Epidemiology of Sarcopenia

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1.1 Introduction

The term sarcopenia derives from the Greek "sarx" meaning flesh and "penia" meaning loss or poverty. It was first introduced by Rosenberg [1] in 1997 to describe the age-related loss of skeletal muscle mass and function, after seminal publications by Evans and Campbell regarding the declining functional status observed in older individuals with changes in body composition [2–4]. Initially, it was thought that only muscle wasting occurred in elderly individuals, but sarcopenia is now recognized as a complex concept that involves not only loss of muscle mass but also decreased muscle strength, and a resulting decline in functional capacity. Functional parameters came to be included in the definition because they have consistently been shown to be a stronger predictor of outcomes than muscle mass alone [5]. Indeed, sarcopenia is a progressive and generalized skeletal disorder that is not necessarily synonymous with leanness. It may also be present in overweight and obese individuals, a condition now termed "sarcopenic obesity" (*see* Chap. 14). A distinction may also be made between primary, or age-related sarcopenia, and secondary sarcopenia, which is more disease-related.

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1.2 Definitions

Over the years since its first description, there has been a steady increase in research and publications about sarcopenia, and a number of groups and societies have published operational definitions of sarcopenia for use in clinical practice and in research settings. Following a meeting of a group of geriatricians and scientists from academia and industry in 2009, the International Working Group on Sarcopenia published a definition of sarcopenia, namely the "age-associated loss of skeletal muscle mass and function" [6]. In 2010, the European Working Group on Sarcopenia in Older People (EWGSOP) developed a clinical definition together with consensus diagnostic criteria for age-related sarcopenia, which recommended that both low muscle mass and low muscle function (i.e., strength or performance) be considered [7]. The EWGSOP further defined stages of severity, with a gradual scale from pre-sarcopenia to sarcopenia to severe sarcopenia. The EWGSOP consensus was updated in 2019 to reflect the growing body of evidence that has emerged since its first publication [8]. In parallel, professional societies in Asia also worked to prepare consensus definitions on sarcopenia, due to the fact that the cultural, lifestyle, and anthropometric differences call for specific considerations when diagnosing sarcopenia in people of Asian descent. In this regard, the Asian Working Group on Sarcopenia published a diagnostic algorithm for sarcopenia using cut-offs and reference levels derived from Asian populations [9], which was updated in 2019, revising some of the component criteria and cut-offs [10]. In 2011, the Society on Sarcopenia, Cachexia and Wasting Disorders Trialist Workshop convened a consensus conference, which concluded that "sarcopenia, i.e., reduced muscle mass, with limited mobility should be considered an important clinical entity" [11]. Their definition was based on walk speed on the 6-min walk test and lean appendicular mass corrected for height. Finally, the Foundation for the National Institutes of Health (FNIH) Sarcopenia Project also developed an operational definition of sarcopenia based on data from 9 sources totalling over 26,000 individuals to identify clinically relevant and independently validated thresholds that could be used to identify participants for clinical trials, and individuals with significant functional limitation [12].

The abundance of research in the field of sarcopenia culminated in the recognition of sarcopenia as a distinct disease, with its inclusion in the International Classification of Diseases tenth Revision (ICD-10) in 2016 (under the ICD code M62.84) [13, 14]. This important step meant that the condition could be cited on medical records, death certificates, and other data sources, which can help harmonize practices, compare data, and promote research. The recognition of sarcopenia as a disease entity also provides additional stimulus for pharmaceutical companies to invest in research and development in this area, by allowing for billing and reimbursement possibilities.

The various definitions of sarcopenia developed by professional societies, as well as other combinations of criteria used in the literature to define sarcopenia, will be discussed in greater detail in Chap. 3. Suffice to say, however, that there are wide variations across all these definitions in the components included, the methods used to measure these components, and the cut-off values used to distinguish

pathological states. For the measurement of muscle mass, dual-energy X-ray absorptiometry (DXA) is a widely available, noninvasive method for determining muscle quantity (i.e., total body lean tissue mass or appendicular skeletal muscle mass) and is considered by many as the gold standard. However, inconsistencies may exist across measurements performed with different machines, rendering comparison difficult [15]. Other methods used to assess muscle mass include bioelectrical impedance analysis (BIA), computed tomography (CT), or magnetic resonance imaging (MRI), as well as simple anthropometric measures. Muscle strength can be measured easily and inexpensively by assessing hand-grip strength with a calibrated handheld dynamometer. For patients in whom disability of any type precludes measurement of hand-grip strength, leg strength can be used as a proxy, for example, via the chair stand test, timed chair stand test, or the timed up-and-go test. Other measures of mobility, such as gait speed, or walk test performance are also widely used. The heterogeneity of definitions, criteria, measurement methods, and cut-off values makes it extremely difficult to compare estimates of sarcopenia prevalence between studies. Estimates are also affected by the populations used to define the normal range reference values and the setting in which those cut-offs are applied (e.g., community-dwelling adults, versus nursing home residents, versus acute hospital care) [16]. This underlines the need for a consensual definition, to enable comparison of the burden of disease worldwide, as the lack of agreement between definitions hampers the integration of sarcopenia into clinical practice.

1.3 Prevalence of Sarcopenia

The prevalence of sarcopenia is notoriously difficult to compare across studies, in view of this heterogeneity of definitions and measurement possibilities. Nevertheless, recent years have seen a striking increase in the number of publications investigating sarcopenia prevalence, risk factors, and outcomes. Many of these are now using established definitions, thus allowing for some comparison of rates across studies as the body of evidence grows. Table 1.1 displays a selection of prevalence estimates from recent publications in various populations. It can be seen that there are wide variations in reported rates between studies, and even within studies, when different criteria are used to define sarcopenia. The burgeoning volume of publications on the prevalence of sarcopenia has led to ever more precise estimates, and reports providing pooled estimates from systematic reviews and/or meta-analysis. For example, in a systematic review and meta-analysis, Mayhew et al. examined 109 studies using 8 different sarcopenia definitions (including the EWGSOP, AWGS, FNIH, and IWGS definitions), with a total of 227 individual prevalence estimates in community-dwelling older adults (>60 years) without specific health conditions [24]. Overall, estimated prevalence ranged from 9.9 to 40.4% and was lowest with the EWGSOP/AWGS (12.9%, 95% CI: 9.9, 15.9%), IWGS (9.9%, 95% CI: 3.2, 16.6%), and FNIH (18.6%, 95% CI: 11.8, 25.5%) definitions [24]. In another systematic review and meta-analysis, Shafiee et al. included 35 population-based studies reporting the prevalence of sarcopenia in healthy adults aged ≥60 years from different regions of

Table 1.1 Selected data from the literature on prevalence of sarcopenia in different populations

Author, year (Reference)	Study population	Age	Findings
Purcell, 2020 [17]	12,592 community-dwelling subjects from the Canadian Longitudinal Study on Aging (6314 men (50.1%), 6278 women (49.9%))	All 65 y or older	Across different definitions, prevalence (all ages combined) ranged from: – 0.2% (EWGSOP2) to 5.2% (IWGS) in men – 0.2% (EWGSOP2) to 7.2% (IWGS) in women
Martone, 2020 [18]	11,253 community-dwelling subjects from the Italian Longevity Check-up 7+ project (4897 men (44%), 6356 women (56%))	Mean 55.6 ± 14.8 y Range 18–98 y	8.6% had probable sarcopenia according to the EWGSOP2 definition. Prevalence increased with age to reach 54.2% in women and 42.4% in men older than 80 y
Ligthart-Melis, 2020 [19]	Meta-analysis of 15 studies totalling 4014 hospitalized patients	Mean ranged from 62 to 86 y across studies	Pooled estimates: – 37% (95% CI 26–48) overall – 44% (95% CI 29–58) in the medical subgroup – 22% (95% CI 19–25) in the surgical subgroup – 25% (95% CI 9–40) in the mixed medical/surgical subgroup
Pang, 2020 [20]	542 community-dwelling Singaporeans (57.9% women)	Mean 58.5 ± 18.8 Range 21–90 y	Prevalence estimates according to definition: AWGS 2014: – 6.7% overall, 6.9% in men, 6.4% in women AWGS 2019: – 13.6% overall, 13% in men, 14.2% in women EWGSOP2: – 7.1% overall, 9.2% in men, 5.3% in women
Wearing, 2020 [21]	219 community-dwelling Swiss subjects	82.6 ± 5.2 (men), 84.1 ± 5.7 (women)	Using the cut-off for hand-grip strength from EWGSOP2, prevalence of probable sarcopenia was 26.3% in women and 28% in men
Nguyen, 2020 [22]	600 outpatients attending the National Geriatric Hospital in Hanoi, Vietnam (60.8% females)	70 ± 8 y	Prevalence estimates according to definition: AWGS 2019: – 54.7% overall FNIH: – 40.5% overall Rates were significantly higher in men than in women in both definitions

Table 1.1 (continued)

Author, year (Reference)	Study population	Age	Findings
Makizako, 2019 [23]	7974 community-dwelling Japanese subjects from 9 studies (3723 men, 4367 women)	All 60 y or older	Using AWGS criteria: In individual studies: – 4.7–25.7% overall prevalence – 4.9–25.0% in men – 4.5–26.1% in women Pooled prevalence estimates: – 9.9% (95% CI 6.2–15.4) overall – 9.8% (95% CI 6.2–15.2) in men – 10.1% (95% CI 6.4–15.5) in women
Mayhew, 2018 [24]	Meta-analysis of 109 articles totalling 58 cohorts from 26 countries; all community-dwelling adults without specific diseases	Minimum 55 y	Pooled prevalence estimates according to definition: EWGSOP/AWGS: – 58,283 participants from 83 studies: 12.9% (95% CI 9.9–15.9) IWGS: – 10,381 participants from 12 studies: 9.9% (95% CI 3.2–16.6) FNIH: – 6467 participants from 16 studies: 18.6% (95% CI 11.8–25.5)
Churilov, 2018 [16]	Meta-analysis of 6 studies of post-acute inpatient rehabilitation (of which 5 post hip fracture)	Mean ranged from 79.7 ± 7.4 to 84.6 ± 6.6 y	Prevalence ranged from 28 to 69% across studies Pooled prevalence: 56% (95% CI 46–65%)
Shafiee, 2017 [25]	Meta-analysis of 35 articles totalling 58,404 community-dwelling individuals (55.9% men, 44.1% women)	All ≥60 y	Articles included used EWGSOP, AWGS, and/or IWGS definitions. Overall prevalence 10% (95% CI 8–12%) in men and 10% (95% CI 8–13%) in women Across individual studies, rates ranged from 0.35% to 36.6% according to the study and definition used
Kim, 2016 [26]	1464 community-dwelling Japanese subjects (246 men, 1218 women)	74.3 ± 5.17 y (men) 79.9 ± 4.43 y (women)	Using DXA-measured definitions: – 2.5–28.0% in men – 2.3–11.7% in women Using BIA-measured definitions: – 7.1–98.0% in men – 19.8–88.0% in women

(continued)

Table 1.1 (continued)

Author, year (Reference)	Study population	Age	Findings
Sousa, 2015 [27]	608 hospitalized adults from medical and surgical wards, conscious and not cognitively impaired; critically ill patients excluded	Median 57 y Range 18–90 y 31.7% ≥65 y 4.6% >80 y	25.3% sarcopenic using the EWGSOP definition. Depending on age and criteria used to define sarcopenia, estimated prevalence ranged from 5% to 41.1% in men and from 4.9% to 38.3% in women
Cruz-Jentoft, 2014 [28]	18 studies of prevalence: 15 in community-dwellers, 2 in long-term institutions, 1 in acute hospital care	Mean (when given) ranged from 59.2 to 85.8 y	Prevalence: – 1–29% in community-dwellers (up to 30% in women) – 14–33% in long-term institutions (up to 68% in men) – 10% in the study of acute hospital care
Volpato, 2014 [29]	730 community-dwelling Italian individuals from the InCHIANTI study	All ≥65 y Mean 83.8 ± 5.92 in sarcopenic vs. 76.3 ± 4.96 in non-sarcopenic individuals	Using the EWGSOP definition, 16.7% were pre-sarcopenic and 7.5% were sarcopenic
Lee, 2013 [30]	386 elderly community-dwellers from the I-Lan Longitudinal Ageing Study, Taiwan (57.8% men)	74.4 ± 6.1 y (men) 72.8 ± 4.9 y (women)	Using relative skeletal mass index: EWGSOP: – 7.8% overall, 10.8% in men, 3.7% in women IWGS: – 4.1% overall, 5.8% in men, 1.8% in women. Using percentage skeletal muscle index: EWGSOP: – 16.6% overall, 14.9% in men, 19.0% in women IWGS: – 11.1% overall, 10.8% in men, 11.7% in women.
Pongchaiyakul, 2013 [31]	832 Thai subjects (435 urban, 397 rural dwellers)	49.34 ± 17.26 y (men) 50.45 ± 15.54 y (women)	35.33% (95% CI, 29.91–40.41) in men 34.74% (95% CI, 30.56–39.10) in women
Janssen, 2006 [32]	5036 noninstitutionalized elderly men and women from the Cardiovascular Health Study	>65 y	Moderate sarcopenia: – 70.7% in men – 41.9% in women Severe sarcopenia: – 17.1% in men – 10.7% in women

Table 1.1 (continued)

Author, year (Reference)	Study population	Age	Findings
Rolland, 2003 [33]	1458 non-institutionalized women recruited from electoral lists; final sample for analysis comprised 1311 women	All >70 y Mean 80.3 ± 3.8 y	Prevalence 9.5% (95% CI 7.9–11.1%)
Lauretani, 2003 [34]	1030 persons (469 men, 561 women) from the InCHIANTI epidemiological study	Range 20–102 y	Men: – 20% at 65 years – 70% at 85 years Women: – 5% at 65 years – 15% at 85 years
Baumgartner, 1998 [35]	808 elderly Hispanic and non-Hispanic white men and women from the New Mexico Elder Health Study (47.3% women)	73.6 ± 5.8 y (men) 73.7 ± 6.1 (women)	<70 y: – 13.5–16.9% (men) – 23.1–24.1% (women) 70–74 y: – 18.3–19.8% (men) – 33.3–35.1% (women) 75–80 y: – 26.7–36.4% (men) – 35.3–35.9% (women) >80 y: – 52.6–57.6% (men) – - 43.2–60.0% (women)

y years, *CI* confidence interval, *EWGSOP* European Working Group on Sarcopenia in Older People, *EWGSOP2* 2019 revised European consensus on definition and diagnosis of sarcopenia, *IWGS* International Working Group on Sarcopenia, *AWGS* Asian Working Group on Sarcopenia, *FNIH* Foundation for the National Institutes of Health, *DXA* dual-energy X-ray absorptiometry, *BIA* bioelectrical impedance analysis

the world, using the EWGSOP, IWGS, and AWGS definitions [25]. They reported an overall prevalence of 10% in both men and women, although estimates ranged from 0.35 to 36.6% across studies, depending on the definition used. There was significant heterogeneity between men and women in Shafiee's meta-analysis [25]. Furthermore, analysis by region showed that individuals in non-Asian countries were more likely to have sarcopenia than those from Asian countries, in both genders (11% vs. 10% in men, 13% vs. 9% in women) [25].

Even though it is almost impossible to pinpoint an actual rate of prevalence of sarcopenia, projections indicate that the rate is rising and looks set to continue increasing in the future, as worldwide population ageing adds growing numbers of older people to the pool of potentially sarcopenic individuals. In a study using the various diagnostic cut-offs proposed by the EWGSOP for lean mass, muscle strength, and gait speed, Ethgen et al. applied interpolated age- and gender-specific estimates of sarcopenia prevalence to the Eurostat population projections for Europe up to 2045 [36]. From a previous publication comparing prevalence rates at

different cut-offs [37], Ethgen et al. chose first the definition yielding the lowest prevalence estimates, applied it to projected population estimates for Europe, and found that it would correspond to a 72.4% increase in overall prevalence of sarcopenia in the elderly, rising from 11.1% in 2016 to 12.9% in 2045. Applying the definition yielding the highest prevalence estimates, overall prevalence rates were projected to increase from 20.2% in 2016 to 22.3% in 2045 [36]. These projections portend a substantial burden of sarcopenia in coming decades, which will have important repercussions for society in terms of healthcare delivery and costs.

1.4 Risk Factors

Numerous risk factors for sarcopenia have been reported in the literature, some of which are non-modifiable, such as age and gender; others are modifiable and exert their influence across the life course. Among the non-modifiable risk factors, the most consistent body of evidence supports an increasing risk of sarcopenia with older age [5, 18, 22, 27, 29, 38]. Indeed, muscle mass begins to decline around the fifth decade of life, with an annual decline rate of 1–2% [39–41], accelerating in the sixth and subsequent decades to reach a loss of around 15% per decade beyond the age of 70 [42, 43]. Regarding gender, conflicting results have been reported regarding the difference in risk in men and women, but consensus seems to be emerging in favor of an increased risk of sarcopenia in men. Landi et al. reported a 13-fold increased risk in male nursing home residents (odds ratio (OR) 13.39; 95% CI 3.51–50.63) [44], while Nguyen et al. reported a twofold increase in risk of sarcopenia among male outpatients at a geriatric hospital (OR 2.03, 95% CI 1.29–3.21) [22]. Despite the existence of differences in baseline strength between the sexes, with men having greater baseline strength than women, it has been reported that muscle strength declines to a greater degree in men, thus potentially contributing to their higher risk of sarcopenia [45–47].

Concerning modifiable risk factors, nutrition and lifestyle behaviors (notably exercise) appear to be associated with muscle mass and strength in older age [48, 49]. Older people experience a natural decline in energy requirements [50], which may be accompanied by declining appetite, impaired taste or smell, and changes in gastrointestinal motility and digestion [51]. If also compounded by functional impairment reducing the ability to prepare food, or social isolation, which may reduce the desire to eat or enjoyment of mealtimes, all these features come together in a vicious circle that may lead to loss of weight and muscle mass and strength, putting older individuals at risk of malnutrition and in turn, sarcopenia and/or frailty [48, 49]. The contribution of adequate nutrition to healthy aging has long been established [52], and there have been a number of studies examining the effects of various dietary components and patterns on sarcopenia and its constituent elements. However, apart from the obvious need to ensure that all older adults have adequate nutrition both in terms of quantity and quality, the potential of individual dietary patterns to affect outcome remains unclear. Indeed, there have been conflicting findings regarding the association between protein intake and muscle strength, for example, although observational

evidence tends to suggest that both strength and function are improved with increased protein intake [48]. In the same way, it is difficult to distinguish the effects of individual nutrients, such as antioxidants and omega-3 fatty acids, although overall, the best evidence supports the benefits of the Mediterranean dietary pattern in terms of functional status and incident disability [48].

The effect of exercise in reducing the negative impact of sarcopenia has been demonstrated by several studies [53–55]. In a systematic umbrella review, Beckwee et al. investigated the efficacy of different exercise interventions to counter sarcopenia in older adults [53]. They found high-quality evidence in favor of a positive and significant effect of resistance training on muscle mass, muscle strength, and physical performance from a total of 14 systematic reviews, of which 7 performed meta-analysis. Based on the evidence from their review, these authors suggest that benefits in terms of muscle mass, muscle strength, and gait speed can be expected with high-intensity resistance training, which they recommend for at least 6–12 weeks, in order to achieve these levels of improvement [53]. Similarly, Lai et al. compared the effects of exercise interventions on lean body mass, muscle strength, and physical performance in a network meta-analysis and found that resistance training (of a minimum 6 weeks duration) was the most effective intervention in improving muscle strength in older individuals [54].

Other risk factors have been less extensively investigated. Nonetheless, a meta-analysis of 12 studies totalling 22,515 participants found smoking to be an independent risk factor for sarcopenia (OR 1.20 (95% CI 1.06–1.35) in men and 1.21 (95% CI 0.92–1.59) in women) [56]. The same group also performed a meta-analysis of 13 studies including 13,155 participants to investigate the effect of alcohol on sarcopenia, but their findings did not support the hypothesis that alcohol consumption could be a risk factor for sarcopenia [57].

Other factors that have been shown to be associated with sarcopenia include age-related loss of motor-neuron end plates [58], loss of anabolic hormones and insulin resistance [42, 59], diabetes [60], obesity/waist circumference [46], level of education [29], and dependency [27, 44].

1.5 The Health Economic Burden of Sarcopenia

Sarcopenia is associated with an increased risk of falls and fractures [61, 62], frailty [63], disability [64], and cognitive impairment [65]. Low grip strength has been shown to be associated with increased morbidity and mortality [66, 67], and a meta-analysis of 11 studies investigating the impact of EWGSOP-defined sarcopenia on mortality found a more than threefold increase in the risk of mortality among sarcopenic subjects (pooled OR 3.596 (95% CI 2.96–4.37)) [68]. These deleterious outcomes can in turn translate into extended recovery time, longer length of hospital stay, and increased medical costs [68, 69].

In community-dwelling adults in the Netherlands, Mijnarends et al. reported that the mean healthcare costs of individuals with sarcopenia were significantly higher than those of non-sarcopenic subjects (€ 4325, 95% CI € 3198–€5471 vs. €1533,

95% CI €1153–€1912, respectively), mainly driven by the living situation (i.e., residential care) [70]. In the hospital setting, two studies from Portugal investigated the costs of hospitalization associated with sarcopenia. Sousa et al. assessed the hospitalization costs in 656 medical and surgical patients (24.2% sarcopenic) using diagnosis-related group codes at discharge [71]. They found that sarcopenic patients were generally older and had a longer length of stay, resulting in a median (interquartile) cost of € 3151 (€ 4175) per sarcopenic patient, compared to non-sarcopenic patients (median (IQR) € 2170 (€ 2515), $p < 0.001$) [71]. After adjustment for confounders, the economic impact of sarcopenia on hospitalization cost, i.e., the incremental cost per patient, in the overall sample was estimated at € 1117 (95% CI €644–1588), and sarcopenia was estimated to increase hospitalization costs by 39.2% in those with no comorbidities and by 54.3% in those with comorbidities [71]. In the second Portuguese study, Antunes et al. assessed hospitalization costs among 201 hospitalized older adults in a general hospital [72]. After adjustment, both sarcopenia (OR = 5.70, 95% CI 1.57–20.71) and low muscle strength alone (OR = 2.40, 95% CI 1.12–5.15) were associated with increased hospital costs. From a societal perspective, Janssen et al. evaluated the costs of sarcopenia in a representative sample of US adults aged 60 years and older, from the NHANES III and National Medical Care Utilization and Expenditures Survey (NMCUES) datasets [73]. They estimated that the direct healthcare cost attributable to sarcopenia in the USA in 2000 was $18.5 billion ($10.8 billion in men, $7.7 billion in women), representing 1.5% of total healthcare expenditure, with sensitivity analyses indicating that the cost could be as low as $11.8 billion and as high as $26.2 billion. They further estimated that a 10% reduction in the prevalence of sarcopenia would result in savings of $1.1 billion (dollar value in the year 2000) per year in US healthcare costs [73]. A more recent study from the USA updates this information and shows that costs are already on the rise; Goates et al. performed a retrospective economic burden study among 4011 adults aged 40 years and over from the NHANES dataset [74], of whom 15.1% were sarcopenic. They reported an annual total cost of hospitalization for individuals with sarcopenia of $40.4 billion, with an average estimated marginal cost increase in annual hospital spending of $2315 per sarcopenic individual, compared to those with normal muscle mass and function. In addition, they reported that individuals with sarcopenia had an almost twofold increase in the risk of hospitalization (OR 1.94, $p < 0.001$) and more hospital stays on average, compared to those without sarcopenia [74]. There is wide heterogeneity among studies on the economic burden of sarcopenia, with different approaches used to estimate costs, different time horizons for measurements, and different definitions of sarcopenia. With populating ageing continuing its onward march around the world, there is a compelling need to continue providing up-to-date estimates of sarcopenia-associated healthcare costs, particularly using standardized definitions and cost analysis parameters, not least to prepare for the substantial burden that this will represent on healthcare systems in the coming decades. The alarming estimates of the burden that sarcopenia represents on healthcare also underscores the need to focus preventive measures on preserving muscle mass, strength, and function as long as possible into older age.

1.6 Conclusion

Sarcopenia is characterized by an age-related loss of muscle mass, muscle strength, and/or physical function. It is associated with a high risk of morbidity and mortality, poor clinical outcomes, and increased events, such as falls, fractures, and hospitalizations. It represents a significant burden on healthcare systems worldwide, which looks set to increase in the coming decades. A strong research agenda is warranted to expand our knowledge of the etiological factors involved in the development of sarcopenia, and which could be leveraged to prevent or slow the onset of sarcopenia, or its progression to more severe forms. Systematic screening of older individuals is warranted to detect those with lower muscle strength, with a view to initiating early interventions to retard sarcopenia. Resistance training, of a minimum 6 weeks duration, has been shown to be most effective in achieving improvements in muscle strength in older adults. The benefit of adequate nutrition in contributing to healthy ageing has also been well established. Other interventions to promote healthy ageing and preserve muscle mass, strength and function into older age are warranted, to counter the effects of ageing and maintain functional capacity as long as possible. The considerable economic burden of sarcopenia on healthcare costs justifies the implementation of preventive measures, perhaps over the life course and almost certainly warranted from midlife onwards, in order to stem the tide of negative consequences that flows from the presence of sarcopenia.

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