Sarcopenic Knee Osteoarthritis: A Risk Factor for Recurrent Falls

Hiroataka Iijima (✉ hirotaka@pitt.edu)

Keio University

Tomoki Aoyama

Kyoto University

Research Article

Keywords: Sarcopenia, Knee osteoarthritis, Recurrent falls

Posted Date: April 22nd, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-435543/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background: Sarcopenia and knee osteoarthritis (OA) are major risk factors for falls in older adults. The coexistence of these two conditions may exacerbate the risk of falls through the sarcopenia-OA interaction. This study aimed to test the hypothesis that older adults with coexisting sarcopenia and knee OA, defined as “sarcopenic OA,” displayed an increased risk of falls.

Methods: Patients in an orthopedics clinic (n = 298, age: 60–90 years, 78.9% women) were divided into 4 groups according to the presence of sarcopenia and radiographic knee OA: isolated sarcopenia, isolated knee OA, sarcopenic knee OA, and control (i.e., non-sarcopenia with non-OA) groups. We used questionnaires to assess fall experience in the prior 12 months. We performed binary and ordinal logistic regression analyses to evaluate the relationship between the 4 groups and falls experience.

Results: Of 298 participants, 27 (9.1%) had sarcopenic knee OA. Patients with sarcopenic knee OA had 4.70 times (95% confidence interval: 1.08, 20.5) higher odds of recurrent falls (≥ 2 falls) than those with control after adjustment for age, sex, and body mass index.

Conclusions: Patients with sarcopenic knee OA displayed higher frailty. This study provides novel interactive relationship between sarcopenia and knee OA in the context of recurrent falls experience.

Trial registration: Not applicable.

Background

Sarcopenia, an age-dependent loss of skeletal muscle mass[1], is a major risk factor for falls in older adults[2]. As falls are the leading cause of unintentional injury[3] and subsequent fear of falling[4], fall prevention in persons with sarcopenia is important. A key component in the prevention of falls is the identification of factors that may increase the risk of falling[5]. The possible underlying mechanism was reported to be sedentary behavior-driven muscle mass reduction due to a chronic reduction in muscle protein synthesis[6].

A potential coexisting risk factor for falls in persons with sarcopenia that was not adequately addressed in earlier studies is knee osteoarthritis (OA). Knee OA, a leading cause of pain and disability, is an independent risk factor for falls in older adults[7–9]. Generally, persons with knee OA share the above-mentioned underlying mechanism of falls. The coexistence of these 2 conditions, occurring in 1.6–5.3% of the community-dwelling elderly[10, 11], may exacerbate the risk of falls through the OA-sarcopenia interaction. However, most previous studies evaluated the fall experience of older adults with sarcopenia and knee OA separately[2, 7–9], and no study has directly addressed the clinical profile of this potential debilitating condition.

This study aimed to test the hypothesis that older adults with coexisting sarcopenia and knee OA, defined as “sarcopenic OA,” had an increased risk of falls. This knowledge would serve as a foundation for future

studies toward the establishment of fall prevention strategies.

Methods

Patients

This study is a secondary analysis of a previous cross-sectional study that investigated the association between knee pain during gait and four clinical phenotypes, based on static varus alignment and varus thrust, in patients with medial knee OA[12]. The research protocol was approved by the ethics committees in Kyoto University Graduate School and Faculty of Medicine, and written informed consent was obtained from all patients before their enrollment. This study was carried out in accordance with STROBE statement (see Supplemental Appendix S1) and regulations under Ethics approval and consent to participate.

Patients were identified through the medical record system and recruited from a community orthopedics clinic located in a rural mountainous community. We distributed an advertisement to patients who were visiting the clinic for the conservative treatment of knee OA. All recruited patients had a history of pain in 1 or both knees. The required sample size was not calculated in the original cross-sectional study; however, there was no limit to the maximum number of recruited patients owing to the observational nature of the study. The eligibility criteria were as follows: (1) age ≥ 50 years and (2) ability to walk independently on a flat surface without any ambulatory assistive device. Bilateral knee OA cases were not considered separately from unilateral cases. As knee pain is common in community-dwelling individuals aged ≥ 45 years in Japan[13], age ≥ 50 years was adopted to generalize the applicability of results. The exclusion criteria were (1) a history of knee surgery, (2) rheumatoid arthritis, (3) periarticular fracture, (4) present neurological problems, or (5) lateral knee OA. Lateral knee OA was defined as Kellgren and Lawrence (K&L) grade ≥ 2 , along with lateral joint space narrowing (JSN) $>$ medial JSN, and lateral osteophytes $>$ medial osteophytes based on the Osteoarthritis Research Society International atlas[14], according to previously described methods[15, 16].

Measurements

Skeletal muscle mass index (SMI), handgrip strength (i.e., a metric of muscle strength), gait velocity (i.e., a metric of physical performance), radiographic knee OA, and fall experience were evaluated as outcome measurements in all patients. All outcome measures were evaluated by experienced physical therapists with > 6 years of clinical experience in musculoskeletal disorders and a postgraduate master's degree qualification at the time of patient inclusion. Demographic characteristics and knee OA-related self-reported measures of knee pain and disability were also assessed as patient characteristics and/or covariates.

SMI

A bioelectrical impedance data acquisition system (Inbody 430; Biospace Co., Ltd., Seoul, Korea) was used to determine bioelectrical impedance[17]. This system uses electrical current at different frequencies (5, 50, and 250 kHz) to directly measure the amount of extracellular and intracellular water in the body. The data acquisition system calculated the resistance value and muscle mass of the respective body parts (right arm, left arm, right leg, left leg, and trunk). The patients stood on 2 metallic electrodes and held metallic grip electrodes. The appendicular skeletal muscle mass was determined using the segmental body composition and muscle mass excluding the trunk part. SMI was calculated by dividing the skeletal muscle mass by height in square meters (kg/m^2)[18].

Handgrip strength

The handgrip strength in both hands was measured using a hand dynamometer[19]. The patients kept their arms by the sides of their body and squeezed the dynamometer using maximum isometric effort. Other body movements were prohibited[19].

Physical performance

The patients were instructed to walk for 10 m at a self-selected speed. A trained examiner measured the time taken to walk 10 m with a stopwatch, in accordance with a previously suggested method[20]. Gait velocity (m/s) was manually calculated as 10 m divided by the time needed to walk 10 m.

Radiographic OA severity

The radiographic severity of the tibiofemoral joint in both knees was assessed by a trained examiner (HI) using the original version of the K&L grading system[21]. We previously reported excellent intra-examiner (κ : 0.876; 95% confidence interval [CI]: 0.829, 0.924) and inter-examiner (κ : 0.845; 95% CI: 0.793, 0.897) reliability scores[22]. The presence of radiographic OA was defined as K&L grade ≥ 2 .

Assessment of falls

A fall was defined as unintentionally coming to rest on the ground or at some other lower level, not because of a major intrinsic event (e.g., stroke) or an overwhelming external force (e.g., impact from a moving vehicle). Falls in the previous 12 months were evaluated using a self-reported question: “How many times did you have a fall within the past year?” An individual was considered a faller and recurrent faller if he or she has had at least 1 fall and 2 falls in the preceding 12 months, respectively.

Patient characteristics and covariates

Data on age, sex, and height were self-reported by the patients. Body mass index (BMI) was calculated by dividing the body mass (kg) by height in square meters (m^2). The knee pain severity and self-reported disability were evaluated using the Japanese Knee Osteoarthritis Measure (JKOM) subcategories “pain and stiffness” (0–32 points) and “activities of daily living” (0–40 points)[23]. The concurrent and construct validities of the JKOM were established by comparing with the Western Ontario and McMaster Universities Arthritis Index and the Medical Outcomes Study 36-item Short-form Health Survey[23].

Definition of sarcopenia

We defined sarcopenia as the presence of both low muscle function (low physical performance or low muscle strength) and low muscle mass in accordance with the recommended diagnostic algorithm of the Asian Working Group for Sarcopenia[24]. If a patient had both low muscle function (slow walking speed [0.8 m/s] or low grip strength [< 26 and < 18 kg for men and women, respectively]) and low SMI (< 7.0 and < 5.7 kg/m² for men and women, respectively), sarcopenia was diagnosed[24]. The prevalences of presarcopenia (i.e., low SMI without low muscle function) and severe sarcopenia (i.e., low SMI with slow walking speed and low grip strength) were provided for descriptive purposes.

Statistical analyses

All subjects were allocated to one of the following four subgroups based on radiographic OA and sarcopenia: (1) control (non-knee OA and non-sarcopenia), (2) isolated sarcopenia, (3) isolated knee OA, and (4) sarcopenic knee OA (i.e., coexisting knee OA and sarcopenia). Figure 1 shows diagnostic algorithms for sarcopenia and sarcopenic OA.

To minimize any bias from similarities between the right and left knees of the same patient, only the K&L grade of 1 knee per patient (index knee) was included in the statistical analysis. The index knee was defined as the more painful knee in the past or present. If a patient considered the pain in both knees to be equal, the index knee was randomly selected using a computer-generated permuted block randomization scheme[25].

To account for missing data, primary analyses included the multiple imputation technique. For SMI and fall experience, 5 and 2 imputed data sets were created, respectively, using the multiple imputation procedure of SPSS Statistics for Windows version 23.0 (IBM Corp., Armonk, NY, USA). Patients with a high missing rate (i.e., $> 50\%$) were excluded from the analyses.

Binary logistic regression analyses were performed to assess the relationship between the 4 subgroups, an independent variable, and a fall (≥ 1 fall; 0: no, 1: yes) or recurrent falls (≥ 2 falls; 0: no, 1: yes) in the preceding 12 months, a dependent variable. In this analysis, the four subgroups were included as a dichotomous variable, such as control (reference), isolated sarcopenia (0: no; 1: yes), isolated sarcopenia (0: no; 1: yes), and sarcopenic knee OA (0: no; 1: yes). As recurrent falls may have different risk factors and have been associated with increased physician contact and functional decline[26–29], this parameter (≥ 2 falls) was also included as a dependent variable in a separate binary logistic regression model. Ordinal logistic regression analysis was also performed, and falls were included as an ordinal dependent variable (1: no fall, 2: 1 fall, 3: ≥ 2 falls). In these analyses, age (continuous), female sex, and BMI (continuous) were included as covariates. These covariates were chosen a priori based on clinical judgment and their potential association with sarcopenia and knee OA[30, 31], not according to the causal pathway. The knee pain intensity (continuous) was further included as a covariate in a separate post-hoc logistic regression analysis. Sensitivity analysis was performed using all available data without imputation (complete cases).

To test the interaction between sarcopenia and radiographic knee OA, another logistic regression analysis was performed with sarcopenia (0: no; 1: yes), knee OA (0: no; 1: yes), and their interaction term (i.e., sarcopenia × knee OA) as independent variables. In this analysis, the dependent variable and covariates were included as mentioned above. Data analyses, except for multiple imputations, were performed using JMP 14.0 (SAS Institute, Cary, NC, USA).

Results

Of the 302 evaluated patients, 4 (1.3%) were excluded because of a high missing rate. Thus, 298 patients (age: 60–90 years, 78.9% women) were finally included in the study. Table 1 compares the patient characteristics among the control (n = 93), isolated sarcopenia (n = 12), isolated knee OA (n = 166), and sarcopenic knee OA (n = 27) groups. Patients with sarcopenic knee OA showed older age, higher proportion of women, and more severe disability than the other 3 groups. Single and recurrent falls in the preceding 12 months were experienced by 84 (28.2%) and 23 (7.7%) patients, respectively. Seven patients (age: 71.1 ± 6.7 years; BMI: 23.3 ± 2.0 kg/m²; 85.7% women) with missing data had similar demographic characteristics to 291 patients without missing data (age: 72.7 ± 7.0 years; BMI: 24.1 ± 3.7 kg/m²; 78.7% women).

Table 1
Patient characteristics

Variable	Mean $\pm$ SD or no. (%)			
	Control n = 93	Isolated Sarcopenia n = 12	Isolated Knee OA n = 166	Sarcopenic Knee OA n = 27
Age, years	70.2 $\pm$ 6.4	75.3 $\pm$ 7.3	73.0 $\pm$ 6.6	78.3 $\pm$ 7.6
Female	70 (75.3)	8 (66.7)	133 (80.1)	24 (88.9)
Height, cm	154.9 $\pm$ 7.3	152.1 $\pm$ 5.2	154.5 $\pm$ 7.2	150.1 $\pm$ 6.2
Mass, kg	56.6 $\pm$ 9.1	48.1 $\pm$ 8.2	59.3 $\pm$ 9.9	52.2 $\pm$ 9.4
BMI, kg/m ²	23.5 $\pm$ 3.0	20.7 $\pm$ 2.8	24.8 $\pm$ 3.7	23.2 $\pm$ 4.3
Obesity*	3 (3.2)	0 (0.0)	14 (8.4)	1 (3.7)
Index knee K&L grade				
Grade 0	2 (2.2)	1 (8.3)	0 (0)	0 (0)
Grade 1	91 (97.8)	11 (91.7)	0 (0)	0 (0)
Grade 2	0 (0)	0 (0)	109 (65.7)	12 (44.4)
Grade 3	0 (0)	0 (0)	37 (22.3)	11 (40.7)
Grade 4	0 (0)	0 (0)	20 (12.1)	4 (14.8)
JKOM, points				
Pain and stiffness†§	5.38 $\pm$ 5.08; 4 [1, 8]	6.08 $\pm$ 6.83; 4.5 [0, 12]	8.89 $\pm$ 6.51; 8 [4, 13]	9.00 $\pm$ 6.23; 9 [3, 14]
Activities of daily living**†	4.08 $\pm$ 4.83; 2 [1, 7]	5.75 $\pm$ 5.85; 4.5 [0, 11]	7.55 $\pm$ 7.13; 5 [2, 12]	10.0 $\pm$ 6.02; 9 [6, 14]
Physical function				
Gait velocity, m/s	1.27 $\pm$ 0.21	1.06 $\pm$ 0.26	1.18 $\pm$ 0.22	1.02 $\pm$ 0.24
Handgrip strength, kg	25.8 $\pm$ 6.9	17.1 $\pm$ 5.3	25.5 $\pm$ 6.4	15.9 $\pm$ 3.7

BMI, body mass index; JKOM, Japanese Knee Osteoarthritis Measure; K&L grade, Kellgren and Lawrence grade; OA, osteoarthritis; SD, standard deviation

* Obesity was defined as BMI $\geq$ 30 kg/m²

† Higher scores indicate severe knee pain or severe disability.

§ Median [interquartile range] was also provided because of the scattered distribution of the answered items.

Variable	Mean ± SD or no. (%)			
	Control n = 93	Isolated Sarcopenia n = 12	Isolated Knee OA n = 166	Sarcopenic Knee OA n = 27
Muscle volume				
Skeletal muscle index, kg/m ²	6.25 ± 0.80	5.50 ± 0.91	6.45 ± 0.78	5.46 ± 0.49
Pre-sarcopenia	38 (40.9)	0 (0.0)	39 (23.5)	0 (0.0)
Sarcopenia	0 (0.0)	12 (100.0)	0 (0.0)	28 (100.0)
Severe sarcopenia	0 (0.0)	11 (91.7)	0 (0.0)	25 (92.6)
BMI, body mass index; JKOM, Japanese Knee Osteoarthritis Measure; K&L grade, Kellgren and Lawrence grade; OA, osteoarthritis; SD, standard deviation				
* Obesity was defined as BMI ≥ 30 kg/m ²				
† Higher scores indicate severe knee pain or severe disability.				
§ Median [interquartile range] was also provided because of the scattered distribution of the answered items.				

Table 2 compares the incidence of single and multiple falls among the four subgroups. Patients with isolated sarcopenia more frequently (41.7%) had a single fall than those in the other 3 groups, and those with sarcopenic knee OA more frequently (18.5%) had multiple falls than patients in the other 3 groups. Binary logistic regression analysis revealed that patients with isolated sarcopenia (odds ratio [OR]: 4.47; 95% CI: 1.25, 16.0; $p = 0.024$) and those with sarcopenic knee OA (OR: 4.70; 95% CI: 1.08, 20.5; $p = 0.044$) had significantly higher prevalence of single fall and recurrent fall experience than the control group, respectively, even after adjustment for age, sex, and BMI. Ordinal logistic regression analysis also showed that patients with isolated sarcopenia (proportional OR: 3.89; 95% CI: 1.13, 13.4; $p = 0.032$) and sarcopenic knee OA (proportional OR: 2.90; 95% CI: 1.11, 7.52; $p = 0.029$) had an increased probability of experiencing single or multiple falls. Additional inclusion of knee pain intensity as a covariate showed similar results; however, the relationship between sarcopenic knee OA and recurrent falls was attenuated (OR: 3.88; 95% CI: 0.87, 17.2; $p = 0.075$). The sarcopenia × knee OA interaction in binary logistic regression analysis was not statistically significant in the association with a single fall ($p = 0.177$) and recurrent falls ($p = 0.611$). The sensitivity analysis, which excluded 7 patients ($n = 291$), revealed similar results in complete case analyses (see **Supplemental Appendix S2**).

Table 2

Results of binary and ordinal logistic regression analyses showing the relationship between the four subgroups and fall experience in older adults

Variable	No. (%) of patients			OR (95% CI)†		Proportional OR (95% CI)†
	No fall	1 fall	2 ≤ falls	1 ≤ fall	2 ≤ falls	
Control (n = 93)	74 (79.6)	13 (14.0)	6 (6.5)	–	–	
Isolated Sarcopenia (n = 12)	6 (50.0)	5 (41.7)	1 (8.3)	4.47 (1.25, 16.0)	1.94 (0.19, 19.6)	3.89 (1.13, 13.4)
Isolated Knee OA (n = 166)	118 (71.1)	37 (22.3)	11 (6.6)	1.46 (0.78, 2.74)	0.88 (0.30, 2.61)	1.40 (0.75, 2.61)
Sarcopenic Knee OA (n = 27)	16 (59.3)	6 (22.2)	5 (18.5)	2.50 (0.94, 6.69)	4.70 (1.08, 20.5)	2.90 (1.11, 7.52)
95% CI, 95% confidence interval; OR, odds ratio						
Bold type indicates a statistically significant result.						
† OR (95% CI) and proportional OR (95% CI) values of the 4 subgroups (control: reference) were calculated to indicate their predictive ability for fall experience (1 ≤ fall or 2 ≤ falls) while simultaneously including (1-step model) age, female sex, and body mass index.						

Discussion

This study found that patients with coexisting sarcopenia and knee OA (i.e., sarcopenic knee OA) had a significantly higher prevalence of recurrent falls in the preceding 12 months than those without sarcopenia and knee OA, which supports our first hypothesis. Figure 2 shows the graphical abstract.

Interpretation of the observed relationship between sarcopenic knee OA and falls

The observed statistically significant relationship between sarcopenic OA and recurrent falls in the preceding 12 months indicates that sarcopenic knee OA may contribute to the incidence of falls, or vice versa. This relationship was consistently observed in the sensitivity analysis that included only complete cases. Sarcopenic obesity is an important confounder and has been associated with a higher probability of falls[30]. However, the current study patients included few individuals with obesity and this study included BMI into the logistic regression model as a covariate, indicating that the observed relationship between sarcopenic knee OA and recurrent falls cannot be attributed to obesity.

It should be noted that this study included orthopedic clinic patients who had a history of pain in 1 or both knees, which is also an important confounder[32]. Including knee pain intensity into the logistic regression model showed similar results but slightly weakened the relationship between sarcopenic knee OA and recurrent falls, indicating that the observed relationship between sarcopenic knee OA and

recurrent falls may be partly attributed to severe knee pain in these patients. Chronic pain may interfere with the necessary cognitive activity to prevent a fall[33]. Successful avoidance or interruption of falls typically requires a cognitively mediated physical maneuver, such as a quick reaction during ambulation. The ability of patients with knee OA to avoid obstacles is impaired[34], and pain relief partially restores this ability[35]. Impaired response to physical hazards when attention is directed elsewhere can result in recurrent falls. Further studies that address these hypotheses would be desirable.

Study significance and clinical impact

Little work has been done on sarcopenic knee OA, although sarcopenic OA is potentially a higher frailty phenotype than sarcopenic and knee OA alone. This study found that the recurrent fall rate in patients with sarcopenic knee OA was > 2 times that of sarcopenia alone. A previous meta-analysis revealed sarcopenia as a risk factor for falls[2]. The current study expands on the previous knowledge by showing that patients with sarcopenic knee OA have a higher risk of recurrent falls. A thorough investigation of the sarcopenia-knee OA interaction may provide novel insights into the pathomechanics of falls in community-dwelling older adults.

The practical relevance of the observed relationship between sarcopenic knee OA and recurrent falls is a function of treatment objectives. It is noteworthy that both sarcopenia and knee OA can be managed non-surgically (e.g., exercise intervention)[36, 37]. When treating knee OA, evaluating the patient for sarcopenia would be important because the relationship between knee OA and falls may be moderated by sarcopenia. Conversely, when treating sarcopenia, evaluating the patient for knee OA, including pain severity, would be important.

Despite the interest in the topic, limited studies have investigated the clinical manifestations of patients with sarcopenic knee OA. Chung et al. revealed that patients with sarcopenic knee OA showed increased risks of metabolic syndrome and insulin resistance[11]. However, frailty in sarcopenic knee OA has not been previously addressed. This study could prompt future studies on how to effectively manage this common and potentially debilitating condition.

Study limitations and strengths

This study has some limitations. First, the cross-sectional design limits our ability to identify causality between sarcopenic knee OA and falls. Sarcopenic knee OA may be a consequence of previous falls, and our findings do not necessarily highlight interventions for patients with sarcopenic knee OA for preventing recurrent falls. Second, the lack of information on the pain profile in other joints and pain medication limited our analysis. Concurrent musculoskeletal pain in other joints may also contribute to falls[38]. Third, this study did not consider the sarcopenia stage in statistical analysis and most patients had severe sarcopenia, which may influence the generalizability of our results. Fourth, this study did not clarify the cause of falls; thus, the mechanism behind the higher prevalence of recurrent falls in patients with sarcopenic knee OA is still unclear. Finally, as this study was a secondary analysis of a previous

cross-sectional study, our findings are hypothesis-generating and should be validated in future clinical trials with large sample sizes.

This study has several strengths, as follows: (1) patients were recruited from a community orthopedic clinic and had the ability to walk independently without any ambulatory assistive device (i.e., a suitable population for a study on fall prevention); (2) multiple imputations were performed to consider missing data, and the robustness of the results was tested using sensitivity analysis; and (3) experienced physical therapists evaluated all outcomes to ensure validated and reliable measurements.

Conclusions

Patients with sarcopenic OA have an increased likelihood of experiencing recurrent falls in the preceding 12 months. A thorough investigation of sarcopenia-OA interaction may provide novel insights into the pathomechanics of recurrent falls in older adults.

List Of Abbreviations

JKOM

Japanese Knee Osteoarthritis Measure, JSN:Joint space narrowing, OA:Osteoarthritis, SMI:Skeletal muscle mass index

Declarations

Ethics approval and consent to participate

The research protocol was approved by the ethics committees in Kyoto University Graduate School and Faculty of Medicine, and written informed consent was obtained from all patients before their enrollment.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts.

Funding

This study was supported, in part, by a JSPS KAKENHI (Grant-in-Aid for Early-Career Scientists; grant no. 18045240) from the Japan Society for the Promotion of Science (<https://www.jsps.go.jp/>). The sponsor had no role in the design, methods, subject recruitment, data collections, analysis, and preparation of paper.

Authors' contributions

All authors made substantial contributions in the following areas: (1) conception and design of the study, acquisition of data, or analysis and interpretation of data; (2) drafting of the article or revising it critically for important intellectual content; and (3) final approval of the article version to be submitted.

The specific contributions of the authors are as follows:

- (1) Conception and design of the study: HI.
- (2) Analysis and interpretation of data: HI and TA.
- (3) Drafting of the article: HI.
- (4) Critical revision of the article for important intellectual content: HI and TA.
- (5) Final approval of the article: HI and TA.
- (6) Statistical expertise: HI.
- (7) Obtaining of funding: HI and TA.
- (8) Collection and assembly of data: HI and TA.

Acknowledgements

The authors would like to express their gratitude to the members of the Aoyama Laboratory (Kyoto University, Kyoto, Japan) and Nozomi Orthopedic Clinic (Hiroshima, Japan) for their assistance with data collection and to Editage (www.editage.jp) for English-language editing.

References

1. Rosenberg IHJTAjocn. Summary comments. 1989;50(5):1231-3.
2. Zhang X, Huang P, Dou Q, Wang C, Zhang W, Yang Y, et al. Falls among older adults with sarcopenia dwelling in nursing home or community: A meta-analysis. Clin Nutr. 2019 Jan 8.
3. Bergen G. Falls and fall injuries among adults aged ≥ 65 years—United States, 2014. MMWR Morbidity and mortality weekly report. 2016;65.
4. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. Age and ageing. 2008

Jan;37(1):19-24.

5. Rubenstein LZ, Josephson KR. Falls and their prevention in elderly people: what does the evidence show? *The Medical clinics of North America*. 2006 Sep;90(5):807-24.
6. Paddon-Jones D, Sheffield-Moore M, Cree MG, Hewlings SJ, Aarsland A, Wolfe RR, et al. Atrophy and impaired muscle protein synthesis during prolonged inactivity and stress. *The Journal of clinical endocrinology and metabolism*. 2006 Dec;91(12):4836-41.
7. Khalaj N, Abu Osman NA, Mokhtar AH, Mehdikhani M, Wan Abas WA. Balance and risk of fall in individuals with bilateral mild and moderate knee osteoarthritis. *PloS one*. 2014;9(3):e92270.
8. Smith TO, Higson E, Pearson M, Mansfield M. Is there an increased risk of falls and fractures in people with early diagnosed hip and knee osteoarthritis? Data from the Osteoarthritis Initiative. *Int J Rheum Dis*. 2018 Jun;21(6):1193-201.
9. Tsonga T, Michalopoulou M, Malliou P, Godolias G, Kapetanakis S, Gkasdaris G, et al. Analyzing the History of Falls in Patients with Severe Knee Osteoarthritis. *Clin Orthop Surg*. 2015 Dec;7(4):449-56.
10. Kemmler W, Teschler M, Goisser S, Bebenek M, von Stengel S, Bollheimer LC, et al. Prevalence of sarcopenia in Germany and the corresponding effect of osteoarthritis in females 70 years and older living in the community: results of the FORMoSA study. *Clin Interv Aging*. 2015;10:1565-73.
11. Chung SM, Hyun MH, Lee E, Seo HS. Novel effects of sarcopenic osteoarthritis on metabolic syndrome, insulin resistance, osteoporosis, and bone fracture: the national survey. *Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA*. 2016 Aug;27(8):2447-57.
12. Iijima H, Fukutani N, Aoyama T, Fukumoto T, Uritani D, Kaneda E, et al. Clinical Phenotype Classifications Based on Static Varus Alignment and Varus Thrust in Japanese Patients With Medial Knee Osteoarthritis. *Arthritis Rheumatol*. 2015 Sep;67(9):2354-62.
13. Muraki S, Akune T, Oka H, En-Yo Y, Yoshida M, Saika A, et al. Impact of knee and low back pain on health-related quality of life in Japanese women: the Research on Osteoarthritis Against Disability (ROAD). *Mod Rheumatol*. 2010 Oct;20(5):444-51.
14. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. *Osteoarthritis Cartilage*. 2007;15 Suppl A:A1-56.
15. Van Ginckel A, Bennell KL, Campbell PK, Wrigley TV, Hunter DJ, Hinman RS. Location of knee pain in medial knee osteoarthritis: patterns and associations with self-reported clinical symptoms. *Osteoarthritis Cartilage*. 2016 Jul;24(7):1135-42.
16. Wise BL, Kritikos L, Lynch JA, Liu F, Parimi N, Tileston KL, et al. Proximal femur shape differs between subjects with lateral and medial knee osteoarthritis and controls: the Osteoarthritis Initiative. *Osteoarthritis Cartilage*. 2014 Dec;22(12):2067-73.
17. Gibson AL, Holmes JC, Desautels RL, Edmonds LB, Nuudi L. Ability of new octapolar bioimpedance spectroscopy analyzers to predict 4-component-model percentage body fat in Hispanic, black, and white adults. *Am J Clin Nutr*. 2008 Feb;87(2):332-8.

18. Janssen I, Baumgartner RN, Ross R, Rosenberg IH, Roubenoff R. Skeletal muscle cutpoints associated with elevated physical disability risk in older men and women. *Am J Epidemiol*. 2004 Feb 15;159(4):413-21.
19. Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing*. 2011 Jul;40(4):423-9.
20. Fritz S, Lusardi M. White paper: "walking speed: the sixth vital sign". *J Geriatr Phys Ther*. 2009;32(2):46-9.
21. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthritis. *Ann Rheum Dis*. 1957 Dec;16(4):494-502.
22. Iijima H, Suzuki Y, Aoyama T, Takahashi M. Interaction between low back pain and knee pain contributes to disability level in individuals with knee osteoarthritis: a cross-sectional study. *Osteoarthritis and cartilage*. 2018 Jul 9.
23. Akai M, Doi T, Fujino K, Iwaya T, Kurosawa H, Nasu T. An outcome measure for Japanese people with knee osteoarthritis. *J Rheumatol*. 2005 Aug;32(8):1524-32.
24. Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al. Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc*. 2014 Feb;15(2):95-101.
25. Vickers AJ. How to randomize. *Journal of the Society for Integrative Oncology*. 2006 Fall;4(4):194-8.
26. Nevitt MC, Cummings SR, Kidd S, Black D. Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA*. 1989 May 12;261(18):2663-8.
27. Kiel DP, O'Sullivan P, Teno JM, Mor V. Health care utilization and functional status in the aged following a fall. *Med Care*. 1991 Mar;29(3):221-8.
28. Wolinsky FD, Johnson RJ, Fitzgerald JF. Falling, health status, and the use of health services by older adults. A prospective study. *Med Care*. 1992 Jul;30(7):587-97.
29. Tinetti ME, Williams CS. The effect of falls and fall injuries on functioning in community-dwelling older persons. *J Gerontol A Biol Sci Med Sci*. 1998 Mar;53(2):M112-9.
30. Scott D, Seibel M, Cumming R, Naganathan V, Blyth F, Le Couteur DG, 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. *Journal of bone and mineral research : the official journal of the American Society for Bone and Mineral Research*. 2017 Mar;32(3):575-83.
31. Newman AB, Kupelian V, Visser M, Simonsick EM, Goodpaster BH, Kritchevsky SB, et al. Strength, but not muscle mass, is associated with mortality in the health, aging and body composition study cohort. *J Gerontol A Biol Sci Med Sci*. 2006 Jan;61(1):72-7.
32. Foley SJ, Lord SR, Srikanth V, Cooley H, Jones G. Falls risk is associated with pain and dysfunction but not radiographic osteoarthritis in older adults: Tasmanian Older Adult Cohort study. *Osteoarthritis Cartilage*. 2006 Jun;14(6):533-9.

33. Berryman C, Stanton TR, Bowering KJ, Tabor A, McFarlane A, Moseley GL. Do people with chronic pain have impaired executive function? A meta-analytical review. *Clin Psychol Rev.* 2014 Nov;34(7):563-79.
34. Pandya NK, Draganich LF, Mauer A, Piotrowski GA, Pottenger L. Osteoarthritis of the knees increases the propensity to trip on an obstacle. *Clinical orthopaedics and related research.* 2005 Feb(431):150-6.
35. Pandya NK, Piotrowski GA, Pottenger L, Draganich LF. Pain relief in knee osteoarthritis reduces the propensity to trip on an obstacle. *Gait & posture.* 2007 Jan;25(1):106-11.
36. Vlietstra L, Hendrickx W, Waters DL. Exercise interventions in healthy older adults with sarcopenia: A systematic review and meta-analysis. *Australas J Ageing.* 2018 Sep;37(3):169-83.
37. Bricca A, Juhl CB, Steultjens M, Wirth W, Roos EM. Impact of exercise on articular cartilage in people at risk of, or with established, knee osteoarthritis: a systematic review of randomised controlled trials. *Br J Sports Med.* 2019 Aug;53(15):940-7.
38. Welsh VK, Clarson LE, Mallen CD, McBeth J. Multisite pain and self-reported falls in older people: systematic review and meta-analysis. *Arthritis research & therapy.* 2019 Feb 22;21(1):67.

Figures

Figure 1

Diagnostic algorithms for sarcopenia and sarcopenic OA Sarcopenic OA was diagnosed as the coexistence of sarcopenia and radiographic knee OA (Kellgren and Lawrence grade ≥ 2). In the diagnosis of sarcopenia, we used the Asian Working Group criteria[24]. Specifically, sarcopenia was diagnosed if a patient had both low muscle function (slow walking speed [0.8 m/s] or low grip strength [< 26 kg and < 18 kg for men and women, respectively]) and low SMI (< 7.0 kg/m² and < 5.7 kg/m² for men and women, respectively). GS, grip strength; OA, osteoarthritis; SMI, skeletal muscle mass index; WS, walking speed; yrs, years.

Figure 2

Graphical abstract Of 298 patients, 27 (9.1%) had coexisting sarcopenia and knee osteoarthritis (OA), defined as sarcopenic knee OA. Patients with sarcopenic knee OA demonstrated significantly higher prevalence of recurrent falls in the preceding 12 months (odds ratio: 4.70; 95% confidence interval: 1.08, 20.5) after adjustment for age, sex, and body mass index.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementalAppendixS1STROBE.pdf](#)
- [SupplementalAppendixS2Sensitivityanalysis.docx](#)