Associations of Obesity Phenotypes with Incident and Recurrent Falls in Older Adults

Hajin Jang

Abstract

Aging-related increases in adiposity and declines in muscle strength give rise to whole-body, abdominal, and sarcopenic obesity, which may elevate fall risk. Using harmonized data from four U.S. aging cohorts (the Health, Aging, and Body Composition Study [Health ABC], the Cardiovascular Health Study [CHS], the Osteoporotic Fractures in Men [MrOS] Study, and the Women's Health Initiative Long Life Study [WHI-LLS]), we evaluated associations between these phenotypes and annual fall outcomes in 15,054 older adults. Whole-body obesity was defined as BMI ≥ 30 kg/m^2, abdominal obesity as elevated waist circumference, and sarcopenic obesity as coexisting obesity and low grip strength. Falls were assessed annually from 1992 to 2016, and associations were estimated using Generalized Estimating Equations.

At baseline, 23.8% had whole-body obesity, 52.2% had abdominal obesity, and 13.1% met criteria for sarcopenic obesity. All three phenotypes were significantly associated with higher odds of incident and recurrent falls. Whole-body obesity increased the odds of incident and recurrent falls by 28% and 40%, respectively, while abdominal obesity by 12% and 17%. Sarcopenic obesity was associated with 45% and 60% higher odds of incident and recurrent falls, respectively. Among sarcopenic obesity categories, sarcopenic obesity had the highest odds, with a confidence interval that did not overlap with that of non-sarcopenic obesity, suggesting an added burden of sarcopenia on fall risk.

These findings demonstrate that obesity and sarcopenia independently heighten fall risk, with sarcopenic obesity representing a particularly vulnerable group and a critical target for fall prevention.

1. Introduction

Obesity is a well-known risk factor for numerous non-communicable diseases [1], and its prevalence among U.S. adults reached 40.3% in 2023 [2, 3]. In older adults, aging-related body composition changes, including increased visceral and intramuscular fat and declines in muscle mass and strength [4-6], give rise to diverse obesity phenotypes such as whole-body, abdominal, and sarcopenic obesity. Abdominal

obesity reflects metabolically active visceral fat linked to inflammation and cardiometabolic disease, while sarcopenic obesity combines excess adiposity with poor muscle strength, heightening risks for mobility limitations, disability, and frailty [7-9]. These age-related fat accumulation and muscle declines can occur independently of overall weight and may substantially contribute to mobility impairments [10-15].

Falls are a leading cause of morbidity and mortality among older adults in the United States [16-18]. Obesity phenotypes may influence fall risk through multiple mechanisms: impaired postural stability, altered gait, reduced mobility, and neuromuscular decline stemming from chronic inflammation and metabolic dysfunction [19-23]. Despite these plausible pathways, prior research has not fully clarified how different obesity phenotypes relate to fall risk. Existing studies are limited by incomplete comparisons across phenotypes, insufficient longitudinal follow-up to capture dynamic fall patterns, and restricted generalizability due to selective study populations [24-39].

To address these gaps, the present study pools data from four major U.S. aging cohorts to evaluate longitudinal associations of whole-body, abdominal, and sarcopenic obesity with incident and recurrent falls. We hypothesize that older adults with one or more obesity phenotypes will have a higher risk of falling compared to those without obesity.

2. Methods

Study Population

We integrated data from four major U.S. aging cohorts (MrOS, Health ABC, CHS, WHI-LLS), each designed to investigate cardiometabolic, cardiovascular, and functional aging [40-43]. Pooling these cohorts allows for harmonized, long-term evaluation of fall-related risk factors with greater statistical power and generalizability than single-cohort studies. Participants were eligible if they had baseline BMI, waist circumference, and grip strength data, as well as at least one fall outcome.

Of the 22,471 participants initially considered, individuals were excluded for missing baseline exposure measures (n=3,723), lacking fall outcomes (n=4), missing demographic covariates (n=410), or

missing health behavioral covariates (n=3,280). The final analytic sample included 15,054 community-dwelling older adults.

Obesity Phenotypes

Three harmonized obesity phenotype variables were examined: whole-body, abdominal, and sarcopenic obesity. Whole-body obesity was defined as BMI ≥ 30 kg/m^2, with BMI categories classified per World Health Organization (WHO) criteria [44]. Abdominal obesity was defined as waist circumference > 102 cm in men and > 88 cm in women [45]. Sarcopenic obesity was defined as meeting either whole-body or abdominal obesity criteria plus low grip strength (< 35.5 kg in men, < 20 kg in women) based on the Sarcopenia Definitions and Outcomes Consortium (SDOC) guidelines [46].

BMI, waist circumference, and grip strength were assessed at baseline in all cohorts using standardized protocols. Weight and height were obtained by trained staff using calibrated equipment, and BMI was calculated as weight divided by height squared. Waist circumference was measured at the iliac crest with a standardized tape. Grip strength was measured using Jamar dynamometers, with the maximum value from two trials per hand used [46].

Fall Outcomes

Two harmonized fall outcomes were used: (1) incident fall, defined as a binary variable indicating whether the participant experienced at least one fall during the past year (no fall vs. ≥ 1 fall) and (2) recurrent falls, defined as a binary variable indicating whether the participant experienced two or more falls during the past year (≤ 1 fall vs. ≥ 2 falls). Falls were assessed using standardized self-report questions asking whether participants had fallen in the past 12 months.

Covariates

Covariates were selected based on biological relevance and prior evidence linking obesity with fall risk. To capture within-person changes, key health and behavioral variables were modeled as time-varying. Demographic variables included age (years; time-varying), sex (women, men), race (White, Black, others), and education (less than high school, some college, college graduate or more). Health behavioral factors included smoking status (never smoker, former smoker, current smoker; time-varying), alcohol consumption (none, < 1 drink/week, ≥ 1 drink/week; time-varying), and self-reported physical activity (MET-hours/week or Physical Activity Scale for the Elderly [PASE] score, standardized values of each cohort; time-varying). A cohort indicator variable was included to account for cohort effects (e.g., CHS=1, Health ABC=2, MrOS=3, and WHI=4).

Statistical Analysis

Descriptive analyses (means and standard deviations for continuous variables and frequencies and percentages for categorical variables) were used to summarize baseline characteristics across sarcopenic obesity categories. Differences between groups were assessed using t-tests or Wilcoxon rank-sum tests for continuous variables and chi-square or Fisher's Exact tests for categorical variables. Baseline was defined as the first visit with complete data. Associations between obesity phenotypes and falls were examined using Generalized Estimating Equations with a binomial distribution and logit link function. Independent, exchangeable, and autoregressive correlation structures were tested to account for possible inconsistent follow-up times, and the autoregressive structure was selected based on Quasi-likelihood under the Independence model Criterion (QIC). Robust standard errors were used to account for potential misspecification. Time-varying covariates included age, smoking, alcohol use, and physical activity. Covariates were added sequentially (cohort indicators, demographics, and health behaviors), with selection guided by significance thresholds of alpha 0.10 for removal and alpha 0.05 for retention. The final models included cohort, age, sex, race, education, smoking status, alcohol consumption, and physical activity. Model diagnostics included assessment of multicollinearity using variance inflation factors (VIF) less than

2 and correlation matrices, as well as residual checks for model fit. All analyses were conducted using SAS 9.4 and R 4.4.1.

3. Results

Participants had a mean age of 75.2 ± 5.9 years (range 64–99), and 75.7% were White. Overall, 67.5% (n=10,157) reported at least one fall during follow-up. The prevalence of whole-body, abdominal, and sarcopenic obesity was 23.8%, 52.2%, and 13.1%, respectively; 93.9% of those with whole-body obesity also had abdominal obesity. By sarcopenic obesity classification, 32.6% were non-sarcopenic non-obese, 40.5% non-sarcopenic obese, 13.8% non-obese sarcopenic, and 13.1% sarcopenic obese. Baseline characteristics differed significantly across the sarcopenic obesity groups ($P < 0.0001$) (**Table 1**). Compared with the non-obese non-sarcopenic group, individuals with sarcopenic obesity were more often women, older, less active, and had higher BMI, more Black participants, and lower education and substance use.

In fully adjusted models (**Figures 1**), whole-body obesity was associated with higher odds of incident fall (OR=1.28, 95% CI=1.20–1.36) and recurrent falls (OR=1.40, 95% CI=1.28–1.54), with no significant associations for overweight or underweight. Abdominal obesity was also associated with higher odds of incident fall (OR=1.12, 95% CI=1.07–1.18) and recurrent falls (OR=1.17, 95% CI=1.09–1.25). Relative to the non-sarcopenic non-obese group, the non-sarcopenic obese group showed higher odds of incident fall (OR=1.15, 95% CI=1.08–1.21) and recurrent falls (OR=1.19, 95% CI=1.10–1.30). Non-obese sarcopenia showed stronger associations: incident fall (OR=1.25, 95% CI=1.16–1.35) and recurrent falls (OR=1.31, 95% CI=1.18–1.46). Sarcopenic obesity showed the highest odds across outcomes, including incident fall (OR=1.45, 95% CI=1.34–1.56) and recurrent falls (OR=1.60, 95% CI=1.43–1.78).

4. Conclusions

In conclusion, this large cross-cohort analysis showed that whole-body obesity, abdominal obesity, and sarcopenic obesity were each independently associated with higher odds of incident and recurrent falls among community-dwelling older adults in the United States. Even in the absence of obesity, low grip

strength was linked to a higher odds of fall outcomes compared to having neither condition, whereas the coexistence of excess adiposity and low muscle strength showed the highest odds of fall outcomes, highlighting the potential combined impact of obesity and sarcopenia. These findings underscore the importance of muscle strength and excess adiposity as fall risk factors. Future research could benefit from incorporating imaging-based body composition and repeated measures of obesity and sarcopenia to better capture how changes in fat distribution and muscle function over time contribute to fall risk.

Table 1. Baseline characteristics of participants by sarcopenic obesity categories (N=15,054)[1]

Mean (SD) or n (%)		Non-Sarcopenic Non-Obese	Non-Sarcopenic Obese	Non-Obese Sarcopenic	Sarcopenic Obese	*P*-value[2]
N (%)		4,907 (32.6)	6,101 (40.5)	2,071 (13.8)*	1,975 (13.1)*	
Male (%)		2,952 (60.2)	2,406 (39.4)	907 (43.8)*	579 (29.3)*	<0.0001
Age, years		74.2 (5.4)	73.9 (5.0)	79.1 (6.5)*	77.8 (6.3)*	<0.0001
Race, n (%)	White	3,778 (77.0)	4,377 (71.7)	1,710 (82.6)*	1,523 (77.1)*	<0.0001
	Black	996 (20.3)	1,645 (27.0)	309 (14.9)*	421 (21.3)*	
	Others	133 (2.7)	79 (1.3)	52 (2.5)*	31 (1.6)*	
Education, n (%)	< High school	587 (12.0)	1,042 (17.1)	230 (11.1)*	289 (14.6)*	<0.0001
	Some college	1,072 (21.9)	1,708 (28.0)	437 (21.1)*	488 (24.7)*	
	≥ College graduate	3,248 (66.2)	3,351 (54.9)	1,404 (67.8)*	1,198 (60.7)*	
Current smoking, n (%)		361 (7.4)	365 (6.0)	116 (5.6)*	126 (6.4)*	<0.0001
Alcohol drinking, n(%)	Never	1,807 (36.8)	2,686 (44.0)	785 (37.9)*	857 (43.4)*	<0.0001
	< 1 drink/week	944 (19.2)	1,356 (22.2)	463 (22.4)*	508 (25.7)*	
	≥ 1 drink/week	2,156 (43.9)	2,059 (33.8)	823 (39.7)*	610 (30.9)*	
BMI, kg/m^2		24.4 (2.6)	30.0 (4.5)	23.9 (2.8)*	29.9 (4.8)	<0.0001
Waist circumference, inch		87.9 (9.4)	104.9 (10.8)	84.4 (9.7)*	102.4 (10.8)*	<0.0001
Maximum grip strength, kg		36.5 (11.1)	22.3 (11.0)	21.4 (8.8)*	19.2 (8.0)*	<0.0001
Standardized weekly physical activity		0.20 (0.94)	-0.02 (0.99)	-0.02 (0.98)	-0.18 (0.99)*	<0.0001
Incident fall, n (%)		866 (17.6)	1,186 (19.5)	531 (25.6)*	577 (29.2)*	<0.0001
Number of falls, n (%)	No fall	4,041 (82.4)	4,915 (80.6)	1,540 (74.4)*	1,398 (70.8)*	<0.0001
	1 time	571 (11.6)	762 (12.5)	332 (16.0)*	339 (17.2)*	
	2 or more times	295 (6.0)	424 (7.0)	199 (9.6)*	238 (12.0)*	

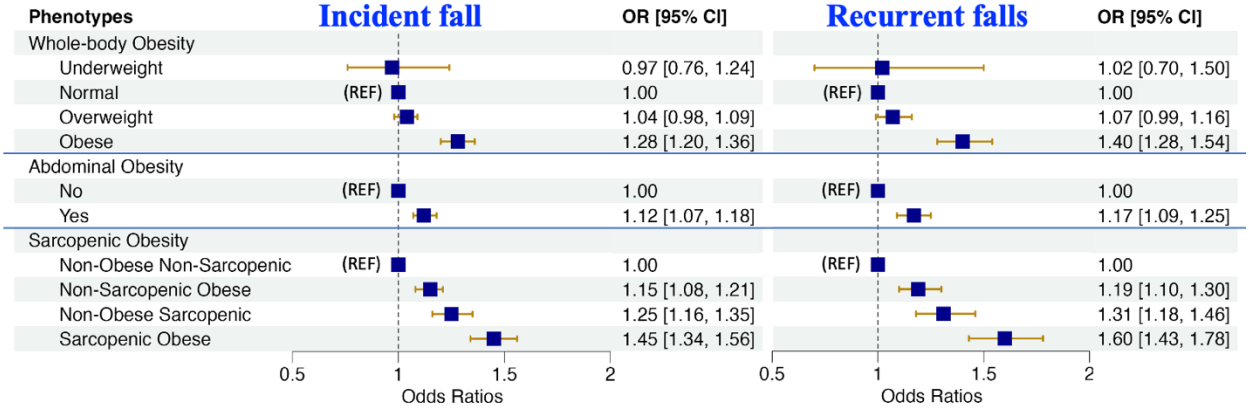
Abbreviations: BMI, body mass index; SD, standard deviation.

[1] Data are presented as mean (standard deviation) for continuous variables and number (percentage) for categorical variables.

[2] *P*-values are derived from ANOVA tests for continuous variables and Chi-square tests for categorical variables, comparing differences across sarcopenic obesity categories.

* Significantly different from Non-Sarcopenic Obese group ($P < 0.05$)

Figure 1. Associations of obesity phenotypes with incident and recurrent falls



References

1. National Heart, L., and Blood Institute, *Managing overweight and obesity in adults: Systematic evidence review from the Obesity Expert Panel*. 2013.
2. Emmerich, S.D., et al., *Obesity and Severe Obesity Prevalence in Adults: United States, August 2021-August 2023.* NCHS Data Brief, 2024(508).
3. *Global, regional, and national burden of diabetes from 1990 to 2021, with projections of prevalence to 2050: a systematic analysis for the Global Burden of Disease Study 2021.* Lancet, 2023. **402**(10397): p. 203-234.
4. Vincent, H.K., S.N. Raiser, and K.R. Vincent, *The aging musculoskeletal system and obesity-related considerations with exercise.* Ageing Res Rev, 2012. **11**(3): p. 361-73.
5. Ponti, F., et al., *Aging and Imaging Assessment of Body Composition: From Fat to Facts.* Front Endocrinol (Lausanne), 2019. **10**: p. 861.
6. Khanal, P., et al., *Sarcopenia, Obesity, and Sarcopenic Obesity: Relationship with Skeletal Muscle Phenotypes and Single Nucleotide Polymorphisms.* J Clin Med, 2021. **10**(21).
7. Batsis, J.A. and D.T. Villareal, *Sarcopenic obesity in older adults: aetiology, epidemiology and treatment strategies.* Nat Rev Endocrinol, 2018. **14**(9): p. 513-537.
8. Wannamethee, S.G. and J.L. Atkins, *Sarcopenic Obesity and Cardiometabolic Health and Mortality in Older Adults: a Growing Health Concern in an Ageing Population.* Curr Diab Rep, 2023. **23**(11): p. 307-314.
9. Roh, E. and K.M. Choi, *Health Consequences of Sarcopenic Obesity: A Narrative Review.* Front Endocrinol (Lausanne), 2020. **11**: p. 332.
10. Fantin, F., et al., *Longitudinal body composition changes in old men and women: interrelationships with worsening disability.* J Gerontol A Biol Sci Med Sci, 2007. **62**(12): p. 1375-81.
11. Hughes, V.A., et al., *Anthropometric assessment of 10-y changes in body composition in the elderly.* Am J Clin Nutr, 2004. **80**(2): p. 475-82.
12. Siervo, M., et al., *Age-related changes in basal substrate oxidation and visceral adiposity and their association with metabolic syndrome.* Eur J Nutr, 2016. **55**(4): p. 1755-67.
13. Zamboni, M., S. Rubele, and A.P. Rossi, *Sarcopenia and obesity.* Curr Opin Clin Nutr Metab Care, 2019. **22**(1): p. 13-19.
14. Atkins, J.L., et al., *Sarcopenic obesity and risk of cardiovascular disease and mortality: a population-based cohort study of older men.* J Am Geriatr Soc, 2014. **62**(2): p. 253-60.
15. Wannamethee, S.G. and J.L. Atkins, *Muscle loss and obesity: the health implications of sarcopenia and sarcopenic obesity.* Proc Nutr Soc, 2015. **74**(4): p. 405-12.
16. Kakara, R., et al., *Nonfatal and Fatal Falls Among Adults Aged ≥65 Years - United States, 2020-2021.* MMWR Morb Mortal Wkly Rep, 2023. **72**(35): p. 938-943.
17. Moreland, B., R. Kakara, and A. Henry, *Trends in Nonfatal Falls and Fall-Related Injuries Among Adults Aged ≥65 Years - United States, 2012-2018.* MMWR Morb Mortal Wkly Rep, 2020. **69**(27): p. 875-881.
18. Centers for Disease Control and Prevention, N.C.f.I.P.a.C. *Web–based Injury Statistics Query and Reporting System (WISQARS)*. 2025; Available from: https://wisqars.cdc.gov/.
19. Dutil, M., et al., *The impact of obesity on balance control in community-dwelling older women.* Age (Dordr), 2013. **35**(3): p. 883-90.
20. Garcia, P.A., et al., *Obesity is associated with postural balance on unstable surfaces but not with fear of falling in older adults.* Braz J Phys Ther, 2021. **25**(3): p. 311-318.
21. De Carvalho, F.G., et al., *Adipose Tissue Quality in Aging: How Structural and Functional Aspects of Adipose Tissue Impact Skeletal Muscle Quality.* Nutrients, 2019. **11**(11).
22. Prado, C.M., et al., *Sarcopenic obesity in older adults: a clinical overview.* Nat Rev Endocrinol, 2024. **20**(5): p. 261-277.
23. Pedersen, B.K. and M.A. Febbraio, *Muscles, exercise and obesity: skeletal muscle as a secretory organ.* Nat Rev Endocrinol, 2012. **8**(8): p. 457-65.

24. Kao, C.Y., Y.C. Su, and S.F. Chang, *The Relationship between Dynapenic Abdominal Obesity and Fall: A Systematic Review and Meta-Analysis of 15,506 Middle to Older Adults.* J Clin Med, 2023. **12**(23).
25. Liu, L.K., et al., *Dynapenic Abdominal Obesity and Adverse Health Effects in Middle-Aged and Older Adults: A Systematic Review and Meta-Analysis.* Healthcare (Basel), 2025. **13**(8).
26. Coelho de Amorim, J.S., et al., *Dynapenic Abdominal Obesity, Single and Recurrent Falls in Older Brazilian Adults: Elsi-Brazil Results.* J Aging Health, 2024. **36**(1-2): p. 35-45.
27. Zhang, L., et al., *Dynapenic abdominal obesity and the effect on long-term gait speed and falls in older adults.* Clin Nutr, 2022. **41**(1): p. 91-96.
28. Veronese, N., et al., *Dynapenic abdominal obesity and susceptibility to fall: a prospective analysis of the Osteoarthritis Initiative.* Front Nutr, 2023. **10**: p. 1153399.
29. Chaksari, H.R., et al., *Association between Dynapenic abdominal obesity and fall risk among older adults: a longitudinal study in Birjand.* Aging Clin Exp Res, 2025. **37**(1): p. 201.
30. Smith, L., et al., *Dynapenic Abdominal Obesity Increases Risk for Falls Among Adults Aged ≥50 Years: A Prospective Analysis of the Irish Longitudinal Study on Ageing.* J Gerontol A Biol Sci Med Sci, 2024. **79**(1).
31. Máximo, R.O., et al., *Abdominal obesity, dynapenia and dynapenic-abdominal obesity as factors associated with falls.* Braz J Phys Ther, 2019. **23**(6): p. 497-505.
32. Lv, D., S. Shen, and X. Chen, *Association Between Dynapenic Abdominal Obesity and Fall Risk in Older Adults.* Clin Interv Aging, 2022. **17**: p. 439-445.
33. Li, R., et al., *Sarcopenic obesity and falls in older adults: A validation study of ESPEN/EASO criteria and modifications in Western China communities.* Arch Gerontol Geriatr, 2024. **127**: p. 105557.
34. Peng, T.C., et al., *Associations between different measurements of sarcopenic obesity and health outcomes among non-frail community-dwelling older adults in Taiwan.* Br J Nutr, 2021. **126**(11): p. 1749-1757.
35. Scott, D., et al., *Sarcopenic Obesity and Its Temporal Associations With Changes in Bone Mineral Density, Incident Falls, and Fractures in Older Men: The Concord Health and Ageing in Men Project.* J Bone Miner Res, 2017. **32**(3): p. 575-583.
36. Follis, S., et al., *Association Between Sarcopenic Obesity and Falls in a Multiethnic Cohort of Postmenopausal Women.* J Am Geriatr Soc, 2018. **66**(12): p. 2314-2320.
37. Ghorbanzadeh, M., et al., *Association of multidimensional frailty and dynapenia with fall risk in older adults.* BMC Geriatr, 2025. **25**(1): p. 442.
38. Huang, L., et al., *Effects of BMI and grip strength on older adults' falls-A longitudinal study based on CHARLS.* Front Public Health, 2024. **12**: p. 1415360.
39. Delbari, A., et al., *Association of Obesity, Sarcopenia, and Functional Mobility with Risk of Fall: A Cross-Sectional Study from Ardakan Cohort Study on Aging (ACSA).* Med J Islam Repub Iran, 2024. **38**: p. 114.
40. Harris, T.B., et al., *Waist circumference and sagittal diameter reflect total body fat better than visceral fat in older men and women. The Health, Aging and Body Composition Study.* Ann N Y Acad Sci, 2000. **904**: p. 462-73.
41. Fried, L.P., et al., *The Cardiovascular Health Study: design and rationale.* Ann Epidemiol, 1991. **1**(3): p. 263-76.
42. Orwoll, E., et al., *Design and baseline characteristics of the osteoporotic fractures in men (MrOS) study--a large observational study of the determinants of fracture in older men.* Contemp Clin Trials, 2005. **26**(5): p. 569-85.
43. *Design of the Women's Health Initiative clinical trial and observational study. The Women's Health Initiative Study Group.* Control Clin Trials, 1998. **19**(1): p. 61-109.
44. Jensen, M.D., et al., *2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force*

on Practice Guidelines and The Obesity Society. J Am Coll Cardiol, 2014. **63**(25 Pt B): p. 2985-3023.
45. *Waist circumference and waist-hip ratio: report of a WHO expert consultation*. 2008, World Health Organization: Geneva.
46. Bhasin, S., et al., *Sarcopenia Definition: The Position Statements of the Sarcopenia Definition and Outcomes Consortium.* J Am Geriatr Soc, 2020. **68**(7): p. 1410-1418.