Psoas Muscle Morphology as a Sarcopenia Marker to Predict Outcomes of Geriatric Trauma Patients: A Systematic Review and Meta-analysis

Yang Wang, MD[1], Lei Li, MD[1], Qinmei Pan, MD[1], Ying Zhong, MD[1], and Xinmei Zou, MD[1] [iD]

Abstract

Objective: To provide pooled evidence on the association between central sarcopenia and risk of mortality and/or complications among geriatric patients with moderate to severe trauma. **Methods:** We conducted a systematic search in PubMed, EMBASE, and Scopus databases for relevant observational studies documenting the association of central sarcopenia with the risk of mortality and/or complications in geriatric patients with moderate to severe trauma. The studies reported computerized tomography (CT) based assessments of the psoas muscle cross-sectional area. We used a random effects model for the analysis and reported effect sizes as pooled odds ratios (ORs) or hazards ratios (HRs) along with 95% confidence intervals. **Results:** We analyzed data from 13 studies and found an association between the presence of psoas muscle size reduction and the risk of in-hospital mortality (OR, 1.47; 95% CI, 1.13, 1.90). In addition, we found increased risk of mortality within 24 months of follow-up in patients with sarcopenia (HR, 2.40; 95% CI, 1.11-5.17). We found each unit increase in psoas muscle cross-sectional area to be significantly associated with reduced risk of mortality within 24 months of follow-up (HR, .92; 95% CI, .90-.95). Patients with sarcopenia also had an increased risk of complications (OR, 1.69; 95% CI, 1.08-2.63). **Conclusion:** Central sarcopenia, assessed using psoas muscle morphology, among geriatric patients with moderate to severe trauma appears to be significantly associated with increased risks of mortality and complications.

Introduction

Improvements in medical care and living environments have enhanced human longevity[1] and resulted in an increased elderly population global burden due to the negative effects of ageing on physical and mental health.[1,2] Individuals of Europe, USA and Asia older than 70 have become the fastest growing population in those areas.[3] According to estimates, around 20% of the global population will be comprised of adults aged 60 years and above by the year 2050.[4]

There is also an increase in the number of elderly patients presenting to trauma centers,[5-8] and the Global

[1]Respiratory Digestive Geriatrics, Huzhou Third People's Hospital, Huzhou, China

Corresponding Author:
Xinmei Zou, Respiratory Digestive Geriatrics, Huzhou Third People's Hospital, Ward 13 Huzhou Thrid Municipal Hospital 2088 Tiaoxi East Road WuXing District, Huzhou 313000, China.
Email: zouxinmei1215@163.com

Burden of Disease study (2019) found that death rates fell considerably among older adults between 1990 and 2019.[3] Interestingly, during the same period, the mortality rates due to falls increased.[3] Traumatic injury events in elderly individuals are associated with increased risk of complications and mortality.[8,9] Studies on elderly populations have shed light into the concept of frailty as a potential driver of adverse outcomes in individuals with underlying diseases such as kidney disease, malignancy, and cardiovascular disease.[10-13] Frailty is diagnosed in individuals with difficulties executing activities of daily living, reduced ambulation, unexplained weight loss, and presence of weakness, as indicated by diminished grip strength and a general feeling of exhaustion.[14] An assessment of frailty based on these parameters is often challenging in trauma patients, and, the association of sarcopenia with outcomes in such patients has been difficult to study. Attempts at identifying a reliable proxy for frailty without the need for active participation of the patient and useful in trauma patients (ie, central sarcopenia detection using radiography) have been made.

Central sarcopenia, as determined by psoas muscle morphology, has been associated with poor disease outcomes.[15-18] Sarcopenia in the psoas muscle is typically measured through imaging modalities such as CT or MRI at the L3-L4 vertebral level.[19] The assessment involves determining the cross-sectional area or volume of the muscle. To classify individuals as having sarcopenia, age-specific cut-off values are employed, often based on percentile comparisons with reference populations. Sarcopenia in the psoas muscle can also be assessed by normalizing the cross-sectional area (CSA) for height. By dividing the psoas muscle CSA by a person's height, researchers can obtain a more standardized measure that accounts for individual variations in body size. However, it's crucial to note that exact methodologies and cut-off values may vary across studies, and adherence to standardized protocols is essential for accurate and meaningful comparisons of sarcopenia prevalence and severity in this muscle group.

Studies have attempted to document the association between central sarcopenia and trauma patient outcomes among the elderly, but their findings have not been systematically synthesized to derive meaningful lessons for clinical practice. Thus, we designed a meta-analysis to include findings from all relevant studies and assess whether sarcopenia measured by psoas muscle morphology is significantly associated with adverse outcomes in geriatric trauma patients.

Methods

Selection of Studies

We conducted a systematic review in PubMed, EMBASE and Scopus databases to identify relevant studies published in English until the 15th of March 2023. Online Supplementary Table 1 presents our search strategy in each of these databases. We registered our protocol at PROSPERO (registration number CRD42023411973) and followed the standard PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to conduct this review.[20]

Selection of Studies and Data Extraction

We included studies that used psoas muscle morphology as a marker for sarcopenia assessment. The studies should have utilized standardized protocols or validated methods for sarcopenia assessment. Studies using imaging modalities (e.g., computed tomography (CT), magnetic resonance imaging (MRI), ultrasound) to assess psoas muscle cross-sectional area, volume, or density were eligible to be included. We were interested in studies documenting the association of sarcopenia with risk of mortality and/or complications in geriatric patients with moderate to severe trauma. We did not select studies that specifically focused on hip trauma/fractures because a systematic review on this issue has recently been published.[21] However, to the best of our knowledge, the evidence in elderly patients with general trauma and more than one organ system affected have not been synthetized. Observational cohort, case-control or cross-sectional studies were eligible for inclusion. We did not exclude any studies on the basis of their criteria for reporting sarcopenia.

After obtaining the search results from all databases, we removed the duplicates. Two study authors independently screened the titles and abstracts of the remaining unique studies. After screening the titles and abstracts, we retrieved full texts and reviewed them independently to obtain the final set of selected studies and extract their data using a pre-tested sheet. All disagreements or discrepancies related to any of the steps mentioned above were resolved by discussions between two authors and/or a third senior author.

Statistical Analysis and Quality Assessment

We conducted all analyses using STATA 16 software (TX, USA). We expressed pooled effect sizes as odds ratios (ORs) or hazards ratio (HRs) along with 95% confidence intervals. We decided a priori to use a random effects model for the analysis as the included studies differed in characteristics such as the mean age and genders of participants, the study settings, and the methods for assessing and defining sarcopenia. We anticipated that these differences might lead to substantial heterogeneity in the reported findings. To assess publication biases, we used Egger's test, and we visually inspected funnel plot

symmetries.[22] Finally, we used the Newcastle-Ottawa scale to assess the risk of bias.[23]

Results

We retrieved 1104 studies through the search strategy from the three databases. We removed 217 duplicates and screened the titles and abstracts of 887 studies for relevance. This step led to further exclusion of 834 studies. We reviewed the full text of the remaining 53 studies and excluded another 40 (Figure 1) to include a total of 13 studies in our analysis.[24-36]

Table 1 presents the specific details of the studies included. All the studies, except one, had a retrospective design. Most studies were conducted in the USA (n = 9) and one each in Australia, Japan, United Kingdom, and Austria. The included studies used different cut-offs for defining sarcopenia (Table 1). The Online Supplementary Table 2 presents the quality assessment of the studies, using the Newcastle Ottawa Scale, with scores between 7 to 9 (out of the maximum attainable score of 9), thereby indicating that they were of acceptable quality.

Mortality Outcome

We found that trauma patients with sarcopenia had an increased risk of in-hospital mortality (OR, 1.47; 95% CI, 1.13, 1.90; n = 7; I^2 = 20.3%) (Figure 2). There was no evidence of publication bias, either on visual inspection of the funnel plot or on Egger's test results ($P > .05$) (Online Supplementary Figure 1). In addition, we examined the association between unit increase in lean psoas muscle cross-sectional area and risk of in-hospital mortality, but we found no statistically significant association (OR, .92; 95% CI, .78, 1.09; n = 2; I^2 = 94.0%) (Online Supplementary Figure 2).

We also found an increased risk of mortality within 24 months of follow-up after hospital discharge in elderly patients who had sarcopenia using a pooled analysis (HR, 2.40; 95% CI, 1.11, 5.17; n = 5; I^2 = 74.6%) (Figure 3). We did not note any evidence of publication bias (Egger's P value >.05) (Online Supplementary Figure 3). We found that each unit increase in psoas muscle cross-sectional area was significantly associated with a reduced risk of mortality within 24 months of follow-up after hospital
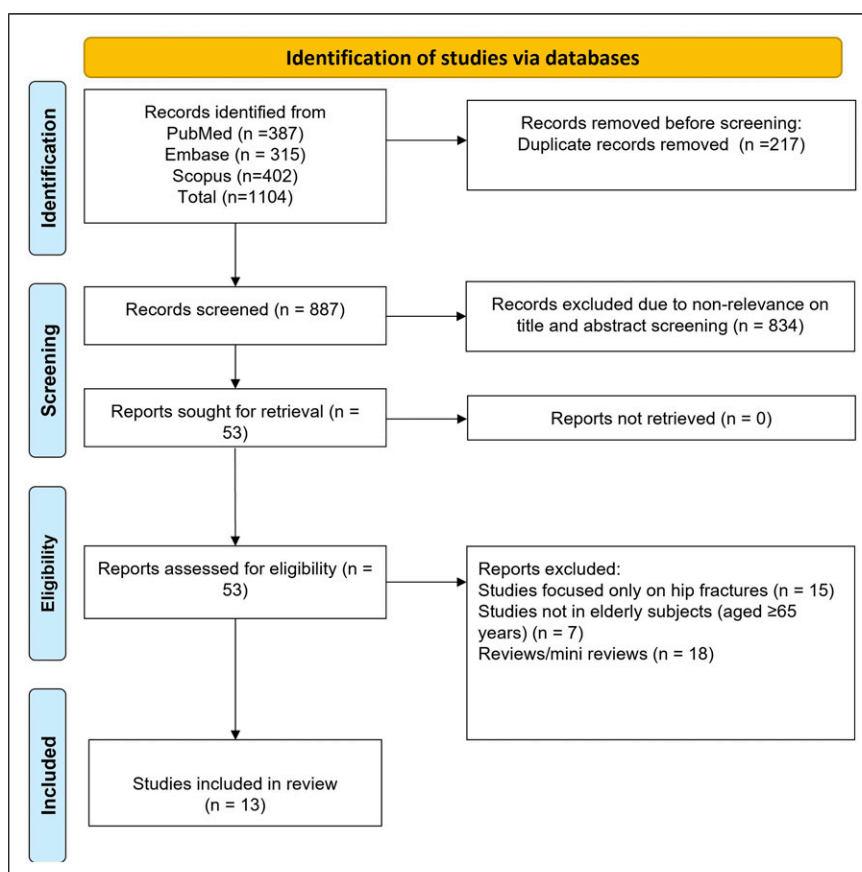

Figure 1. Selection process of studies included in the review.

Table I. Summary of the Studies Included in the Meta-Analysis.

Author (year of publication)	Study design	Country	Participant characteristics	Sample size	Operational definition and method of assessment	Key outcomes
Ebbeling (2014) (24)	Retrospective	USA	Subjects with median age of 74 years; males (58%); with severe injury (Injury severity score, ISS >15), intensive care unit stay >48 hours	180	High psoas lumbar vertebral index (PLVI): >.84 Low PLVI: ≤.83 (sarcopenia) CT- based; L4 vertebral level Calculated as a ratio between the mean cross-sectional areas of the psoas muscles and the L4 vertebral body at the level of the L4 pedicles	Reference: high PLVI Mortality (in-hospital): OR 1.20 (95% CI: .44, 3.26) Morbidity/complications (in-hospital)*: OR 4.91 (95% CI: 2.28, 10.6) *Includes respiratory and infectious complications, thromboembolism, haemorrhage and organ failure
Couch (2018) (25)	Retrospective	Australia	Mean age of around 77 years; males (55%); with moderate to severe injury (ISS >12)	225	Lean psoas area (LPA) measured as a cross-sectional area of the psoas muscle at the inferior endplate of L4 CT-based assessment	Δ LPA (in-hospital mortality): OR 1.0 (95% CI: .998, 1.002) Δ LPA (in-hospital morbidity/complications): OR 1.0 (95% CI: .998, 1.002)
Touban (2019) (26)	Retrospective	USA	Subjects with mean age of 77 years; females (54%); with long bone fractures (extremity and/or pelvis)	558	Lean psoas muscle area measured using CT at L3-L4 disk space	Δ LPA (mortality at 1 year): HR .93 (95% CI: .90, .96)
Mccusker (2019) (27)	Retrospective	USA	Subjects with mean age of 76 years; males (64%); subjects admitted to level-1 trauma center	325	Total psoas area (TPA) measured on both sides and subsequently averaged. The average TPA adjusted for height to calculate the total psoas index (TPI) Sarcopenia defined as the lowest quartile of TPI (males: <3.51 cm^2/m^2; females: <2.42 cm^2/m^2)	Reference: no sarcopenia Mortality (in-hospital): OR 1.21 (95% CI: .91, 1.50) Complications (in-hospital): OR 1.12 (95% CI: .87, 1.35)
Malekpour (2017) (28)	Retrospective	USA	Subjects with mean age of 75 years; females (49%); with blunt trauma	1175	Total psoas area (TPA) normalized for height (TPI); Sarcopenia defined as the lowest quartile of TPI (males: <242.6 mm^2/m^2; females: <187.8 mm^2/m^2)	Reference: no sarcopenia Mortality (in-hospital): OR 1.61 (95% CI: 1.01, 2.56) Complications (in-hospital): OR 1.31 (95% CI: .91, 1.91)
Leeper (2016) (29)	Retrospective	USA	Subjects aged ≥65 years; females (58%); subjects had injury due to fall	445	Total psoas area (TPA) normalized for height (TPI); Sarcopenia defined as the lowest quartile of TPI (TPI <524 mm^2/m^2 in males and <385 mm^2/m^2 in females)	Mortality (at 6 months follow up): HR 4.77 (95% CI: 2.71, 8.40)

(continued)

Table 1. (continued)

Author (year of publication)	Study design	Country	Participant characteristics	Sample size	Operational definition and method of assessment	Key outcomes
Nishimura (2020) (30)	Retrospective	Japan	Subjects aged ≥65 years; mean age of around 75 years; males (66%); with severe injury (ISS >15)	405	Psoas muscle index (PMI), defined as the psoas muscle area at the third lumbar vertebra level divided by the body surface area. Sarcopenia defined as PMI <717.6 mm²/m² in males and <506 mm²/m² in females	Mortality (in-hospital): OR 2.20 (95% CI: 1.12, 4.32) Complications (in-hospital)*: OR 2.43 (95% CI: 1.47, 4.03) Mortality (at 12 months follow up): HR 1.28 (95% CI: .35, 4.71) *Included pneumonia, urinary tract infections, venous thromboembolism, pulmonary embolism
Varma (2022) (31)	Retrospective	United Kingdom	Subjects aged ≥65 years with trauma and undergoing abdominal CT; mean ISS of around 16; mean age of around 78 years; males (60%)	204	Psoas muscle cross sectional area (P-CSA) measured bilaterally at the level of L4. Ratio of the average P-CSA to the vertebral body cross-sectional area was used (PLVI). High PLVI: >.53 Low PLVI: ≤.53 (sarcopenia)	Mortality (in-hospital): OR 3.38 (95% CI: 1.47, 9.73) Complications (in-hospital)*: OR 1.08 (95% CI: .52, 2.21) Mortality (at 2 years follow up): HR 1.90 (95% CI: 1.11, 3.25) *Included respiratory failure, myocardial infarction or heart failure, venous thromboembolism, acute kidney injury and sepsis
Wallace (2017) (32)	Retrospective	USA	Subjects aged ≥65 years with blunt trauma; mean age of around 80 years; males (50%)	226	Psoas cross-sectional area (P-CSA) measured on abdominal CT; bilateral psoas area measured on CT at L4 level	Δ P-CSA (mortality at 24 months follow up): OR .68 (95% CI: .46, 1.00)
Proksch (2022) (33)	Prospective	USA	Subjects aged over 50 years; mean age of around 70 years; admitted to level 1 trauma care facility with mean ISS of around 17 and admitted in ICU for over 24 hours	76	Total psoas cross-sectional area normalized for height (TPI); measured on CT at L4 level; Sarcopenia defined as the TPI <373 mm²/m²	Mortality (in-hospital): OR 1.57 (95% CI: .42, 5.82) Mortality (at 6 months follow up): HR .76 (95% CI: .27, 2.12)
Farichild (2015) (34)	Retrospective	USA	Subjects with mean age of around 76 years; with blunt trauma and median ISS of 9.0; males (49%)	252	Psoas area measured bilaterally as a cross-sectional area of the psoas muscle; CT based; at L4-L5	Δ Psoas area (in-hospital mortality): OR .84 (95% CI: .77, .91)
Wollner (2023) (35)	Retrospective	Austria	Subjects with mean age of around 76 years; with ISS of over 16; with multiple injuries; males (63%)	158	Based on measurement of length of short and long axis of musculus psoas major bilaterally at L3	Mortality (1-month): OR 10.6 (95% CI: 2.40, 47.2) Δ psoas muscle area (mortality at 1 month): OR .92 (95% CI: .89, .96)
Hwang (2019) (36)	Retrospective	USA	Subjects with trauma and admitted to level-1 center; majority aged over 75 yrs (>50%); with moderate to severe injury	230	Total skeletal muscle (Psoas) cross-sectional area measured using CT at L3 level; subsequently normalized for height; Sarcopenia defined as skeletal muscle index <55.4 cm²/m² for males and <38.9 cm²/m² for females	Mortality (In-hospital): OR .98 (95% CI: .43, 2.27)

discharge (HR, .92; 95% CI, .90, .95; n = 3; I^2 = 23.0%) (Online Supplementary Figure 4).

Morbidities and Complications

Elderly patients with sarcopenia had a higher risk of complications than those without sarcopenia (OR, 1.69; 95% CI, 1.08, 2.63; n = 5; I^2 = 79.2%) (Figure 4). The reported complications were mainly respiratory-related (pneumonia, pulmonary embolism), thromboembolism, hemorrhage, sepsis, urinary tract infections, myocardial infarction, heart failure, and acute kidney injury (Table 1).
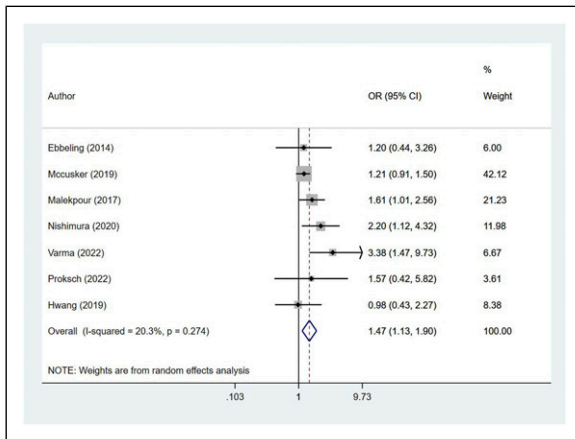

Figure 2. Risks of in-hospital mortality among elderly patients with trauma and associated sarcopenia and those without sarcopenia.

We found no evidence of publication bias, either upon visual inspection of the funnel plot or on Egger's test (P > .05) (Online Supplementary Figure 5).

Discussion

Our meta-analysis results indicate that central sarcopenia is associated with an increased risk of mortality, both short term (in-hospital) and long term (within 24 months of hospital discharge) in elderly patients with moderate to severe trauma. In addition, the risk of complications was also high in the elderly trauma patients with sarcopenia. Our findings suggest that sarcopenia, as assessed by a single radiological measurement, may be a reliable predictor of frailty and trauma outcomes in elderly patients and that it may be useful as a standalone measure to avoid using a plethora of biochemical and physical assessment variables. Our findings are similar to those in the review by Chiang et al, in which the authors showed that older adults with hip fracture and associated sarcopenia have a poorer postoperative functional recovery than those without sarcopenia.[21]

Dealing with patients trauma is challenging due in part to the substantial variation in the types, severity, extent, and distribution of their injuries, all of which can make decision-making and prognoses difficult. Assessing sarcopenia on the basis of psoas muscle area measurements in trauma patients has practical advantages. For example, radiological examinations, including CT scans that show psoas characteristics, are often needed during the initial evaluation,[37,38] and these objective assessments can be
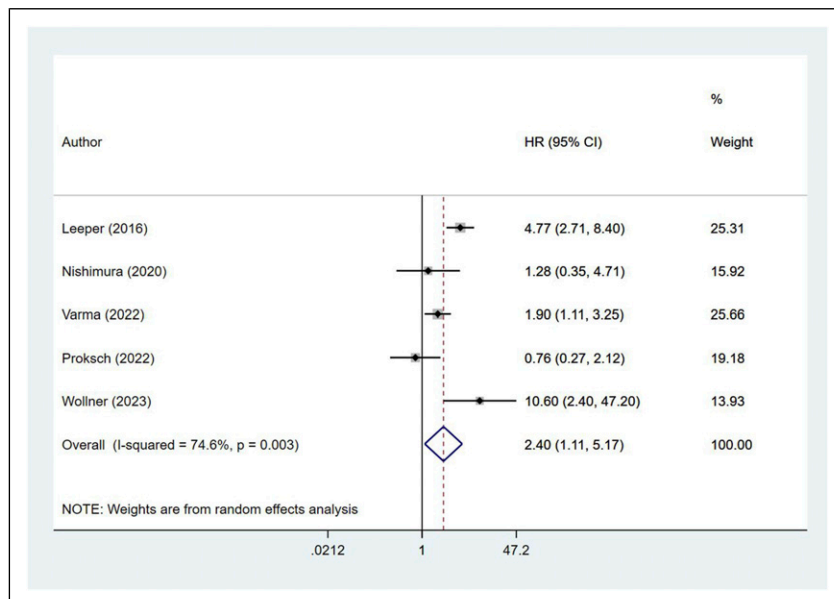

Figure 3. Risks of mortality within 24 months of follow-up after hospital discharge among elderly patients with sarcopenia and those without sarcopenia.
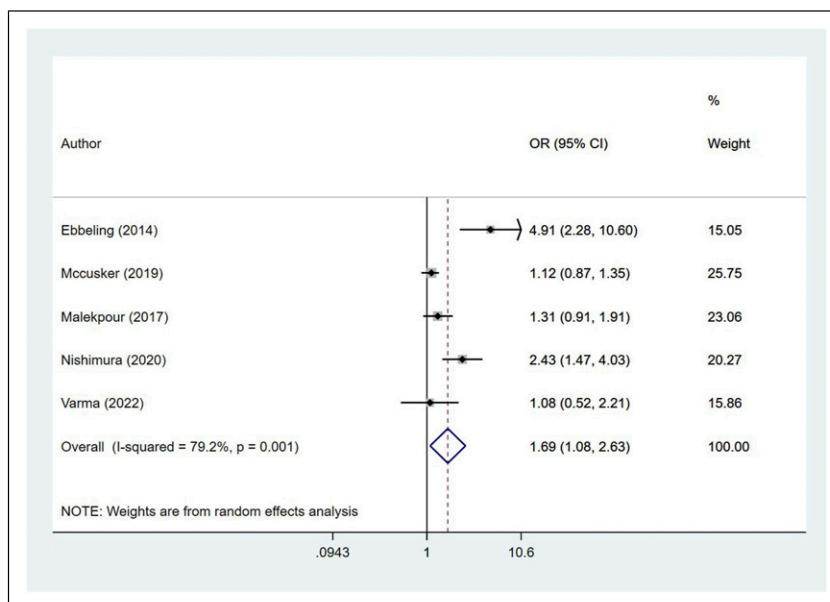
Figure 4. Risks of complications among elderly patients with trauma and associated sarcopenia and those without sarcopenia.

performed even in immobilized patients with trauma. Central sarcopenia has been used for predicting outcomes in several patient groups, and a reduced psoas muscle cross-sectional area has been associated with poor outcomes in patients with pancreatic and gastric cancer, pathological fractures, elective abdominal aneurysm repair, and hepatic transplantation.[39-43] We propose that combining an objective assessment of central sarcopenia with a clinical frailty score may result in an accurate multi-dimensional frailty assessment. This, may facilitate clinical decision-making and prognostication. Moreover, such an approach may aid in identification of patients that require multi-disciplinary interventions and those that require conservative monitoring, discharge planning, and continued follow-up.

We found that patients with sarcopenia, according to the radiological psoas size measurement, had increased risks of complications related to infections, sepsis, and thromboembolism compared to patients without sarcopenia. Previous evidence indicates that frailty is associated with abnormalities in both innate and adaptive immunity that affect immune responses[44-46] and may explain the patients' increased risk of infectious complications. In addition, elderly individuals with sarcopenia and frailty may not recover their mobility early and may need prolonged use of indwelling urinary catheters, leading to increased risks of kidney infections. Delayed mobilization may also be a predisposing factor for thromboembolism.[47]

The studies considered in this review did not include subjects with congenital/developmental neuro muscular disorders or systemic muscle wasting diseases in whom pre-existing sarcopenia may be expected. However, it is important to note that adjusting for expected pre-existing sarcopenia requires careful consideration. Since sarcopenia may already be present due to the underlying condition, it's essential to differentiate between disease-related muscle wasting and age-related sarcopenia. One of the ways to do so is to utilize age-specific reference standards for muscle measurements. This allows us to compare the subjects muscle characteristics with what would be expected for individuals of the same age, helping to separate disease-related changes from normal age-related changes. Another way could be to assess muscle quality, such as muscle density or fat infiltration, through imaging techniques like CT or MRI. This is because muscle quality can differ between disease-related and age-related muscle changes.

We are aware of the limitations of our meta-analysis. First, most analyzed studies were retrospective in design and unadjusted confounders may have had an impact on our results. Second, we found considerable heterogeneity (>50%) for the outcomes in the studies included; possibly be due to methodological differences among them (different cut-offs for sarcopenia definition, and different treatments and assessment time points for outcomes). Therefore, these differences need to be considered before generalizing our findings in other contexts. Third, we used "overall complications" as an outcome and did not focus on individual complication risks. While this approach may be questioned, we think presenting data on complications as an aggregate is appropriate as it reflects the overall patient condition and host response to trauma. Fourth, all the studies included were conducted in high income settings, particularly in the USA. This limits the external

generalizability of the findings, which may not be applicable to low- and middle-income settings. Fifth, the sarcopenia diagnoses in the studies were based on the psoas muscle cross-sectional area assessed bilaterally and, in some studies, this measurement was normalized for height. However, most studies failed to consider the quality of the psoas muscle. Muscle quality is an important index of functionality that has a role in contributing to an individual's fitness. It's also important to note that muscle mass and muscle strength are positively correlated, but they are not one and the same. Generally, individuals with larger muscle mass tend to have greater muscle strength. However, the relationship between muscle mass and muscle strength can be influenced by various factors. These factors include neural adaptations, muscle fiber type, neuromuscular coordination, and muscle quality (which includes factors like fat infiltration and fibrosis within the muscle). Finally, only some included studies were adjusted for comorbidities while exploring the association between sarcopenia and outcomes in the elderly trauma patients. The presence of comorbidities in this high-risk age group may have influenced the observed association.

Conclusion

On the basis of our findings, central sarcopenia is associated with increased risks of mortality and complications in elderly patients with moderate to severe trauma. Individuals with sarcopenia, according to CT-based assessments, should be kept under careful supervision and follow-up. Heterogeneity in the cut-offs used to define sarcopenia may reduce the validity of our findings; however, this highlights the need for global scale standard cut-offs. Future prospectively conducted studies should conclusively establish any causal associations between the presence of comorbidities, sarcopenia, and adverse trauma outcomes in elderly patients.

Declaration of Conflicting Interests

Funding

ORCID iD

Xinmei Zou https://orcid.org/0009-0001-9834-4842

Supplemental Material

Supplemental material for this article is available online.

References

1. Brown GC. Living too long: the current focus of medical research on increasing the quantity, rather than the quality, of life is damaging our health and harming the economy. *EMBO Rep*. 2015;16(2):137-141. doi:10.15252/embr.201439518

2. Chang AY, Skirbekk VF, Tyrovolas S, Kassebaum NJ, Dieleman JL. Measuring population ageing: an analysis of the global burden of disease study 2017. *Lancet Public Health*. 2019;4(3):e159-e167. doi:10.1016/S2468-2667(19)30019-2

3. Collaborators 2019 GA. Global, regional, and national burden of diseases and injuries for adults 70 years and older: systematic analysis for the Global Burden of Disease 2019 Study. *BMJ*. 2022;376:e068208. doi:10.1136/bmj-2021-068208

4. Leeson GW. The growth, ageing and urbanisation of our world. *Population Ageing*. 2018;11(2):107-115. doi:10.1007/s12062-018-9225-7

5. Benhamed A, Batomen B, Boucher V, et al. Epidemiology, injury pattern and outcome of older trauma patients: a 15-year study of level-I trauma centers. *PLoS One*. 2023;18(1):e0280345. doi:10.1371/journal.pone.0280345

6. Dinh MM, Roncal S, Byrne CM, Petchell J. Growing trend in older patients with severe injuries: mortality and mechanisms of injury between 1991 and 2010 at an inner city major trauma centre. *ANZ J Surg*. 2013;83(1-2):65-69. doi:10.1111/j.1445-2197.2012.06180.x

7. Kehoe A, Smith JE, Edwards A, Yates D, Lecky F. The changing face of major trauma in the UK. *Emerg Med J*. 2015;32(12):911-915. doi:10.1136/emermed-2015-205265

8. Vanzant EL, Hilton RE, Lopez CM, et al. Advanced age is associated with worsened outcomes and a unique genomic response in severely injured patients with hemorrhagic shock. *Crit Care*. 2015;19(1):77. doi:10.1186/s13054-015-0788-x

9. Wongweerakit O, Akaraborworn O, Sangthong B, Thongkhao K. Age as the impact on mortality rate in trauma patients. *Crit Care Res Pract*. 2022;2022:2860888. doi:10.1155/2022/2860888

10. Liu X, Dai G, He Q, Ma H, Hu H. Frailty index and cardiovascular disease among middle-aged and older Chinese adults: a nationally representative cross-sectional and follow-up study. *J Cardiovasc Dev Dis*. 2022;9(7):228. doi:10.3390/jcdd9070228

11. Chowdhury R, Peel NM, Krosch M, Hubbard RE. Frailty and chronic kidney disease: a systematic review. *Arch Gerontol Geriatr*. 2017;68:135-142. doi:10.1016/j.archger.2016.10.007

12. Tsai HH, Yu JC, Hsu HM, et al. The impact of frailty on breast cancer outcomes: evidence from analysis of the Nationwide Inpatient Sample, 2005-2018. *Am J Cancer Res*. 2022;12(12):5589-5598.

13. Handforth C, Clegg A, Young C, et al. The prevalence and outcomes of frailty in older cancer patients: a systematic review. *Ann Oncol*. 2015;26(6):1091-1101. doi:10.1093/annonc/mdu540

14. Xue QL. The frailty syndrome: definition and natural history. *Clin Geriatr Med*. 2011;27(1):1-15. doi:10.1016/j.cger.2010.08.009

15. Balsam LB. Psoas muscle area: a new standard for frailty assessment in cardiac surgery? *J Thorac Dis*. 2018;10(Suppl 33):S3846-S3849. doi:10.21037/jtd.2018.10.96

16. Kim DU, Park HK, Lee GH, et al. Central sarcopenia, frailty and comorbidity as predictor of surgical outcome in elderly patients with degenerative spine disease. *J Korean Neurosurg Soc*. 2021;64(6):995-1003. doi:10.3340/jkns.2021.0074

17. Yajima T, Arao M, Yajima K. Psoas muscle index and psoas muscle density as predictors of mortality in patients undergoing hemodialysis. *Sci Rep*. 2022;12(1):10496. doi:10.1038/s41598-022-14927-y

18. Wu XL, Shen J, Danzeng CD, Xu XS, Cao ZX, Jiang W. CT psoas calculations on the prognosis prediction of emergency laparotomy: a single-center, retrospective cohort study in eastern Asian population. *World J Emerg Surg*. 2022;17(1):31. doi:10.1186/s13017-022-00435-x

19. Tagliafico AS, Bignotti B, Torri L, Rossi F. Sarcopenia: how to measure, when and why. *Radiol Med*. 2022;127(3):228-237. doi:10.1007/s11547-022-01450-3

20. PRISMA. Transparent reporting of systematic reviews and meta-analyses. https://www.prisma-statement.org/

21. Chiang MH, Kuo YJ, Chen YP. The association between sarcopenia and postoperative outcomes among older adults with hip fracture: a systematic review. *J Appl Gerontol*. 2021;40(12):1903-1913. doi:10.1177/07334648211006519

22. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315(7109):629-634. doi:10.1136/bmj.315.7109.629

23. Well G, Shea B, O'Connell D, et al. *The Newcastle-Ottawa (NOS) for Assessing the Quality of Nonrandomized Studies in Meta-Analysis*. Ottawa Hospital Research Institute. https://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed January 5, 2023.

24. Ebbeling L, Grabo DJ, Shashaty M, et al. Psoas:lumbar vertebra index: central sarcopenia independently predicts morbidity in elderly trauma patients. *Eur J Trauma Emerg Surg*. 2014;40(1):57-65. doi:10.1007/s00068-013-0313-3

25. Couch AP, Ho K, Darwood R, Hsu JM. Lean psoas area does not correlate with clinical outcomes in moderately to severely injured older people. *Australas J Ageing*. 2018;37(1):E7-E11. doi:10.1111/ajag.12482

26. Touban BM, Pavlesen S, Smoak JB, et al. Decreased lean psoas cross-sectional area is associated with increased 1-year all-cause mortality in male elderly orthopaedic trauma patients. *J Orthop Trauma*. 2019;33(1):e1-e7. doi:10.1097/BOT.0000000000001331

27. Mccusker A, Khan M, Kulvatunyou N, et al. Sarcopenia defined by a computed tomography estimate of the psoas muscle area does not predict frailty in geriatric trauma patients. *Am J Surg*. 2019;218(2):261-265. doi:10.1016/j.amjsurg.2018.07.024

28. Malekpour M, Bridgham K, Jaap K, et al. The effect of sarcopenia on outcomes in geriatric blunt trauma. *Am Surg*. 2017;83(11):1203-1208.

29. Leeper CM, Lin E, Hoffman M, et al. Computed tomography abbreviated assessment of sarcopenia following trauma: the CAAST measurement predicts 6-month mortality in older adult trauma patients. *J Trauma Acute Care Surg*. 2016;80(5):805-811. doi:10.1097/TA.0000000000000989

30. Nishimura T, Naito H, Fujisaki N, Ishihara S, Nakao A, Nakayama S. The psoas muscle index as a predictor of mortality and morbidity of geriatric trauma patients: experience of a major trauma center in Kobe. *Surg Today*. 2020;50(9):1016-1023. doi:10.1007/s00595-020-01980-1

31. Varma S, Wilson MSJ, Naik M, et al. The associations of psoas and masseter muscles with sarcopenia and related adverse outcomes in older trauma patients: a retrospective study. *Aging Clin Exp Res*. 2022;34(8):1901-1908. doi:10.1007/s40520-022-02119-7

32. Wallace JD, Calvo RY, Lewis PR, et al. Sarcopenia as a predictor of mortality in elderly blunt trauma patients: comparing the masseter to the psoas using computed tomography. *J Trauma Acute Care Surg*. 2017;82(1):65-72. doi:10.1097/TA.0000000000001297

33. Proksch DM, Kelley KM, White S, Burgess JR. Identification of sarcopenia in elderly trauma patients: the value of clinical competency and experience. *Am Surg*. 2022;88(3):339-342. doi:10.1177/0003134820982854

34. Fairchild B, Webb TP, Xiang Q, Tarima S, Brasel KJ. Sarcopenia and frailty in elderly trauma patients. *World J Surg*. 2015;39(2):373-379. doi:10.1007/s00268-014-2785-7

35. Wollner G, Weihs V, Frenzel S, Aldrian S, Negrin LL. Musculus psoas major morphology - a novel predictor of mortality in elderly polytraumatized patients. *BMC Emerg Med*. 2023;23(1):13. doi:10.1186/s12873-023-00783-0

36. Hwang F, McGreevy CM, Pentakota SR, et al. Sarcopenia is predictive of functional outcomes in older trauma patients. *Cureus*. 2019;11(11):e6154. doi:10.7759/cureus.6154

37. Hassan R, Abd Aziz A. Computed tomography (CT) imaging of injuries from blunt abdominal trauma: a pictorial essay. *Malays J Med Sci*. 2010;17(2):29-39.

38. Shanshou L, Wei Z, Xianqi W, et al. Composition and associated factors of radiological examination in major trauma patients: a prospective observational study. *Pediatr Emerg Care*. 2020;36(1):34-38. doi:10.1097/PEC.0000000000001363

39. Lee JS, Kim YS, Kim EY, Jin W. Prognostic significance of CT-determined sarcopenia in patients with advanced gastric cancer. *PLoS One*. 2018;13(8):e0202700. doi:10.1371/journal.pone.0202700.

40. Sakamoto T, Yagyu T, Uchinaka E, et al. Sarcopenia as a prognostic factor in patients with recurrent pancreatic cancer: a retrospective study. *World J Surg Oncol*. 2020; 18(1):221. doi:10.1186/s12957-020-01981-x

41. Bayram S, Yıldırım AM, Salduz A. Is central sarcopenia a predictor of prognosis for patients with pathological fracture? *Surgeon*. 2023;21(2):108-118. doi:10.1016/j.surge.2022.03.005

42. Englesbe MJ, Patel SP, He K, et al. Sarcopenia and mortality after liver transplantation. *J Am Coll Surg*. 2010;211(2): 271-278. doi:10.1016/j.jamcollsurg.2010.03.039

43. Lee JSJ, He K, Harbaugh CM, et al. Frailty, core muscle size, and mortality in patients undergoing open abdominal aortic aneurysm repair. *J Vasc Surg*. 2011;53(4):912-917. doi:10.1016/j.jvs.2010.10.111

44. Qu T, Yang H, Walston JD, Fedarko NS, Leng SX. Upregulated monocytic expression of CXC chemokine ligand 10 (CXCL-10) and its relationship with serum interleukin-6 levels in the syndrome of frailty. *Cytokine*. 2009;46(3): 319-324. doi:10.1016/j.cyto.2009.02.015

45. Leng SX, Hung W, Cappola AR, Yu Q, Xue QL, Fried LP. White blood cell counts, insulin-like growth factor-1 levels, and frailty in community-dwelling older women. *J Gerontol A Biol Sci Med Sci*. 2009;64(4):499-502. doi:10.1093/gerona/gln047

46. De Fanis U, Wang GC, Fedarko NS, Walston JD, Casolaro V, Leng SX. T-lymphocytes expressing CC chemokine receptor-5 are increased in frail older adults. *J Am Geriatr Soc*. 2008;56(5):904-908. doi:10.1111/j.1532-5415.2008.01673.x

47. Anderson FA, Spencer FA. Risk factors for venous thromboembolism. *Circulation*. 2003;107(23 Suppl 1): I9-16. doi:10.1161/01.CIR.0000078469.07362.E6