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Central Versus Lower Body Obesity Distribution and the Association With Lower Limb Physical Function and Disability

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Abstract

Objective—To determine whether fat distribution in obese adults is significantly associated with decreased function and increased disability.

Design—Cross-sectional epidemiologic analysis.

Setting—Multicenter, community-based study.

Participants—Multicenter Osteoarthritis Study participants included adults ages 50–79 years at high risk of developing or already possessing knee osteoarthritis. A total of 549 men and 892 women from the Multicenter Osteoarthritis Study who had a body mass index ≥30 kg/m^2 and who underwent dual energy x-ray absorptiometry (DEXA) scans were included in these analyses. Exclusion criteria included bilateral knee replacements, cancer, or other rheumatologic disease.

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Methods—Body fat distribution was determined using baseline DEXA scan data. A ratio of abdominal fat in grams compared with lower limb fat in grams (trunk:lower limb fat ratio) was calculated. Participants were divided into quartiles of trunk:lower limb fat ratio, with highest and lowest quartiles representing central and lower body obesity, respectively. Backward elimination linear regression models stratified by gender were used to analyze statistical differences in function and disability between central and lower body obesity groups.

Main Outcome Measures—Lower limb physical function measures included 20-meter walk time, chair stand time, and peak knee flexion and extension strength. Disability was assessed using the Late Life Function and Disability Index.

Results—Trunk:lower limb fat ratio was not significantly associated with physical function or disability in women or men (*P* value .167–.972). Total percent body fat (standardized $\beta = -0.1533$ and −0.1970 in men and women, respectively) was a better predictor of disability when compared with trunk:lower limb fat ratio (standardized $\beta = 0.0309$ and 0.0072).

Conclusions—Although fat distribution patterns may affect clinical outcomes in other areas, lower limb physical function and disability do not appear to be significantly influenced by the distribution of fat in obese older adults with, or at risk for, knee osteoarthritis. These data do not support differential treatment of functional limitations based on fat distribution.

INTRODUCTION

Obesity has become a public health concern for both developed and developing countries. Research in obesity trends in the United States has shown that the prevalence of obesity has increased considerably in the past few decades and is expected to continue to increase [1-3]. Currently linked to a myriad of health concerns ranging from type II diabetes to heart disease, obesity is a problem for one third of the U.S. population and results in considerable health care expenditures [4]. The prevalence of obesity is greatest in adults ages 45–74 years [1-4]. As the average life expectancy and the aging population in the United States likewise continues to grow, it is increasingly important to understand the effects of obesity.

Evidence indicates that the distribution of adipose tissue throughout the body may also be a health concern [5-7]. For example, a central distribution of adipose tissue has been associated with increased risk of coronary heart disease, type II diabetes mellitus, cancer, and all-cause mortality [8-10]. As a result, it has been suggested that assessments of abdominal obesity may be more appropriate and valuable measures than body mass index (BMI) [5-7]. Clinically, measurements of BMI, waist circumference, and waist-hip ratio are used to assess cardiovascular risk and the presence of metabolic syndrome [8-11]. In contrast, significantly less research has been conducted to evaluate the health effects of lower body obesity. Available information does suggest a contrasting role whereby fat accumulation in the hips and thighs may have a much lower pathologic significance, may decrease cardiovascular risk, and may be protective against metabolic disturbances such as impaired glucose metabolism [12-14].

Although the effects of the distribution of adipose tissue on the body, particularly with regard to the cardiovascular and endocrine systems, are becoming better understood, the musculoskeletal effects still require further research. To date, studies have shown an association between obesity and osteoarthritis (OA) as well as an association between body weight or BMI and functional limitation and disability [15-29]. However, to our knowledge, no reports have described how lower body obesity affects physical function or how lower and central obesity might compare when assessing risk for functional limitations. The presence or absence of an association between fat distribution and function could be a significant concern for the aging U.S. population. In 2004, 6.1% of U.S. adults aged 65 years and older reported a limitation in performing activities of daily living, and 11.5% reported a limitation in instrumental activities of daily living [4]. Further, it is estimated that by 2050, the number of functionally limited adults will be nearly 3 times that of 1985 [30]. Because central obesity is associated with such negative health effects, we hypothesized that individuals with central obesity would be at greater risk of functional impairment and disability compared with those with lower body obesity. Therefore, the aim of this study was to determine whether an association exists between fat distribution in obese adults and lower limb physical function and disability.

METHODS

Subjects

The Multicenter Osteoarthritis (MOST) study is a longitudinal study of a community-acquired cohort of adults aged 50–79 years who are considered to be at high risk of developing knee OA (based on being overweight, having knee pain, or a history of knee injury or surgery) or who already have knee OA. Potential participants were contacted by mass mailings or by advertisements posted in the counties surrounding the 2 study sites. Individuals who expressed interest in the study were initially screened by telephone for eligibility. Participants were excluded if they had bilateral knee replacements, cancer, or other rheumatologic disease. They also were excluded if their weight exceeded 300 lb (for persons located near the University of Alabama) or 350 lb (for persons located near the University of Iowa), because these were the weight limits for the dual energy x-ray absorptiometry (DEXA) scanners at these institutions. Only participants with a BMI greater than or equal to 30 were included in the present study. The Institutional Review Boards at each study site approved this study, and all participants provided written informed consent.

Knee OA—Knee OA status was defined as the presence of Kellgren and Lawrence grade ≥2 on fixed-flexion posteroanterior weight-bearing knee radiographs [31].

Frequent Symptoms—Questionnaires that assessed demographic variables and the presence of pain were administered both by phone and at the baseline clinic visit. Participants were asked whether they had experienced knee pain, aching, or stiffness on most of the past 30 days. Participants who answered yes were considered to have frequent knee symptoms.

Body Composition Measures

Height, Weight, and BMI—Weight was measured to the nearest 0.1 kg on a standard medical beam balance scale by certified MOST personnel following a written protocol. Participants wore paper shorts and a shirt and were asked to empty their bladders and bowels, empty pockets, or remove any jewelry they wished before stepping on the scale. The scales used were calibrated monthly with a 50-kg weight for accuracy and with 5-, 10-, 15-, and 20-kg weights for linearity calibration. The local Department of Weights and Measures also calibrated the scales annually.

Height was measured on full inspiration to the nearest 1 mm with a wall-mounted Harpenden stadiometer by certified MOST personnel following a written protocol. Participants were asked to stand either barefoot or with thin stockings, their heels together, their head in the Frankfort horizontal plane, and their scapulae, buttocks, and heels touching the wall plate. A soft 0.5-kg weight was placed on the headboard to standardize pressure on the head while measuring. Height was measured twice, and if these measures differed by ≥3 mm, 2 additional measurements were taken. The stadiometer was calibrated at each clinic site daily using a 600-mm rod.

BMI was calculated as weight in kilograms divided by the height in meters squared. Obesity was defined as a BMI greater than or equal to 30 kg/m^2.

DEXA—A whole-body DEXA scan was obtained using Hologic QDR 4500A and QDR 4500W scanners operating Windows-based software. The participant weight limit of the scanner used at the University of Alabama site was 300 lb. The participant weight limit of the scanner used at the University of Iowa was 350 lb.

Participants were positioned in the center of the table with their arms separated from the sides of their bodies and their hands placed palms down. In the event that the participant did not completely fit on the table, it was preferred to have the arms out of the scan field as opposed to placing them in the abdomen or rib areas, which could affect the body composition values in the abdominal area. Operators were trained and certified and performed daily quality control scans as well as cross-calibration scans of phantoms used on both machines. Quality control data were collected using standard quality assurance protocols and reviewed monthly [32].

For segmental body composition analysis, a horizontal line was placed just above the iliac crest and angled lines defining the pelvic triangle bisected the femoral neck. The vertical line between the legs ran between the participant's feet and evenly divided the legs. The lateral leg lines included as much of the thigh soft tissue as possible without including the hands. The following areas of interest were used for this study: trunk fat mass, right and left leg fat mass, and percent whole body fat mass.

Fat Distribution Classification

Within participants who were considered obese (BMI ≥30 kg/m^2), the ratio of trunk fat to lower limb fat was calculated using the data obtained from participants' DEXA scan at the baseline visit comparing the fat in grams in the abdomen (trunk fat) and the fat in grams in the lower limbs (right and left leg fat). This ratio represented a central or lower body obesity tendency. Because of the lack of a consistent definition of central obesity found in the literature, a ratio was used for this study as opposed to a measured numerical cutoff to classify central obesity. This ratio, although novel, enables reproducibility by other investigators for comparison and for future research. The greater the trunk:lower limb fat ratio, the stronger the tendency for central obesity. Participants within this group were then divided into equal quartiles of trunk: lower limb fat ratio. Participants were considered to have central obesity if they were within the highest quartile. Participants in the lowest quartile were considered to have lower body obesity. Participants in the interquartile range of trunk: lower limb fat ratio were excluded because they would be less likely to be truly characteristic of either central or lower body fat distribution in comparison with the extremes.

Lower Limb Physical Function Measures

Chair Stand—The chair stand test is an assessment of lower limb physical function that involves multiple aspects of performance such as lower limb strength and balance [33]. Participants' chair stand time in seconds was recorded as the time it took for the participant to stand from a seated position 5 times without using their arms.

The chair used at clinic sites for the chair stand was a straight-backed chair without arms and with a seat height of 45 cm. MOST personnel administered the test, and scripted instructions were provided to ensure uniformity.

20-meter Walk—The 20-meter walk is a measurement of lower limb physical function that assesses the time it takes participants to walk 20 meters at their usual pace. Clinic sites used a dedicated and unobstructed hallway for the walking course. The 20-meter walk was performed twice, and the average time in seconds for the 2 walks was computed.

Isokinetic Strength Measures—The concentric isokinetic strength of the knee extensor muscles was assessed with a Cybex 350 computerized isokinetic dynamometer (Avocent, Huntsville, AL) following a protocol described previously [34]. This test was performed after the 20-meter walk and chair stand tests to allow a short warm-up period. Participants were given the opportunity to practice 3 times before 4 repetitions were measured on each leg. Limbs for which participants reported pain that had interfered with their performance were excluded from analyses. For the purposes of our study, the peak leg flexion and extension torque measured in N•m was used for each person.

Disability Measures

Late Life Function and Disability Instrument—Disability was assessed using the Late Life Function and Disability Instrument (LLFDI) [35], an assessment of function and disability in older adults. Only a portion of the complete LLFDI, the instrumental limitation subscale, was used. The frequency and limitation dimensions of the disability component are each scored on a 0 to 100 scale, with higher scores indicating higher levels of functioning. Participants were asked to complete the questionnaire at the baseline visit.

Data Analysis

Because of previous research suggesting that the relationship between BMI and physical function is gender-dependent [36], we tested our hypotheses separately in men and women. Univariate analysis of the trunk:lower limb fat ratio from DEXA data was used to include participants in the gender-specific highest (central fat distribution) and lowest (lower body fat distribution) quartiles. Characteristics of subjects in these 2 groups were analyzed with the χ^2 test (prevalence of knee OA) and 2-sample *t*-tests (all continuous *t* variables including age, BMI, height, weight, total body fat percentage, 20-meter walk time, chair stand time, peak knee extension and flexion strength, and LLFDI score). Differences in function and disability measures (20-meter walk time, chair stand time, peak knee extensor and flexion strength, and scores on the LLFDI instrumental limitation subscale) between the gender-specific body fat distribution groups were compared using backwards elimination linear regression models. Because of significant differences in characteristics of the groups and potential for colinearity between those factors, backwards elimination linear regression models also were used to assess the association of the body fat distribution group with the 5 functional measures while adjusting for the following confounders (found to be related to both the fat distribution group as well as each of the lower limb physical function measures): BMI and total percent body fat. Secondary analyses controlled for self-report of knee pain on most days, given the potential for an effect on lower limb physical function. Standardized β coefficients were calculated to compare percent body fat as a predictor with trunk:lower limb fat ratio as a predictor of disability. Correlation coefficients were calculated to assess relationships between total percent body fat and outcome measures. All analyses were completed using SAS Version 9.1 software (SAS Institute, Inc, Cary, NC). An α level of <0.05 was considered significant.

RESULTS

Body Fat Distribution

Of the 1820 women and 1206 men in the MOST study, 42 men and 23 women did not have available DEXA data and were not included in the analyses because a trunk:lower limb fat ratio could not be calculated. Of the remaining participants who were below the DEXA table weight limitations, 549 men and 892 women had a BMI range of 30.0–52.2 kg/m^2 and 30.0–55.8 kg/m^2, respectively. The mean ± standard deviation ratio of trunk fat to lower limb fat was significantly greater for men (1.865 ± 0.493) compared with women (1.304 ± 0.375) ($P < .0001$). The highest quartile and lowest quartile of trunk:lower limb fat ratio for men contained 136 and 142 men, respectively. The highest quartile and lowest quartile of trunk:lower limb fat ratio for women contained 223 and 225 women, respectively. The range of the trunk:lower limb fat ratio for men was 2.242–3.846 in the highest (central obesity) quartile and 0.975–1.589 in the lowest (lower body obesity) quartile. The range of the trunk:lower limb fat ratio for women was 1.551–3.581 in the highest (central obesity) quartile and 0.509–1.129 in the lowest (lower body obesity) quartile. Age was associated with walk time ($P < .0001$ in men; $P = .0004$ in women), chair time ($P = .0186$ in men; $P = .0007$ in women), and both knee extensor and flexor strength ($P < .0001$ in men and women), but it was not associated with disability level ($P > .15$ in both men and women).

Characteristics of Subjects

A description of the men and women at baseline is provided in Table 1. Women accounted for 61.9% of the study sample. Men with a lower body fat distribution on average were taller and had a greater prevalence of knee OA than did men with a central fat distribution, although neither of these characteristics differed significantly between groups ($P = .096$ and .901, respectively). Women with a lower body fat distribution tended to have a lower weight ($P = .068$), a lower BMI ($P = .029$), and a higher percentage of total body fat ($P < .001$) compared with women with a central body fat distribution. Age did not differ significantly between fat distribution groups in men or women.

Associations of Body Fat Distribution With Lower Limb Physical Function and Disability

Analyses of the associations between body fat distribution group and lower limb physical function and disability are summarized in Table 2. None of the 5 lower limb physical function measures were significantly associated with body fat distribution in adjusted or unadjusted analyses in men or in women.

In addition, fat distribution was not associated with self-reported disability on the LLFDI in men ($P = .767$) or women ($P = .872$). Total percent body fat (standardized $\boldsymbol{\beta} = -0.1533$ and −0.1970 in men and women, respectively) was a better predictor of disability when compared with trunk: lower limb fat ratio (standardized $\boldsymbol{\beta} = 0.0309$ and 0.0072). In addition, although no correlation was found between trunk:lower body fat ratio and disability for men or women ($r = 0.02$, $P = .7003$ and $r = 0.04$, $P = .3623$, respectively), a correlation was found between total percent body fat and disability in both men and women (r = −0.15, $P = .0124$ and r = −0.20, $P < .0001$, respectively).

DISCUSSION

Our results demonstrate the lack of a clear association between body fat distribution and lower limb physical function measures in men and women, suggesting that a significant relationship between the two may not exist. This finding does not concur with several cross-sectional studies that found associations between abdominal fat, functional limitations [37,38], and disability [19,39]. In comparison with the aforementioned studies, which used bioelectrical impedance, waist circumference, and waist-hip ratio, our study used DEXA as means of determining central obesity. Also differing from our study is the use in some cases of predominately self-reported questionnaires and the standardized SF-36 Health Survey to evaluate physical function. Our study focused on the objective physical function measures

20-meter walk time, chair stand time, and peak knee flexion and extension strength. These differences in functional assessment may account for our conflicting results.

Unlike previous studies, we did not find that body fat distribution in obese adults was associated with disability. For example, Angleman et al [40] found that out of the 5 anthropometric measures of obesity they studied (weight, BMI, waist circumference, hip circumference, and waist-hip ratio), waist circumference was the best predictor of disability over a 5-year period. Likewise, Sternfeld et al [37] found that central obesity, independent of lean mass and fat mass, negatively affects physical function. Conversely, some researchers have suggested that people with a lower body fat distribution may be at a biomechanical disadvantage compared with those with a central obesity fat distribution because of adipose deposits between the thighs altering weight bearing at the knee. Modeling has supported this postulate, proposing that the increased thigh circumference found in people with lower body obesity increases the genu varum [41,42]. Because malalignment of the knee joint has been associated with increased external knee adduction moment [43], such a change could contribute to altered loads at the knee, thereby altering gait. The aforementioned studies illustrate the uncertainty still surrounding the question of fat distribution and its impact on physical function; however, it does not appear that lower limb physical function, as measured in this study, differed by fat distribution in obese older adults.

What is more certain and well established in the current literature is the negative effect of obesity on physical function [15-29]. We found that although body fat distribution was unrelated to all lower limb physical function measures and disability, all lower limb physical function measures and disability were significantly associated with total body fat percentage for both men and women. The correlation between total percent body fat and disability in men and women was $r = -0.15$ ($P = .0124$) and $r = -0.20$ ($P < .0001$), respectively. This finding demonstrated that as the total body fat percentage increased, the LLFDI score decreased, indicating greater disability.

Given this correlation, body fat percentage may be a useful tool of assessment for physical function deficits and disability in obese adults and also a target for treatment and risk reduction. Methods of assessment of body fat percentage include DEXA, underwater weighing, calipers, air displacement, or bioelectrical impedance. After a risk has been established, how best to treat and meet the goal of decreasing total body fat percentage is more controversial. The position statement of the American Society for Nutrition and the North American Association for the Study of Obesity [44] is that therapy targeted at weight reduction in persons older than 65 years improves physical function, quality of life, and obesity-associated medical complications. However, one must assess the benefits of weight reduction with respect to physical function and disability against the adverse effects of weight loss such as muscle and bone loss. Although some studies suggest that weight loss and exercise can ameliorate frailty in obese older adults [45], another study by the same author suggests that weight loss, even when combined with exercise, decreases hip bone mineral density in obese older adults [46]. Given our significant findings relating lower limb physical function and disability with total body fat percentage, perhaps additional studies focused on the goal of decreasing total body fat percentage versus weight would result in fewer negative outcomes.

Our study may have been limited by the following factors. First, the study design was cross-sectional, and as a result, our findings cannot establish whether distribution of body fat with obesity leads to limitations in function or disability. However, because a cross-sectional relationship did not exist, it is highly unlikely that a longitudinal study would show a relationship. Next, while DEXA has become widely used for measurement of body composition, its precision is best in young healthy subjects and may be slightly compromised in older, obese adults such as our study population [47,48]. Additionally, the supine positioning required for whole-body DEXA scans may have resulted in a variable lie of the abdominal pannus. If the pannus were to overlie the hip and upper thigh region and consequently there was poor delineation between the upper body and the lower body, the lower limb fat mass could have been mistakenly overestimated. The number of scans that included the abdominal pannus in the lower limb measure could not be determined. This factor could have then skewed our fat distribution groupings, resulting in differential misclassification, although this scenario is unlikely because we only included the highest and lowest quartiles of trunk:lower limb fat ratio. The use of DEXA scans also limited the study because individuals who weighed more than 300–350 lb were excluded by weight restrictions of the DEXA scanner. Confirmatory analyses stratifying by class of obesity (mild: 30–35 kg/m^2, moderate: 35–40 kg/m^2, and severe: ≥40 kg/m^2) revealed very similar results to those presented in this study, except for walk time differing by fat distribution in mildly obese women (P = .0383) and chair stand time differing by fat distribution in moderately obese men (P = .0443), neither of which was believed to be significant after correcting for the numerous analyses completed. Last, our study population was predominately white (77.0%), which may limit generalizability, but also could be a strength in improving homogeneity in this dataset.

Insufficient evidence was found to conclude a difference in lower limb physical function or disability from fat distribution in our study population. However, because several studies have shown that fat distribution as well as obesity negatively affects physical function and disability [15-29], we recommend that future studies continue to investigate this relationship to determine methods to prevent or to ameliorate these functional limitations. Specifically, if weight reduction is the goal of treatment, there is a need to understand the best way to positively affect physical function and disability while minimizing any adverse effects on muscle and bone mass. In addition, given that it seems unlikely that fat distribution is a significant contributor to physical function and disability, there is a need to characterize which tools currently in use, such as total body fat percentage or those not yet discovered, could be used to stratify obese individuals into physical activity interventions that will be of most benefit to them.

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Table 1

Selected participant characteristics at baseline for obese men and women[*]

	Lower Body Obesity (Men, n = 142) (Women, n = 225)	Central Obesity (Men, n = 136) (Women, n = 223)	*P* Value (Unadjusted)
Age (y)			
Men	61.1 ± 8.4	61.9 ± 7.2	.398
Women	62.5 ± 8.3	61.8 ± 7.5	.314
Weight (kg)			
Men	108.2 ± 14.1	107.3 ± 14.7	.605
Women	93.5 ± 13.4	95.9 ± 14.7	.068
Height (cm)			
Men	177.3 ± 7.0	175.9 ± 6.4	.096
Women	162.7 ± 6.3	162.5 ± 6.0	.722
Body mass index (kg/m^2)			
Men	34.3 ± 3.9	34.6 ± 4.2	.618
Women	35.3 ± 4.6	36.3 ± 5.1	.029
Total body fat (%)			
Men	30.0 ± 5.4	30.5 ± 5.1	.487
Women	43.5 ± 3.7	42.1 ± 4.5	<.001
Presence of knee osteoarthritis (%)[†]			
Men	74.2	57.1	.901
Women	81.7	67.3	.910

[*] Mean ± standard deviation.

[†] Frequency in one or both knees.

Table 2

Physical function outcome measures and LLFDI stratified by gender and fat distribution*

	Mean Performance for Lower Body Obesity Group (Men, n = 142) (Women, n = 225)	Mean Performance for Central Obesity Group (Men, n = 136) (Women, n = 223)	*P* Value (Unadjusted)	*P* Value† (Adjusted)
20-m Walk time (s)				
Men	17.0 ± 3.4	16.8 ± 2.7	.625	.510
Women	18.9 ± 4.1	18.6 ± 7.1	.709	.972
Chair stand time (s)				
Men	11.6 ± 4.42	10.9 ± 2.8	.721	.899
Women	13.2 ± 4.7	12.7 ± 4.0	.443	.427
Peak extensor strength (N•m)				
Men	126.2 ± 43.5	133.9 ± 42.1	.858	.684
Women	68.6 ± 26.5	74.3 ± 28.3	.514	.510
Peak flexor strength (N•m)				
Men	82.6 ± 30.9	85.5 ± 28.4	.235	.167
Women	45.1 ± 17.8	48.3 ± 18.1	.613	.273
LLFDI score				
Men	77.0 ± 14.0	77.9 ± 15.4	.698	.767
Women	72.7 ± 15.5	72.9 ± 15.1	.863	.872

LLDDI = Late Life Function and Disability Index.

*Mean ± standard deviation.

†Adjusted for body mass index and total percent body fat.