REVIEW

Journal of Cachexia, Sarcopenia and Muscle 2022; **13**: 1653–1672
Published online 20 March 2022 in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/jcsm.12981

Roles of nutrition in muscle health of community-dwelling older adults: evidence-based expert consensus from Asian Working Group for Sarcopenia

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Abstract

General muscle health declines with age, and in particular, sarcopenia—defined as progressive loss of muscle mass and strength/physical performance—is a growing issue in Asia with a rising population of community-dwelling older adults. Several guidelines have addressed early identification of sarcopenia and management, and although nutrition is central to treatment of sarcopenia, there are currently few guidelines that have examined this specifically in the Asian population. Therefore, the Asian Working Group for Sarcopenia established a special interest group (SIG) comprising seven experts across Asia and one from Australia, to develop an evidence-based expert consensus. A systematic literature search was conducted using MEDLINE on the topic of muscle health, from 2016 (inclusive) to July 2021, in Asia or with relevance to healthy, Asian community-dwelling older adults (≥60 years old). Several key topics were identified: (1) nutritional status: malnutrition and screening; (2) diet and dietary factors; (3) nutritional supplementation; (4) lifestyle interventions plus nutrition; and (5) outcomes and assessment. Clinical questions were developed around these topics, leading to 14 consensus statements. Consensus was achieved using the modified Delphi method with two rounds of voting. Moreover, the consensus addressed the impacts of COVID-19 on nutrition, muscle health, and sarcopenia in Asia. These statements encompass clinical expertise and knowledge across Asia and are aligned with findings in the current literature, to provide a practical framework for addressing muscle health in the community, with the overall aim to encourage and facilitate broader access to equitable care for this target population.

Keywords Muscle; Sarcopenia; Older adults; Community; Nutrition; Malnutrition

Received: 21 December 2021; Accepted: 15 February 2022
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Introduction

By 2050, a quarter of Asia's population is predicted to be ≥60 years old, while those aged ≥80 years old will account for one-fifth of all 'older adults' (≥60 years) in Asia.[1] This trend towards an increasingly older population will inevitably lead to an increased prevalence of not just chronic diseases but also disability and loss of ability to live independently due to a multitude of underlying etiologies. Therefore, public health strategies to maintain healthy, independent living among community-dwelling older adults are of utmost importance both in terms of maintaining a fulfilled life for this age group and in managing available healthcare resources.

Age-related loss of skeletal muscle plus loss of muscle strength or/and reduced physical performance, known as 'sarcopenia', are growing public health problems in healthy community-dwelling older adults in Asia.[2,3] The Asian Working Group for Sarcopenia (AWGS) set out clear statements in a 2019 expert consensus, building on previous publications in 2014 and 2016, to aid early identification of individuals at risk of sarcopenia in Asian countries.[4] Topics included epidemiology, screening and diagnosis, cut-off points for sarcopenia diagnosis methods and criteria, associations of sarcopenia with other diseases, as well as management of sarcopenia. However, although physical activity and a healthy diet/good nutrition are core strategies for the management and prevention of sarcopenia, the topic of nutrition was not well addressed. Therefore, this expert consensus aimed to address that gap and to set out a series of clear statements regarding clinical decision-making around nutrition in muscle health that will be specifically applicable to community-dwelling older adults living in Asia (aged ≥60 years) and contribute to the global view of care for people with sarcopenia.

Consensus procedures

The AWGS established a special interest group (SIG) of eight experts in the Asia-Pacific region, to develop this expert consensus. The SIG convened for three meetings via videoconferencing, with active participation and attendance by all members. Prior to the first meeting, a literature search was carried out using MEDLINE to identify articles relevant to the roles of nutrition in muscle health in healthy, community-dwelling adults aged ≥60 years. Although the global cut-off for older persons is ≥65 years, we included those aged ≥60–65 as well, to account for a younger definition of 'older adults' in some Asian countries. A few studies cited do include adults below this age range, but they were only included if the mean age was ≥60 years. The search was limited to English language articles published from 2016 (inclusive) to July 2021; studies were included if they were conducted in Asia or had relevance to the Asian population (including Japan, Korea, China, Hong Kong, Taiwan, the Philippines, Vietnam, Malaysia, Thailand, Singapore, Indonesia, Laos, Myanmar, and Cambodia). Selected articles included randomized controlled trials (RCTs), meta-analyses, systematic reviews, longitudinal observational studies, cross-sectional studies, and/or retrospective studies. Case studies, and surveys, general reviews, pre-prints, and congress abstracts were excluded. The search terms were selected to avoid filtering out relevant studies; for example, middle-aged adults (45–65 years) were initially included, and then all irrelevant studies (e.g. patients <60 years, hospitalized, with co-morbidities, biomarkers, animal studies, and outside of Asia) were de-selected. Some studies have enrolled participants younger than 60 years, but only studies with subset analysis for people aged 60 years or older were included in this consensus paper.

Key topics were established from the literature search and the first meeting was used to match these topics to key clinical questions (in PICO—Patient/Population, Intervention, Comparison, Outcome, format), with active discussion and round table agreement. The clinical questions were then matched with supporting literature (and the search expanded if specific terms were missed the first time), and based on this, a first set of draft statements were prepared. The draft statements and their supporting literature were presented at the second meeting. Active discussion took place around the strength of statement support evident in the literature, other relevant information from clinical practice, and supplementary sources (e.g. websites) that could be used to further support/inform the statements. The initial 15 draft statements and supporting text providing a rationale for each statement were further refined and sent to each SIG member for anonymous online voting, using a 5-point Likert scale: (1) accept completely, (2) accept with some reservation, (3) accept with major reservations, (4) reject with reservations, and (5) reject completely. The percentage agreement was calculated based on a weighted scale for each vote, with >80% agreement sufficient for the statement to achieve consensus. Agreement was reached for all statements in the first round of voting, with only minor changes to the wording suggested. At the third meeting, the final wording of each statement was proposed, and a second vote took place to establish full consensus; two statements remained unchanged and did not require re-voting. All statements reached >92.5% agreement and final discussion took place with regard to information that should be included in the supporting text. The final 14 statements are detailed in *Table* 3, with a literature overview providing rationale for each statement detailed below.

Nutritional status

Malnutrition and screening

With an increasingly aging Asian population, malnutrition is also a growing problem. The reported prevalence of being at risk for malnutrition in Asia among community-dwelling older adults varies from 16% to 73%, whereas that of being malnourished can be as high as 22%.[5–13] There is also a growing body of evidence that nutritional status may be a modifiable risk factor for the development of muscle health issues, including sarcopenia. Therefore, identifying individuals at risk of malnutrition, to provide early intervention, is an important public health strategy for preventing the development of sarcopenia and related complications, such as frailty.[14] Although older adults with obesity are also at risk for muscle health problems, the SIG members consider this a topic worthy of separate consideration at another forum. This consensus focuses on undernutrition as an underlying cause of sarcopenia, and therefore malnutrition as a starting point for issues pertaining to muscle health.

Several cross-sectional studies in Asia make a link between malnutrition and sarcopenia and advise early identification of older adults with associated risk factors. Relative appendicular skeletal muscle mass in community-dwelling older adults was examined in both a 'nourished cohort' (n = 400, mean age 71) and an 'at risk of malnutrition cohort' (n = 811, mean age 74) and found that the latter subgroup were four times more likely to have low muscle mass based on AWGS 2019 cut-off values.[15,16] In a study of older adults (≥65 years) conducted in Taiwan, participants were evaluated for nutritional status using the Mini Nutritional Assessment-Short Form (MNA-SF) and for frailty via the Study of Osteoporotic Fractures (SOF) index.[5] It was concluded that malnutrition risk should be evaluated in community-dwelling older adults, and frailty was identified as a major risk factor for malnutrition.[5] Those most at risk of malnutrition were predominantly male with lower body weight, lower body mass index (BMI), lower skeletal mass indices, and poorer muscle strength, had less energy, and more often had sarcopenia and measures of frailty, compared with well-nourished older adults. A further study examined the overlapping prevalence of malnutrition and sarcopenia and the association between parameters of malnutrition with muscle mass/strength in a community-dwelling Singaporean adult population (N = 541; 21–90 years old; average age 58.6 years).[13] Nutritional status was measured using MNA-SF and other questionnaires assessed levels of physical activity and cognition. The study concluded that being at nutritional risk/malnourished was significantly associated with 2–3 times increased risk of sarcopenia in a multivariate analysis adjusting for age.[13] Additionally, favorable Mini Nutritional Assessment (MNA) parameter scores on food intake and BMI were positively associated with greater muscle mass and handgrip strength (HGS) ($P < 0.05$).

A study of 301 older adults in Malaysia (mean age: 67.1 years) screened for frailty and malnutrition to find associations between the two conditions.[12] The study found that the mid-upper arm circumference, calf circumference (CC), and skeletal muscle mass index were all significantly associated with malnutrition risk; lower skeletal muscle mass also independently increased the odds of being at risk for malnutrition in multivariate analysis. Similarly, a cross-sectional study in Indonesia among older adults (N = 527, mean age: 74 ± 7 years) reported a significant correlation between malnutrition risk and muscle function in terms of HGS and gait speed.[6] All studies concluded that community screening protocols should combine screening of nutritional status and sarcopenia, as early intervention can help maintain independent and healthy living in old age.

Social and environmental factors

Behavioral factors such as dietary and eating patterns play a large role in malnutrition, but social/environmental factors such as living conditions and low socio-economic status also need to be acknowledged. In studies from different Asian countries (Hong Kong, Malaysia, Myanmar, and the Philippines), older adults belonging to low-income strata uniformly comprised majority of the study population, representing up to 81.1% of participants.[7,10–12] Generally conducted in urban settings, these studies found prevalence rates of 28.1–59.4% for malnutrition risk and 1.1–21.7% for malnutrition. In contrast, these rates may even be higher among rural dwellers. In a cross-sectional study in Indonesia, rural older people were more likely than those in urban communities to be malnourished and cognitively impaired and to have associated decreases in functional capacity and independence, suggesting the roles of education and socio-economic status.[6] The proportion of subjects at risk for malnutrition were almost twice as high in rural than urban areas while monthly income was ~3.5 times lower in rural-living than urban-living subjects. Therefore, individuals at high risk for malnutrition can potentially be identified by certain social determinants, such as those living in rural settings vs. those in urban areas, and people with low socio-economic status.

Screening tools

Most studies in Asia have used the MNA or its short form (MNA-SF) to screen for malnutrition among older adults.[6–13] In 2002, the European Society for Clinical Nutrition and Metabolism (European Society of Parenteral and Enteral Nutrition) recommended the MNA as a screening tool for the older adults as it is easy to put into practice and takes <10 min to complete.[17] A subsequent systematic review deemed MNA-SF the most appropriate screening tool for community-dwelling older adults, based on the presence of extensive testing for validity and reliability as well as good results.[18] The review found MNA-SF, which contains only 6 questions compared with the 28-item MNA, to have high internal consistency, sensitivity (97.9–98%), and specificity (94–100%), albeit according to predominantly non-Asian studies. In Asia, the MNA-SF has demonstrated sensitivities of 81.8–100% and specificities of 74–97.3%.[19–21] It has exhibited predictive validity for sarcopenia, poor quality of life (QoL), and mortality among Asian older adults.[9,13,22,23]

The Short Nutritional Assessment Questionnaire (SNAQ©) is a three-item questionnaire assessed to have only fair validity and reliability as a screening tool for community-dwelling older adults, with a reported sensitivity of 45–88%, and specificity of 83–99% in non-Asian studies[18,24] and a sensitivity of 32.9–69.2% and specificity of 61.3–73.1% in Asian studies, compared against MNA-SF, MNA, and GLIM-criteria, respectively.[25–27] Therefore, with lower overall sensitivity and specificity, SNAQ is a less favourable choice for community screening. The Malnutrition Universal Screening Tool (MUST) has been evaluated in hospitalized patients, community-dwellers, and care homes, but although it is widely used in the BAPEN circle (bapen.org.uk), we did not find any studies in Asia examining its sensitivity and specificity for community-dwelling older adults and therefore cannot comment on this population.

There is limited literature to help determine who should carry out screening protocols, but from our clinical experiences, and in order to broaden access to screening, we have recommended both healthcare professionals such as physicians, dietitians, as well as 'trained personnel'. We can envision scenarios in different countries and different settings where additional personnel, such as community care providers or social workers, who may not officially be considered healthcare professionals, could effectively complete this task.

In conclusion, there is a strong link between muscle health and malnutrition, indicating that early identification of older adults at risk of malnutrition could prevent the onset of sarcopenia in many healthy, community-dwelling adults, and some subgroups at higher risk (e.g. people living in rural areas and those with low socio-economic status) may need closer observation. Please see *Table* 1, Consensus Statements 1–3.

Diet and dietary patterns

Communal eating

Specific diets and dietary patterns in older adults often lead to undernutrition and ultimately malnutrition, as discussed above. Therefore, finding ways to promote regular food intake and healthy eating in this age group is crucial to promoting and maintaining muscle health. Older adults often make simpler food choices when eating alone and are influenced by several societal factors.[28–30] Therefore, encouraging eating in communal and social settings (within the parameters of any COVID-19 regulations), where there is a variety of food on offer, could potentially improve food choices and consumption in this age group, which will have an overall benefit on well-being and muscle health.[31,32]

There are a limited number of trials within Asia that have specifically addressed communal eating in relation to muscle health. However, one RCT (n = 86; average age 75.6 ± 5.6 years) in Japan examined an integrated 12 week programme of specially devised lunch gatherings containing textured foods (that are hard and cut into larger pieces, therefore require more chewing—so-called munchy lunch) in community centres, with physical exercises, on the improvement of physical function in community-dwelling older adults.[32] A greater decrease in body fat percentage and results of the timed up-and-go test were observed in the intervention group (exercise plus munchy lunch) compared with the controls (only exercise) ($P < 0.05$), indirectly suggesting some benefits on overall muscle health from combining communal eating with exercise.[32]

Two other studies of note in Asia support social measures to improve overall healthy eating.[33,34] A cross-sectional survey among 2196 Japanese older adults revealed that a higher frequency of 'eating together with someone was significantly associated with more diet satisfaction and not being frail.[33] In women, this higher frequency was associated with a subjective health feeling as well as higher food diversity.[33]

Dairy and alternative dietary components

Although we do not have a statement specifically recommending dairy as a dietary component, we feel that it is relevant to consider the literature in the wider context of diet, particularly in the Asian population, and therefore present a brief literature overview here.

There are considerable data supporting that a diet high in dairy products is good for muscle health as they contain many of the essential components for muscle growth and development.[35] However, due to historic availability of dairy products in Asia, and a high prevalence of lactose intolerance in the Asian population, there is generally lower dietary consumption of dairy.[36] Therefore, studies in Asia have focused on the benefits of the nutritional components of dairy products, for example, milk fat globule membrane (MFGM) and whey protein. However, two small-scale RCTs involving healthy older adults in Japan (total N = 86, range of mean age: 72.3–73.1 years) found limited evidence of treatment benefits from MFGM in terms of muscle mass muscle strength, and overall physical performance, although Watanabe *et al*. measured significant changes in motor firing rates following resistance training compared with the placebo group, and Yoshinaka *et al*. measured improvements in foot tapping and open–close stepping scores.[37,38] Therefore, both studies concluded that MFGM may enhance the benefits of light-intensity exercise.

Three RCTs have examined the effects of whey protein supplementation.[39–41] Two are discussed in further detail in the later section of this article 'Protein Supplementation'

Table 1 Consensus statements

Malnutrition and screening
1 Initial screening for malnutrition risk should be conducted annually in older adults living in the community. Older adults who present with low body mass index (BMI), unintentional weight loss, and low muscle mass or exhibit poor muscle strength at any time should be assessed for malnutrition.
2 Community screening should be carried out by healthcare professionals or trained personnel and use standard tools. Older adults identified as being malnourished or at risk of malnutrition should be referred to a relevant healthcare professional for further assessment. Those at risk of malnutrition should be re-screened every 3 months.
3 Older adults in certain settings such as those living in rural areas, in social isolation, and with low socio-economic status may be at higher risk for malnutrition and should be screened more often than once a year.
Diet and dietary patterns
4. Opportunities for communal and social eating among older adults, using a variety of food types, may improve healthy eating, overall well-being, and muscle health, with observance of public health measures for COVID-19.
5. When possible, nutritional counselling around good dietary practice for those at risk of malnutrition or sarcopenia should be provided by healthcare professionals prior to dietary enrichment or supplementation.
Nutritional supplementation
6. To maintain sufficient protein intake, we recommend a daily protein intake of ≥1.0 g/kg BW for healthy older adults and ≥1.2 g/kg BW for those with sarcopenia and/or frailty. This target protein intake should be achieved primarily by diet, and where that is not possible, then protein supplementation can be considered.
7. For older adults who are candidates for supplementation, high-quality protein, amino acids such as leucine and L-carnitine, or oral nutritional supplement (ONS) containing beta-hydroxy-beta-methylbutyrate (HMB) may be considered and should be taken according to the specific prescribing information.
8. Determination of serum 25-OH vitamin D levels can be considered in patients at risk of malnutrition or sarcopenia. Oral vitamin D supplementation (800–1000 IU/day) may be beneficial for older adults with vitamin D insufficiency. Higher doses may be required for those who are deficient in 25-OH vitamin D.
Lifestyle interventions
9. Nutritional supplementation in older adults, combined with an exercise regimen, is recommended for additional benefit in the management and prevention of sarcopenia.
10. When feasible, the exercise component of the combined intervention should be varied to include resistance training, moderate-intensity aerobic exercise, and balance training. Each exercise session should be structured (e.g. warm-up–resistance/balance–aerobic–cool-down) and have a frequency of two to three times per week.
11. Where possible, the combined intervention should be tailored, preferably guided by a trained personnel and in a group exercise setting, either delivered in-person or remotely via suitable videoconferencing platforms.
Outcomes and assessments
12. Screening or assessment using appropriate measurements such as weight, body mass index (BMI), calf circumference (CC), hand grip strength (HGS), or the 5-time chair stand test (CST) can be performed at follow-up appointments to monitor outcomes and response to initiated interventions, referring to a physician when required.
13. Measurement of health-related quality of life (QoL) and impairments in instrumental activities of daily living (IADL) are additional measures that may be used to assess outcomes in response to initiated interventions.
Impacts of COVID-19
14. Ongoing public health measures for COVID-19 (lockdown/circuit-breakers/social distancing) are an increased risk factor for malnutrition and sarcopenia; therefore, more attention should be paid to improved nutrition and exercise during the COVID-19 pandemic.

Please note that all statements refer to healthy community-dwelling older adults (age ≥ 60 years).

and the third by Mori and Tokuda is summarized: a multi-domain study in women (n = 81; average age 70.6 years) to assess whey protein supplementation along with exercise.[40] Participants were allocated to three groups: (1) exercise and protein supplementation, (2) exercise only, and (3) protein supplementation only taking part in a 24 week programme with twice-weekly intervention of exercise and/or 22.3 g of protein. The total protein intake for all three experimental groups was adjusted to a level of ≥1.2 g/kg/day, with more during the intervention period for those assigned protein supplementation alone or in addition to exercise. An increase in skeletal muscle mass was significantly higher for those in the exercise and protein supplementation group compared with exercise only (P = 0.007) or supplementation only ($P <$ 0.001). A similar increase was seen in the dual intervention group for HGS (P = 0.014) and gait speed (P = 0.026), compared with the protein supplementation only group. It was concluded that whey protein supplementation administered after resistance exercise could provide benefits for the prevention of sarcopenia among community-dwelling older Japanese women.

Dietary patterns

Two Asian studies assessed dietary patterns. One cross-sectional study (n = 861; 71.0 ± 4.8 years) explored the association between dietary patterns, nutrients, and sarcopenia in community-dwelling older Chinese people across three regions.[42] Dietary intake was assessed via a questionnaire and anthropometric body measurements were taken; sarcopenia was diagnosed according to the AWGS 2014 criteria. A 'mushrooms–fruits–milk' pattern (high protein intake and low percentage of energy from fat) was found to be protective for sarcopenia, suggesting that in addition to protein, lowering the percentage energy from fat may also be considered for sarcopenia prevention and management. The second study was a prospective cohort study (mean age 72.2 and

76.2 years for non-sarcopenic and sarcopenic at baseline), which examined adherence to dietary patterns relating to the Diet Quality Index-International (DQI-I) and the Mediterranean Diet Score.[43] A cross-sectional analysis (n = 3957) was used to assess the associations between dietary patterns and prevalent sarcopenia, and a longitudinal analysis (n = 2948) for the 4 year incidence of sarcopenia with adjustment for sociodemographic and lifestyle factors. Higher DQI-I, a higher 'vegetables–fruits' and a higher 'snacks–drinks–milk product' dietary pattern score were all associated with lower odds of having sarcopenia in Chinese older men. However, the same effect was not observed in women, and there was no association of dietary patterns with 4 year incidence of sarcopenia with either sex. Therefore, the currently available literature does not support a specific recommendation for a particular dietary pattern in relation to muscle health. This is also difficult given varying diets between countries, but the findings do relate to the general recommendation for balanced meals comprising 1/4 protein, 1/4 wholegrains, and 1/2 fruit and vegetables (adapted from My Healthy plate, www.healthub.sg).

A pro-inflammatory diet

A diet with pro-inflammatory potential has been associated with a higher risk of sarcopenia,[44–46] and therefore, it follows that a diet with anti-inflammatory potential, that is, diets including specific antioxidant-rich food, would be preventative for this condition. In a cross-sectional study (n = 2451), the consumption of dietary chilli and sweet pepper (antioxidant rich) were evaluated using a self-administered food frequency questionnaire.[47] Higher consumption of chilli and sweet pepper was found to significantly correlate with a lower risk of sarcopenia, suggesting that capsaicins and capsiates (the active anti-inflammatory compounds in these foods) may be beneficial to prevent onset of sarcopenia. Additionally, some benefit of a diet rich in betaine was observed in a 4 year community-based study (n = 1996; aged 50–75 years), which found that higher levels of serum betaine correlated with greater levels of lean percentage body mass (LM%) and a decreased risk of having lower LM%.[48]

A diet rich in red meat or processed meat has been linked with having a high pro-inflammatory index; therefore, the source of protein for muscle build-up needs to be considered carefully.[49] In a study by Peng *et al*., a 25% daily calorie intake of protein resulted in an improved 6 min walking distance, but at the expense of higher C-reactive protein.[50] Animal vs. plant proteins were compared in terms of supporting build-up of lean muscle mass in a systematic review and meta-analysis.[51] From the 18 RCTs analysed, it was concluded that the protein source did not significantly affect changes in absolute lean mass or muscle strength, but animal protein did favor the per cent lean mass, and was especially prominent in younger adults (<50 years). There was no link between protein source and benefits from resistance exercise training. Therefore, the protein source, dose, and frequency are potentially important, in particular so it does not inadvertently drive inflammation. This is further discussed in the 'Protein Supplementation' section but also adds strength to the need for nutritional counselling ahead of prescribed dietary enrichment and supplementation.

Nutritional supplementation

Proteins, amino acids, and beta-hydroxy-beta-methylbutyrate

Protein energy malnutrition increases the risk of sarcopenia among older adults.[52] Besides insufficient protein intake from anorexia of aging, older adults may have an aging-related decreased anabolic response to dietary proteins (i.e. anabolic resistance), reducing their ability to maintain muscle mass.[52,53] Accordingly, because older people may need more dietary protein than recommended levels for younger adults (0.8 g/kg BW/day), the following guidance on protein consumption has been advocated in previous literature: 1.0–1.2 g/kg BW/day for healthy older adults, 1.2–1.5 g/kg BW/day for those with acute or chronic disease, and 2.0 g/kg BW/day for those with frailty, severe illness, or malnutrition.[54]

One study comparing the effects of regular dietary protein (15% of total calorie per meal) vs. high dietary protein (25% of total calorie per meal) in community-dwelling older adults found that the estimated glomerular filtration rate was significantly decreased in the high protein group (from 103.5 ± 12.6 pre-test to 99.2 ± 15.5 ml/min/1.73m^2 post-test, P = 0.03). The high protein group also demonstrated an increase in high-sensitivity C-reactive protein.[50] No differences were observed between the high protein group and the regular protein group in terms of muscle mass or strength, although 6 min walking distance was significantly increased in the high protein group. In another trial of older adults with sarcopenia, a target protein consumption of 1.2–1.5 g/kg BW/day led to increased appendicular muscle mass index, regardless of treatment group (supplementary group received vitamin D-enriched and leucine-enriched whey protein supplement in addition to meeting dietary target).[41] A cross-sectional analysis of 3213 community-dwelling middle-aged and older adults (mean age: 60.7 years) in China found that participants with a total protein intake of >0.96 g/kg BW/day were less likely to have low muscle mass by skeletal muscle index compared with those ingesting ≤0.96 g/kg WB/day; the lowest risk of having low muscle mass was in subjects with ≥1.68 g/kg BW/day of protein intake (odds ratio 0.3, 95% confidence interval 0.2–0.4).[55] Collectively, this points to an unquantified role of increasing dietary protein intake in place,

DOI: 10.1002/jcsm.12981

or in addition, to supplementation, noting potential adverse events (AEs) at higher levels of intake.[41,50] Older adults presenting with renal impairment need to be advised separately on safe protein levels, but as this consensus specifically targets healthy older adults, we have not addressed this here.

Essential amino acids, and principally leucine, represent the major stimuli for protein synthesis[56]; hence, the amino acid profile of dietary protein sources may be an important consideration during supplementation. The muscle-building potential of protein supplementation is also affected by digestion and absorption kinetics, with some debate pertaining to possible differences between 'fast' proteins (e.g. whey) over 'slow' proteins (e.g. casein) in older populations, although overall the main aim is to meet the necessary protein requirements.[57,58]

To evaluate the effects of protein supplementation on muscle health, multiple small-scale RCTs[39,41,59–61] and one large-scale RCT[15] have been conducted in five Asian countries (China, Korea, Malaysia, Singapore, and Taiwan) with a total of 1320 subjects. See *Table* 2 for a summary of the relevant studies.

In general, the trials involved older adults aged ≥50 years (range of mean age: 58.4–74.8 years). Nutritional status ranged from non-malnourished[59] to medium–high nutritional risk as defined by the MUST,[15] although most participants had low malnutrition risk at baseline by MNA. Three studies[41,60,62] were performed solely among sarcopenic subjects, whereas three studies[39,59,63] were exclusive to pre-frail/frail subjects. Only one study included community-dwelling independently ambulating older adults with a high functional ability and little or no co-morbidities.[15]

Protein supplementation in three trials was primarily by whey protein[1,39,60] though in one study leucine was an additional ingredient with a duration of 10–26 weeks[41] and in another the protein supplement contained whey and leucine but was predominantly casein (50%).[61] While the methods of preparation differed, the supplements provided approximately 40–60 g of protein per day, divided into 2–3 doses before meals or 30 min after exercise. Additionally, we found three trials in which the intervention consisted mainly of amino acids: one trial on the lysine-derivative L-carnitine (500 mg three times a day)[59] and two trials[15,63] using an oral nutritional supplement (ONS) containing the leucine derivative beta-hydroxy-beta-methylbutyrate (HMB) 1.5–3 g/day divided into two doses.

There was insufficient evidence of benefits from casein supplementation in terms of muscle health,[61] but in the rest of the RCTs, protein supplementation was associated with significantly greater improvements in muscle strength, muscle mass, and physical performance, compared with controls or no intervention. Furthermore, studies with primarily whey-based supplementation improved QoL,[60] and supplementation with L-carnitine improved frailty scores.[59]

In a double-blind, randomized, placebo-controlled trial consisting of 811 older adults at risk of malnutrition in Singapore (the SHIELD study), participants were asked to consume either an ONS containing HMB or placebo twice a day for 180 days, along with dietary counselling as the standard of care. There was a significant improvement in malnutrition risk and nutritional outcomes such as weight, BMI, mid-upper arm circumference, and vitamin D levels in the intervention group compared with the placebo group. The intervention group was also found to have stringer leg strength and greater HGS in females.[15] Another study among community-dwelling older Chinese adults with sarcopenia showed that an exercise programme with or without an HMB containing ONS significantly improved leg extension and results from the five-stand chair test, and those that received ONS had additional benefits of increased total lean muscle mass and lower limb muscle mass.[62] The secondary analysis of this study showed that T-cell-specific inflammatory gene expression was changed significantly after 12 weeks of intervention in the group with ONS, which was associated with improved leg extensions in older adults with sarcopenia.[64]

No serious AEs were reported in any of the RCTs, with only constipation cited as an AE in two studies.[60,61] Benefits of protein supplementation in terms of muscle strength occurred in both males and females[39] and were observed among older adults with sarcopenia or low muscle mass,[15,41,60] pre-frail/frail patients,[60–62] patients at medium–high nutritional risk,[15] as well as patients with no malnutrition.[59] Notably, the presence of co-interventions may have confounded some of the results.

In three studies,[39,61,62] all subjects were instructed to perform regular exercise, while in four RCTs, all participants were given nutritional counselling, such as advice on meal compositions or prescription of specific levels of protein intake.[15,39,41,63] The issue of confounding was addressed in a double-blind RCT, which provided dietary counselling in both arms of the clinical study as standard care and included the use of a placebo in the control arm and ONS in the intervention arm.[15] In conclusion, sufficient dietary protein intake is crucial for improving muscle health, but high-quality protein supplements and ONS containing HMB are beneficial where this is not possible. Please see *Table* 1, Consensus Statements 6 and 7.

In a distinct study, some benefit to muscle health was found with a unique chicken-based ONS.[65] This double-blind RCT (n = 38, mean age: 81.5 years) compared older adults receiving either the chicken-based ONS or a similarly flavored placebo over a period of 6 months and divided participants into higher or lower level of physical activity. The higher-level group had a significantly improved usual gait speed compared with the lower-level physical activity group (indicating that physical activity improved usual gait speed but was not related to the ONS). Significant changes were

Table 2 Summary of studies addressing supplementation in muscle health

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
Badrasawi 2016	Double-blind RCT Pre-frail older adults without malnutrition, sarcopenia, and cognitive impairment Size (FAS): 50 Intervention group: 26 Control group: 24 Mean age: 68.2–68.8 years Female: 46.2–62.5%	Intervention: L-carnitine supplement (500 mg per capsule/day) for 10 weeks Control: placebo (corn starch filling) Measures: HGS, frailty score, feeling more energetic (self-reported), pulmonary expiratory flow rate	Significantly higher in intervention group than control: HGS, frailty index score, (P = 0.05 for both parameters).	L-Carnitine supplementation has a favourable effect on the functional status and fatigue in pre-frail older adults.
Bo 2019	Double-blind RCT Older adults with sarcopenia without disabilities Size (FAS): 60 Intervention group: 30 Control group: 30 Mean age: 73.23–74.83 years Male: 43.3–46.75% BMI: 19.74–21.34 kg/m^2 Malnutrition (MNA-SF): 3.3%	Intervention: whey protein, vitamins D and E (40 g per serving, one serving before breakfast and another before dinner) for 6 months Control: isocaloric placebo Measures: RSMI, HGS, SF-36 MCS score, SF-36 PCS score, appendicular muscle mass, 6 m gait speed, time to complete 5 stands, time to stand up	Significantly higher in intervention group than control: RSMI, CFB HGS, SF-36 MCS score, SF-36 PCS score.	Combined supplementation of whey protein, vitamin D, and vitamin E significantly improved RSMI, muscle strength, and anabolic markers such as IGF-1 and IL-2 in older adults with sarcopenia.
Kang 2019	2 parallel-group Case–control study Older adults with frailty and without co-morbidities Size (FAS): 115 Intervention group: 49 Control group: 66 Mean age: 77.3 years Female: 61.7% BMI: 21.02–22.73 kg/m^2 Malnutrition (MNA-SF): 4.1–4.5%	Intervention: whey protein supplementation (32.4 g of whey protein) before breakfast and lunch or 30 min after resistance exercises in addition to meals daily for 12 weeks Control: no intervention Co-intervention: exercise programme, information about diet (both groups) Measures: HGS, gait speed, CST, SPPB, balance test	Significantly higher in intervention group than control: gait speed (male and female), CST.	The 12 week intervention of whey protein oral nutritional supplement revealed significant improvements in muscle function among the frail elderly besides aiding with resistance exercise.
Kang 2020	Double-blind RCT Healthy older adults without co-morbidities Size (FAS): 120 Intervention group: 60 Control group: 60 Mean age: 58.38–61.23 years Female: 68.33–76.67% BMI: 23.59–23.74 kg/m^2	Intervention: protein mixture powder [protein 20 g (casein 50% + whey 40% + soy 10%, total leucine 3000 mg), vitamin D 800 IU (20 μg), calcium 300 mg, fat 1.1 g, carbohydrate 2.5 g] twice a day for 12 weeks Control: isocaloric-placebo supplement powder Co-intervention: instructed to do light exercise (both groups) Measures: ASM, ASMI, ASMI/Wt, ASM/BMI, calf circumference, arm circumference, femoral muscle strength, femoral muscle strength/Wt, grip strength, SPPB	Significantly higher in intervention group than control: LBM normalized by body weight (LBM/Wt) ($P < 0.001$). No significant difference between groups: ASM, ASMI, ASMI/Wt, ASM/BMI, CC, arm circumference, femoral muscle strength, femoral muscle strength/Wt, grip strength, SPPB.	Leucine-enriched protein supplementation was found to have beneficial effects by preventing muscle loss, mainly for late middle-aged adults.

(*Continues*)

Table 2 (continued)

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
Lin 2021	Open-label, parallel-group study Older adults with sarcopenia and without co-morbidities Size (FAS): 56 Intervention group: 28 Control group: 28 Mean age: 73.1 ± 6.92 years Male: 71.4% BMI: 19.8–20.6 kg/m^2	Intervention: supplements in addition to their regular daily meals to achieve 1.5 g protein/kg BW/day [88 kcal, 12.8 g of protein (including 8.5 g of whey protein concentrate), 1.2 g leucine, 7.3 g carbohydrates, 0.8 g fat, 120 IU vitamin D per serving] before a meal for 12 weeks Control: ordinary high-protein foods to achieve 1.5 g protein/kg BW/day (no intervention) Co-intervention: nutritional counselling (both groups) Measures: gait speed, appendicular muscle mass index, handgrip strength	Significantly higher in intervention group than control: gait speed.	The AMMI can be improved if sufficient protein is consumed (1.2–1.5 g/kg body weight/day) in sarcopenic elders. Nutritional supplement allows sarcopenic elderly to conveniently meet their protein requirements. Supplementation with whey protein and vitamin D can further improve gait speed in elderly sarcopenic subjects, especially in the 'younger' age group.
Peng 2021a	RCT Middle-aged and older adults without co-morbidities and impairment Size (FAS): 52 Intervention group: 27 Control group: 25 Mean age: 53.7 ± 8.3 years Male: 53.8% BMI: 25.3 ± 3.8 kg/m^2 Malnutrition (MNA): 27.7 ± 1.3	Intervention: high-protein group (HPG, 25% of total calories of the meal was protein, 600 kcal per meal for women and 750 kcal per meal for men), 10 meals per week for 12 weeks Control: regular-protein group (RPG, 15% of total calories of the meal was protein, 600 kcal per meal for women and 750 kcal per meal for men), 10 meals per week for 12 weeks Co-intervention: required regular daily physical activities (both groups) Measures: 6 min walking distance, handgrip strength, 5-time chair rise test, 6 m walking speed, physical activity, MNA, MoCA, PCS, MCS, CSA, IMAT-to-CSA ratio	Significantly higher in intervention group than control: 6 min walking distance, CFB. No significant difference between groups: HGS, 5-time chair rise test, 6 m walking speed, physical activity, MNA, MoCA, PCS, MCS, CSA, IMAT-to-CSA ratio.	Higher dietary protein intake significantly improved physical endurance and marginally reduced intramuscular adiposity but increased the inflammatory biomarker among middle-aged and older adults.
Peng 2021b	RCT Pre-frail older adults without co-morbidities Size (FAS): 62 Intervention group: 29 Control group: 33 Mean age: 71.1 ± 3.8 years Female: 69.4% BMI: 22.55 ± 2.9 kg/m^2	Intervention: HP-HMB-containing oral nutritional supplementation (3 g of HMB/day), two services daily for 12 weeks Control: no intervention Co-intervention: dietary consultation for sufficient dietary protein intake Measures: mid-thigh muscle CSA, MNA-SF, gait speed, HGS, SPPB	Significantly higher in intervention group than control: mid-thigh muscle CS, CFB.	The 12 week supplementation programme with a high-protein nutrition shake supplemented with 3 g HMB significantly increased muscle mass, as well as nutritional status and physical performance, and ameliorated the intramuscular adiposity of pre-frail older persons.

(*Continues*)

Table 2 (continued)

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
	Malnutrition (MNA-SF): 12.94 ± 1.13	score, 5-time chair stand, mid-thigh muscle CSA ratio, intramuscular adipose tissue (IMAT)-to-CSA ratio		
Chew 2021	RCT Older adults at medium or high nutritional risk without co-morbidities Size (FAS): 805 Intervention group: 401 Control group: 404 Mean age: 74.15 Female: 60% BMI: 18.42 kg/m^2	Intervention: ONS with HMB [10.5 g protein, 8.5 g fat, 34.2 g carbohydrate, 310 IU vitamin D3, 0.74 g calcium HMB per serving; 2 servings per day for 180 days (~26 weeks)] Control: placebo supplement (1.07 g protein, 1.21 g fat, 11.9 g carbohydrate per serving) Co-interventions: dietary counselling (both groups) Measures: mid-upper arm circumference, CC, HGS, leg strength, handgrip endurance, SPPB, muscle mass, ASM, ASMI, Physical Activity Scale for the Elderly score, nutritional status, composite outcome—survival without hospital (re)admission and with at least 5% weight gain up to Day 180	Significantly higher in intervention group than control: odds of better nutritional status (lower MUST risk) and composite outcome, CC, mid-upper arm circumference at Days 30, 90, and 180; leg strength at Day 90. Subgroup analysis (significantly higher in intervention group than control): females, HGS at Day 180. Low ASMI group: significantly greater CC at Days 90 and 180 compared with placebo (both $P = 0.0289$).	Daily consumption of a specialized ONS containing HMB and vitamin D for 6 months, along with dietary counselling, significantly improved nutritional and functional outcomes compared with participants receiving the placebo plus dietary counselling.
Ma S-L 2021	RCT Community-dwelling Chinese subjects Age: >65 years Size: 12 control, 11 exercise: 11 Combined group: 12	12 week intervention with exercise and nutrition supplementation	Blood samples at baseline and 12 weeks. T-cell gene expression. Correlation analysis to relate gene expression with lower limb muscle strength performance, using leg extension tests.	T-cell-specific inflammatory gene expression was changed significantly after 12 weeks of intervention with combined exercise and HMB supplementation in sarcopenia, and this was associated with lower limb muscle strength performance.

ASM, appendicular skeletal muscle mass; ASMI, appendicular skeletal muscle mass index; BMI, body mass index; CC, calf circumference; CFB, change from baseline; CSA, cross-sectional area; CST, chair stand test; FAS, full analysis set; HGS, handgrip strength; HMB, beta-hydroxy-beta-methylbutyrate; IGF-I, insulin-like growth factor-1; IL-2, interleukin-2; IMAT, intramuscular adipose tissue; LBM, lean body mass; MCS, mental component summary; MNA-SF, Mini Nutritional Assessment-Short Form; MoCA, Montreal Cognitive Assessment; MUST, Malnutrition Universal Screening Tool; ONS, oral nutritional supplement; PCS, physical component summary; RCT, randomized controlled trial; RSMI, relative skeletal mass index; SPPB, Short Physical Performance Battery; Wt, weight.

observed in two bone markers at baseline and 6 months in the intervention group, indicating improved bone resorption. Therefore, beneficial effects on age-related bone resorption were observed for this ONS, but it did not directly benefit sarcopenia-related measures. This is therefore insufficient evidence to inform a consensus statement, but it will be interesting to see further data from this supplement as it emerges.

Vitamins

Vitamin D triggers genomic and non-genomic pathways in muscle cells that preserve muscle function through various mechanisms, including maintenance of calcium homeostasis and proliferation of muscle fibres.[66,67] Historically, the clinical link between vitamin D and muscle health comes from cases of severe vitamin D deficiency that caused myopathies and severe muscle weakness or pain.[66,68] Increasing evidence indicates muscle–bone crosstalk and an integrative role for vitamin D in this relationship.[69] Observational studies indicate that lower levels of vitamin D result in reduced muscle mass and strength.[70] A recent meta-analysis of predominantly non-Asian trials found insufficient evidence for benefit from vitamin D supplementation in terms of muscle mass or function,[71] although it has been highlighted that there were a number of limitations of the included studies, such as vitamin-D replete populations, small sample sizes, and inconsistent intervention methods in terms of dose and metabolites.[72]

In Asia, a limited number of recent clinical trials directly assessed the effects of vitamin D supplementation on muscle health parameters. In one RCT involving Japanese older adults (*N* = 130, mean age: 70.5 years) who received either oral vitamin D3 alone (1000 IU/day), exercise alone, or a combination of the two interventions for 24 weeks, the mean baseline serum vitamin D levels varied by treatment group (range: 27.2–29.0 ng/mL).[73] Compared with exercise alone and exercise plus vitamin D, there was insufficient evidence of benefit from vitamin D alone in terms of muscle mass, muscle strength, and physical performance, despite a significant increase in serum vitamin D levels from baseline. In several other RCTs, vitamin D was supplemented orally at a dose of 260–1600 IU/day in combination with various types of supplements (e.g. whey, leucine, and HMB), with or without exercise, for a duration of 12 weeks.[41,61,62,74,75] Although most of these trials demonstrated benefits from the intervention overall, they were not specifically designed to examine benefit from vitamin D alone, and so it is difficult to attribute independent benefit of vitamin D based on these data.

Multiple cross-sectional studies in Asia (total *N* = 11 769) may provide indirect evidence of a role for vitamin D supplementation in muscle health.[76–79] Two studies conducted in China[77,79] and one in Japan[80] among middle-aged and older adults (mean age: 75.4 years) found a significant, positive correlation between serum vitamin D levels and HGS. The odds of having low HGS increased four-fold among community-dwelling older adults with vitamin D insufficiency (serum level $<$ 20 ng/mL) compared with vitamin D-sufficient subjects.[80] Two studies have shown that serum levels of vitamin D were also significantly associated with sarcopenia among Korean older adults (range of mean age: 67.4–74.5 years).[76,78] Specifically, subjects with serum vitamin D levels $\leq$ 18.67 ng/mL were twice as likely to have sarcopenia than those with levels $\geq$ 23.73 ng/mL,[78] although stratified analyses by sex have shown conflicting results across different studies.[76,77,79,80]

Despite their observational nature, these studies lend evidence to the correlation between vitamin D status and muscle health and are also indicative of the value of screening vitamin D levels in community-dwelling older adults. In these studies, the commonly applied criteria to classify vitamin D status were $<$20 ng/mL (i.e. μg/L) for deficiency, 20–29.9 ng/mL for insufficiency, and $\geq$30 ng/mL for sufficiency.[77,80] The cut-offs reflect recommendations of the Endocrine Society in 2011, in which the evidence mostly originates from non-Asian populations.[81] Interestingly, data from Asia suggest that different ethnic cultures, linked, for example, with clothing choices, may influence vitamin D levels,[82] indicating a possible need for population-specific reference values. However, in Japan, after analysis of country-level data, an expert panel proposed definitions of vitamin D deficiency/insufficiency, which closely matched the aforementioned values.[83]

To assess vitamin D status, the majority of studies in Asia measured serum levels of 25-hydroxyvitamin D or 25-OH vitamin D via radioimmunoassay,[76–78,80] which may not be routinely available in community-based testing facilities. A recent systematic review did not find any studies directly evaluating the benefits of screening for vitamin D deficiency.[84] Hence, routine testing of vitamin D levels in community-dwelling older adults may be undertaken upon careful consideration of feasibility and applicability, and in resource-limited settings, a more targeted approach may be reasonable, for example, screening for suspected osteoporosis.

The role of vitamin E in sarcopenia has drawn attentions due to its antioxidant and anti-inflammatory properties.[85] However, we did not find any RCTs in Asia that directly evaluated vitamin E supplementation in terms of muscle health outcomes. Two cross-sectional studies examined serum levels and dietary vitamin E but provided inconclusive evidence for vitamin E supplementation.[86,87] Therefore, evidence to support a role of vitamin supplementation in Asian studies was only found for vitamin D. Please see *Table* 1, Consensus Statement 8.

Lipids

Although proteins are the building blocks for muscle, lipids such as omega-3 or *n*-3 polyunsaturated fatty acids are suggested to affect muscle health indirectly by preventing low-grade inflammation.[88] Significantly lower levels of serum *n*-3 fatty acids were linked with sarcopenia and higher dietary intake of fats (66.7–143.8 g/day vs. 6.8–41.4 g/day) correlated with lower odds of sarcopenia.[87] Overall, we found scarce evidence to support a statement around dietary/supplementary lipid intake in muscle health, but the findings support a balanced and healthy diet to maintain muscle health and so are relevant in the broader context.

Lifestyle interventions in addition to nutrition

Aside from aging, other pathologic factors that affect muscle quantity and quality include inactivity (e.g. sedentary behaviour and physical inactivity) and malnutrition (e.g. undernutrition). In a retrospective cohort study among 552 older adults (mean age 74.6 years) in Japan, age, obesity, and malnutrition were independent risk factors for sarcopenia.[89] This study also revealed that the number of daily conversations, which was an index of physical, cognitive, and social function, independently predicted sarcopenia.[89] Collectively, these findings suggest a role in muscle health for multi-domain interventions that address physical, cognitive, and social aspects on top of nutritional factors.

Several RCTs (total number of subjects = 1200), conducted in three countries in Asia (Hong Kong, Japan, and Taiwan), have evaluated the efficacy of combined exercise and nutritional supplementation in terms of improvement in muscle health.[40,62,73,75,90–92] Although some of the aforementioned studies described in the 'Protein' section also included exercise, we have focused on studies here that had a separate exercise group, so that the specific benefit of exercise could be assessed. Please see *Table* 3 for a summary of studies addressing exercise in addition to supplementation, in muscle health.

One RCT was conducted exclusively among sarcopenic patients,[62] one among non-sarcopenic patients,[40] one among pre-frail/frail patients,[90] and one among robust patients.[92] Most studies involved older participants (range of mean age: 60.9–84.2 years) and a predominantly female study population, although two trials recruited solely female participants.[40,91] With regard to baseline BMI, the majority of the trials enrolled non-obese subjects (range of mean BMI: 18.8–25.5 kg/m^2).

Despite the variety in exercise regimens applied, the combined intervention in the RCTs generally included resistance training, using body weight in-chair exercises or resistance bands. Apart from two studies,[40,75] resistance exercises were mixed with other types, including aerobic and balance training. A few studies employed specific approaches such as progressive (i.e. a structured, gradual increase in the weights used),[40,91,92] predominantly home-based[40,73,90] group (i.e. multiple people exercising together),[62,92] and personalized programmes.[62,90] The sessions ranged from 5 to 60 min, with frequencies ranging from 2 to 7 times per week, for a duration of 3–6 months, and were initially supervised, and in virtually all RCTs, the exercise sessions were structured.

In terms of the nutritional component, protein or derivatives were the major component of the additional supplement[40,62,75,92] although the component, that is, whey, branched-chain amino acids, HMB, or a combination, and the amount differed per trial. In one of these studies,[40] the experimental arm received a co-intervention in the form of nutritional management, whereby protein intake was maintained at 1.2 g/kg BW/day; individuals with a baseline protein consumption of $<$1.2 or $>$1.3 g/kg BW/day were excluded. The mean baseline protein intake among participants in other trials was 1.5–1.8 g/kg BW/day, depending on the study arm,[62] 60.8–64.9 g of protein/day, which increased by 7.2–8.6 g/day in the intervention arms after 6 months of supplementation with skimmed milk and mixed nuts.[90] One trial[91] provided the intervention groups with MFGM as the nutritional supplement while another trial gave vitamin D.[73] All studies reported at least one muscle health parameter as an outcome of interest (i.e. muscle mass, muscle strength, or physical performance).

In the majority of RCTs, combined exercise and nutrition resulted in greater improvements in muscle mass, muscle strength, and physical performance, compared with no intervention.[40,62,75,90,91] Benefits from combined exercise and nutrition were observed as early as 1 month from the start of intervention[90] and lasted up to 3 months after the intervention.[62] The combined intervention also had benefits in terms of walking parameters,[91] flexibility,[90] levels of physical activity, and activities of daily living (ADL).[62]

Two RCTs did not show sufficient evidence of benefits from combined exercise and nutrition in terms of at least one muscle health parameter.[73,92] However, Aoki *et al*. was the only study that did not supplement with a macronutrient, whereas Woo *et al*. enrolled a younger study population (mean age: 61 years) compared with the rest of the studies, which may have contributed to this result. Data from two studies,[62,92] as well as two subgroup analyses,[64,75] revealed that, regardless of sarcopenia status, combined exercise and nutrition had benefits on muscle health.

Both RCTs that applied only resistance training demonstrated benefits from combined exercise and nutrition,[40,75] while the benefit was not consistent among the studies that added aerobic, balance, flexibility, or gait training. In terms of approach, evidence of benefit was consistent among studies that employed an individualized programme.[62,90] There

DOI: 10.1002/jcsm.12981

Table 3 Summary of studies addressing exercise in addition to nutritional supplementation in muscle health

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
Hsieh 2019	Single-blind RCT Pre-frail/frail older adults without severe co-morbidities or impairment Size (FAS): 319 Ex + N: 77, Ex: 79, N: 83, control: 80 Mean age: 71.6–72.5 years Female: 35.1–45.8% BMI: 24.4–25.5 kg/m^2	Ex: personalized, home-based combination of strength, flexibility, balance, and endurance training (5–60 min, 3–7×/week for 6 months) N: skim milk powder (25 g/day), mixed nuts (10 g/day), 3 fish oil capsule (500 mg per capsule), 1 vegetable and fruit concentrate capsule (200 mg/cap) Control: no intervention Co-intervention: inspirational cards (Ex + N, Ex, N) Measures: HGS, 10 m gait speed, upper body flexibility, lower body flexibility, lower extremity strength, GDS, SF-12 MCS	Significantly higher in Ex + N than control: handgrip strength, CFB at 6 month 10 m gait speed, CFB at 6 months Upper body flexibility, CFB at 3 and 6 months Lower body flexibility, CFB at 3, 6 months Lower extremity strength, CFB at 1, 3, and 6 months	The designated home-based exercise and nutrition interventions can help pre-frail or frail older adults to improve their frailty score and physical performance.
Mori 2018	RCT Healthy, non-obese, female older adults without sarcopenia or co-morbidities Size (FAS): 75 Ex + N: 25, Ex: 25, N: 25 Mean age: 70.6 years Female: 100% BMI: 22.1–22.9 kg/m^2	Ex: Progressive, home-based resistance exercise using chair and elastic bands (for 24 weeks) N: whey protein supplementation [92 kcal, protein (22.3 g), fat (0.3 g), carbohydrate (0.1 g), valine (1225 mg), leucine (2975 mg), isoleucine (1175 mg)] Co-intervention: nutritional management (all groups) Measures: lower limb muscle mass, SMI, knee extension strength, upper limb muscle mass, grip strength, gait speed	Significantly higher in Ex + N than Ex or N alone: lower limb muscle mass, %CFB SMI, %CFB Knee extension strength, %CFB	Whey protein supplementation, ingested after resistance exercise, could be effective for the prevention of sarcopenia among healthy community-dwelling older Japanese women.
Kim 2019	RCT Female older adults with walking ability declines and without severe impairment or co-morbidities Size (FAS): 122 Ex + N: 29 Ex + Placebo: 31 N: 31 Control: 31 Mean age: 82.8–83.8 years Female: 100%	Ex: progressive resistance exercise using chair and resistance bands, in combination with balance and gait and strengthening exercises (60 min, 2×/week for 3 months) N: MFGM (1 g/day) Control: placebo (whole milk powder) Measures: usual walking speed, stride, foot progression angle, step length, arm muscle mass, leg muscle mass, skeletal muscle mass, TUG, knee extension strength, grip strength, cadence, step width, step count	Significantly higher in Ex + N than control (CFB): usual walking speed, step length	The exercise interventions alone or combined with nutrition were effective in improving walking speed as well as other walking parameters. Improvement in stride and foot progression angle may have contributed to the increase in walking speed. However, augmented effects of MFGM with exercise could not be confirmed.
Yamada 2019	Four-arm RCT Sarcopenic or dynapenic older adults without severe impairment or co-morbidities	Ex: resistance exercise using body weight or elastic bands (30 min, 2×/week for 12 weeks)	Significantly higher in Ex + N than control (CFB): knee extension torque, phase angle, echo intensity for rectus femoris	The present study confirmed the synergistic effect of body weight resistance exercise and protein supplement with vitamin D on

(*Continues*)

Table 3 (continued)

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
	Size (FAS): 122 Ex + N: 28 Ex: 28 N: 28 Control: 28 Mean age: 84.2 ± 5.5 Female: 65.2% Sarcopenia: 30.4%	N: protein and vitamin D supplements [100 kcal, whey protein (10.0 g), vitamin D (800 IU)], daily Control: no intervention Measures: knee extension torque, phase angle, echo intensity for rectus femoris, echo intensity for vastus intermedius, appendicular muscle mass, comfortable walking time, maximum walking time, one-leg standing time, five-chair stand time, grip strength	Subgroup analyses significantly higher in Ex + N than control (CFB): sarcopenic patients: AMM, maximum walking time. Dynapenic patients (low physical function, normal muscle mass): knee extension torque, phase angle, echo intensity for rectus femoris	muscle quality and muscle strength in sarcopenic or dynapenic older adults.
Zhu 2019	RCT Older adults with sarcopenia and without impairment or co-morbidities Size (FAS): 113 Ex + N: 36 Ex: 40 Control: 37 Mean age: 72.2–74.8 years Female: 72.5–80.6% BMI: 18.8–18.9 kg/m^2	Ex: predominantly group, personalized, resistance exercise using chair or resistance bands, in combination with aerobic exercise (45–60 min, 3×/week for 12 weeks) N: ensure NutriVigor sachet [231 calories, protein (8.61 g), HMB (1.21 g), vitamin D (130 IU), omega-3 fatty acid (0.29 g)], 2 sachets daily Control: no intervention Measures: ASM, lower limb muscle mass, leg extension, five-chair stand, Physical Activity Scale for the Elderly (PASE), IADL, gait speed, upper limb muscle mass, maximum grip strength, medicine ball, 6 min walk test, SF12-physical, SF12-mental	Significantly higher in Ex + N than control: ASM, CFB at 12 weeks Lower limb muscle mass, CFB at 12 weeks Leg extension, CFB at 12 and 24 weeks Five-chair stand, CFB at 12 and 24 weeks PASE, CFB at 12 weeks Instrumental ADL	The exercise programme with and without nutrition supplementation had no significant effect on the primary outcome of gait speed but improved the secondary outcomes of strength and the five-chair stand test in community-dwelling Chinese sarcopenic older adults.
Aoki 2018	RCT Older adults not taking osteoporosis medications and without impairment Size (FAS): 130 Ex + N: 43 Ex: 45 N: 42 Mean age: 70.5 ± 6.06 years Female: 78.5% BMI: 22.2 ± 2.91 kg/m^2	Ex: home-based, single leg standing and squatting (daily for 24 weeks) N: vitamin D3 supplementation [25 mcg (1000 IU) per day for 24 weeks] Co-interventions: contacted every 2 weeks for motivation (all groups) Measures: muscle strength during knee extension, muscle strength during hip flexion, lower limb muscle mass, single leg stance test, single leg stance test, five times sit-to-stand test, functional reach test, serum 25OHD levels	No significant difference between groups: muscle strength during knee extension, muscle strength during hip flexion, lower limb muscle mass, single leg stance test, single leg stance test, five times sit-to-stand test, functional reach test Significantly higher serum 25OHD levels than baseline in N and Ex + N	Both exercise and vitamin D supplementation independently improved physical function and increased muscle mass in community-dwelling elderly individuals. Moreover, the combination of exercise and vitamin D supplementation might further enhance these positive effects.
Woo 2020	RCT Non-obese, robust older adults without co-morbidities Size (FAS): 163	Ex: group, progressive, resistance exercise in combination with balance and aerobic exercises (1 h, 2×/week for 24 weeks)	Significantly higher in Ex + N than control (CFB): self-rated health No significant difference between groups: gait speed, grip strength,	A 24 week exercise and nutrition supplementation programme among community-living people in late midlife to early old age

(*Continues*)

Table 3 (continued)

Study	Population and control	Intervention and measures	Result/outcome	Conclusion
	Ex + N: 80, control: 83 Mean age: 60.9–61.7 years Female: 50.0–54.2% BMI: 22.4–22.9 kg/m^2	N: fortified milk supplement sachet [212 kcal, protein (13.6 g)] Control: no intervention Measures: self-rated health, gait speed, grip strength, 5-chair stand, SPPB, 6 min walk distance, dual task gait speed, digital span, Chinese Frontal Assessment Battery, SMDT corrected response, SF-12, Life Satisfaction Scale-Chinese, instrumental ADL	5-chair stand, SPPB, 6 min walk distance, dual task gait speed, digital span, CFAB, SMDT corrected response, SF-12, Life Satisfaction Scale-Chinese, IADL	improved self-rated health and the overall level of physical activity, without objective improvements in physical and cognitive function.

25OHD, 25-hydroxyvitamin D; ASM, appendicular skeletal muscle mass; CFAB, Chinese Frontal Assessment Battery; CFB, change from baseline; CST, chair stand test; Ex, exercise; FAS, full analysis set; HGS, handgrip strength; HMB, beta-hydroxy-beta-methylbutyrate; IADL, instrumental activities of daily living; MCS, mental component summary; MNA-SF, Mini Nutritional Assessment-Short Form; MUST, Malnutrition Universal Screening Tool; N, nutrition or nutritional supplement; PASE, Physical Activity Scale for the Elderly; PCS, physical component summary; RCT, randomized controlled trial; RSMI, relative skeletal mass index; SMDT, Symbol Digit Modalities Test; SPPB, Short Physical Performance Battery; TUG, timed up and go.

were no studies that specifically addressed who should guide such exercise programmes, but in order to widen access, we feel this can be carried out by a range of 'trained personnel', such as exercise instructors, physiotherapists, and community care providers.

Therefore, there is a reasonable level of evidence, among Asian studies, to support additional benefits from including an exercise component along with other dietary/nutritional interventions, in selected subjects. This is also supported by the WHO guidelines on physical activity and sedentary behavior, and the ICFSR guidelines.[93,94] Please see *Table* 1, Consensus Statements 9, 10, and 11. It is important to note that any additional exercise as part of a multi-domain intervention should be in addition to maintaining basic levels of daily physical activity such as walking to the shops, to maintain general overall health.

Outcomes and assessments

Randomized controlled trials in Asia have evaluated the effects of nutritional supplementation through a variety of outcome measures such as body composition, muscle mass, muscle function, instrumental activities of daily living (IADLs), and QoL. Among community-dwelling older adults, practicality is an important consideration in choosing tests to monitor the effects of a given intervention. For instance, BMI and weight are simple measurements in clinical practice that may translate to improvements in physical performance and ADLs. In contrast, some validated tests that directly assess muscle health may require complex equipments. For example, appendicular skeletal muscle mass was measured via bioelectrical impedance analysis or dual energy X-ray absorptiometry in the majority of RCTs but may be applicable only in healthcare facilities or clinical research settings.[15,37,40,41,60,73–75]

One relatively easy test to perform is rhe determination of CC, which is the maximum value measured with a non-elastic tape on both calves or a dominant or non-dominant calf as specified and displays moderate-to-high sensitivity (73–92%) and specificity (50–88%) in detecting sarcopenia or low skeletal muscle mass.[86,95–97] In 2019, the AWGS recommended CC as a screening tool for sarcopenia in the community, using a cut-off of $<$34 cm for males and $<$33 cm for females.[4] A cross-sectional study among 139 Japanese older adults (mean age: 76.7 ± 6.6 years) has shown that these cut-offs achieved a sensitivity of 83.3% and specificity of 62.8% in predicting sarcopenia.[98]

While the AWGS has similarly advocated the use of HGS (with cut-offs of 28 and 18 kg for males and females, respectively), to identify possible sarcopenia in the community,[4] its measurement entails access to a dynamometer, which may not be routinely available. In addition, for those with a hand abnormality or limitation, knee extension or quadriceps strength can be used as an alternative strength measurement with high levels of sensitivity and specificity for sarcopenia diagnosis.[4,99] The AWGS has also endorsed several physical performance tests to diagnose sarcopenia, including the 6 m walk for establishing gait speed and the Short Physical Performance Battery for judging impaired mobility.[4] However, there may be limited space in community healthcare clinics to allow the distance involved in these two tests.

Among the physical performance tests, the 5-time chair stand test (CST) has been recognized by AWGS as a surrogate for gait speed in the community, with a cut-off of ≥12 s for low physical performance.[4] Apart from a chair, the CST does not necessitate any advanced apparatus or wide space to accomplish and has been shown to have a sensitivity of 75% and specificity of 94% for predicting low gait speed.[100] In a more recent cross-sectional study involving 678 Japanese older adults (mean age: 74.7 ± 7.2 years), the 30 s CST had a sensitivity of 75.0–76.4% and specificity of 71.7–76.8% for diagnosing sarcopenia, using 17 and 15 stands as cut-offs for males and females, respectively.[101] Based on these findings, a cross-sectional study concluded that sit-to-stand tests better represent the physical performance compared with muscle strength, the 30 s CST may be a suitable alternative to the 5-time CST.[102]

To measure impairments in IADLs, most RCTs in Asia have utilized a five-item questionnaire assessing the ability of community-dwelling older adults to (1) walk two to three blocks outdoors on level ground, (2) climb 10 steps without resting, (3) prepare own meals, (4) do heavy housework like scrubbing floors or washing windows, and (5) shop for groceries or clothes.[62,92] In studies that performed a health-related QoL assessment, it was quantified most frequently by the health survey short forms SF-12 and SF-36, both of which were divided into physical and mental component scores.[50,60,62,90,92] Recently, a Chinese version of a sarcopenia-specific QoL questionnaire (SarQOL®) has also been validated, exhibiting high correlation with SF-36.[103] Although there are several blood-based measurements to examine nutritional outcomes in muscle health, these may be difficult to perform in community healthcare settings and thus we have excluded them in this consensus. Please see *Table* 1, Consensus Statements 12 and 13 for statements relating to outcome measures.

Impacts of COVID-19

Sarcopenia has been an increasing problem during the COVID-19 pandemic, as a result of sedentary behavior imposed during circuit breakers and lockdowns globally.[104,105] In Asia, a retrospective cohort study among 121 adult patients in Korea with COVID-19 (median age 62 years) showed that low skeletal muscle index at baseline independently predicted longer hospital stay while also increasing the risk of mortality.[106] This finding highlights the importance of maintaining muscle health among older adults during the COVID-19 pandemic. Acknowledging the direct health effects of COVID-19 on older people, as well as the indirect consequences of corresponding public health measures, the AWGS released recommendations for Asian older adults, including adequate nutrition and exercise to enhance physical resilience in the context of the pandemic.[107] Although essential, public health strategies, such as social distancing and community quarantine, can impact not only the psychosocial well-being of older adults but also their physical activity and dietary habits.[107] In a systematic review of four studies from China, the prevalence rates of malnutrition risk among older adults with COVID-19 ranged from 41.1% (n = 58) to 100% (n = 4) while the prevalence of malnutrition was 52.7% (n = 96).[108] Altogether, the emerging body of evidence from the COVID-19 pandemic emphasizes the relevance of nutritional management for muscle health among community-dwelling older adults. Please see *Table* 1, Consensus Statement 14.

Conclusions

Our research identified key topics regarding muscle health, with robust data from cross-regional studies in Asia. Although there was considerable heterogeneity among studies, and a mix of cross-sectional studies and RCTs, we were able to expand on this with evidence from previous guidelines and our own clinical experience and expertise, to develop a set of 14 statements that guide practice from screening strategies and assessment methods, to impacts of dietary nutrition, supplements, exercise, and COVID-19. Of note, it is clear that muscle health and good overall nutrition are intimately linked, and at screening, there is a need to assess these factors in combination. Our aim is for these consensus statements to provide a practical framework, with the hope of broadening healthcare options for community-dwelling older adults, leading to improved overall muscle health in this target population.

Acknowledgements

Four AWGS members, L.-K.C., J.W., H.A., and M.A., initiated the plan for this project and selected the additional members of the SIG based on their relevant expertise. All SIG members attended the three meetings and contributed equally to the search criteria protocol, literature evaluation,

reviewing topics and statements at all stages of the process, and voting. In addition, all members provided views and perspectives from their clinical experience to support the statements. All authors contributed to writing the manuscript and reviewed the draft several times. The authors certify that they comply with the ethical guidelines for authorship and publishing of the *Journal of Cachexia, Sarcopenia and Muscle*.

Funding

Medical writing support, in accordance with Good Publication Practice 3 ethical guidelines, was provided by Fiona Clare Chaplin and Tristan Marvin Uy of MIMS Pte Ltd and was funded by the Abbott Nutrition, and Taiwan Association for Integrated Care.

Conflicts of interest

G.D. is a member of the Scientific Advisory Board at Abbott Australia and TSI Pharmaceuticals and holds a research grant from TSI Pharmaceuticals but has no other conflicts of interest to declare beyond this. HL.C.D. provides medical and lay lectures for Abbott but has no other conflicts of interest beyond this. M.A. received research funding from Astellas Pharma, Bayer HealthCare, Boehringer Ingelheim, Chugai Pharmaceutical, Daiichi Sankyo, Eli Lilly Japan, Eisai, Kracie Pharma, Mitsubishi-Tanabe Pharma, MSD, Novartis Japan, Ono Pharmaceutical, Sanofi, Takeda Pharmaceutical, Teijin Pharma, and Tsumura and lecture fees from Daiichi Sankyo, Mitsubishi-Tanabe Pharma, MSD, Sumitomo Dainippon Pharma, and Takeda Pharmaceutical. He has no other conflicts of interest to declare. S.T.H.C. has previously received grant co-funding, travel grant, and honoraria from Abbott Nutrition. L.-K.C., J.W., H.A., and P.A. have no conflicts of interest to declare.

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