Prevalence of Sarcopenia and Associated Outcomes in the Clinical Setting

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Abstract

Sarcopenia refers to age-associated decrease in muscle mass and function. The condition was originally described in the elderly, but emerging evidence suggests that it is also a concern among the chronically ill nonelderly. Currently there are a number of definitions for diagnosing sarcopenia; however, in the clinical setting, abdominal computed tomography (CT) scans completed for diagnostic purposes can be utilized to identify CT-defined sarcopenia. Recent studies suggest that prevalence of CT-defined sarcopenia is high among chronically ill patients, ranging from 15%–50% in patients with cancer, 30%–45% with liver failure, and 60%–70% for critically ill patients in the intensive care unit. Depleted muscle mass is associated with infectious complications, prolonged duration of mechanical ventilation, longer hospitalization, greater need for rehabilitation care after hospital discharge, and higher mortality. In consideration of the growing population of older adults with multiple comorbidities, more research is needed to identify sarcopenia and develop interventions that are directed at attenuating or reversal muscle loss. (*Nutr Clin Pract*.XXXX;xx:xx-xx)

Keywords

Sarcopenia—a term created by Irwin Rosenberg from the Greek phrase *sarx* meaning "flesh/muscle" and *penia* meaning "loss"[1]—was first recognized as a significant health concern when Evans and Campbell published a review that highlighted age-associated loss of muscle that resulted in decreased strength, metabolic rate, aerobic capacity, and functional status.[2-4] Sarcopenia develops as type II (fast-twitch) muscle fibers begin to atrophy in early adulthood,[5-9] and it progresses as a result of anabolic hormone reduction[10,11] and environmental factors.[12] These alterations in metabolism induce approximately 1% loss of muscle mass annually, beginning at 30 years of age and accelerating after 65 years.[12,13]

Although the initial definition of sarcopenia was confined to the elderly, muscle loss can also occur with disuse (immobility, physical inactivity, or prolonged bed rest), inflammation (insulin resistance or activation of proinflammatory pathways), and inadequate macro- and micronutrient intake[14-16] associated with acute and chronic disease. Since etiologies of age-related sarcopenia versus disuse-, inflammation-, and malnutrition-related sarcopenia differ, the distinctions of "primary sarcopenia" and "secondary sarcopenia" have been proposed by the European Working Group on Sarcopenia in Older People.[14] "Primary sarcopenia" indicates muscle wasting related to aging, while "secondary sarcopenia" refers to muscle loss related to disuse, inflammation, or malnutrition.[14] Distinguishing the mechanism leading to muscle loss is important for identification and treatment for maintenance and/or repletion of muscle integrity. However, in many chronically ill patients, multiple contributing factors likely lead to the development of sarcopenia.

Definition for Sarcopenia

In the 1998 classic New Mexico Elder Health Survey, Baumgartner et al[17] defined sarcopenia as an appendicular skeletal muscle mass (SMM; kg/m^2), measured by dual-energy X-ray absorptiometry (DXA), that is 2 standard deviations below that of sex-matched healthy 18- to 40-year-old adults. Since Baumgartner's original definition, clinicians and researchers recognized the relationship between deterioration in muscle mass and a decline in strength, metabolic rate, and aerobic capacity and subsequently added the assessment of functional status to the characterization of sarcopenia.[3,18] Together, the assessment of muscle mass with strength and performance provides a synergistic determinant for sarcopenia.

As seen in Table 1, 4 professional organizations have proposed 4 different definitions of sarcopenia.[14,19-21] The unifying element among these proposed definitions is the inclusion of depleted muscle mass with compromised functional status. However, there is a lack of consensus on the definition of

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Table 1. Summary of Sarcopenia Definitions and Diagnostic Criteria Proposed to Identify Both Muscle Mass and Functional Status.

Organization	Definition	Diagnostic Criteria to Identify Muscle Mass	Diagnostic Criteria to Characterize Functional Status
Sarcopenia Working Group of the European Union Geriatric Medicine Society[14]	"Sarcopenia is a syndrome characterized by progressive and generalized loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability poor quality of life and death." **Proposed sarcopenia categories** *Primary sarcopenia*: muscle wasting related to aging *Secondary sarcopenia*: muscle loss related to disuse, inflammation or malnutrition **Proposed sarcopenia staging** *Presarcopenia*: low muscle mass without impact on muscle strength or physical performance *Sarcopenia*: low muscle mass with either low muscle strength or physical performance *Severe sarcopenia*: combination of low muscle mass, muscle strength and impaired physical performance.	Muscle mass measured by computed tomography, magnetic resonance imaging, DXA,[17,22,23] bioelectrical impedance analysis,[18,24,25] or total body potassium counting using appropriate cut points	Low muscle strength characterized by poor handgrip strength,[56,61] knee flection/extension,[62,63] or peak expiratory flow[64,65] Low physical performance identified by the impaired Short Physical Performance Battery[66-69] or gait speed[70,71] or timed get-up-and-go test[72] or stair climb power test[73]
European Society of Parenteral and Enteral Nutrition Clinician Nutrition and Metabolism Special Interest Group[19]	"Sarcopenia is a condition characterized by loss of muscle mass and muscle strength."	Percentage of muscle mass measured via bioelectrical impedance analysis, at least 2 SDs below mean for sex- and race-matched adults aged 18–39 y from the third NHANES population	Low physical performance defined as gait speed <0.8 m/s during a 4-min walking test
International Working Group on Sarcopenia[20]	"Sarcopenia is the age-associated loss of skeletal muscle mass and function."	Low appendicular muscle mass corrected for height defined as ≤ 7.23 kg/m^2 in men and ≤ 5.67 kg/m^2 in women, measured via DXA	Low physical performance defined as gait speed <1 m/s during a 4-m walking test
Society of Sarcopenia, Cachexia and Wasting Disorders[21]	"Sarcopenia with limited mobility."	Low appendicular muscle mass corrected for height defined as at least 2 SDs below mean for sex- and race-matched adults aged 20–30 y	Low physical performance defined as gait speed <1 m/s or walking distance <400 m during a 6-min walk

DXA, dual-energy X-ray absorptiometry; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation.

functional status. The International Working Group on Sarcopenia does not provide further explanation of functional status.[20] The Society of Sarcopenia, Cachexia and Wasting Disorders defines impaired functional status as limited mobility.[21] However, both the European Working Group on Sarcopenia in Older People[14] and the ESPEN (European Society of Parenteral and Enteral Nutrition) Clinician Nutrition and Metabolism Special Interest Group[19] highlight the importance of muscle strength.

Similarly, a universal consensus diagnosis of sarcopenia is not currently available, even though each professional society

has proposed an operational designation that combines muscle mass and function. Remarkably, as seen in Table 1, multiple body composition methodologies utilizing different cut points with varying methods of strength assessment have been proposed by various professional societies to diagnose sarcopenia.[14,19-21] For example, both the International Working Group on Sarcopenia[20] and the Society of Sarcopenia, Cachexia and Wasting Disorders[21] recommend utilizing DXA to identify decreased muscle mass, although the organizations specify different cut points for low appendicular muscle mass. The

ESPEN Clinician Nutrition and Metabolism Special Interest Group[19] considers BIA an appropriate tool to recognize low muscle mass, while the European Working Group on Sarcopenia in Older People[14] suggests utilizing a range of body composition techniques, including computed tomography (CT), magnetic resonance imaging, DXA,[17,22,23] bioelectrical impedance analysis (BIA),[18,24,25] or total body potassium counting using appropriate cut points, based on the feasibility of tools available. In regard to assessment of functional status, all 4 organizations recommend application of gait speed as an assessment for physical performance; however, 3 of 4 groups propose different cut points to identify muscle weakness. The ESPEN Clinician Nutrition and Metabolism Special Interest Group[19] defines low physical performance as a gait speed <0.8 m/s during a 4-minute walking test; the International Working Group on Sarcopenia[20] recommends a gait speed <1 m/s during a 4-m walking test; and the Society of Sarcopenia, Cachexia and Wasting Disorders[21] suggests the diagnostic cutoff to be a gait speed <1 m/s or walking distance <400 m during a 6-minute walk. The European Working Group on Sarcopenia in Older People[14] recommends assessing for diminished strength and performance to define and diagnose sarcopenia in the research and clinical settings. As with the diagnostic criteria to identify low muscle mass, this group allows for a wide range of techniques to assess functional status. A concerning issue with each diagnostic criterion is the variety of body composition measures—including DXA, CT, magnetic resonance imaging, and BIA—and functional measures recommended, encompassing poor handgrip strength, knee flexion/extension, peak expiratory flow, gait speed, timed get-up-and-go test, stair climb power test, and the Short Physical Performance Battery. However, utilization of one body composition and functional assessment tool to define sarcopenia may be unrealistic, as patients may have varied tolerance for techniques to assess muscle mass and functional status. More research is needed to validate these proposed tools and existing cutoffs in different population.

The European Working Group on Sarcopenia in Older People has 2 unique features in its definition of sarcopenia: the distinctions of "primary sarcopenia" and "secondary sarcopenia," as discussed in the previous section, and the adoption of "sarcopenia staging," which reflects the severity of sarcopenia. "Presarcopenia" is defined as low muscle mass without impact on muscle strength or physical performance; "sarcopenia" is characterized by low muscle mass with either low muscle strength or physical performance; and "severe sarcopenia" is the combination of low muscle mass, low muscle strength, and impaired physical performance.

Perhaps one of the most promising methods to diagnose sarcopenia in the clinical setting exploits diagnostic abdominal CT scans. This technology provides an extremely precise method, 1.4% precision error for tissue areas, for the estimation of body composition.[26] Furthermore, skeletal muscle cross-sectional area from the abdomen, specifically the third lumbar vertebra (L3) region, is strongly correlated to whole body muscle distribution ($r = 0.924$, $P < .001$).[27] As a result, the L3 slice allows for estimation of total muscle mass. Prado et al created a definition for "CT-identified sarcopenia" utilizing the L3 region from diagnostic abdominal CT in a sample of 250 obese patients with cancer who had routine abdominal CT scans completed as part of their cancer treatment.[28] Patients with respiratory/gastrointestinal (GI) cancer were included in the study if a their body mass index (BMI) was >30 kg/m^2, and a CT scan was completed within 30 days of a BMI assessment. The sample population was 46% female and had an average age of 63.9 ± 10.4 years and BMI of 34.3 ± 4.4 kg/m^2. The L3 was identified, and the muscle cross-sectional area in this region was assessed, including the psoas, paraspinal muscles (erector spinae, quadratus lumborum), and abdominal wall muscles (transversus abdominis, external and internal obliques, rectus abdominis). Images were analyzed with medical imaging software: Slice-O-Matic, version 4.3 (Tomovision, Montreal, Canada). Skeletal muscles were identified via Hounsfield unit thresholds (–29 to +150), and cross-sectional area (cm^2) was computed by summing tissue pixel and multiplying by the pixel surface area. Skeletal muscle index was then calculated (cm^2/m^2) to normalize L3 skeletal muscle cross-sectional area for stature. Log-rank statistics were utilized to establish L3 skeletal muscle index sex-specific cutoffs that were associated with mortality: ≤38.5 cm^2/m^2 for women and ≤52.4 cm^2/m^2 for men. Based on this definition 15% of patients were sarcopenic.[19]

In 2013, Martin et al extended the usefulness of Prado's approach by establishing BMI thresholds for classifying sarcopenia.[29] For this study, a convenience sample was utilized comprising 1473 patients with respiratory/GI cancer with diagnostic abdominal CT scans. The patient sample was 44% female with average ages of 64.7 ± 11.2 and 64.8 ± 11.5 years for men and women, respectively. Mean BMI was 26.0 ± 4.9 for men and 25.1 ± 5.8 for women. Log-rank statistics were used to determine the survival-related threshold for BMI and skeletal muscle index: for men and women with a BMI <25 kg/m^2, *sarcopenic* was defined as a skeletal muscle index of ≤43 cm^2/m^2. For women and men with a BMI of ≥25 kg/m^2, *sarcopenic* was defined as a skeletal muscle index of ≤41 cm^2/m^2 and ≤53 cm^2/m^2, respectively. Based on the updated definition of sarcopenia that included BMI and skeletal muscle index, the prevalence of sarcopenia was 53% in women and 31% in men.[29] Collectively, these results highlight the availability of diagnostic CT scans in the clinical setting. Utilization of this technology provides important prognostic data and a promising approach to identifying sarcopenia. Further research is needed to determine if inclusion of strength assessment parameters with CT scans provides a more accurate diagnosis of sarcopenia.

Sarcopenic obesity is the final and possibly most important point to consider in reference to the definition of sarcopenia. The prognosis associated with sarcopenia is evident among
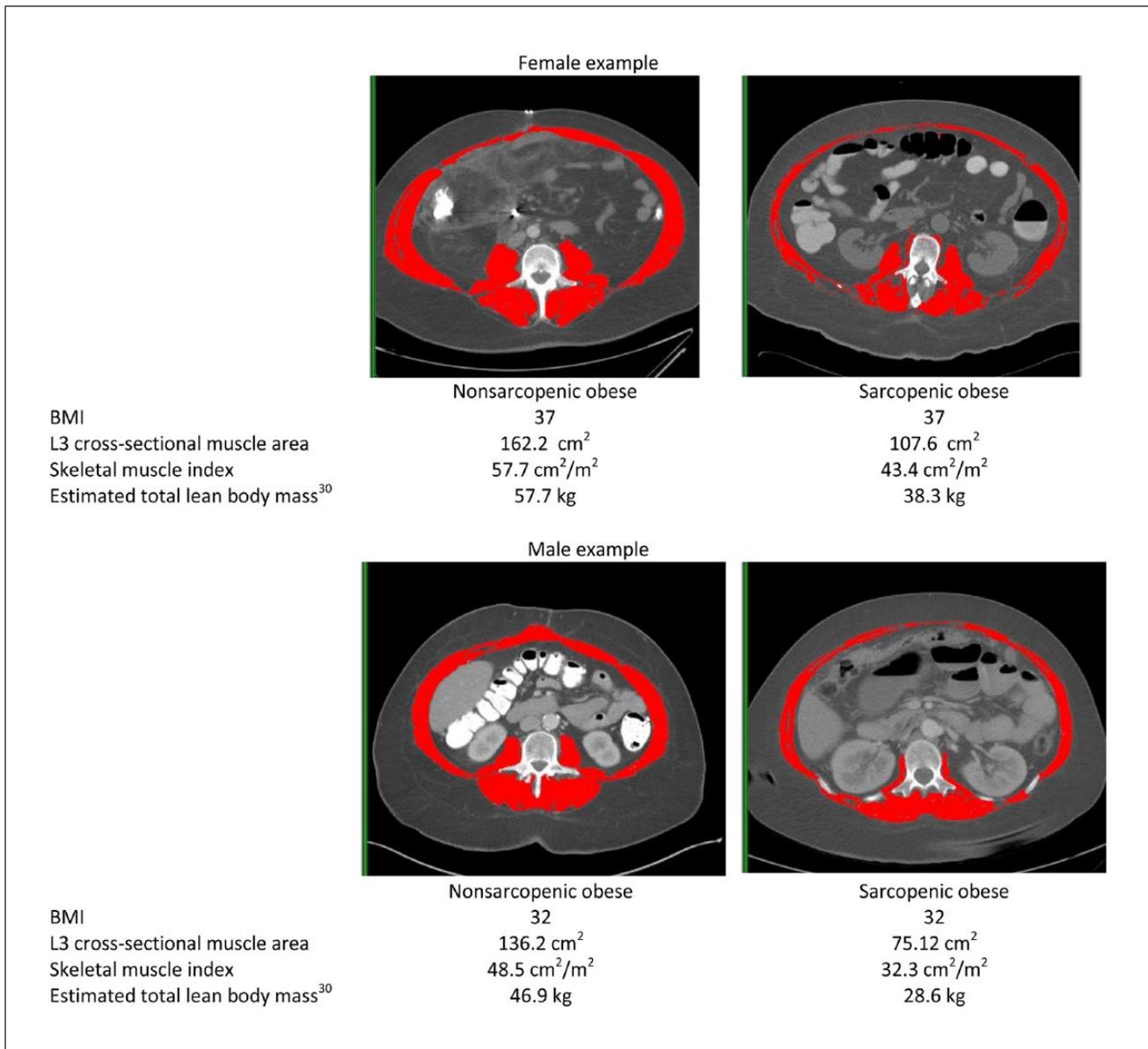
Figure 1. Example of sarcopenic obesity. BMI, body mass index; L3, third lumbar vertebra.

patients who present with obvious physical assessment findings consistent with low muscle mass—namely, thin and wasted appearance or history of significant weight loss. Often these patients will receive nutrition intervention to prevent further muscle loss and increase lean tissue in an effort to improve outcomes. Unfortunately, many clinicians may overlook the potential for low muscle mass in overweight/obese patients due to excess body habitus. As seen in Figure 1, sarcopenia is difficult to detect using only anthropometric assessment in overweight and obese patients. In the female example, both patients have a BMI of 37; however, the sarcopenic female's L3 skeletal muscle cross-sectional area is only 107.6 cm^2,

which translates to a skeletal muscle index of 43.4 cm^2/m^2. Cross-sectional skeletal muscle from the L3 region can be used to estimate lean body mass via the following regression equation, created by Mourtzakis et al[30]:

$$0.30 \times (\text{skeletal muscle at L3 region using CT } [\text{cm}^2] + 6.06).$$

With this equation, the sarcopenic female in the example has only 38 kg of lean body mass, compared with 58 kg in the nonsarcopenic female—this difference in metabolically active tissue is undetectable based on BMI alone. A similar example exists with the male patients; despite having the same BMI,

the sarcopenic male patient has a lower L3 skeletal muscle cross-sectional area, skeletal muscle index, and estimated lean body mass.

Accurate and timely identification of sarcopenia is essential to introduce appropriate interventions and prevent negative health outcomes. The etiology of sarcopenia is traditionally considered to be increasing age; however, due to the influence of inflammation and disuse on muscle mass, sarcopenia should be assessed in all chronically ill patients, regardless of weight or nutrition status. Among the overweight and obese, depleted muscle mass can be reliably detected only with estimation or direct measurement of body composition. Reliance on simple anthropometric assessment may overlook the diagnosis of sarcopenia.

Prevalence of Sarcopenia

Sarcopenia has been estimated to affect 5%–13% of 60- to 70-year-olds[31,32] and 11%–50% of those ≥80 years.[32,33] Surprisingly, few studies have described the prevalence of sarcopenia and its associated outcomes in the hospital setting.[34-40] As a result, rates and outcomes of sarcopenia among patients with chronic disease are also considered in this review.[28,29,41-47]

Seven studies have examined the prevalence in the hospital setting: 4 examined the general medical population,[34-37] and 3 included patients in the ICU.[38-40] Smoliner et al evaluated the prevalence of sarcopenia among patients admitted to a geriatric ward over a 6-month period.[34] Patients were included if they were ≥65 years of age and had a Mini Mental State Examination score of at least 19 (or at least 10 with capacity to perform muscle strength measurements). The European Working Group on Sarcopenia in Older People's proposed definition of sarcopenia was utilized.[14] Muscle mass was estimated with BIA according to the following equation[48]:

$$SMM \ (kg) = [(height^2 \ / \ BIA \ resistance \ \times \ 0.401) + (sex \ \times \ 3.825) + (years \ \times \ 0.071)] + 5.102,$$

where height^2 = cm^2, BIA resistance = ohm, and sex = 1 (men) and 0 (women).

SMM index,[25] or SMM/height (m)^2, was calculated to normalize muscle mass to height. Muscle strength was assessed by handgrip strength, measured by the Jamar dynamometer, and the Short Physical Performance Battery.[49] A total of 198 patients were included; mean age and BMI were 82.8 ± 5.9 years and 26.0 ± 5.4 kg/m^2. The majority of patients were female (70%). Prevalence of sarcopenia was unexpectedly low: only 7% of patients were classified as sarcopenic, and 19% were defined as severely sarcopenic.[34] Gariballa et al evaluated rates of sarcopenia among geriatric patients enrolled in their randomized controlled trial.[36] The European Working

Group on Sarcopenia in Older People[14] criteria were used to diagnose sarcopenia. The muscle mass was estimated by midarm muscle circumference according to the following formula:

$$midarm \ circumference \ - \ (3.14 \ \times \ triceps \ skinfold \ thickness).$$

Low muscle mass was defined as midarm muscle circumference <21.1 cm for men and <19.2 cm for women.[50] Muscle strength was assessed via handgrip strength; low muscle strength was classified as handgrip <30 kg for men and <20 kg for women. A total of 432 patients were included in the study. Only 10% were classified as sarcopenic. Patients with sarcopenia were significantly older (79 ± 7 vs 77 ± 6 years, $P < .05$) and more likely to be female (66% vs 45% compared to nonsarcopenic patients.[36] Rossi et al evaluated prevalence of sarcopenia among geriatric patients (>65 years of age) admitted between to the hospital over a 5-month period.[37] The European Working Group on Sarcopenia in Older People[14] criteria were used to diagnose sarcopenia. Muscle mass was estimated with BIA; SMM[48] and SMM index were calculated (see above equations).[14] Muscle strength was measured by handgrip dynamometer and 4-m gait speed. A total of 119 patients were included; subjects had a mean age of 80.4 ± 6.9 years and BMI of 26.3 ± 4.9 kg/m^2. A quarter of patients were classified as sarcopenic: 5% were classified as sarcopenia, and 21.0% had severe sarcopenia.[37] Finally, Sousa et al determined the prevalence of sarcopenia among patients admitted to general medical and surgical floors over a 2-year period. Patients >18 years of age were included.[35] Sarcopenia was defined according to the European Working Group on Sarcopenia in Older People's proposed definition.[14] Muscle mass was estimated by midarm muscle circumference and BIA. Muscle strength was measured with handgrip strength. A total of 608 patients were included. Subject's age ranged from 18–90 years, and the median age was 57 years. Sarcopenia was identified in 25% of patients. A higher proportion of patients with sarcopenia were found in medical wards (n = 91) than in surgical wards (n = 63; $P < .001$).[35]

Three additional studies utilized diagnostic abdominal CT scan to describe prevalence of sarcopenia in intensive care unit (ICU) populations.[38-40] Moisey et al described the occurrence of sarcopenia in a sample of elderly (≥65 years) trauma patients.[38] Sarcopenia was defined per skeletal muscle index cutoffs: <55.4 cm^2/m^2 for men and <38.9 cm^2/m^2 for women. Median age was 79 years (interquartile range [IQR]: 72–85), and median injury severity score was 19 (IQR: 14–26). BMI was calculated on admission: 7% (10 of 149) were underweight (BMI <18.5); 37% (55 of 149), normal weight; 42% (62 of 149), overweight; and 15% (22 of 149), obese. A total of 71% of the sample was sarcopenic (106 of 149): 90% of underweight, 85% of normal weight, 65% of overweight, and 45% of obese patients.[38] Sheean et al described rates of sarcopenia

in a convenience sample of 56 patients with respiratory failure requiring mechanical ventilation and diagnostic abdominal CT scans completed within 2 weeks of ICU admission.[39] Low muscle mass was defined with skeletal muscle index cutoffs proposed by Prado et al.[28] Within 24 hours of ICU admit, Subjective Global Assessment[51] was completed, and patients were classified as normally nourished, moderately malnourished, or severely malnourished. Within the sample, the mean age was 59.2 ± 15.6 years; APACHE II was 26 ± 8.0; and BMI was 28.3 ± 5.8. Overall prevalence for sarcopenia was 60% (34 of 56). Among overweight (BMI 25–29.9, 21 of 56 = 37.5%) and obese subjects (BMI $\geq$30, 19 of 56 = 34%), the proportion with sarcopenia was 62% (13 of 21) and 42% (8 of 19), respectively. Importantly, low muscle mass was not detected by Subjective Global Assessment: 60% (18 of 30) of patients classified as normally nourished by the assessment were sarcopenic, and 67% of these misclassified patients were overweight (6 of 18) or obese (6 of 18).[39] Weijs et al evaluated rates of sarcopenia in 240 patients requiring mechanical ventilation who had a diagnostic abdominal CT scan completed 1 day before to 4 days after ICU admit.[40] Sarcopenia was defined according to sex-specific receiver operating characteristic curve analysis to define muscle cross-sectional area cutoff values (women, <110 cm^2; men, <170 cm^2) that best predict hospital mortality. Patients had a mean age of 57 ± 17.8 years with an average APACHE II and BMI of 23.4 ± 8.1 and 25.1 ± 4.2, respectively. Reason for mechanical ventilation ranged from trauma to cardiovascular, postsurgical, neurologic, and septic. Overall prevalence of sarcopenia was 67%.[40]

Researchers in the cancer and liver failure setting have used diagnostic abdominal CT scans to provide some insight into rates of sarcopenia in the health care setting.[28,29,41-47] In addition to the original study by Prado et al[28] and Martin et al[29] that reported 15%–50% prevalence of sarcopenia among patients with respiratory/GI cancer, additional research has described rates of sarcopenia in lung, colorectal, and urothelial cancer. Baracos et al[41] characterized body composition among 441 patients with non–small cell lung cancer. Approximately half the sample was female (48%), and the mean age was 67.0 ± 10.0 and 65.0 ± 10.7 years for men and women, respectively. Average BMI was 25.2 ± 4.1 kg/m^2 for men and 24.6 ± 5.9 kg/m^2 for women. Slightly different sex-specific L3 skeletal muscle index cutoffs were generated to define sarcopenia (women, $\leq$38.9 cm^2/m^2; men, $\leq$55.4 cm^2/m^2). Based on this definition, 47% of patients were sarcopenic.[41] Lieffers et al[42] utilized diagnostic L3 scans from patients with colorectal cancer undergoing primary tumor resection. A total of 234 patients were included; 58% of the sample was male; and patients had a mean age and BMI of 63 ± 12 years and 28.5 ± 5.3 kg/m^2.[42] According to the sarcopenia cutoffs defined by Prado et al,[28] the prevalence of sarcopenia was 39%. Finally, Fukushima et al utilized the BMI-specific L3 skeletal muscle index cutoffs developed by Martin et al[29] to describe the prevalence of sarcopenia among patients with urothelial carcinoma.[43] A total of 88

patients were included; 68% of the group was male; and median age and BMI were 68 years (range: 39–91) and 22.1 kg/m^2 (range: 16.7–35.9). Among this patient population, 60% were diagnosed with sarcopenia.[43] Collectively, the prevalence of CT-defined sarcopenia ranged from 15%–60% in patients with cancer.[28,29,41-43]

Montano-Loza et al,[46] Tandon et al,[47] Meza-Junco et al,[44] and Montano-Loza et al[45] utilized diagnostic abdominal CT scans to identify prevalence of sarcopenia using skeletal muscle index among patients with liver failure. Montano-Loza et al[46] investigated the incidence of low muscle mass among patients with cirrhosis evaluated for liver transplantation (n = 112) to determine associations between sarcopenia and mortality. Cut points for CT-defined sarcopenia were based on the study by Prado et al.[28] The average age and BMI were 54 ± 1 years and 28 ± 6 kg/m^2. Etiology of liver cirrhosis included hepatitis C (29%), alcohol abuse (22%), autoimmune liver disease (19%), and other (29%). Average Model for End-Stage Liver Disease (MELD) score was 13 ± 0.6, and 11%, 59%, and 30% of patients were categorized as Child-Pugh A, B, and C, respectively. Overall the prevalence of sarcopenia was 40%.[46] Tandon et al determined rates of sarcopenia among patients with cirrhosis listed for liver transplant (n = 142) using skeletal muscle index values provided by Prado et al.[28,47] Patients had a median age of 53 years (IQR: 47–57) and median BMI of 27 kg/m^2 (IQR: 24–31). Median MELD score was 15 (IQR: 12–22) and 30%, 62% and 8% of patients were categorized as Child-Pugh A, B and C, respectively. A total of 41% were sarcopenic.

Moreover, 30% of patients with sarcopenia were overweight/obese.[47] Meza-Junco et al examined the prevalence of CT-defined sarcopenia in patients with cirrhosis and hepatocellular carcinoma.[44] The skeletal muscle index cutoffs proposed by Martin et al were utilized to define sarcopenia.[29] A total of 116 patents were included, and mean age and BMI were $58 + 1$ years and 29 ± 1 kg/m^2. Average MELD score was 9 ± 0.5. The majority of patients (53%) were categorized as Child-Pugh A, while 33% and 14% were considered Child-Pugh B and C, respectively. The researchers reported that 30% of participants were sarcopenic.[44] Finally, Montano-Loza et al explored if sarcopenia categorization predicted morbidity and mortality after liver transplantation in a cohort of 248 patients with cirrhosis.[45] The sex- and BMI-specific L3 skeletal muscle index cutoffs developed by Martin et al were utilized to determine rates of CT-defined sarcopenia.[29] The mean age was 55 ± 1 years. The etiologies of cirrhosis included hepatitis C (51%), alcohol abuse (19%), autoimmune liver diseases (15%), hepatitis B (9%), and other (6%). A total of 45% of patients met criteria for sarcopenia. Patients with sarcopenia had a lower BMI (25 ± 1 vs 29 ± 1, $P < .001$) and higher MELD score (20 ± 1 vs 16 ± 1, $P = .002$) and were more likely to be categorized as Child-Pugh C (51% vs 41%, $P = .02$).[45] Based on the collective data, CT-defined sarcopenia ranges from 30%–45% among those with liver failure.[44-47]

Decreased muscle mass is frequently observed among chronically patients; interestingly, rates of sarcopenia varied significantly among different populations. Patient admitted to general medical and surgical floors had relatively low rates of sarcopenia: only 5%–25% of patients presented with the combination of low muscle mass and strength.[34-37] Patients admitted to the ICU had much higher rates of sarcopenia: 60–70% of critically ill patients were sarcopenic.[38-40] This large difference may be related to differences in patient population; it should also be noted that body composition tools to identify sarcopenia differed between the 2 groups. The observed prevalence of CT-defined sarcopenia ranges between 15%–60% in those with chronic disease. Sarcopenia was prevalent in 15%–60% in patients with cancer,[28,29,41-43] while patients with liver disease had rates of sarcopenia ranging from 30%–45%.[44-47] More research is needed to determine if rates of CT-defined sarcopenia agree with more traditional definitions that include an assessment of muscle mass and functional status.

Outcomes Associated With Sarcopenia

An obvious consequence of sarcopenia is worse outcome. In 2000, US healthcare costs directly attributed to sarcopenia were an estimated $18.5 billion.[52] This substantial cost is related to the decrease in functional status and autonomy,[23,53,54] with a subsequent increase in falls,[17,55] disability[17,18,22,56,57] and mortality.[55,58-60] In the clinical setting, depleted muscle mass is associated with infectious complications,[42] prolonged duration of mechanical ventilation,[38] longer hospitalization,[36,38,42] readmission to the hospital,[36] greater need for rehabilitation care after hospital discharge,[42] and higher mortality[38,46,47] among patients identified as sarcopenic.

Increased mortality is the most common complication reported among patients with sarcopenia.[28,29,36,38,40,43-47] Gariballa et al utilized survival analysis to determine the relationship of mortality at 6 months between sarcopenic and nonsarcopenic patients. After adjustment for known confounders, nonsarcopenic patients had a significantly lower hazard of death at 6 months as compared with patients with sarcopenia (hazard ratio [HR], 0.45; 95% confidence interval [95% CI], 0.21–0.97; $P < .05$).[36] Moisey et al found that each unit decrease in skeletal muscle index (cm^2/m^2) increased the risk of ICU mortality by 7% (odds ratio, 0.93; 95% CI, 0.88–0.99; $P = .03$).[38] Similarly, Weijs et al observed significantly higher mortality among patients in the ICU (females: 47.5% vs 20.0%, $P = .008$; males: 32.3% vs 7.5%, $P < .001$).[40] Both Prado et al and Fukushima et al reported sarcopenia as a predictor of cancer survival; the presence of sarcopenia was an independent predictor of survival among patients with GI and respiratory cancer (HR, 4.2; 95% CI, 2.4–7.2; $P < .0001$)[28] and urothelial cancer (HR, 3.36; 95% CI, 1.90–6.08; $P < .001$).[43] However, Martin et al[59] found that a decreased muscle attenuation (mean Hounsfield unit <33) was independently associated with poor

survival.[29] Sarcopenia has also been associated with lower survival rates in liver failure.[44,46,47]

Patients with sarcopenia are at risk for worse hospital-associated outcomes. Gariballa et al observed longer hospital length of stay (13.4 ± 8.8 vs 9.4 ± 7.0, $P < .01$) and more frequent readmissions (55% vs 32%, $P = .001$) among patients with sarcopenia compared with nonsarcopenics.[36] In a convenience sample of patients with colorectal cancer with an abdominal CT scan, Lieffers et al reported longer hospital length of stay (15.9 ± 14.2 vs 12.3 ± 9.8 days, $P = .04$), higher frequency of inpatient rehabilitation (14% vs 6%, $P = .02$), and more infectious complications (24% vs 13%, $P = .03$) among patients with sarcopenia.[42] However, Moisey et al reported lower median ventilator-free days (19 [IQR: 0–28] vs 27 [IQR: 18–28], $P = .004$) and ICU-free days (19 [IQR: 0–25] vs 16 [IQR: 0–24], respectively, $P = .002$) in sarcopenic ICU patients compared with nonsarcopenics.[38]

Sarcopenia is also related to worse outcomes among patients with liver failure. Montano-Loza et al reported lower median survival (34 ± 11 vs 19 ± 6 months) and higher mortality (55% vs 45%, $P < .05$) among patients with sarcopenia with liver failure as compared with those with normal muscle mass.[46] Tandon et al observed lower 1-, 2-, and 3-year survival between sarcopenic and nonsarcopenic patients with liver failure (sarcopenic: 63%, 51%, and 51% vs nonsarcopenic: 79%, 74%, and 70%, respectively).[47] Yet, Meza-Junco et al reported that overall, 6-month, and 1-year survival rates were lower in sarcopenic compared to nonsarcopenic patients with cirrhosis (overall: 16 ± 6 vs 28 ± 3 months, $P = .003$; 6 months: 71% vs 90%, $P = .005$; 1 year: 53% vs 83%, $P = .005$).[44]

Loss of muscle mass represents a major risk factor for disability, morbidity, and mortality. Regardless of etiology, both "primary sarcopenia" and "secondary sarcopenia" increase the likelihood of poor outcomes. Within the health care setting, current evidence of CT-defined sarcopenia is associated with more infectious complications, prolonged hospitalization, and higher mortality. However, more research is needed to investigate the relationship between decrease in muscle mass and function with healthcare outcomes. Additionally, prospective interventions that target low muscle mass and functional status are needed to determine if reversing sarcopenia can improve outcomes.

Conclusion

There are a surprisingly small number of studies describing the prevalence and outcomes of sarcopenia in the hospital setting. Overall rates of sarcopenia in the clinical setting range between 5%–25% among patients admitted to general medical/surgical units,[34-37] 60%–70% for critically ill patients,[38-40] 15%–50% in patients with cancer,[28,29,41-43] and 30%–45% for liver failure.[44-47] These prevalence rates reflect a small number of studies that utilized either the European Working Group on Sarcopenia in Older People's diagnosis of sarcopenia or

CT-defined sarcopenia. Considering the growing population of older adults with multiple comorbidities, more research is needed to identify sarcopenia and develop interventions that are directed at attenuating or reversal muscle loss.

Statement of Authorship

S. J. Peterson contributed to conception/design of the work and drafted the manuscript; C. A. Braunschweig contributed to acquisition, analysis, or interpretation of the data and critically revised the manuscript. Both authors agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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