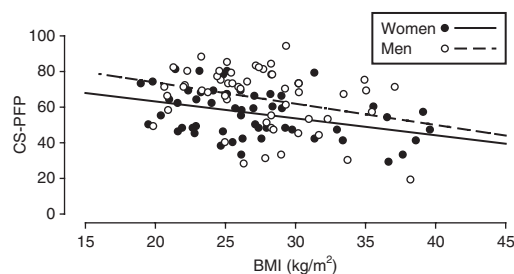
Table 2 Performance-based (CS-PFP) and perceived (SF36_{PF}) physical function in older women and men classified by levels of obesity, adiposity, and muscularity

	n Women/men	CS-PFP	SF36 _{PF}
Obesity by BMI (28)			
Normal weight	21/14	65 ± 13 ^a	90 ± 10 ^a
Overweight	23/25	61 ± 16	82 ± 17 ^a
Obese	11/15	54 ± 16	69 ± 24
Adiposity by FI tertiles			
Low	18/18	66 ± 15 ^b	91 ± 9 ^b
Intermediate	18/18	61 ± 16	83 ± 17 ^b
High	19/18	56 ± 15	71 ± 22
Muscularity by ASMI, categories of sarcopenia (9)			
Normal	47/43	61 ± 16	81 ± 18
Sarcopenic	8/11	59 ± 13	82 ± 20
Muscularity by ASMI tertiles			
High	19/18	63 ± 17	82 ± 17
Intermediate	17/18	60 ± 16	76 ± 21
Low	19/18	59 ± 14	86 ± 16

All values are mean ± s.d. Body composition variables include Lunar and transformed Hologic data.

ASMI, appendicular skeletal muscle index, kg/m²; CS-PFP, total score on the Continuous Scale-Physical Functional Performance test; FI, fat index, kg/m²; SF36_{PF}, physical function subscale of the 36-Item Medical Outcomes Survey. Superscripts designate significant ($P < 0.05$) post-hoc comparisons for each performance outcome: ^acompared to obese; ^bcompared to high FI tertile.

lower in the obese than the normal weight tertile, and lower in the high FI tertile than in the low FI tertile (both $P < 0.05$). SF36_{PF} was significantly lower in the obese than in the normal weight or overweight tertiles, and lower in the high FI tertile

**Figure 1** Association of BMI with Continuous Scale-Physical Functional Performance (CS-PFP) test total scores in older women and men.

than in the intermediate or low FI tertiles (all $P < 0.05$). There were no significant differences in CS-PFP or SF36_{PF} between sarcopenia categories or across ASMI tertiles.

Relative contributions of body mass, adiposity, and muscularity to physical function: regression models

The relative contributions of body mass, adiposity, and muscularity to CS-PFP and SF36_{PF} were tested using linear regression (Table 3). During model development sex was found to be highly collinear with ASMI (Kendall's τ correlation coefficient = 0.60) and FI (Kendall's τ correlation coefficient = -0.32); the interaction of sex with ASMI or FI was not significant ($P = 0.09$ and $P = 0.86$ respectively). Therefore, in the primary analysis sex was dropped from models that included ASMI or FI. Sex remained a significant independent predictor of function in the presence of BMI, such that the level of function was higher in men than in women for any given BMI (Figure 1).

The four regression models evaluated were: (i) CS-PFP as a function of age, FI, and ASMI; (ii) CS-PFP as a function of age, sex, and BMI; (iii) SF36_{PF} as a function of age, FI, and ASMI; and (iv) SF36_{PF} as a function of age, sex, and BMI. After adjustment for age, which was a significant independent and inverse predictor of function in all models, FI was a significant inverse determinant of CS-PFP and SF36_{PF}. ASMI was of borderline significance in predicting CS-PFP (CI: -0.02, 3.46) but not a significant determinant of SF36_{PF}. Therefore, we added two simplified Adiposity models: CS-PFP as a function of age and FI and SF36_{PF} as a function of age and FI. BMI, when adjusted for sex, was almost as robust a determinant of CS-PFP and SF36_{PF} as FI. ASMI explained $\leq 2\%$ of the variability in either outcome.

In an exploratory analysis, sex-specific regression models of the relative contributions of ASMI and FI to CS-PFP and SF36_{PF} (adjusted for age) were tested. These results concur with the primary analysis: FI is a consistent, highly significant ($P < 0.001$ for all models) predictor of function whereas ASMI ranged from just significant (e.g., prediction of CS-PFP only in older men) to not significant, depending on the model. FI was inversely related to function in all of the sex-specific models, and the absolute value of the standardized coefficient on FI ranged from 0.5 to >20 times greater than that of ASMI. Therefore, adiposity was more important to physical function than was muscularity in healthy older adults.

Table 3 Linear regression models of performance-based (CS-PFP) and perceived (SF36_{PF}) physical function in older women and men

Dependent variables	Models	Predictor variables	R ²	$\hat{\beta}$	s.e. ($\hat{\beta}$)	95% CI
CS-PFP	Adiposity+muscularity	Age	0.54	-1.27	0.16	-1.59, -0.99
		FI		-2.04	0.29	-2.63, -1.50
		ASMI		2.06	0.87	-0.02, 3.46
	Adiposity	Age	0.52	-1.35	0.15	-1.64, -1.07
		FI		-2.02	0.30	-2.62, -1.47
	Obesity	Age	0.50	-1.38	0.17	-1.72, -1.07
		BMI		-1.38	0.25	-1.88, -0.91
		Sex		8.90	2.13	4.94, 13.28
SF36 _{PF}	Adiposity+muscularity	Age	0.37	-0.94	0.25	-1.43, -0.47
		FI		-2.60	0.42	-3.47, -1.85
		ASMI		-0.25	0.97	-2.11, 1.73
	Adiposity	Age	0.37	-0.93	0.24	-1.41, -0.46
		FI		-2.60	0.42	-3.48, -1.85
	Obesity	Age	0.34	-1.01	0.26	-1.50, -0.51
		BMI		-2.02	0.37	-2.78, -1.34
		Sex		5.91	2.90	0.61, 11.82

Confidence intervals (CI) were based on the bootstrap percentile method: 5,000 samples with replacement were drawn from the original data, estimates of the parameters saved, and the results sorted. The 95% confidence limits are the 2.5th and 97.5th percentile points of the ordered estimates. Body composition variables include Lunar and transformed Hologic data.

ASMI, appendicular skeletal muscle index, kg/m²; CS-PFP, overall score on the Continuous Scale-Physical Functional Performance test; FI, fat index, kg/m²; s.e. ($\hat{\beta}$), bootstrap estimates of variance; SF36_{PF}, physical function subscale of the 36-Item Medical Outcomes Survey; $\hat{\beta}$, parameter estimate of the original linear regression. Bold type indicates rejection of the null hypothesis ($H_0: \beta=0$).

DISCUSSION

The aim of this study was to determine the relative contributions of body mass, adiposity, and muscularity to measured (i.e., performance-based) and perceived (i.e., self-reported) physical function in community-dwelling, older women and men. The major finding, based on both categorical and regression analyses, was that adiposity (FI) and obesity (BMI), but not muscularity (ASMI), were strong determinants of both measured and perceived physical function.

Categorical analyses

We evaluated functional status according to the category of BMI and sarcopenia because this approach has been used by other investigators (3,5,8,14,17,18). However, because BMI is not a sex-specific index of obesity (i.e., at a given BMI, women have a greater relative FM than men) and because there is no accepted definition of sarcopenia, we also conducted categorical analyses according to tertiles of FI and ASMI. Both of these approaches yielded similar findings; measured and perceived function were different across categories of BMI and FI, but not across categories of sarcopenia or ASMI (Table 2). The observed associations of BMI with function concurred with previous studies that included multi-dimensional, performance-based measures of function (17,18).

By contrast, the results of this study were not consistent with previous findings that showed that measured functional limitations were significantly more prevalent in older adults with low, as compared to normal, relative skeletal muscle mass (5

or relative FFM (18). This discordance may be partly explained by the small number of participants in this study who were sarcopenic. However, we also found no trends for function to vary across tertiles of ASMI.

Regression models

We also evaluated the impact of age, BMI, FI, and ASMI, as continuous variables, on physical function using regression models. It is important to note that FI and ASMI are parameters that differ based on sex, whereas BMI does not (Table 1). Therefore, the regression models in the primary analysis that included FI or ASMI were not adjusted for sex, but models that included BMI were.

The age-adjusted regression models corroborated the categorical analyses that BMI and FI were independent determinants of measured and self-reported function, but ASMI was not. Importantly, when adjusted for age and sex, a simple clinical index of obesity (BMI) was nearly as good at predicting functional ability as the DXA measurement of adiposity (FI). Although the results indicate that muscularity is of little importance in predicting physical function in older adults, this must be interpreted cautiously because the lower CI for ASMI in the Adiposity+Muscularity model predicting CS-PFP approached zero (Table 3). Furthermore, the sex-specific models in the exploratory analysis suggest that muscularity was an independent determinant of CS-PFP in older men. It is possible that ASMI would have emerged as an independent determinant of function if we had studied a larger or more diverse group of older adults.

We and others (23) found a moderate, positive correlation between CS-PFP and SF36_{PF} in older adults even though 8 of the 10 questions within the SF36_{PF} are similar to tasks performed in the CS-PFP. One of the strengths of the CS-PFP test is the absence of a ceiling effect because performance is based on workload and time to complete tasks (23). Self-reporting can overestimate performance-based function if, e.g., a person is able to climb a flight of stairs but does so very slowly (29). Despite the limitations in the use of self-reported physical function, the regression and categorical analyses support the hypothesis of worse function in those persons with greater body mass or adiposity.

Limitations

One limitation of this study was the cross-sectional design. In two prospective studies (12,30), absolute and relative FM at baseline were significantly and directly associated with incidental self-reported disability in older women and men. One study (30) also found that low relative FFM at baseline predicted disability. There is little knowledge as to whether interventions aimed at reducing FM in older adults result in improved physical function. However, in two studies of obese older women, measured and self-reported physical function improved significantly in response to exercise and diet interventions that resulted in reductions in FM and preservation of FFM (18,31).

Other limitations to this study must also be recognized. The CS-PFP and SF36_{PF} scores were indicative of independently living older adults (32) with minor medical conditions (25). Thus, the findings may not extend to clinical populations with muscle wasting (i.e., cancer cachexia, nursing home residents). The cutoff values for categorizing ASMI as normal or sarcopenic were population-specific (6,9,10) and may have led to the misclassification of cases in this study. Furthermore, sarcopenic obesity was defined using BMI criteria, as opposed to other measures of adiposity. Finally, it was beyond the scope of the study to include measures of regional fat distribution. Upper body adiposity may explain some of the variance in functional performance in our study population.

In conclusion, we found that adiposity or obesity was a stronger predictor of physical function than was muscularity in older, community-dwelling adults. Longitudinal intervention studies will be needed to determine if strategies for protecting physical functional abilities with aging should focus on minimizing the accumulation of body fat. Studies of this nature will benefit from the use of performance-based physical function tests, such as the CS-PFP, that do not have a ceiling effect.

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DISCLOSURE

The authors declared no conflict of interest.

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REFERENCES

- Gallagher D, Ruts E, Visser M *et al*. Weight stability masks sarcopenia in elderly men and women. *Am J Physiol Endocrinol Metab* 2000;279:E366–E375.
- Kohrt WM, Malley MT, Dalsky GP, Holloszy JO. Body composition of healthy sedentary and trained, young and older men and women. *Med Sci Sports Exerc* 1992;24:832–837.
- Friedmann JM, Elasy T, Jensen GL. The relationship between body mass index and self-reported functional limitation among older adults: a gender difference. *J Am Geriatr Soc* 2001;49:398–403.
- Bannerman E, Miller MD, Daniels LA *et al*. Anthropometric indices predict physical function and mobility in older Australians: the Australian Longitudinal Study of Ageing. *Public Health Nutr* 2002;5:655–662.
- Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. *J Am Geriatr Soc* 2002;50:889–896.
- Baumgartner RN. Body Composition in Healthy Aging. *Ann NY Acad Sci* 2000;904:437–448.
- Heber D, Ingles S, Ashley JM *et al*. Clinical detection of sarcopenic obesity by bioelectrical impedance analysis. *Am J Clin Nutr* 1996;64(Suppl 3):S472–S477.
- Davison KK, Ford ES, Cogswell ME, Dietz WH. Percentage of body fat and body mass index are associated with mobility limitations in people aged 70 and older from NHANES III. *J Am Geriatr Soc* 2002;50:1802–1809.
- Baumgartner RN, Wayne SJ, Waters DL *et al*. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes Res* 2004;12:1995–2004.
- Baumgartner RN, Koehler KM, Gallagher D *et al*. Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* 1998;147:755–763.
- Hedley AA, Ogden CL, Johnson CL *et al*. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA* 2004;291:2847–2850.
- Visser M, Langlois J, Guralnik JM *et al*. High body fatness, but not low fat-free mass, predicts disability in older men and women: the Cardiovascular Health Study. *Am J Clin Nutr* 1998;68:584–590.
- Visser M, Harris TB, Langlois J *et al*. Body fat and skeletal muscle mass in relation to physical disability in very old men and women of the Framingham Heart Study. *J Gerontol A Biol Sci Med Sci* 1998;53:M214–M221.
- Zoico E, Di Francesco V, Guralnik JM *et al*. Physical disability and muscular strength in relation to obesity and different body composition indexes in a sample of healthy elderly women. *Int J Obesity* 2004;28:234–241.
- Sternfeld B, Ngo L, Satariano WA, Tager IB. Associations of body composition with physical performance and self-reported functional limitation in elderly men and women. *Am J Epidemiol* 2001;156:110–121.
- Newman AB, Kupelian V, Visser M *et al*. Sarcopenia: alternative definitions and associations with lower extremity function. *J Am Geriatr Soc* 2003;51:1602–1609.
- Apovian CM, Frey CM, Wood CG *et al*. Body mass index and physical function in older women. *Obes Res* 2002;10:740–747.
- Villareal DT, Banks M, Siener C, Sinacore DR, Klein S. Physical frailty and body composition in obese elderly men and women. *Obes Res* 2004;12:913–920.
- McAuley E, Konopack JF, Motl RW, Rosengren K, Morris KS. Measuring disability and function in older women: psychometric properties of the late-life function and disability instrument. *J Gerontol A Biol Sci Med Sci* 2005;60:901–909.
- Yesavage JA, Brink TL, Rose TL. Development and validation of a geriatric depression screening scale. *J Psychiatr Res* 1983;17:37–49.
- Folstein MF, Folstein SE, McHugh PR. "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189–198.

22. Jankowski CM, Gozansky WS, Schwartz RS *et al*. Effects of dehydroepiandrosterone replacement therapy on bone mineral density in older adults: a randomized, controlled trial. *J Clin Endocrinol Metab* 2006;91:2986–2993.
23. Cress ME, Buhner DM, Questad KA *et al*. Continuous-scale physical functional performance in health older adults: a validation study. *Arch Phys Med Rehabil* 1996;77:1243–1250.
24. Ware JE, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992;30:473–483.
25. McHorney CA, Ware JE, Lu JFR, Sherbourne CD. The MOS 36-Item Short-Form Health Survey (SF-36): III. Tests of data quality, scaling assumptions, and reliability across diverse patient groups. *Med Care* 1994;32:40–66.
26. Linnet K. Performance of Deming regression analysis in case of misspecified analytical error ratio in method comparison studies. *Clin Chem* 1998;44:1024–1031.
27. World Health Organization. Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation on Obesity. Geneva, Switzerland. 2000.
28. Efron B, Tibshirani RJ. *An Introduction to the Bootstrap*. Chapman & Hall: London, 1993.
29. Merrill SS, Seeman TE, Kasl SV, Berkman LF. Gender differences in the comparison of self-reported disability and performance measures. *J Gerontol A Biol Sci Med Sci* 1997;52:M19–M26.
30. Broadwin J, Goodman-Gruen D, Slymen D. Ability of fat and fat-free mass percentages to predict functional disability in older men and women. *J Am Geriatr Soc* 2001;49:1641–1645.
31. Jensen GL, Roy M-A, Buchanan AE, Berg MB. Weight loss intervention for obese older women: improvements in performance and function. *Obes Res* 2004;12:1814–1820.
32. Cress ME, Buhner DM, Questad KA *et al*. Exercise: effects on physical functional performance in independent older adults. *J Gerontol A Biol Sci Med Sci* 1999;54:M242–M248.