Review

Financial impact of sarcopenia or low muscle mass − A short review

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SUMMARY

Background & aims: Low muscle mass is associated with increased falls, medical complications, length of hospital stay and loss of independence. An increasing number of studies has also shown the association between sarcopenia and health care expenditure. The following narrative review summarizes the current evidence on the economic relevance of low muscle mass (MM) or sarcopenia.
Methods: An extensive search of the literature in Medline identified twelve studies in English, which evaluated direct and indirect health care expenditure in patients with low muscle mass or sarcopenia (low MM and strength or mobility).
Results: Three studies analysed the cost of age-related loss of MM or strength in large surveys of the general, older population. Six retrospective analyses evaluated perioperative medical costs related to low MM in primarily older patients from different medical areas. One prospective study presented hospital costs related to sarcopenia in patients with gastric cancer. Two studies presented data from general hospital patients. Despite the difference in diagnostic criteria, study population and statistical design, low MM and sarcopenia were consistently identified as predictors of increased health care expenditure in community, perioperative and general hospital settings.
Conclusions: Low MM and sarcopenia are prevalent and associated with significantly higher health care costs. Considering the demographic change, which will lead to an increasing number of patients with sarcopenia, every effort should be made to identify and treat patients with sarcopenia. The use of a unified definition and diagnostic criteria would allow a better comparison of data.

1. Introduction

Sarcopenia describes the age-related loss of skeletal muscle mass (SMM) [1] and results in the loss of physical capacity [2]; the latter being associated with prolonged convalescence and reduced independence [3]. Furthermore, a reduction in muscle mass can have metabolic implications ranging from insulin resistance and a change in myokine production [4,5] to an altered reaction to disease and treatment [6]. Ultimately, morbidity and mortality increase in patients with sarcopenia [7]. Depending on the study population, age and especially diagnostic criteria, the prevalence of sarcopenia ranges from 10% in healthy adults over 60 years old [8] to 33% in long-term care populations [9].

Reduced muscle mass in chronic disease, immobility or obesity with low physical activity has been described by some authors as secondary sarcopenia in order to distinguish it from the age-associated, or primary, sarcopenia [10,11]. Ultimately, there is often an overlap of the two phenotypes as, for example, in older, obese patients with cancer. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) consensus defined sarcopenia as low muscle mass and low muscle strength or function [10], thus accounting for the non-linear relationship between muscle mass and muscle strength. Furthermore, an ICD-CM code (M62.84) for age-related sarcopenia was introduced in the United States in 2016. Together, the common definition and ICD-CM code in the US represent the increasing awareness of sarcopenia as a prevalent and relevant syndrome and provide urgently needed incentive to screen for and treat sarcopenia.

As a result of impaired physical capacity, loss of independence, extended recovery and increased risk for the development of the frailty syndrome, the length of hospital stay (LOS) and health care

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utilization increase, leading to an increased strain on the health care system. Sarcopenia is also known to be associated with polypharmacy [12], which, aside from implications on health, can be a private or public financial burden depending on the health care system. Figure 1 provides a schematic representation of the interrelationship between sarcopenia and hospitalization.

Considering our ageing society, an increase in health care costs can be expected. The following narrative review summarizes current studies that have investigated the economic relevance of sarcopenia. We included original studies which investigated health care costs associated with sarcopenia, low muscle mass or low muscle strength.

2. Methods

We conducted an extensive search in Medline using the following search terms 'sarcopenia', 'muscle mass' and combined them with 'healthcare' (health care), or 'costs', 'health care expenditure' or 'economic' in title and abstracts. We repeated the search using MeSH terms. We identified 261 papers. After screening all abstracts, we identified 11 papers that corresponded to our inclusion criteria. By further checking the references of the articles, we identified one further study. After including only original studies and those which calculated health care costs related to low muscle mass, strength or sarcopenia, twelve studies were included in this review.

For the purpose of this review, we refer to *sarcopenia* when classified according to consensus definitions for age-related sarcopenia such as EWGSOP and to *low muscle mass* when only skeletal muscle mass was assessed, such as in general hospital or surgical settings.

2.1. Age-associated sarcopenia

Table 1 presents studies that evaluated the costs related to low muscle mass or strength within larger, population-based health surveys. A first rough estimation of costs resulting from age-associated SMM depletion was carried out by Janssen and colleagues in 2004 [13]. Their calculations were based on the relative risk of developing disability with low SMM and prevalence of low SMM in subjects over 60 years of age from two representative health surveys: The third National Health and Nutrition Examination Survey (NHANES) and the National Medical Care and Utilization Expenditure Survey (NMCUES). Using this information, the contribution of low SMM on the risk of disability was estimated (population-attributable risk) and combined with the economic cost of disability. The authors estimated direct costs attributable to

Fig. 1. Schematic concept of the interrelationship between sarcopenia and hospitalization.

low SMM of approximately 18.5 billion USD (10.8 billion USD in men and 7.7 USD billion in women), representing 1.5% of total national health care expenditure. According to a sensitivity analysis, however, which accounted for variations in the population-attributable risk of low SMM and cost of disability, costs could be as low as 11.8 billion USD and as high as 26.2 billion USD. The excess expenditure was slightly higher in women at 860 USD and 933 USD per male and female patient with low SMM, respectively. The authors estimated potential cost savings of 1.1 billion USD (figures adjusted for the year 2000) if the prevalence of low SMM were reduced by 10% (either severely low SMM to moderate or moderate to normal).

Using data from the Survey of Health, Ageing and Retirement in Europe (SHARE), Steffl et al. employed a cost-of-illness approach to analyse the costs associated with muscle weakness in Czech participants aged over 70 without severe chronic disease [14]. According to their estimations, low strength alone in this study population (9.4%) incurred significantly higher direct, e.g. medical care, and indirect costs, e.g. replacement costs for caregivers. Individuals with low strength were one third more likely to be hospitalized. In a general linear regression model adjusted for age and body mass index (BMI), low muscle strength was associated with the risk of significantly higher direct costs (OR 2.11, 95% CI: 1.43–3.09).

Lo et al. assessed annual expenditure in the Elderly Nutrition and Health Survey, a prospective study with an eight-year follow-up in a large sample of community-dwelling individuals aged 65 years and over. Nearly 25% had a low skeletal muscle mass index (SMMI, kg/m^2). After eight years, hospitalization (duration and cost) as well as total medical costs were highest in the participants with a low SMMI. The authors also assessed dietary diversity and physical activity at baseline and found that these factors attenuated the effects of low muscle mass on health care utilization and expenditure [15]. Interestingly, individuals with higher SMMI had less hospital stays and hospital emergency visits but higher outpatient, preventive and dental care service utilization than those with lower SMMI.

2.2. Financial impact of low skeletal muscle mass on hospital costs in surgical settings

Cost analyses of most of the available studies are largely limited to hospital-related costs and in the form of retrospective analyses of existing data in a perioperative setting and include health care utilization in the year following surgery (Table 2). This data is often restricted to patients who received an evaluable computer tomography (CT) scan to determine low SMM.

The following two publications analysed data from the Michigan Surgical Quality Collaborative (MSQC) data registry regarding LOS, hospital costs [16] and health care utilization in the postoperative year [3] in patients with and without low muscle mass who had undergone elective surgery. Low SMM was defined using preoperative CT scans as reduced lean psoas muscle area (LPA; lowest, sex-specific tertile). Sheetz et al. reported extended LOS in patients with low versus normal SMM (7 versus 4 days, p < 0.001) and both payer (reimbursement) and hospital costs were higher in patients with low SMM. Following adjustment for confounders, low SMM was independently associated with increased payer costs, which increased further when postoperative complications occurred. Interestingly, mean costs in patients with normal SMM and complications were similar to those in patients with low SMM and without complications. Furthermore, the average hospital margin (payer costs − hospital costs) was negative (−873 USD) after the treatment of patients with low SMM compared to average patients (1806 USD) and those with normal SMM (3170 USD).
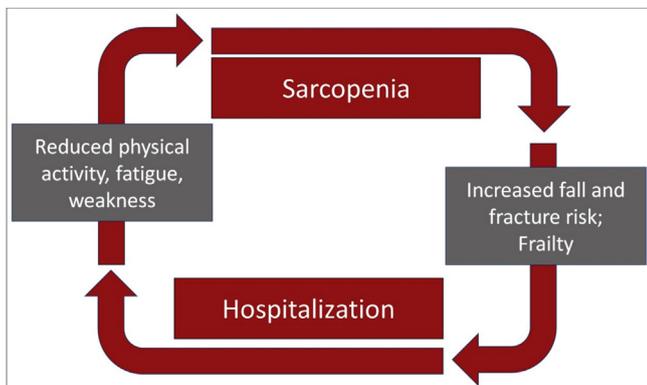
Table 1
Evaluation of healthcare costs related to low muscle mass in population-based health surveys.

Author	Setting and population	Age	Assessment of low muscle mass and cut-offs	Costs of low muscle mass
Janssen 2004 USA [13]	Retrospective analysis of data from two representative surveys (NHANES III and NMCUES)[a]	≥60 years	Indirectly evaluated based on disability prevalence and known risk to develop disability due to low muscle mass (population attributable risk calculated from NHANES III)	Total direct costs of low muscle mass: 18.5 billion USD in 2000. Additional annual costs per individual with low muscle mass: 860 USD for men, 933 USD for women.
Steffl 2017 Czech Republic [14]	Retrospective analysis of data from SHARE study, wave 6 n = 689 (65 with muscle weakness)	≥70 years (75.6 ± 5.1)	Muscle strength assessed by handgrip strength (men: <26 kg, women: <16 kg [30])	Average total annual costs (direct medical care and indirect costs): 1125.3 ± 1367.2 EUR in patients with low muscle strength vs. 561.4 ± 762.6 EUR in patient with normal strength, p = 0.001
Lo 2017 Taiwan [15]	Elderly Nutrition and Health Survey, prospective study with 8 year follow-up n = 1337 (330 with low SMMI)	≥65 years	Muscle mass assessed by BIA and adjusted for patients' height squared (SMMI; lowest quartiles: men: <11.4 kg/m^2, women: 8.5 kg/m^2)	Total annual expenditure was higher in low SMMI vs. normal SMMI (mean (median): (2802.7 (945.2) vs. 1852.0 (917.8)) EUR, p < 0.001[b]

Abbreviations: BIA: bioelectrical impedance analysis; NHANES III: Third National Health and Nutrition Examination Survey; NMCUES: National Medical Care Utilization and Expenditures Survey; SHARE: Survey of Health, Ageing and Retirement in Europe; SMMI: skeletal muscle mass index (kg/m^2).
[a] Population size not available.
[b] Currency (NT$) in Lo 2017 converted into EUR.

The analysis from Kirk and colleagues investigated whether LOS and the utilization of health care resources in the year following the operation differ in patients with and without low SMM and estimated the corresponding costs [3]. Costs included hospital expenditure within one year of the operation and were higher in patients with low compared to normal SMM (unadjusted; 67,525 USD versus 39,720 USD, p < 0.001). Patients with low SMM had a significantly higher rate of postoperative complications (33.3% versus 17.6%, p < 0.001). Adjusted in multivariate analyses, low SMM was an independent predictor of admission to the intensive care unit (OR 2.24, CI: 1.38–3.64, p < 0.001), prolonged hospital stays (OR 3.47, CI: 1.91–5.02, p < 0.001) as well as postoperative 1-year mortality (OR 3.26, CI: 1.73–6.15, p < 0.001). Interestingly, while the postoperative readmission rate in patients with low SMM was not increased, the likeliness of not being discharged back to their homes was significantly higher for patients with low SMM in a multivariate adjusted model (OR 4.42, CI: 2.28–8.55, p < 0.001). The costs for care homes could not be included in the study and represent a substantial financial expense, of which the meaning becomes all the more profound when considering that the risk of not being released home independently was 4-fold in this study for patients with low SMM.

Gani et al. assessed 1169 patients who underwent major abdominal surgery [17]. Based on psoas muscle volume, 25.1% of patients had low SMM. Using adjusted multivariable regression analysis, they showed that the presence of low SMM was associated with significantly higher total hospital costs than in patients with normal muscle mass (38,804 USD versus 24,482 USD, p < 0.001). When stratifying the study population into subgroups with versus without postoperative complications, the costs remained significantly higher in patients with low SMM (for patients with complications, low versus normal SMM: 65,856 USD (IQR 43,730–70,784) versus 59,609 USD (IQR 40,527–63,291), p < 0.001, compared to without complications, low versus normal SMM: 26,282 USD (IQR 24,530–39,802) versus 23,763 USD (IQR 22,220–35,254), p < 0.001). Similarly, when looking at costs for length of stay (LOS), low SMM was associated with higher costs irrespective of whether length of hospital stay was longer than expected (observed:expected LOS < 1: low versus normal SMM: 25,038 USD (IQR 24,106–26,358) versus 22,827 USD (IQR 21,768–23,972), p < 0.001) or not (observed:expected LOS > 1: low versus normal SMM: 43,283 USD (IQR 39,818–66,145) versus 38,679 USD (IQR 35,563–58,015), p < 0.001).

Van Vugt and colleagues investigated hospital costs in patients undergoing abdominal cancer surgery [18] and in patients listed for liver transplantation [19]. The first retrospective analysis included patients over 18 years of age with cancer of the gastrointestinal or hepatopancreatobiliary tracts undergoing elective curative surgery and who had a preoperative CT scan within 90 days. Low skeletal muscle index (SMI, cm^2/m^2) was identified in 45.6% of patients. These patients experienced more postoperative complications and longer hospital stays than patients with normal SMMI. Total costs included surgical and postoperative costs during the hospital stay. While total costs varied between cancer type and major versus minor surgery, they were 12.7% higher in patients with low versus normal SMI (17,144 EUR (IQR 12,694–25,102) versus 14,961 EUR (IQR 10,744–21,200), p < 0.001). A multivariable linear regression analysis revealed that low SMI was independently associated with an increase in costs and total expenditure decreased with incremental increase of SMI. Total costs remained higher for patients with low SMI in the subgroup of patients 65 years and older (18,256 EUR (IQR 12,808–25,131) versus 15,490 EUR (IQR 11,060–21,098), p = 0.041).

The second retrospective analysis from Van Vugt et al. included 224 patients with cirrhosis and listed for liver transplantation [19]. Twenty-four percent of patients had low SMI based on CT scans. Total costs included both hospital and outpatient costs during the time on the waiting list. Costs were significantly higher in liver transplant candidates with low SMI independent of the total waiting time (median waiting time: 170 days (IQR 47–306)) and corresponded to 68 EUR (IQR 16–503) per day on the waiting list for patients with low SMI versus 40 EUR (IQR 10–108) per day for patients with normal SMI (p = 0.013). Similar to the above-mentioned analysis in cancer patients, an incremental increase in SMI was associated with decreased health care expenditure in a multivariable regression analysis adjusted for confounders.

One study was found that used both muscle mass and strength and/or physical performance to define sarcopenia in gastric cancer patients undergoing gastrectomy [20]. Huang et al. differentiated between sarcopenia (low SMI and low handgrip strength or gait speed) and severe sarcopenia (low SMI, low handgrip strength and low gait speed). The prevalence of sarcopenia and severe sarcopenia together was 16.8%. Patients with sarcopenia and severe sarcopenia had a longer LOS (11 [7], p = 0.001, 14 (IQR 7), p < 0.001

Table 2
Evaluation of healthcare costs related to low muscle mass in the perioperative setting.

Author	Setting and population	Age	Assessment of low muscle mass or sarcopenia and cut-offs	Costs of low muscle mass or sarcopenia
Sheetz 2013 USA [16]	Retrospective analysis of patients with elective major general or vascular surgery from the MSQC databank n = 1593	48.5 ± 14.8 years (normal LPA) – 66.4 ± 14.4 years (low LPA)	L4 lean psoas area (LPA; mm^2) assessed by CT (lowest sex-specific tertile, exact values not available)	Low LPA was independently associated with increased payer costs (reimbursements) (6989.17 USD per 1000 mm^2 LPA, p < 0.001), which further increased with postoperative complications (26988.41 USD per 1000 mm^2 LPA, p < 0.001).
Kirk 2015 USA [3]	Retrospective analysis of patients with elective surgery from the MSQC databank n = 1279	49.8 ± 13.9 years (normal LPA) – 66.1 ± 14.0 years (low LPA)	L4 LPA assessed by CT (mm^2; lowest sex-specific tertile, exact values not available)	Low LPA was independently associated with increased in-hospital costs at 30 (β = 0.746, SE 0.191, p < 0.001), 90 (β = 0.198, SE 0.057, p < 0.001) and 180 days (β = 0.164, SE 0.065, p = 0.012).
Gani 2016 USA [17]	Retrospective analysis from hospital data; hepatobiliary, pancreatic or colorectal resection n = 1169 (293 with low TPV)	≥18 years (median age: 62 (IQR 52–70))	L3 total psoas volume (TPV) assessed by CT and adjusted for patients' height squared (lowest sex-specific quartile: men: <56.1 cm^3/m^2, women: 34.5 cm^3/m^2)	14,322 USD increase in total median covariate-adjusted hospital cost for patients with low TPV: 38,804 USD (IQR 25,027–43,462) in low TPV vs. 24,482 USD (IQR 22,573–38,025) in normal TPV, p < 0.001.
Huang 2017 China [20]	Prospective study in gastric cancer surgery n = 470 (79 sarcopenic)	≥18 years (median age: 65 (IQR 15))	EWGSOP [10] and AWGS [31] criteria: i) SMI assessed with CT of L3 for abdominal muscle area and adjusted for patients' height squared (sex-specific cut-offs: men: <40.8 cm^2/m^2, women: <34.9 cm^2/m^2), and ii) muscle strength by handgrip strength (men: <26 kg, women: <18 kg) and/or low physical performance as gait speed (≤0.8 m/s). Sarcopenia: low SMI and low strength or physical performance; severe sarcopenia: low SMI, strength and physical performance.	Median hospital costs higher in patients with increasing degree of sarcopenia (sarcopenia, severe sarcopenia vs. without sarcopenia): 8206.7 (IQR 4032.9.00), 8462.3 (IQR 3657.8) vs. 6975.5.30 (IQR 2260.2) EUR,[a] sarcopenia/normal: p = 0.001, severe sarcopenia/normal: p < 0.001.
Bokshan 2017 USA [21]	Retrospective analysis from hospital data; elective orthopaedic (thoracolumbar spine) surgery n = 50 (16 with low TPA)	>55 years	L4 total psoas area (TPA) assessed by CT (lowest sex-specific tertile; mean TPA for sarcopenic patients ± SD: 1297.6 ± 105.2 mm^2)	1.75-fold greater mean total hospital costs in patients with low vs. normal TPA (53,128 USD vs. 30,292 USD, p = 0.04).
Van Vugt 2017 The Netherlands [18]	Retrospective analysis in abdominal cancer surgery (curative surgery for gastrointestinal or hepatopancreatobiliary cancers) n = 452 (206 with low SMI)	≥18 years (median age: 65 years, IQR 58–71)	SMI assessed with CT of L3 for skeletal muscle area and adjusted for patients' height squared (sex- and BMI-specific cut-offs: men with BMI < 25 kg/m^2: <43 cm^2/m^2, with ≥25 kg/m^2: <53 cm^2/m^2, women: <41 cm^2/m^2 [32])	In the multivariable linear regression analysis, low SMI was independently associated with a cost increase of 4061 EUR (95% CI: 809–7312, p = 0.015). Costs decreased by 278 EUR (95% CI: 32–524, p = 0.027) per incremental increase in SMI.
Van Vugt 2018 The Netherlands [19]	Retrospective analysis in liver transplant candidates n = 224 (55 with low SMI)	Median: 56 years (IQR 48–62)	SMI (cm^2/m^2) assessed with CT of L3 for skeletal muscle area and adjusted for patients' height squared (lowest sex-specific quartile, exact values not available)	In the multivariable linear regression analysis, costs decreased by 455 EUR (95% CI: 11–900, p = 0.045) per incremental increase in SMI.

Abbreviations: AWGS: Asian Working Group for Sarcopenia; β: beta coefficient; CI: Confidence interval; CT: computer tomography; EWGSOP: European Working Group on Sarcopenia in Older People; IQR: Interquartile range; LPA: lean psoas area (mm^2); MSQC: Michigan Surgical Quality Collaborative; SD: Standard deviation; SE: Standard error; SMI: Skeletal muscle index (cm^2/m^2); TPA: Total psoas area (mm^2); TPV: Total psoas volume (cm^3/m^2).

[a] Currency (CNY) in Huang et al. converted to EUR.

versus 12 (IQR 6) days) and severe sarcopenia was an independent predictor of postoperative complications in a multivariate analysis (OR 8.957, CI: 3.876–20.697, p < 0.001). Hospital costs were also higher in patients with sarcopenia and severe sarcopenia (Table 2).

Bokshan and colleagues conducted a retrospective analysis on the cost of low SMM in a smaller group of patients over 55 years of age who received an elective orthopaedic operation [21]. Thirty-two percent of patients had low SMM based on perioperative CT scans yielding psoas muscle volume. The total hospital-related costs for patients with low SMM were nearly twice that of patients with normal muscle mass. Patients with low SMM were also twice as likely to require blood transfusion (43.8% versus 20.6%, p = 0.04) and in 2.6-fold greater need of diagnostic imaging (68.8% versus 26.5%, p = 0.002) accompanied by the corresponding higher costs (2452 USD versus 801 USD, p = 0.01). Furthermore, patients with low muscle mass had a higher use of medication and higher laboratory and emergency department costs. These results are however, limited due to the small sample size.

2.3. Financial impact of low skeletal muscle mass and strength – sarcopenia – in a general hospital setting

Two cross-sectional studies were found that included patients from various hospital departments and used both muscle mass and strength to characterize sarcopenia (Table 3). The study by Sousa and colleagues analysed costs associated with sarcopenia in a

Table 3
Evaluation of sarcopenia-related healthcare costs in a general hospital setting.

Author	Setting and population	Age	Assessment of sarcopenia and cut-offs	Costs of sarcopenia
Sousa 2016 Portugal [22]	Prospective study in general hospital patients (medical and surgical wards) n = 656 (159 sarcopenic)	≥18 years, range 18–90 years, median age 56 with IQR of 22	EWGSOP criteria [10]: i) muscle mass assessed by BIA and adjusted for patients' height squared (sex-specific cut-offs: men: <10.75 kg/m^2, women: 6.75 kg/m^2), and ii) muscle strength by handgrip strength (men: <30 kgf, women: <20 kgf)	Patients with vs. without sarcopenia had higher hospitalization costs (3151 EUR (IQR 4175) vs. 2170 (IQR 2515), p < 0.001). Adjusted additional hospital costs per patient due to sarcopenia: 1117 EUR (95% CI: 644–1588, p < 0.001); Patients aged < 65 years: sarcopenia increased costs by 1240 EUR (95% CI: 596–1887); patients aged ≥ 65 years: 721 EUR (95% CI: 13 –1429).
Antunes 2017 Portugal [23]	Cross-sectional study in general hospital patients (medical, surgical and orthopaedics) n = 201 (21 sarcopenic)	≥65 years	EWGSOP criteria [10]: i) muscle mass assessed by anthropometric measurements (mid-upper arm muscle circumference; cut-off: % muscle mass ≤ 2 SD of reference group), and ii) muscle strength by handgrip strength (men with BMI ≤ 24 kg/m^2: ≤29 kg, with BMI 24.1–28 kg/m^2: ≤30 kg, with BMI > 28 kg/m^2: ≤32 kg; women with BMI ≤ 24 kg/m^2: ≤17 kg, with BMI 24.1 –26 kg/m^2: ≤17.3 kg, with BMI 26.1–29 kg/m^2: ≤18 kg with BMI > 29 kg/m^2: ≤21 kg)	Sarcopenia (OR = 5.70, 95% CI 1.57–20.71, p = 0.008) and low muscle strength alone (OR = 2.40, 95% CI 1.12–5.15, p = 0.025) were associated with hospital costs exceeding mean cost of an average patient.

Abbreviations: BIA: bioelectrical impedance analysis; BMI: body mass index; CI: confidence interval; EWGSOP: European Working Group on Sarcopenia in Older People; IQR: interquartile range; OR: odds ratio; SD: standard deviation.

general, hospitalized, adult population [22]. They included all ages (18 years and older) and found that 24% presented with sarcopenia. Hospital costs were based on the diagnosis-related group codes at discharge and were higher in patients with versus without sarcopenia in the entire population as well as when stratified according to age (under and over 65 years).

The study performed by Antunes et al. included 201 patients aged 65 years and over and also from various hospital departments [23]. Sarcopenia, as defined by low muscle mass and low handgrip strength, was identified in approximately 10% of patients. Hospitalization costs were calculated based on weighted diagnosis-related group codes. After adjustment for confounders, both sarcopenia and low muscle strength alone were associated with higher hospitalization costs compared to the mean cost of an average patient.

3. Discussion

This review assessed the economic impact of age related sarcopenia and disease-related low muscle mass and consistently found higher costs associated with low muscle mass. However, the studies differ remarkably with regard to setting, population, method and diagnostic criteria for classification of low muscle

mass, sample size and last but not least statistical design including adjustment for confounders. While most of the studies adjusted for important confounders such as age, sex and comorbidities, one study only compared differences between patients with and without low SMM. Most of the existing studies were carried out in surgical patients, including younger subjects, and retrospectively analysed the additional costs for patients with low SMM in hospital as well as post-discharge. In these studies, low SMM was mostly evaluated based on available CT scans, which clearly represents a population selection such that the data cannot be extrapolated to all hospital patients. In addition, studies in surgical patients included patients with cancer. While this fact does not preclude age-associated sarcopenia, it makes it difficult to combine these studies with studies carried out in older (e.g. community-dwelling) populations. More importantly, studies investigating loss of muscle mass in patients with cancer or severe chronic disease did not control for cachexia or involuntary weight loss. Cachexia is a complex syndrome, accompanied by systemic inflammation, which is associated with a worsened clinical outcome [24]. Since loss of muscle mass undeniably is a hallmark symptom of cachexia, disentangling the effects on outcome and thus costs are difficult, particularly because costs were frequently driven by length of hospital stay, which is already increased in
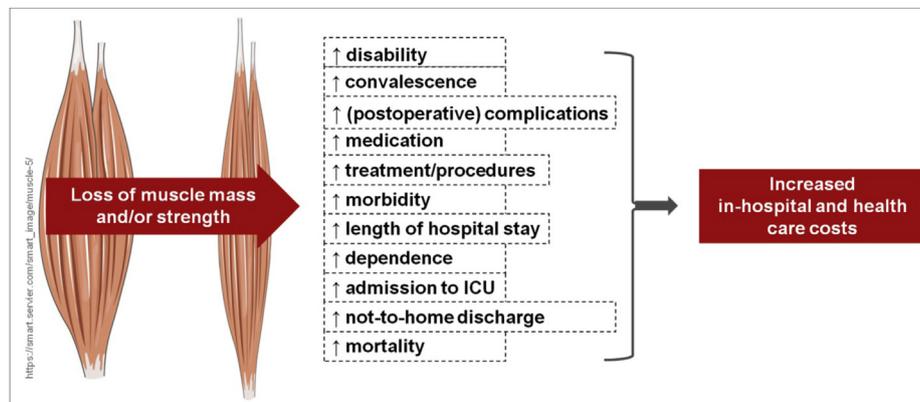

Fig. 2. Consequences of reduced muscle mass and/or strength for health care utilization and costs.

malnutrition or cachexia [25]. Another limiting factor for the interpretation of the results in this review is that the methods used in these studies differ, which reflects their availability in the respective settings. Bioimpedance analysis and anthropometric measures of muscle mass are noninvasive and inexpensive bedside methods, but the validity of muscle mass estimation is highly dependent on standardized measurements as well as appropriate equations and correct prerequisites. Computer tomography is an elegant approach; however, it is limited to available and evaluable scans. Also, while whole-body muscle volume can be estimated with an abdominal cross-sectional CT-image at the L3 level [26,27], four of the studies here just use total psoas area or volume, which has been criticised as an unsuitable marker for whole body skeletal muscle due to the frequent regional atrophy in the lower back region [28]. Furthermore, not only the methods, but the use of different summary definitions and cut-offs may have a significant impact on the results. A recent analysis showed that none of the common summary definitions (including EWGSOP, International Working Group or Foundation for the NIH Sarcopenia Project) were associated with likelihood of hospitalisation or rate of inpatient days in a sample of comparatively healthy older men from the Osteoporotic Fractures in Men Study [29]. This questions the validity of these definitions with regard to incident hospitalisation in this group of relatively healthy older men, which of course would have an impact on costs.

Nevertheless, the data show that low MM and sarcopenia are associated with increased health care utilization outside of the hospital as well as during a hospital stay in the form of extended LOS and increased complications, especially in the post-operative setting (Fig. 2). It appears that it may be possible to influence the increased costs, for example, by allocating more resources to the preoperative and 30-day postoperative period.

4. Conclusion

Despite different methodology used for the evaluation of muscle mass or diagnosis of sarcopenia and differing settings as well as sample size numbers, the findings of these studies consistently show that direct and indirect health care costs are increased in the case of low muscle mass or sarcopenia. Thus, the prevention of muscle loss and treatment of already existing sarcopenia are expected to lead to cost savings for the health care system. Prevention and early treatment of loss of muscle mass and/or sarcopenia will likely not only improve prognosis and convalescence of patients but also reduce the financial burden on health care expenditure. Considering the demographic change, which will lead to a higher number of patients with sarcopenia, health care should focus on identifying and treating sarcopenia or low muscle mass.

Conflict of interest

The authors declare no conflict of interest and both approve the final article.

Contributions

The authors contributed equally to the article.

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