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RISK OF KNEE OA WITH OBESITY, SARCOPENIC OBESITY AND SARCOPENIA

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Abstract

Objective: Obesity, defined by anthropometric measures, is a well-known risk factor for knee osteoarthritis (OA) but there is a relative paucity of data regarding the association of body composition (fat and muscle mass) on knee OA risk. We examined the longitudinal association of body composition categories based on fat and muscle mass with incident knee OA risk.

Methods: We included participants from The Multicenter Osteoarthritis (MOST) Study, a longitudinal cohort of individuals with or at risk for knee OA. Based on body composition (i.e. fat and muscle mass) from whole body Dual Energy X-ray (DXA), subjects were categorized as: 1) obese; 2) sarcopenic obese; 3) sarcopenic; and 4) non-sarcopenic non-obese. We examined the relation of baseline body composition categories to the risk of incident radiographic OA at 60 months using binomial regression with robust variance estimation, adjusting for potential confounders.

Results: Among 1653 subjects without radiographic knee OA at baseline, significant increased risk of incident radiographic knee OA was found among obese (women RR 2.29, 95% CI 1.64-3.20; men RR 1.73, 95% CI 1.08-2.78) and sarcopenic obese women (RR 1.91, 95% CI 1.17-3.11), but not men (RR 1.74, 95% CI 0.68-4.46) subjects. Sarcopenia was not associated with knee OA risk (women RR 0.96, 95% CI 0.62-1.49; men RR 0.66; 95% CI 0.34-1.30).

Conclusions: In this large longitudinal cohort, we found body composition based obesity and sarcopenic obesity but not sarcopenia, to be associated with knee OA risk. Weight loss strategies for knee OA should focus on obesity and sarcopenic obesity.

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Keywords

Obesity; Sarcopenic obesity; Sarcopenia; Knee OA

INTRODUCTION:

Obesity, a state of excess adiposity, is a major risk factor for knee osteoarthritis (OA).[1]

Prior studies of obesity and knee OA have mostly defined obesity using anthropometric measures, such as body weight or body mass index (BMI). [1–3] Anthropometric measurements are not exclusive measures of adiposity though, but rather reflect the composite of fat, muscle and bone mass. Thus, whether the effects of "BMI", typically interpreted as effects of obesity, is truly due to excess adiposity versus overall loading due to the combined weight of body mass is not clear. The few studies that have examined body composition in relation to knee OA have mostly been cross-sectional in design, which limits one's ability to make an inference regarding directionality of the association.[4–6] To better understand how total body mass vs. adiposity leads to knee OA a longitudinal study of body composition and knee OA risk is needed.

Further, studying body composition with knee OA lends an opportunity to examine another unique body composition state that cannot be well studied by anthropometric measures alone, i.e. sarcopenic obesity. While in young healthy adults, fat and muscle mass grow in synchrony, uncoupling of the two processes can occur with aging, leading to a state of high fat mass with relatively low muscle mass, referred to as sarcopenic obesity.[7] A number of risk factors for development of sarcopenic obesity have been identified, such as low physical activity, inflammation, and malnutrition, among others.[7] Thus, studying body composition allows evaluation of the additional risk posed by the state of high adiposity and low muscle mass over obesity without sarcopenia. Such insights would have novel clinical therapeutic implications in OA given the development and evaluation of treatments targeting sarcopenia. On the other hand, the absence of obesity may not necessarily be associated with reduced risk of developing knee OA because those who are not obese can have appropriate vs. low muscle mass (i.e., sarcopenia). Sarcopenia itself is associated with several adverse outcomes, including functional limitations, but whether inappropriately low muscle mass as reflected by sarcopenia adversely impacts risk of developing knee OA is not known.

Thus, evaluation of the effect of body composition on knee OA risk may provide more insight into the relation of obesity (vs. body mass) to knee OA than traditional anthropometric measurements. The aim of this study was therefore to examine the longitudinal association of body composition defined by the relative presence of adiposity and sarcopenia with the risk of incident radiographic knee OA.

METHODS:

Study sample:

We included participants from The Multicenter Osteoarthritis (MOST) Study, a multicenter, an NIH-funded longitudinal cohort of community-dwelling older adults with or at risk for

knee OA, designed to study risk factors for knee OA. Details of the MOST study have been published elsewhere.[8] Subjects included in this study sample were those who were free of radiographic knee OA (defined below) at baseline, and who completed follow-up at the 60-month clinic visit.

Exposure:

Fat and muscle mass were estimated from the whole body Dual Energy X-ray Absorptiometry (DXA, Hologic Inc., Bedford, MA: Software Version 12.0) obtained at baseline, using a published protocol.[9] Fat and lean muscle mass (referred to as muscle mass from here on) variables were recorded in kilograms from the DXA. **Sarcopenia** was defined using the modified residual method used in geriatrics research[10] as the lowest quintile of the residuals of appendicular skeletal muscle mass (sum of absolute muscle mass of upper and lower limbs), adjusting for age, height (in meters) and total body fat mass (in kilograms).[10] To keep it consistent with sarcopenia definition, we divided total body fat mass (in kilograms) into quintiles and the highest quintile was defined as **Obesity.** Given the difference in body composition between men and women, **obesity** and **sarcopenia** were defined in sex-specific manner. In a sensitivity analysis, obesity was defined as body mass index≥ 30kg/m^2, instead of fat mass by DXA.

Subjects were then categorized into four sex-specific body composition categories: 1) **obese non-sarcopenic:** met definition for obesity but not sarcopenia and will be referred to as **obese** from here on in this manuscript; 2) **sarcopenic obese:** met definition for sarcopenia and obesity; 3) **sarcopenic non-obese:** met definition for sarcopenia but not obesity and will be referred to as **sarcopenic** from here on in this manuscript; and 4) **non-sarcopenic non-obese:** did not meet definition for obesity or sarcopenia (referent category).

Outcome:

Bilateral fixed-flexion posteroanterior knee radiographs were obtained at baseline and at the 60-month follow-up. **Incident (new-onset) radiographic knee OA**, was defined as the presence of Kellgren and Lawrence (KL) grade ≥2 in either or both knees at the 60 month follow-up visit, among those free of radiographic knee OA at baseline (i.e. KL grade <2 in both knees at baseline).[11]

Confounders:

The following covariates were selected as confounders based on literature review: age, height, race, physical activity measured by the physical activity scores for elderly (PASE), smoking status, Charlson's comorbidity index and history of knee injury.

Statistical analyses:

We first assessed the longitudinal relation of fat and muscle mass at baseline as continuous variables to the risk of incident radiographic knee OA over 60 months, using binomial regression with robust variance estimation to calculate risk ratios (RR). We then examined the longitudinal relation of the body composition categories (obese, sarcopenic obese, sarcopenic, non-obese non-sarcopenic) defined at baseline to the risk of incident radiographic knee OA at 60 month follow-up, using the same regression approach as

described above. We adjusted for potential confounders as described above in the multivariable models.

In a sensitivity analysis, we defined obesity by BMI >=30kg/m2 instead of the DXA-derived fat mass and recategorized subjects based on this BMI-based definition to enable comparison of the results defined by body composition vs. the standard anthropometric measure of obesity used in prior studies of knee OA. All analyses were performed in the overall study population and then sex-stratified due to our *a priori* hypothesis of effect measure modification by sex.

SAS 9.3 (Cary, NC) was used to perform the analyses. The protocol was approved by Institutional Review Board at Boston University School of Medicine and from MOST Study review and executive committee.

RESULTS:

3026 subjects were enrolled in the MOST study, of which 1667 (mean age 62 years, 58% women, and mean BMI 30 kg/m^2) subjects were free of radiographic OA at baseline and eligible for inclusion into our study. Our final analytic cohort was 1653 subjects after excluding those subjects not completing the 60 month visit. Among those included, 315 subjects developed incident radiographic knee OA by the 60-month follow-up visit (19%). The baseline characteristics of subjects by body composition categories (obese, sarcopenic obese, sarcopenic and non-obese non-sarcopenic) are outlined in Table 1. The differences in body weight, total body fat and appendicular skeletal muscle mass among the groups were in the expected direction.

In the multivariable adjusted analysis of fat and muscle mass assessed as linear variables, we found greater fat mass to be numerically and statistically associated with increased risk of knee OA at 60 months in the overall population (RR 1.02, 95% CI 1.0-1.04) and in women (RR 1.03, 95% CI 1.00-1.06) when stratified by sex. In men the association between fat mass and knee OA risk was neither numerically nor statistically associated (RR 1.00, 95% CI 0.95-1.13). Increased muscle mass was associated with increased risk of knee OA at 60 months in the overall population (RR 1.03, 95% CI 1.0-1.06). When stratified by sex, women (RR 1.02, 95% CI 0.98-1.06) although not significantly but in men, it was numerically and statistically associated with increased risk (RR 1.07, 95% CI 1.01-1.13).

In the evaluation of body composition based on fat and muscle mass categorized as obese, sarcopenic obese, sarcopenic compared to non-obese non-sarcopenic , both obese (RR 2.05; 95% CI 1.56-2.68) and sarcopenic obese (RR 1.91; 95% CI 1.17-3.11) subjects had increased knee OA risk over 60 months (Table 2). When stratified by sex, the results in women and men were similar. In women, compared with non-obese non-sarcopenic subjects, a greater than 2-fold increased risk of radiographic knee OA was found in obese (RR 2.29; 95% CI 1.64-3.20), and sarcopenic obese (RR 2.09; 95% CI 1.17-3.73) subjects (Table 2). Similarly in men, compared with non-obese non-sarcopenic subjects, >70% increased risk of radiographic knee OA was noted among obese (RR 1.73; 95% CI 1.08-2.78) and sarcopenic

obese (RR 1.74; 95% CI 0.68-4.46) subjects, although the results for sarcopenic obese men did not reach statistical significance (Table 2).

No significant association between sarcopenia without obesity was noted in the overall (RR 0.87; 95% 0.06-1.25), and sex-stratified analyses (women RR 0.96; 95% CI 0.62-1.49; men (RR 0.66; 95% CI 0.34-1.30), as shown in Table 2.

In the sensitivity analyses in which obesity was defined by BMI instead of DXA-derived fat mass, we found similar results as the body composition analysis, with increase in knee OA risk among obese (RR 1.87, 95% CI 1.46-2.40) and sarcopenic obese (RR 1.99, 95% CI 1.32-3.02) subjects compared with non-obese non-sarcopenic subjects (Table 3). When stratified by sex, the risk of knee OA in women was 87% greater in obese (RR 1.87, 95%CI 1.37-2.54) and 60% greater in sarcopenic obese subjects, though not statistically significantly (RR 1.60, 95% CI 0.93-2.77) compared with non-obese non-sarcopenic women (Table 3). In men, the risk of knee OA was almost 2-fold greater in obese (RR1.92, 95%CI 1.23-2.96) and sarcopenic obese subjects (RR 2.90, 95%CI 1.49-5.59) compared with non-obese non-sarcopenic subjects. Similar to the body composition-based analyses, no significant association was noted in sarcopenic subjects in the overall (RR 1.03, 95%CI 0.68-1.54) and sex-stratified analyses (women: RR 1.15, 95%CI 0.70-1.86; men: RR 0.80 95%CI 0.38-1.67).

DISCUSSION:

In this large longitudinal study of knee OA risk in relation to DXA-derived body composition categories (obesity, sarcopenic-obesity and sarcopenia) we found increased risk of radiographic knee OA among obese women and men. Increased risk of knee OA was also found in sarcopenic obese women and men, although the results did not reach statistical significance in men. While the relation of anthropometrically measured obesity and knee OA risk is well known, this is the first longitudinal study to demonstrate an increased risk of knee OA with body composition based obesity and also sarcopenic obesity. Our findings have implications for management of knee OA, such that weight loss interventions should target both high fat and low muscle mass. Similar results of increased risk with obesity and sarcopenic obesity were noted when obesity was defined by BMI instead of fat mass and muscle mass by DXA.

Few prior studies that have examined the association of body composition and knee OA have found conflicting results.[4–6, 12] Issues with study design and lack of consistency in definition of obesity and sarcopenia from body composition assessment (i.e., fat and muscle mass) partly explains discordant results. For example, consistent with our results, a cross-sectional study by Lee et al found increased prevalence of radiographic knee OA among obese and sarcopenic obese subjects compared with non-obese non-sarcopenic individuals.[4] Of note, sarcopenia was defined by low muscle mass, while obesity was defined by BMI, similar to our sensitivity analysis. In contrast, another cross-sectional study found anthropometric measures (BMI and body weight) more strongly associated with radiographic knee OA than fat or lean muscle mass from DXA assessed separately.[5] Yet another cross-sectional study found increasing odds of knee OA with increasing quartiles of BMI and fat mass but no

association was found with lower extremity muscle mass.[6] In the same study, obese subjects with low percentage of lower extremity muscle mass (comparable to sarcopenic obese subjects in our study), and non-obese with low percentage of lower extremity muscle mass, (comparable to sarcopenic category in our study), were found to have greater odds of radiographic OA compared with non-obese with normal lower extremity muscle mass. In contrast, obese subjects with normal lower extremity muscle mass (akin to obese subjects in our study) had no additional increased risk for knee OA [6] Further, yet another study using bioimpedance for assessment of body composition, found increasing risk of severe radiographic OA and joint space narrowing with increase in fat and muscle mass (in separate analyses), although more variability was explained by muscle mass.[12] To overcome some of the limitations of prior studies, we designed a longitudinal study using incident radiographic knee OA as the outcome and defined both obesity and sarcopenia based on fat and muscle mass assessment from whole body DXA, using definitions described in prior studies of body composition.[7,10]

Knee OA is known to disproportionately affect women more than men, but the reason for this gender disparity is not known. Despite the known difference in body composition between men and women, similar increased risk of knee OA by adiposity for obese and sarcopenic obese categories were noted for both sexes, although not statistically significant in men. Of note, in additional analyses (see appendix), upon additionally adjusting for body weight in the multivariable analysis of DXA-derived body composition categories and knee OA risk, the association of obesity in women attenuated slightly but in men the effect estimates attenuated considerably. These results might suggest differential effect of loading on knee OA risk by sex, although body weight may be problematic to use as a surrogate marker for loading effect. Sarcopenia was not significantly associated with knee OA risk in men or women, although the effect estimates in men showed a trend towards protective effect. Our results suggest that the risk of knee OA in both women and men is primarily through adiposity, with perhaps lesser independent effect of muscle mass.

Adiposity confers increased risk for many diseases primarily through a metabolic effect of adipose tissue products (adipokines). The role of adipokines, have been demonstrated in knee OA.[13] However, there is also evidence to suggest increased loading across the joint in obesity leading to cartilage damage and knee OA.[14] While the present study did not provide direct evidence for a metabolic or mechanical pathway for knee OA in obesity, it indicates the important role of adiposity i.e., fat mass over muscle mass.

Although this is the first longitudinal study that we are aware of to address this question, we acknowledge that our study has limitations. First, the sample size of the sarcopenic obesity category was small, limiting our ability to precisely estimate the relation of sarcopenic obesity to knee OA risk in men, though all of the effect estimates were consistent in the direction and magnitude of effect. Second, the subjects in this study were primarily Caucasians; thus these findings may not be generalizable to other racial groups, though we do not know of a biologic hypothesis to suggest that obesity and sarcopenia have effects that differ by race. Third, as physical activity levels can affect body composition, the use of the PASE instrument as a measure of physical activity level to control for its potential confounding effects is a limitation. Fourth, quintile based approach used to define obesity

and sarcopenia may not be generalizable to other populations. However, these are approaches that have been developed to study the body composition, particularly combination of sarcopenia with obesity. Fifth, as with any observational study, there is a possibility of residual confounding.

There are also several strengths of this study. The longitudinal design allows us to infer directionality. We assessed the relative individual and combined effects of fat and muscle mass by combining the categories of obesity and sarcopenia. The comprehensive data with validated measurement of knee OA and whole body DXA, in large numbers are strengths.

In conclusion, body composition assessment allows for new insights into the association between obesity and knee OA, especially the finding of the increased risk conferred by sarcopenic obesity. Preventive efforts may need to not only focus on reducing obesity, but also ameliorating sarcopenic obesity to reduce the burgeoning incidence and prevalence of knee OA.

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Appendix

Appendix table 1:

Relation of obesity, sarcopenic obesity, sarcopenia at baseline with the risk of incident radiographic knee osteoarthritis among community-dwelling older adults women and men separately, additionally adjusting for body weight

		Women	
Sex-specific body composition category	**n/N**	**Crude RR**	**Adjusted RR**
Obese	54/137	2.11	1.59 (0.98-2.56)
Sarcopenic Obese	13/36	1.94	1.51 (0.80-2.86)
Sarcopenic	25/139	1.00	0.72 (0.47-1.09)
Non-obese (ref)	121/650	1.00	1.0
		Men	
Obese	25/107	1.70	1.05 (0.54-2.05)
Sarcopenic Obese	5/26	1.40	0.73 (0.24-2.25)
Sarcopenic	10/107	0.70	0.70 (0.33-1.48)
Non-obese (ref)	62/451	1.00	1.0

*Adjusted for age, height, physical activity (PASE score), smoking, charlson's comorbidity index and knee injury and body weight (Kg)

Reference:

1. Felson DT, Anderson JJ, Naimark A, Walker AM, Meenan RF. Obesity and knee osteoarthritis. The Framingham Study. Ann Intern Med 1988;109:18–24. [PubMed: 3377350]

2. Hart DJ, Spector TD. The relationship of obesity, fat distribution and osteoarthritis in women in the general population: the Chingford Study. J Rheumatol 1993;20:331–5. [PubMed: 8474072]

3. Grotle M, Hagen KB, Natvig B, Dahl FA, Kvien TK. Obesity and osteoarthritis in knee, hip and/or hand: an epidemiological study in the general population with 10 years follow-up. BMC Musculoskelet Disord 2008;9:132. [PubMed: 18831740]

4. Lee S, Kim TN, Kim SH. Sarcopenic obesity is more closely associated with knee osteoarthritis than is nonsarcopenic obesity: a cross-sectional study. Arthritis Rheum 2012;64:3947–54. [PubMed: 23192792]

5. Abbate LM, Stevens J, Schwartz TA, Renner JB, Helmick CG, Jordan JM. Anthropometric measures, body composition, body fat distribution, and knee osteoarthritis in women. Obesity (Silver Spring) 2006;14:1274–81. [PubMed: 16899809]

6. Suh DH, Han KD, Hong JY, et al. Body composition is more closely related to the development of knee osteoarthritis in women than men: a cross-sectional study using the Fifth Korea National Health and Nutrition Examination Survey (KNHANES V-1, 2). Osteoarthritis Cartilage 2016;24:605–11. [PubMed: 26518994]

7. Stenholm S, Harris TB, Rantanen T, Visser M, Kritchevsky SB, Ferrucci L. Sarcopenic obesity: definition, cause and consequences. Curr Opin Clin Nutr Metab Care 2008;11:693–700. [PubMed: 18827572]

8. Englund M, Guermazi A, Roemer FW, et al. Meniscal tear in knees without surgery and the development of radiographic osteoarthritis among middle-aged and elderly persons: The Multicenter Osteoarthritis Study. Arthritis Rheum 2009;60:831–9. [PubMed: 19248082]

9. Segal NA, Findlay C, Wang K, Torner JC, Nevitt MC. The longitudinal relationship between thigh muscle mass and the development of knee osteoarthritis. Osteoarthritis Cartilage 2012;20:1534–40. [PubMed: 22954456]

10. Newman AB, Kupelian V, Visser M, et al. Sarcopenia: alternative definitions and associations with lower extremity function. J Am Geriatr Soc 2003;51:1602–9. [PubMed: 14687390]

11. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16:494–502. [PubMed: 13498604]

12. Sowers MF, Yosef M, Jamadar D, Jacobson J, Karvonen-Gutierrez C, Jaffe M. BMI vs. body composition and radiographically defined osteoarthritis of the knee in women: a 4-year follow-up study. Osteoarthritis Cartilage 2008;16:367–72. [PubMed: 17884608]

13. Hu PF, Bao JP, Wu LD. The emerging role of adipokines in osteoarthritis: a narrative review. Mol Biol Rep 2011;38:873–8. [PubMed: 20480243]

14. Bennell KL, Bowles KA, Wang Y, Cicuttini F, Davies-Tuck M, Hinman RS. Higher dynamic medial knee load predicts greater cartilage loss over 12 months in medial knee osteoarthritis. Ann Rheum Dis 2011;70:1770–4. [PubMed: 21742637]

15. Felson DT, Chaisson CE. Understanding the relationship between body weight and osteoarthritis. Baillieres Clin Rheumatol 1997;11:671–81. [PubMed: 9429730]

Table 1:

Baseline participant characteristics

Characteristics	Obese (N=244)	Sarcopenic obese (N= 62)	Sarcopenic (N=283)	Normal (N=1107)
Age (years), mean (±SD)	63 (7.7)	60 (7.8)	65 (8.3)	62 (8.0)
Sex, % women	61	61	61	61
Race, % Caucasian	83	96	92	84
Physical activity, mean PASE score (±SD)	182 (±93.4)	160 (±85.0))	187 (±95.0)	185 (±86.4)
Charlson's comorbidity index, mean (±SD)	0.7 (±1.2)	0.8 (±1.4)	0.5 (±0.9)	0.6 (±1.1)
Smoking, % never	57	55	54	56
Knee injury, %yes	43	43	45	41
Body weight (Kg), mean (±SD)	107(±13.2)	104 (±16.3)	76 (±11.5)	80 (±13.1)
Height (m), mean (±SD)	1.7 (0.09)	1.7 (0.10)	1.7 (0.10)	1.7 (0.09)
Total body fat mass (Kg), mean (range)	45 (32-80)	46 (32-88)	27 (6-41)	26 (6-41)
Appendicular skeletal muscle mass(kg), mean (range)	51 (39-74)	45 (35-63)	32 (21-46)	37 (20-56)

Table 2:

Relation of obesity, sarcopenic obesity, and sarcopenia at baseline with risk of incident radiographic knee osteoarthritis over 5 years among community-dwelling older adults

Sex-specific body composition category	n/N	Crude RR	Adjusted *RR
Overall:			
Obese	79/244	1.95	2.05 (1.56-2.68)
Sarcopenic Obese	18/62	1.75	1.91 (1.17-3.10)
Sarcopenic	35/246	0.86	0.87 (0.06-1.25)
Non-obese Non sarcopenic (ref)	183/1101	1.0	1.00
Women:			
Obese	54/1 37	2.11	2.29 (1.64-3.20)
Sarcopenic Obese	13/36	1.94	2.09 (1.17-3.73)
Sarcopenic	25/139	1.00	0.96 (0.62-1.49)
Non-obese (ref)	121/650	1.00	1.00
Men:			
Obese	25/107	1.70	1.73 (1.08-2.78)
Sarcopenic Obese	5/26	1.40	1.74 (0.68-4.46)
Sarcopenic	10/107	0.70	0.66 (0.34-1.30)
Non-obese (ref)	62/451	1.00	1.00

*Adjusted for age, height, race, physical activity (PASE score), smoking, Charlson's comorbidity index and knee injury

Table 3:

Sensitivity analysis with BMI-defined obesity categories to evaluate the relation of obesity, sarcopenic obesity and sarcopenia with risk of incident radiographic knee osteoarthritis over 5 years among community-dwelling older adults

Sex-specific body composition category	n/N	Crude RR	Adjusted *RR
Overall:			
Obese	151/585	1.81	1.87 (1.46-2.40)
Sarcopenic Obese	29/110	1.77	1.99 (1.32-3.02)
Sarcopenic	31/212	1.00	1.03 (0.68-1.54)
Non-obese (ref)	111/760	1.00	1.00
Women:			
Obese	98/326	1.80	1.87 (1.37-2.54)
Sarcopenic Obese	16/64	1.50	1.60 (0.93-2.77)
Sarcopenic	22/114	1.16	1.15 (0.71-1.86)
Non-obese (ref)	77/461	1.00	1.00
Men:			
Obese	53/259	1.80	1.92 (1.24-3.00)
Sarcopenic Obese	13/46	2.49	2.89 (1.49-5.59)
Sarcopenic	9/98	0.80	0.80 (0.38-1.67)
Non-obese (ref)	34/299	1.00	1.00

*Adjusted for age, height, race, physical activity (PASE score), smoking, Charlson's comorbidity index and knee injury