The Association between Malnutrition and Physical Performance in Older Adults: A Systematic Review and Meta-Analysis of Observational Studies

Charlotte S Kramer,1 Inge Groenendijk,1 Sonja Beers,1 Hugo H Wijnen,2 Ondine van de Rest,1 and Lisette CPGM de Groot1

1Division of Human Nutrition and Health, Wageningen University & Research, Wageningen, The Netherlands and 2Department of Geriatrics, Rijnstate Hospital, Arnhem, The Netherlands

ABSTRACT

In recent years the focus of healthcare and nutritional science in older adults has shifted from mortality towards physical performance and quality of life. The aim of this review was to summarize observational studies on physical performance in malnourished (MN) or at risk of malnutrition (RMN) older adults compared with well-nourished (WN) older adults. Eligible studies had to report on nutritional status and objectively measured physical performance in older adults (≥60 y). MN or RMN groups had to be compared with a WN group, measured with a validated nutrition screener. Ovid Medline and Web of Science were searched until 13 November, 2020. Study quality was scored using a modified Newcastle–Ottawa Scale (NOS). Results were analyzed by meta-analysis when possible, or narratively reviewed otherwise. Forty-five studies (16,911 participants in total) were included from studies in outpatient clinics (n = 6), nursing homes (n = 3), community-dwelling older adults (n = 20), hospitalized patients (n = 15), or a combination (n = 1). Studies used 11 different screeners of malnutrition, and 8 types of physical performance measures. Meta-analysis showed that compared with MN, WN groups had better hand grip strength (mean difference [MD] = 4.92 kg; 95% CI: 3.43, 6.41; P < 0.001; n = 23), faster gait speed (MD = 0.16 m/s; 95% CI: 0.05, 0.27; P = 0.0033; n = 7), performed faster on timed-up-and-go (MD = −5.94 s; 95% CI: −8.98, −2.89; P < 0.001; n = 8), and scored 1.2 more short physical performance battery points (95% CI: 1.32, 2.73; P < 0.001; n = 6). Results were less pronounced when compared with RMN.Narratively, all studies showed an association for knee extension strength, 6-min walking test, and multicomponent tests, except for the chair stand test. Study limitations include no studies scoring “good” on NOS, lack of confounder adjustment, and high heterogeneity. Overall, evidence from cross-sectional studies indicate an association between malnutrition and worse physical performance in older adults. This study is registered in PROSPERO as CRD42020192893. Curr Dev Nutr 2022;6:nzac007.

Keywords: malnutrition, sarcopenia, undernutrition, aging, physical function, muscle strength, muscle function, elderly, community-dwelling

Introduction

Malnutrition, sarcopenia, and low physical performance are prevalent among the older population (1, 2). Malnutrition (here used synonymously with undernutrition) can be defined as “a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat-free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease” (3). Low dietary intake is usually regarded as the main determinant of malnutrition, but many other factors can be at play (4); experts in geriatric nutrition consider low intake, high requirements, and impaired bioavailability as core determinants of malnutrition. These 3 are directly or indirectly affected by dozens of possible determinants at various levels and from various domains, including diarrhea, poverty, and multimorbidity for example (4–6).

The main diagnostic criteria for sarcopenia are low muscle strength and low muscle quantity or quality. Muscle quantity is measured by muscle mass, whereas quality considers muscle architecture or muscle function per unit of muscle mass (7). When additionally low physical performance is present, sarcopenia is categorized as severe (7). Low physical performance is an important indicator as it predicts adverse outcomes (7).
Physical performance is a broad and multidimensional concept. It has been described as including ambulatory status, postural control and stability, functional mobility, functional extremity strength, dynamic balance, and overall endurance (8). Recently, the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO) defined it as “an objectively measured whole-body function related with mobility,” and that low physical performance may be evident before effects on activities of daily living can be measured (9). To study the treatment of sarcopenia they advise using the combination of muscle strength and physical performance (10).

Malnutrition, sarcopenia, and physical performance are thought to have complex origins and are interrelated. Malnutrition affects sarcopenia and physical performance via the loss of muscle mass and strength, and changes in the nervous and skeletal systems (11, 12). All 3 result in poor health outcomes such as higher morbidity, lower quality of life, and higher mortality (13–15).

Quality of life is among the most important outcomes among older adults, of which physical performance is a key element (16). Improving physical performance or preventing decline is a goal of many interventions aimed at older adults. Contrary to factors such as age, gender, and many comorbidities, nutritional status is a modifiable factor and nutritional interventions are a popular intervention aimed at improving physical performance. However, the effectiveness of improving physical performance via nutritional interventions remains unclear.

Systematic reviews on the association of nutritional interventions with physical performance are inconsistent (17–20); the included studies focused on a broad range of nutritional interventions and varying outcomes. Moreover, the nutritional status of the participants in these systematic reviews was not defined. Instead, participants were defined as frail, sarcopenic, or healthy older adults (17–20), potentially causing further discrepancies since the intervention effects may differ between well-nourished and malnourished older adults (21). The systematic review and meta-analysis that did include well-defined malnourished patients found inconsistent results (14).

Systematic reviews on the association of malnutrition with sarcopenia do exist. However, these reviews focused on hospitalized patients specifically (22) or reported that the lack of generally accepted definitions in the past prevented valid comparison (23). Additionally, the use of BMI in these reviews as a single measure of nutritional status is inadequate and likely contributes to inconclusive results due to the existence of sarcopenic obesity (23).

In order to improve understanding of the inconsistent results of nutritional intervention effects on physical functioning, it is important to clarify the underlying assumption that malnourished older adults have reduced physical performance compared with well-nourished (WN) peers. A systematic review on the association between malnutrition and physical performance is lacking despite many observational studies that report on these outcomes. Therefore, with this systematic review we aim to clarify current knowledge and summarize existing findings of observational studies on physical performance in malnourished compared with well-nourished older adults. We focus on studies that used validated, multidimensional screeners, or assessment tools of malnutrition as well as objectively measured outcomes of physical performance tests or muscle strength.

Methods

This systematic review is registered in PROSPERO as CRD42020192893 and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for systematic reviews and meta-analyses (24).

Search strategy

We conducted a systematic search in 2 online databases: “Ovid Medline” and “Web of Science core selection.” Publications from any date until 13 November, 2020 were searched with terms selected based on literature, which consisted of synonyms of malnutrition, physical performance, older adults, and observational studies (full search strategy in Tables 1 and 2). Hand searching consisted of a nonsystematic pre-search in Google Scholar and backward snowballing of the included studies from the systematic search. If full-text publications could not be obtained via the university library, the corresponding author was contacted via ResearchGate or email twice. If corresponding authors could not provide the full-text article, or if after 2 approaches no answer was received, the study was excluded. Abstracts and unpublished studies were not considered in the current review.

Study selection

The title and abstract of the systematic search results were screened to remove duplicates, animal studies, in vitro studies, intervention studies, and review articles. Subsequently, full-text articles of potentially relevant publications were independently screened based on study inclusion and exclusion criteria. Screening and data extraction were separately performed by 2 researchers. Conflicts were resolved through discussion between the 2 researchers. Remaining disagreements were discussed among the research team until consensus was reached.

Eligibility criteria

Studies published in Dutch or English were considered eligible. For full-text screening, inclusion criteria were used in the following order: the general older adult population was the target population of this review. As age cut-offs for “older adults” vary around the world, a low cut-off of 60 y or older was chosen to enable a broad worldwide inclusion. For validity and comparability, a common and validated nutrition screener or assessment tool that measured more than only BMI or unintentional weight loss had to be used. The studies had to compare participants who were malnourished (MN) or at risk of malnutrition (RMN) to a reference group of WN older adults. Physical performance had to be measured in an objective way for accuracy and comparability and had to measure ambulatory status, postural control, and stability, functional mobility, functional extremity strength, dynamic balance, or overall endurance. We included measures of muscle strength for their strong association with adverse outcomes and importance in activities of daily living (25) and recommendation by ESCEO (10). Due to the scarcity of cohort studies, the included studies had to report on the cross-sectional association between nutritional status and physical performance. Studies comprising mostly individuals with highly fatal disease were excluded.
Malnutrition and physical performance

TABLE 1  Ovid Medline search query

| Query                                                                 | Hits    |
|-----------------------------------------------------------------------|---------|
| 1 exp malnutrition/                                                   | 122,680 |
| 2 (malnutrition or malnourished or undernutrition or undernourished) | 52,821  |
| 3 1 or 2                                                              | 150,594 |
| 4 exp physical functional performance/                               | 1744    |
| 5 (physical performance or functional performance or functional status or performance status or physical function or physical fitness or gait speed or walking speed or mobility or handgrip or leg strength or short physical performance battery or SPPB or EPESE or chair stand or sit to stand or timed up or TUG or balance) | 466,631 |
| 6 4 or 5                                                              | 467,049 |
| 7 3 and 6                                                             | 4844    |
| 8 exp aged/                                                           | 3,160,522 |
| 9 (aged or aging or ageing or older adult or elderly or geriatric)    | 5,610,038 |
| 10 8 or 9                                                             | 5,610,038 |
| 11 7 and 10                                                           | 2197    |
| 12 exp observational study/                                           | 87,463  |
| 13 (observational study or cohort or epidemiologic or case-control or cross-sectional or longitudinal) | 1,576,745 |
| 14 12 or 13                                                           | 1,576,745 |
| 15 11 and 14                                                          | 770     |

EPESE, Established Populations for the Epidemiologic Study of the Elderly; SPPB, short physical performance battery; TUG, timed-up-and-go test.

Data extraction

The following data were extracted from each included study: bibliographic information [last name of first author, publication year, name of study (if applicable)]; country and setting; sample size; age and gender distribution; malnutrition screener or assessment tool; proportion of population that was MN or RMN; physical performance measure(s) used; association measures (including means for meta-analysis); co-variates. For each study, a plus sign was added to indicate hypothesized results (MN/RMN was associated with significantly worse physical performance compared with WN people), a minus sign to indicate opposing results, and a zero indicates no significant association was found. When expected associations were only found in subgroups (in either the RMN or MN groups and/or when an association was only observed in men or women), this was indicated by 0/+ . Studies were tabled in alphabetical order.

Quality assessment

The quality of the studies was assessed using the Newcastle–Ottawa Scale (NOS) for cohort studies adapted to cross-sectional studies (Table 3) (26, 27). The NOS assesses subject selection (representation of the sample, justification of sample size, nonrespondents’ characteristics), ascertainment of the exposure (malnutrition screening or assessment tool), comparability of the studied groups and confounders, objectivity of the outcome assessment (physical performance or muscle strength measure), and appropriateness of the statistical analysis. A maximum score of 9 points could be obtained; selection (max. 5 points), comparability (max. 2 points), and outcome (max. 2 points). The overall study score was defined as unsatisfactory (0–4 points), satisfactory (5–7 points), or good (8–9 points). The quality assessment was independently performed by 2 reviewers and conflicting results were resolved.

TABLE 2  Web of Science search query

| Query                                                                 | Hits    |
|-----------------------------------------------------------------------|---------|
| 1 ALL = (malnutrition OR malnourished OR undernutrition OR undernourished) | 57,549  |
| 2 ALL = (physical performance OR functional performance OR functional status OR performance status OR physical function OR physical fitness OR gait speed OR walking speed OR mobility OR handgrip or leg strength OR short physical performance battery or SPPB or EPESE or chair stand or sit to stand or Timed Up OR TUG OR balance) | 3,119,235 |
| 3 #2 AND #1                                                           | 6825    |
| 4 ALL = (aged OR aging OR ageing OR older adult OR elderly OR geriatric) | 3,650,889 |
| 5 #4 AND #3                                                           | 3766    |
| 6 ALL = (observational study OR cohort OR epidemiologic OR case-control OR cross-sectional OR longitudinal) | 1,719,562 |
| 7 #6 AND #5                                                           | 1413    |

EPESE, Established Populations for the Epidemiologic Study of the Elderly; SPPB, short physical performance battery; TUG, timed-up-and-go test.
### TABLE 3 Modified Newcastle–Ottawa Scale

| Category | Points |
|----------|--------|
| **Selection (max. 5)** | |
| 1 Representative of the sample (max 1) | |
| a. Truly representative of the average in the target population (random sample or whole population) | 1 |
| b. Somewhat representative of the average in the target population (nonrandom sample) | 1 |
| c. Selected group/convenience sample | |
| d. No description of the sampling strategy | |
| 2 Sample size (max 1) | |
| a. Justified and satisfactory (including sample size calculation) | 1 |
| b. Not justified | |
| 3 Nonrespondents (max 1) | |
| a. Comparability between respondents and nonrespondents characteristics is established, and the response rate is satisfactory (>60%) | 1 |
| b. The response rate is unsatisfactory, or the comparability between respondents and nonrespondents is unsatisfactory | |
| c. No description of the response rate or the characteristics of the responders and nonresponders | |
| 4 Ascertainment of the exposure (malnutrition) (max 2) | |
| a. A validated measurement tool is described and does not include a measure of physical functioning | 2 |
| b. A validated measurement tool is described, but includes measure of physical functioning | 1 |
| c. No description of the measurement tool or criteria | |
| **Comparability (max. 2)** | |
| 5 The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled for | |
| a. Study controls for age and gender | 1 |
| b. Study controls for any additional factor | 1 |
| **Outcome (max. 2)** | |
| 6 Assessment of the outcome (physical performance measure) | |
| a. Measurements are taken in a standardized manner/via a standardized protocol | 1 |
| b. Record linkage | 1 |
| c. Self-report | |
| d. No description of standardization or reference to standardized way | |
| **Statistical test** | |
| 7 a. The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented as either an OR/PR, CI, and \(P\) value, a \(\beta\)-coefficient, SE, and \(P\) value or means, SD; \(P\) value | 1 |
| b. The statistical test is not appropriate, not described, or incomplete | |

through discussion between the 2 researchers. Remaining disagreements were discussed among the research team until consensus was reached.

### Synthesis of results
If information did not match up and authors did not reply, numbers in tables were chosen over numbers in text or over percentages. Narrative results reported effect measures from the articles, except for categorical data reported as numbers: these were converted to ORs where possible. The number of studies reporting an association were reported per category of physical functioning [categories data-driven and based on domain(s) of physical performance or muscle strength: hand grip strength (HGS), gait speed, timed-up-and-go (TUG), short physical performance battery (SPPB), chair stand test (CST), knee extension strength (KES), other multicomponent tests, 6-min walking test (6MWT), and remaining measures as “other”), and per setting (hospital inpatient, hospital outpatient, nursing home, community dwelling). For studies which assessed malnutrition with several screeners or assessment tools, the choice was made in the following order: Mini Nutritional Assessment (MNA), Nutritional Risk Screening 2002 (NRS2002), Subjective Global Assessment (SGA), Seniors in the Community: Risk Evaluation for Eating and Nutrition II (SCREEN II), Mini Nutritional Assessment–Short Form (MNA-SF), Short Nutritional Assessment Questionnaire (SNAQ) (based on times used in the other studies and ascertainment of exposure).

### Meta-analysis
Meta-analysis was conducted if sufficient data were available (≥5 studies) and if outcomes between studies were reasonably homogeneous (e.g. same unit, scale, classification of malnutrition). Authors of relevant articles were contacted if required data were not reported. The Cochrane Handbook for conducting meta-analyses was followed (28). Results (mean differences) were pooled using a random-effects model. The extent of statistical heterogeneity was quantified using both the chi-squared test and the I-squared statistic. With respect to the latter, a value of >50% was used as a threshold for indicating substantial statistical heterogeneity (28). If >5 studies were included, sensitivity analyses were conducted to assess the influence of a single study on the overall estimate and to explore the impact of studies that were judged to be at high risk of bias as assessed by NOS.

The meta-analyses were conducted using R (version 3.6.3, R Foundation for Statistical Computing, Vienna). The “meta” package was used for calculations and data visualizations.
FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of identification, screening, and inclusion of studies. Excluded reports mention the primary reason of exclusion.

Results

The searches resulted in a total of 2250 records, from which 270 duplicates were removed. The remaining 1980 records were screened based on title and abstract, leading to the further exclusion of 1755 studies. One other record could not be retrieved, leaving 224 records for full-text screening. At this stage, 179 records were excluded for not meeting the inclusion criteria, leaving 45 studies for the qualitative review (Figure 1). The included studies (Table 4) were published between 2002 and 2020 and included between 41 and 1425 participants, totaling 16,911 participants. Most studies were performed in Europe (n = 20) or Asia (n = 14). Others took place in Oceania (n = 3), South Amer-
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size$^2$ | Adjusted covariates | Strength (NOS) | Association (+/-)$^1$ | Outcome |
|-------------------|-----------------------------|------------------|---------------------------------|-----------------------|----------------------------------|----------------|-------------------|----------------|-----------------|---------|
| Adly, 2020 (29)   | Hospital, Egypt             | Total: 190; W: 96, M: 94 | 68.67 ± 7.33                   | MNA-SF: 12–14: WN, 8–11: RMN, 0–7: MN | RMN: 37.4%, MN: 18.4% | Impaired sit-to-stand (>2 s) OR$^3$ (95% CI): MN vs. WN: 0.491 (0.12–1.94), P = 0.31; RMN vs. WN: 0.35 (0.11–1.05), P = 0.06 | —                | 2               | 0                   | 1 CST |
| Akin, 2014 (30)   | Community dwelling, Turkey  | Total: 845; W: 437, M: 408 | 71.6 ± 5.6                     | MNA: <23.5: RMN/MN, ≥23.5: WN | MN+RMN: 45.6% | Gait speed, s (4 m): OR (95% CI): 1.16 (1.07–1.25), (P < 0.001) | 4                | +               | 0                   | Gait speed |
| Bertschi, 2020 (31)| University department of geriatric medicine, Switzerland | Total: 305; W: 200, M: 105 | 84.0 [10.0]                    | NRS-2002: ≥3: RMN, <3: WN | RMN: 54.1% | low HGS (age ≥75: <34 kPa women, <50 kPa men; age ≤75: <42 kPa women, <64 kPa men): OR: 0.68 (0.35–1.29), P = 0.236 | 7                | 0               | 0                   | HGS |
| Borkent, 2020 (32)| Community dwelling, Netherlands | Total: 200; W: 129, M: 71 | 78.2 ± 6.9                     | SCREEN II: <54 RMN. SNAQ 65+: severe risk: ≥4 kg weight loss last month or UAC <0.25 cm, moderate risk: poor appetite and not able to walk stairs without rest | RMN (SCREEN II): 68.5%. RMN (SNAQ65+): moderate/severe: 13.5% | SCREEN II: TUG, s: WN: 9.8 sec [8.6–12.4], RMN: 10.5 sec [8.5–14.1], P = 0.203. HGS, kgF: WN: 28.8 kgF [23.8–35.3], RMN: 25.8 kgF [19.0–31.0], P = 0.005. SNAQ65+: TUG, S: WN: 9.9 s [8.3–13.3], RMN: 12.1 s [9.0–19.7], | 3 (SCREEN II-TUG and SNAQ-HGS), 4 (SCREEN II-HGS), 2 (SNAQ-TUG) | 0 (SCREEN II-TUG), + | TUG, HGS |

(Continued)
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/0) | Outcome |
|-------------------|-------------------------------|-------------------|--------------------------------|----------------------|----------------------------------|------------|-------------------|--------------|----------------|---------|
| Chang, 2017 (33)  | Community dwelling, Taiwan    | Total: 432; W: 264, M: 168 | RMN: 72.95 ± 9.28, WN: 71.55 ± 10.64 | MNA-SF: 12–14: WN, 8–11: RMN, 0–7: MN | RMN: 30.6, MN: 0 | 0.026. HGS, kgF: WN: 27.1 kgF [21.5–34.0], RMN: 20.9 kgF [16.0–26.6], P < 0.001 | — | 4 | + | 30 s CST, TUG |
| Chatindiara, 2019 (34) | Community dwelling, Auckland, New Zealand | Total: 257; W: 137, M: 120 | MNA-SF: ≤11: RMN/MN, ≥12: WN | 11.7 | Low gate speed <0.8 m/s (2.4 m): OR <sub>3</sub> (95% CI): 3.46 (1.20–10.03), WN: 16 (7.1%), RMN: 6 (20.0%), P 0.028. Low 5CST, ≥17 s: OR <sub>3</sub> (95% CI): 0.76 (0.27, 2.11), WN: 57 (37.7%), RMN: 6 (31.6), P = 0.600. Low HGS: women <20 kg, men <30 kg: OR <sub>3</sub> (95% CI): 0.75 (0.30–1.87), WN: 123 (54.2%), RMN: 15 (50.0%) P = 0.626 | — | 4 | + (Gait speed), 0 | Gait speed, 5 CST, HGS |
| Chevalier 2008 (35) | Hospital, Canada | Total: 182; W:121, M: 61 | WN: 78.1 ± 0.6, RMN: 82.2 ± 1.6, MN: 85.9 ± 1.5 | MNA: <17: MN, 17–23.5: RMN, >24: WN | RMN: 52.5, MN: 3.4 | — | 5 | 0 (HGS), +/- | HGS, gait speed |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/0) | Outcome |
|-------------------|-------------------------------|-------------------|-------------------------------|----------------------|-------------------------------|------------|-------------------|----------------|-----------------|---------|
| Dent, 2018 (36)   | Hospital, Australia           | Total: 172; W: 123 M: 49 | 85.2 ± 6.4                    | MNA: <17; MN, 17–23.5: RMN ≥24: WN | MN: 30.81, RMN: 48.84 | (15 m): WN: 0.64 ± 0.03 m/s, RMN: 0.53 ± 0.03 m/s, N means ± SD: 0.56 ± 0.13 m/s (WN vs. RMN: P < 0.05); (WN vs. MN: NS) HGS, kg: WN: 19.7 ± 8.2 kg, RMN: 17.3 ± 7.7 kg, MN: 12.7 ± 6.2 kg, (WN vs. RMN: NS) (WN vs. MN: <0.001) | —    | 4              | +/0     | HGS              |
| Ferdous, 2009 (37) | Community dwelling, Bangladesh (rural area) | Total: 457; W: 249, M: 208 | 69.5 ± 7.0                    | MNA. (excluding mobility): <15: MN, 15–21.5: RMN, ≥22: WN | MN: 26, RMN: 62 | HGS, kg (max. value): WN women: 16.6 ± 4 kg, RMN women: 16.3 ± 6 kg, MN women: 13.8 ± 4 kg, women WN vs. RMN: N.S women WN vs. MN: P = 0.003; WN men: 30.3 ± 11 kg, RMN men: 27.1 ± 7 kg, MN men: 23.9 ± 4 kg, men WN vs. RMN: P = 0.034, men WN vs. MN: P = 0.001. 6-item performance test, % limitation in any of the tasks, OR (95% CI): MN: OR 4.24 (2.17–8.27)RMN: OR 1.92 (1.07–3.45); (WN: 36%, RMN: 53%, P = 0.032) (WN: 36%, MN: 71%, P = 0.001) | Stratified by gender (HGS) | 6    | 0/+ (HGS), +   | HGS, 6-item performance test |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size 2 | Adjusted covariates | Strength (NOS) | Association (+/0) 1 | Outcome |
|-------------------|-----------------------------|------------------|-------------------------------|-----------------------|---------------------------------|-------------|-------------------|----------------|------------------|---------|
| Gingrich, 2019 (38) | Hospital, Germany | Total: 100; W: 481, M: 52 | 76.5 ± 4.7 | ESPEN | MN: 15% | Low HGS lowest 20% (by gender, BMI); 66.7% in MN group. MN vs. WN: NS. Low gait speed: 33% in MN group. MN vs. WN: NS. Reduced performance SPPB (<10 pts): 75.0% in MN group. MN vs. WN: P < 0.05 | — | 2 | 0, 0, + (SPPB) | HGS, gait speed, SPPB |
| Goldfarb, 2018 (39) | Hospital, Canada, USA, and France | Total: 1158; W: 481, M: 677 | 81.3 ± 6.1 | MNA-SF: 12–14: WN, 8–11: RMN, 0–7: MN | RMN: 32.8, MN: 8.7 | Gait speed, m/s (4 m): WN: 0.79 ± 0.35, RMN: 0.64 ± 0.35, MN: 0.49 ± 0.36, P < 0.001. HGS, kg: WN: 27.5 ± 10.4, RM: 24.0 ± 10.4, MN: 20.9 ± 9.9, P < 0.001. SPPB, score: WN: 7.4 ± 3.0, RM: 6.1 ± 3.3, MN: 4.9 ± 3.1, P < 0.001 | — | 4 | + | Gait speed, HGS, SPPB |
| Gurina, 2011 (40) | Community dwelling, Russia | Total: 611; W: 438, M: 173 | Women: 75.7 ± 6.1; men: 73.6 ± 5.3 | MNA: ≤23.5: RMN/MN | MN: 1.8, RMN: 17.3 | SPPB, score: RMN: β = -0.219, (P < 0.05) | Slow gait, less PA, exhaustion, muscle weakness | 5 | + | SPPB |
| Hegendörfer, 2020 (41) | BELFRAIL cohort, community dwelling, Belgium | Total: 567; (MNA: 556) W: 356, M: 211 | 84.7 ± 3.7 y | MNA: RMN: <24 or screener >11, WN: ≥24 | RMN: 12.2% | Physical test (score 0–14): RMN: 6.5 [4, 9.79], WN: 9 [6, 12], P < 0.002. HGS, highest of 3: RMN: 16.5 [12.6–20.2], WN: 21.5 [16.7, 27.4], P < 0.001 | — | 5 | + | Physical performance test, HGS |

(Continued)
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/−) | Outcome |
|-------------------|-----------------------------|------------------|---------------------------------|-----------------------|----------------------------------|------------|-------------------|---------------|-----------------|---------|
| Holst, 2013 (42)  | Hospitals, Denmark and Sweden | Total: 233; W: 152 M: 81 | 81.0 ± 7.64 | MNA: ≤23.5: RMN/MN, >23.5: WN. MUST: 0 = WN 1–2 = RMN/MN. NRS-2002: ≥3: RMN | MNA: 68. MUST: 47. NRS-2002: 54 | HGS, kg (max. value, predominant hand): MNA: WN: 15.8 ± 6 kg, RMN: 12.3 ± 7 kg, P < 0.05. MUST: WN: 14.4 ± 7 kg, RMN/MN means ± SD: 11.4 ± 7 kg, P < 0.05. NRS-2002: WN: 14.5 ± 7 kg, RMN: 12.4 ± 7 kg, P < 0.05 | − | 4 | + | HGS |
| Inoue, 2017 (43)  | Hip fracture patients at hospitals, Japan | Total: 204; W: 165, M: 39 | 82.7 ± 9.2 | MNA-SF: 12–14: WN, 8–11 RMN, 0–7: MN, | RMN: 48.04, MN: 25.00 | HGS, kg (max. value dominant hand): RMN: 11.9 ± 7.0 kg, WN: 14.6 ± 6.0 kg, MN: 8.7 ± 6.7 kg; WN vs. RMN: NS; WN vs. MN: <0.01 | − | 3 | 0/+ | HGS |
| Johansson, 2009 (44) | Community dwelling, Sweden | Total: 583; W: n = 278, M: n = 305 | Aged 75 y and 80 y | MNA: 24–30: WN, <24: RMN/MN | All: 14.5; women: 18.8, men: 10.6 | HGS, kg (max. measure of dominant hand): women: RMN: 19.7 ± 6.1, WN: 23.5 ± 5.7, P < 0.001; men: RMN: 34.2 ± 9.1, WN: 41.3 ± 8.5, P < 0.001 | − | 5 | + | HGS |
| Kaburagi, 2011 (45) | Community dwelling, Japan | Total: 130; W: 104, M: 26 | 76.6 ± 6.3 | MNA: >23.5: WN, ≤23.5: RMN | 20.77 | HGS, kg (mean of both hands): RMN: 18.9 ± 7.4 kg, WN: 22.9 ± 6.8 kg, P = 0.009. Usual gait speed, s (5 m): RMN: 5.1 ± 1.8 s, WN: 4.3 ± 1.2 s, P = 0.002; max. gait speed, s (5 m): RMN: 3.6 ± 1.1 s, WN: 3.2 ± 0.7 s, P = 0.001 | − | 5 | + | HGS, gait speed |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size \( ^2 \) | Adjusted covariates | Strength (NOS) | Association (+/-) \( ^1 \) | Outcome |
|-------------------|-----------------------------|------------------|----------------------------------|-----------------------|----------------------------------|-----------------|-----------------|----------------|---------------------|--------|
| Kiesswetter, 2013 (46) | Community dwelling (home care), Germany | Total: 296; W: 185 M: 111 | 80.7 ± 7.7 | MNA: > 23.5: WN, 17–23.5: RMN, < 17: MN | RMN: 56.8, MN: 12.2 | TUG, s: WN: 19.9 ± 13.3, RMN: 23.2 ± 13.0, MN means ± SD: 23.8 ± 1.27, \( P = 0.247 \). HGS, bar (max. value) WN 0.57 ± 0.21 bar, RMN: 0.53 ± 0.20 bar, MN: 0.43 ± 0.20 bar, \( P \) trend: 0.014, SPPB, score: WN: 4.8 ± 2.6, RMN: 3.6 ± 2.5, MN: 3.8 ± 2.4, \( P = 0.006 \). | Gender, age, MMSE, GDS, no. chronic diseases | 7 | 0 | sTUG, HGS, SPPB |
| Kocyigit, 2018 (47) | Outpatients, Turkey | Total: 862; W: 563, M: 299 | 74 ± 8.05 | MNA-SF: 0–7: MN, 8–11: RMN, 12–14: WN | MN: 26.9, RMN: 7.7 | Tinetti POMA: WN: 25.20 ± 3.82, RMN: 22.15 ± 6.28, MN: 20.09 ± 6.29; WN vs. RMN: \( P < 0.0001 \); WN vs. MN: \( P < 0.0001 \). Tinetti gait, score: WN: 10.82 ± 1.74, RMN: 9.51 ± 2.74, MN: 9.06 ± 2.68; WN vs. RMN: \( P < 0.0001 \); WN vs. MN: \( P < 0.0001 \). Tinetti balance, score: WN: 14.38 ± 2.30, RMN: 12.64 ± 3.76, MN: 11.03 ± 3.88; WN vs. RMN: \( P < 0.0001 \); WN vs. MN: \( P < 0.0001 \). TUG, s: WN: 12.68 ± 6.66, RMN: 17.10 ± 11.47, MN: 21.21 ± 12.90; WN vs. RMN: \( P < 0.0001 \); WN vs. MN: \( P < 0.0001 \). | — | 2 | + | Mobility, Tinetti gait, balance, TUG |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size \(^2\) | Adjusted covariates | Strength (NOS) | Association (+/0) \(^1\) | Outcome |
|-------------------|-----------------------------|-----------------|-----------------|---------------------|-----------------------------|----------------|-------------------|----------------|-------------------|---------|
| Lecheta, 2017 (48) | Elderly Care Unit for Alzheimer’s, Brazil | Total: 96; W: 68, M: 28 | 78.0 ± 6.52 | MNA: >23.5: WN, 17–23.5: RMN, <17: MN | RMN: 55.2, MN: 5.2 | TUG, s: WN: 12.7 ± 6.09, RMN: 12.8 ± 4.82, MN: 23.7 ± 14.24, \(P\) trend = 0.190. HGS, kg (mean, right hand): WN: 18.6 ± 5.74, RMN: 15.2 ± 5.70, MN: 20.5 ± 6.76; WN vs. RMN: \(P < 0.05\); WN vs. MN: NS | — | 5 | 0 (\(s\)TUG), +/0 | TUG, HGS |
| Lelli, 2020 (49) | Chronic heart failure out-patients, Italy | Total: 88; W: 15, M: 73 | 77.8 ± 7.1 | MNA: <17 MN, 17–23.5: RMN, ≥24: WN | MN \(n = 1\) excluded, RMN: 33% | Gait speed m/s: (4 m usual pace): RMN: \(\beta = -0.138, P = 0.055\) | Age, sex, ejection fraction, GDS, ASMMI, caloric intake/ideal body weight | 6 | 0 | Gait speed (4 m) |
| Lim, 2018 (50) | Community dwelling, Korea | Total: 464 | 69.6 ± 2.96 | Nutritional screening initiative (Korean): 0–2: WN, ≥6: MN | 34.7 | Mobility scale: WN: 86.14 ± 16.71, MN: 66.29 ± 23.23, \(P < 0.001\), 5CST, points (max. 3 points): WN: 2.88 ± 0.35, MN: 2.57 ± 0.37, \(P < 0.001\) | — | 5 | + | Mobility, 5CST |
| Mendes, 2018 (51) | Representative sample to the national level, Portugal | Total: 1425; W: 834, M: 591 | WOMEN: low gait speed: 78.5 ± 7.1; normal gait speed: 72.4 ± 5.9; MEN: low gait speed: 77.4 ± 7.4; normal gait speed: 72.7 ± 5.8 | Low gait speed, ≤0.8 m/s (4.6 m): women OR (95% CI): 5.98 (2.46–14.53), men OR (95% CI): 2.96 (1.31–6.64) | | | | | 5 | + | Gait speed | (Continued)
### TABLE 4 (Continued)

| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size² | Adjusted covariates | Strength (NOS) | Association (+/-)? | Outcome |
|--------------------|------------------------------|------------------|---------------------------------|-----------------------|----------------------------------|-------------|----------------------|----------------|-------------------|---------|
| Mendes, 2019 (52)  | Representative to the national level, Portugal | Total: 1425; W: 834, M: 591 | Total: 74.9 ± 7.0; WOMEN: 75.0 [11.0]; MEN: 73.0 [10.0] | MNA-SF: <12: RMN/MN, ≥12: WN | WOMEN: 17.7, MEN: 11.7 | Low HGS (<20 kgF women, <30 kgF men) (max. of nondominant hand): women OR (95% CI): 1.54 (1.01–2.36); men OR (95% CI): 1.57 (0.91–2.72) | Stratified by gender, adjusted for age | 5 | +/- | HGS |
| Misu, 2017 (53)    | Community dwelling, Japan | Total: 204; W: 107, M: 97 | 73.4 ± 4.3 | MNA-SF (Japanese): 12–14: WN; <11: RMN/MN | MN + RMN: 23.04 | Gait speed: Model 1: age, sex, BMI, musculoskeletal pain; Model 2: plus: skeletal muscle mass index, HGS, 5CST, TUG. Model 2: 5CST/sTUG/HGS: none | 3 (HGS), 5 (gait speed), 4 | 0 | HGS, gait speed, 5CST, sTUG |
| Norman, 2007 (54)  | Institutionalized people, Germany | Total: 112; W: 78, M: 34 | 85.1 [79.1–91.4] | MNA: >23.5: WN, 17–23.5: RMN, <17: MN | RMN: 71.4, MN: 8.9 | HGS, kg median [IQR] (max., nondominant hand): WN: 16.3 [11.8–21.4], MN: 6.3 [3.6–10.8]; WN vs. RMN: N.S; WN vs. MN: P < 0.01. Knee extension strength, kg, median [IQR]: WN: 10.3 [7.3–16.4], RMN: 8.0 [5.0–12.0], MN: 5.0 [3.0–7.0], WN vs. RMN: P < 0.05; WN vs. MN: P < 0.05 | — | 4 | 0/+ (HGS), + | HGS, leg strength |
TABLE 4 (Continued)

| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size² | Adjusted covariates | Strength (NOS) | Association (+/-)¹ | Outcome |
|--------------------|-------------------------------|------------------|-------------------------------|-----------------------|-----------------------------------|-------------|---------------------|----------------|---------------------|---------|
| Ogawa, 2017 (55)   | Hospital inpatients for cardiology-mendary bypass, Japan | Total: 131; W: 54, M: 77 | 73.7 ± 5.8 | Geriatric nutritional risk index: ≥92: WN, <92: RMN | 19.08 | SPPB, score: RMN: 9.6 ± 2.9, WN: 11.6 ± 1.2, P < 0.0001. 6MWT, m: RMN: 320.9 ± 132.0, WN: 421.2 ± 141.4, P = 0.0012. HGS, kg (max. value): RMN: 21.0 ± 4.8, WN: 27.6 ± 6.9, P = 0.034. KES, Nm/kg: RMN: 35.8 ± 7.29, WN: 42.8 ± 10.9, P = 0.009 | Sex, serum hemoglobin | 5 | + | SPPB, 6MWT, HGS, leg strength |
| Persson, 2002 (56) | Hospital, Sweden | Total: 83; (n = 68 for this analysis) W: 56, M: 27 | 83.0 ± 7.0 | SGA: MN, moderate MN, WN. MNA: <17: MN, 17–23.5: RMN, >24: WN | HGS, kg (max. value, dominant hand): SGA: women: WN: 16.5 ± 3.7, moderate MN: 12.9 ± 6.1, MN: 15.5 ± 3.5; WN vs. moderate MN: P < 0.05; WN vs. MN: NS; men: WN: 29.0 ± 7.4, moderate MN: 26.6 ± 6.8, MN: 19.0 ± 7.6, WN vs. moderate MN: NS WN vs. MN: NS. HGS, kg: best of 2, MNA: women: WN: 16.4 ± 3.3, RMN: 16.4 ± 4.1, MN: 12.7 ± 5.7; WN vs. RMN: NS; WN vs. MN: NS; men: WN: 26.5 ± 16.3, RMN: 31.3 ± 9.1, MN: 24.3 ± 6.3; WN vs. RMN: NS; WN vs. MN: P < 0.05. MNA-SF: Only stratified by gender | SGA, MNA: 3.2 (MNA-SF) | +/- (SGA, MNA), + (MNA-SF) | HGS |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size² | Adjusted covariates | Strength (NOS) | Association (+/-)¹ | Outcome |
|-------------------|-----------------------------|------------------|--------------------------------|----------------------|----------------------------------|-------------|---------------------|----------------|------------------|---------|
| Pierik, 2017 (57) | EMPOWER study, hospital, The Netherlands | Total: 374; W: 183, M: 191 | 79.7 ± 6.39 | SNAQ: RMN: ≥2, WN: ≤1 | RMN: 34.8% | — | — | 7 | 0 | HGS |
| Pourhassan, 2020 (58) | Acutely ill older adults in hospital, Germany | Total: 41; W: 30, M: 11 | 82.4 ± 6.6 | GLIM: MN: ≥1 phenotypic and ≥1 etiologic component | MN: 17% | — | — | 3 (HGS), 4 | 0 (HGS), + | HGS, KES |
| Ramsey, 2020 (59) | Outpatients, The Netherlands | Total: 286; W:170, M: 116 | 81.8 ± 7.4 | SNAQ: ≥2; RMN/MN, <2; WN | 19.9 | Z | gait speed, m/s (4 m): β (95% CI): -0.49 (-0.78, -0.20), P < 0.001. Side-by-side balance (unable to maintain 10 s): OR (95% CI): 0.69 (0.23, 2.02), P = 0.497; semi-tandem balance (unable to maintain 10 s): OR (95% CI): 0.67 (0.31, 1.43), P = 0.294; tandem balance (unable to maintain 10 s): OR (95% CI): 0.57 (0.28, 1.16), P = 0.030; Z LN 5 CST, s: β (95% CI): 0.53 | 6 | +, 0 (balance, HGS) | Gait speed, balance, 5CST, TUG, SPPB |
| First author, country, study name | Setting, sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of malnutrition status (%)) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/0) | Outcome |
|----------------------------------|---------------------------|---------------------------------|-----------------------|-----------------------------------|------------|---------------------|----------------|----------------|---------|
| **Reijnierse, 2015 (60)**        | Outpatients, The Netherlands Total: 185; W: 111, M: 74 | 82.0 ± 7.3 | SNAQ: ≤2: WN, ≥2: RMN/MN | 16 | Z gait speed, m/s (4 m): Model 1: $\beta$ (P value): −0.35, SE = 0.24 (0.151); Model 2: $\beta$ (P value): −0.35, SE = 0.25 (0.157). Z HGS, kg (best performance of both hands): Model 3: $\beta$ = −0.37, SE = 0.20 (P = 0.067) | Gender specific Z-scores. Model 1: age; Model 2: age, height. HGS: Model 3: age, body mass, height | 7 | 0 | Gait speed, HGS |
| **Riviati, 2017 (61)**           | Geriatric outpatient ward at hospital, Indonesia Total: 352; W: 212, M: 140 | 69.7 ± 6.3 | MNA: MN, WN | 14.6 | Low HGS, kg (unknown how measured): R (95% CI) 1.9 (1.4–2.6) | | | | |
| **Romero-Ortuno, 2011 (62)**     | Community dwelling, Ireland Total: 556; W: 388, M: 168 | 72.08 ± 6.9 | MNA: ≥24: WN, <24: RMN/MN | 7.2 | TUG, s: OR (95% CI): 1.111 (1.048–1.177) | LSNS-18, age, gender, living alone, material deprivation | 6 | + | TUG |
| **Schrader, 2016 (63)**          | Hospital, Germany Total: 190; W: 137, M: 53 (186 with association SPPB) | 80 [75–84] | MNA: >24: WN, 17–23.5: RMN, <17 points: MN | MNA: RMN: 44.7, MN: 5.8. MNA-SF: RMN: 36.3, MN: 8.9 | SPPB, score median [IQR]: MNA: WN: 6 [5–8], RMN: 5 [3–8], MN: 5 [3–8], P = 0.33. MNA-SF median [IQR]: WN: 6 [4–8], RMN: 6 [4–8], MN: 6 [3–9.5], P = 0.717 | | | | SPPB |

(Continued)
### TABLE 4 (Continued)

| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size² | Adjusted covariates | Strength (NOS) | Association (+/0)¹ | Outcome |
|--------------------|-------------------------------|-------------------|-------------------------------|-----------------------|-----------------------------------|-------------|---------------------|----------------|-----------------|---------|
| Schrader, 2014 (64) | Acute ward at hospital, Germany | Total: 205; W: 141, M: 64 (86 with TUG) | 82 [80–86] | MNA: ≥24: WN. 17–23.5: RMN. <17: MN | RMN: 60.00, MN: 29.76 | TUG (n = 86); s: WN: 15.5 ± 5.2 s, RMN: 18.9 ± 5.8 s, MN: 21.3 ± 8.0; WN vs. RMN: N.S; WN vs. MN: NS | — | 6 | 0 | $s_{TUG}$ |
| Soundararajan, 2017 (65) | Community dwelling, India | Total: 60; W: 41, M: 19 | MN: 71.33 ± 7.41, WN: 68.67 ± 5.91 | MNA: WN: ≥24, MN: 17–23.5 | 50.0 (selection from original 20%) | 42.5 | TUG, score: WN: 1.36 ± 0.49, MN: 2.16 ± 0.83, P < 0.001 | — | 5 | + | TUG |
| Suzana, 2013 (66) | Community dwelling, Malaysia | Total: 160; W: 102, M: 58 | 65.0 ± 3.9 | MNA-SF: >11: WN |  |  | — | 1 | 0 (HGS), + | HGS, Mobility |
| Tian, 2016 (67) | Hospital and community dwelling, China | Total: 531, W: 299, M: 232 | 72.3 ± 7.7 | MNA-SF: MN: ≤11 | RMN: 18% | Gait speed: RMN: ≤0.8 m/s; n = 64, >0.8 m/s; n = 34, OR: 1.81 (CI: 1.14, 2.85), P = 0.011 | — | 3 | + | Gait speed |
| Tramontano, 2016 (68) | Community dwelling, Peru | Total: 222; W: 120, M: 102 | 73.8 ± 7.0 | MNA: ≤17 MN, 18–23: RMN, ≥24: WN | RMN: 52.7, MN: 9.4 | Poor gait speed, s (>4.4 s) (4 m); RMN vs. WN: OR (95% CI): 1.47 (0.68–3.18), P = 0.33; MN vs. WN: OR (95% CI): 3.30 (0.74–14.76) P = 0.12. Poor 6MWT, m (<331 m); RMN vs. WN: OR (95% CI): 1.91 (0.86–4.22), P = 0.19; MN vs. WN: OR (95% CI): 2.73 | Age, sex, education, number of drugs, presence of chronic disease, BMI, work, calf and arm circumference | 6 | 0⁺, 0 (SCST) | Gait speed, 6MWT, SCST, SPPB |
| First author, year | Setting, country, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/-) | Outcome |
|-------------------|-----------------------------|------------------|-------------------------------|------------------------|-----------------------------------|------------|---------------------|----------------|-----------------|---------|
| Turusheva, 2017 (69) | Community dwelling, Russia | Total: 602; W: 436, M: 166 | Age range: 65–91 | MNA: 17–23.5; Women: RMN: 17.7, MN: 81.2; men: RMN: 15.7, MN: 82.5 | Average/maximum P5 HGS or > P5 HGS: RMN OR (95% CI): 3.09 (1.81–5.27); MN OR (95% CI): 9.02 (2.19–37.21); (RMN: P5, n: 26 (32.9%), >P5: 76 (14.6%), P < 0.05; MN: P5: 4 (5.1%), >P5: 4 (0.8%), P < 0.05) | — | 4 | + | HGS |

(Continued)
| First author, year, study name | Setting, country | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/0) | Outcome |
|-------------------------------|-----------------|------------------|-------------------------------|-----------------------|----------------------------------|------------|-------------------|----------------|----------------|---------|
| **Vahlberg, 2016** (70)       | Community dwelling, Sweden | 134 | 74 ± 7 | MNA-SF (except mobility item): RMN: < 10 | MN: 0%, RMN: 14% | Low mobility (SPPB ≤ 8), OR (95% CI): 4.3 (1.9–9.8) | — | 6 | + | SPPB |
| **Wang, 2019** (71)           | Care home, Taiwan | Total (M): 333 | 85.4 ± 5.7 | MNA-SF: < 12: MN, ≥ 12: WN | 50.15 | Slow gait speed (< 0.8 m/s, 6 m) reported: WN: 85 (54.1%), MN: 81 (68.6%), P = 0.015; OR (95% CI): 0.90 (0.58, 1.39), P = 0.62. HGS, kg (max. value, dominant hand): WN: 27.7 ± 7, MN: 21.3 ± 7.6, P < 0.001. | — | 2 | + | Gait speed, HGS |
| **Zhang, 2017** (72)          | Hospital, China | Total: 1343, W: 652, M: 691 | 73.8 ± 5.9 | NRS-2002: ≥ 3: RMN, < 3: WN, SGA: SGA A: WN, SGA B or C: RMN/MN | NRS-2002: 63.81. SGA: 28.22 | Optimal HGS, kg (mean of dominant hand), MN+RMN vs. WN: NRS-2002: WOMEN OR (95% CI): 0.93 (0.89–0.98); MEN OR (95% CI): 0.93 (0.90–0.97). Optimal HGS, kg (mean of dominant hand), MN+RMN vs. WN: SGA: WOMEN OR (95% CI): 0.93 (0.88–0.98); MEN OR (95% CI): 0.93 (0.89–0.96). | NRS-2002: Stratified by gender. SGA: age, disease state | 5 | + | HGS |

(Continued)
TABLE 4  (Continued)

| First author, year | Setting, study name | Sample size, (n); | Age (y), mean ± SD/median [IQR] | Malnutrition criteria | (Risk of) malnutrition status (%) | Effect size | Adjusted covariates | Strength (NOS) | Association (+/0) | Outcome |
|-------------------|---------------------|------------------|---------------------------------|-----------------------|---------------------------------|-------------|---------------------|---------------|-----------------|---------|
| Zhou, 2015 (73)   | Surgery department of hospital, China | Total: 142; W: 66, M: 76 | WOMEN: 71.8 ± 5.4, MEN: 72.0 ± 5.9 | NRS-2002: 0–2: WN, ≥3: RMN/MN. MNA-SF: >11: WN, ≤11: RMN/MN | NRS-2002: 38. MNA-SF: 45 | HGS, kg (max. value, but unknown hand): NRS-2002: WN: 24.40 ± 19.32 kg, MN: 18.01 ± 15.54 kg, P = 0.04. MNA-SF: WN: 24.91 ± 19.52 kg, MN: 18.38 ± 15.85 kg, P = 0.03 | — | 5 (NRS), 4 | + | HGS |

1 Plus sign (+): MN or RMN is associated with worse physical functioning than WN; zero (0): MN or RMN is not associated with physical functioning compared to WN; minus sign (-): MN or RMN is associated with better physical functioning than WN.

2 Values are means ± SD or median [IQR] or otherwise specified.

3 ORs derived by calculation.

4 OR approximated as exact number of missing participants per category in this analysis is unknown; ASMMI, appendicular skeletal muscle mass index; BELFRAIL, Belgian Cohort of the Very Elderly; EMS, Elderly Mobility Scale; ESPEN, European Society of Clinical Nutrition and Metabolism consensus statement on malnutrition; GDS, Geriatric Depression Scale; GLIM, Global Leadership Initiative on Malnutrition criteria; HGS, handgrip strength; KES, knee extension strength; kgF, kilogram force; kPa, kilo pascal; LSNS-18, Lubben social network scale-18; M, men; MMSE, Mini Mental State Examination; MN, malnourished; MNA, Mini Nutritional Assessment; MNA-SF, Mini Nutritional Assessment - Short Form; MUAC, midupper arm circumference; MUST, Malnutrition Universal Screening Tool; NOS, Newcastle-Ottawa Scale; NRS-2002, Nutrition Screening 2002; NSI, Nutritional screening initiative; PA, physical activity; POMA, Performance Oriented Mobility Assessment; RMN, risk of malnutrition; SCREEN II, Seniors in the Community Risk Evaluation for Eating and Nutrition, version II; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; SPPB, short physical performance battery; TUG, timed-up-and-go; W, women; WN, well-nourished; Z LN, Z-scores of the natural logarithm; 1CST, 1-time chair stand test; 5CST, 5 times chair stand test; 6MWT, 6-min walking test; 30sCST, 30-second chair stand test.
### TABLE 5  Study quality scoring according to the modified Newcastle–Ottawa Scale

| Study            | Substudy difference | Representation | Sample size | Nonresponders | Ascertainment of exposure | Comparability | Assessment of the outcome | Statistical test | Total NOS (max. 9) |
|------------------|---------------------|----------------|-------------|---------------|---------------------------|---------------|--------------------------|------------------|-------------------|
| Adly, 2020 (29)  |                     | 0              | 0           | 0             | 1                         | 0             | 0                        | 1                | 2                 |
| Akin, 2014 (30)  |                     | 1              | 0           | 0             | 2                         | 0             | 0                        | 1                | 4                 |
| Bertschi, 2020   |                     | 0              | 1           | 0             | 2                         | 2             | 1                        | 1                | 7                 |
| Borkent, 2020    | TUG/SCREEN II       | 0              | 0           | 0             | 2                         | 0             | 0                        | 1                | 3                 |
|                  | HGS/SCREEN II       | 0              | 0           | 0             | 2                         | 0             | 1                        | 1                | 4                 |
|                  | TUG/SNAQ            | 0              | 0           | 0             | 1                         | 0             | 0                        | 1                | 2                 |
|                  | HGS/SNAQ            | 0              | 0           | 0             | 1                         | 0             | 1                        | 1                | 3                 |
| Chang, 2017 (33) |                     | 0              | 1           | 0             | 1                         | 0             | 1                        | 1                | 4                 |
| Chatindiara, 2019|                     | 1              | 0           | 0             | 1                         | 0             | 1                        | 1                | 4                 |
| Chevalier, 2008  |                     | 1              | 0           | 0             | 2                         | 0             | 1                        | 1                | 5                 |
| Dent, 2018 (36)  |                     | 0              | 0           | 1             | 2                         | 0             | 0                        | 1                | 4                 |
| Ferdous, 2009    |                     | 1              | 1           | 1             | 2                         | 1             | 0                        | 1                | 6                 |
| Gingrich, 2019   |                     | 0              | 0           | 0             | 1                         | 1             | 0                        | 1                | 2                 |
| Goldfarb, 2018   |                     | 1              | 0           | 0             | 1                         | 0             | 1                        | 1                | 4                 |
| Gurina, 2011 (40)|                     | 1              | 0           | 0             | 2                         | 1             | 1                        | 0                | 5                 |
| Hegendorfer, 2020|                     | 1              | 0           | 0             | 2                         | 0             | 1                        | 1                | 5                 |
| Holst, 2013 (42) | MNA/MUST/NRS2002    | 0              | 0           | 0             | 2                         | 0             | 1                        | 1                | 4                 |
| Inoue, 2017 (43) |                     | 1              | 0           | 0             | 1                         | 0             | 0                        | 1                | 3                 |
| Johannson, 2008  |                     | 1              | 0           | 0             | 2                         | 0             | 1                        | 1                | 5                 |
| Kaburagi, 2011   |                     | 1              | 0           | 0             | 2                         | 1             | 0                        | 1                | 5                 |
| Kiesswetter, 2013|                     | 1              | 0           | 1             | 2                         | 1             | 1                        | 1                | 7                 |
| Kocyigit, 2018   |                     | 0              | 0           | 0             | 1                         | 0             | 0                        | 1                | 2                 |
| Lecheta, 2017 (48)|                    | 0              | 1           | 0             | 2                         | 0             | 1                        | 1                | 5                 |
| Lelli, 2020 (49) |                     | 1              | 0           | 0             | 2                         | 2             | 0                        | 1                | 6                 |
| Lim, 2018 (50)   |                     | 1              | 1           | 0             | 1                         | 0             | 1                        | 1                | 5                 |
| Mendes, 2018     |                     | 1              | 0           | 0             | 1                         | 1             | 1                        | 1                | 5                 |
| Mendes, 2019     |                     | 1              | 0           | 0             | 1                         | 1             | 1                        | 1                | 5                 |

(Continued)
| Study                        | Substudy difference | Representation | Sample size | Nonresponders | Ascertainment of exposure | Comparability | Assessment of the outcome | Statistical test | Total NOS (max.9) |
|-----------------------------|---------------------|----------------|-------------|---------------|--------------------------|---------------|----------------------------|-----------------|------------------|
| Misu, 2017 (53)*            | Gait speed          | 1              | 0           | 0             | 1                        | 1             | 1                          | 1               | 5                |
|                            | HGS                 | 1              | 0           | 0             | 1                        | 0             | 0                          | 1               | 3                |
|                            | 5CST, TUG           | 1              | 0           | 0             | 1                        | 0             | 1                          | 1               | 4                |
| Norman, 2007 (54)           |                     | 0              | 0           | 0             | 2                        | 0             | 1                          | 1               | 4                |
| Ogawa, 2017 (55)            |                     | 0              | 0           | 0             | 2                        | 1             | 1                          | 1               | 5                |
| Persson, 2002 (56)*         | SGA, MNA            | 0              | 0           | 0             | 2                        | 0             | 0                          | 1               | 3                |
|                            | MNA-SF              | 0              | 0           | 0             | 1                        | 0             | 0                          | 1               | 2                |
| Pierik, 2017 (57)           |                     | 1              | 1           | 0             | 2                        | 1             | 1                          | 1               | 7                |
| Pourhassan (58)*            | HGS                 | 0              | 1           | 0             | 1                        | 0             | 0                          | 1               | 3                |
|                            | KES                 | 0              | 1           | 0             | 1                        | 0             | 1                          | 1               | 4                |
| Ramsey, 2019 (59)           |                     | 1              | 0           | 0             | 2                        | 1             | 1                          | 1               | 6                |
| Reijnenise, 2015 (60)       |                     | 1              | 0           | 0             | 2                        | 2             | 1                          | 1               | 7                |
| Riviati, 2017 (61)          |                     | 1              | 0           | 0             | 0                        | 0             | 0                          | 0               | 1                |
| Romero-Ortuno, 2011 (62)    |                     | 1              | 0           | 0             | 2                        | 1             | 1                          | 1               | 6                |
| Schrader, 2014 (64)         |                     | 1              | 0           | 0             | 2                        | 1             | 1                          | 1               | 6                |
| Schrader, 2016 (63)*        | MNA                 | 1              | 0           | 0             | 2                        | 0             | 1                          | 1               | 5                |
|                            | MNA-SF              | 1              | 0           | 0             | 1                        | 0             | 1                          | 1               | 4                |
| Soundararajan, 2017 (65)    |                     | 1              | 0           | 0             | 2                        | 0             | 1                          | 1               | 5                |
| Suzana, 2013 (66)           |                     | 0              | 0           | 0             | 1                        | 0             | 0                          | 0               | 1                |
| Tian, 2016 (67)             |                     | 0              | 0           | 0             | 1                        | 0             | 1                          | 1               | 3                |
| Tramontano, 2016 (68)       |                     | 0              | 0           | 0             | 2                        | 2             | 1                          | 1               | 6                |
| Turusheva, 2017 (69)        |                     | 1              | 0           | 0             | 2                        | 0             | 1                          | 0               | 4                |
| Vahlberg, 2016 (70)         |                     | 1              | 0           | 1             | 1                        | 1             | 1                          | 1               | 6                |
| Wang, 2019 (71)             |                     | 0              | 0           | 0             | 1                        | 0             | 0                          | 1               | 2                |
| Zhang, 2017 (72)            | NRS-2002/SGA        | 0              | 0           | 0             | 2                        | 1             | 1                          | 1               | 5                |
| Zhou, 2015 (73)*            | NRS-2002            | 1              | 0           | 0             | 2                        | 0             | 1                          | 1               | 5                |

*Quality differs within the study, based on the use of malnutrition tools and/or outcomes; HGS, hand grip strength; KES, knee extension strength; MNA, Mini Nutritional Assessment; MNA-SF, Mini Nutritional Assessment Short Version; MUST, Malnutrition Universal Screening Tool; NRS-2002, Nutrition Screening 2002; SCREEN II, Seniors in the Community: Risk Evaluation for Eating and Nutrition, version II; SGA, Subjective Global Assessment; SNAQ, Short Nutritional Assessment Questionnaire; TUG, timed-up-and-go; 5CST, 5 times chair stand test.
TABLE 6  Number of studies showing an association between malnutrition or risk of malnutrition and worse physical performance, split per type of physical performance test, both when all studies are included and when only studies of satisfactory quality (NOS ≥ 5) are included1

| Type of physical performance test | No association, n (%) | Association in subgroups only,* n (%) | Expected association, n (%) | Total, n |
|----------------------------------|-----------------------|--------------------------------------|-----------------------------|---------|
|                                  | All | NOS ≥5 | All | NOS ≥5 | All | NOS ≥5 | All | NOS ≥5 | All | NOS ≥5 |
| HGS (n = 4) | 9 (30%) | 4 (26.7%) | 8 (26.7%) | 4 (26.7%) | 13 (43.3%) | 7 (46.7%) | 30 | 15 |
| Gait speed (n = 6) | 6 (42.9%) | 5 (62.5%) | 0 (0%) | 0 (0%) | 8 (57.1%) | 3 (37.5%) | 14 | 8 |
| TUG (n = 5) | 5 (50%) | 3 (50%) | 0 (0%) | 0 (0%) | 5 (50%) | 3 (50%) | 10 | 6 |
| CST (n = 4) | 4 (57.1%) | 1 (33.3%) | 0 (0%) | 0 (0%) | 3 (42.9%) | 2 (66.7%) | 7 | 3 |
| KES (n = 0) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 3 (100%) | 1 (100%) | 3 | 1 |
| 6MWT (n = 0) | 0 (0%) | 0 (0%) | 1 (50%) | 1 (50%) | 1 (50%) | 1 (50%) | 2 | 2 |
| SPPB (n = 1) | 1 (11.1%) | 1 (14.3%) | 1 (11.1%) | 1 (14.3%) | 7 (77.8%) | 5 (71.4%) | 9 | 7 |
| Multi-component (n = 0) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 5 (100%) | 3 (100%) | 5 | 3 |
| Other (n = 1) | 1 (33.3%) | 1 (100%) | 0 (0%) | 0 (0%) | 2 (66.7%) | 0 (0%) | 3 | 1 |
| Total | 26 (31.3%) | 15 (32.6%) | 10 (12.1%) | 6 (13.0%) | 47 (56.6%) | 25 (54.5%) | 83 | 46 |

1CST, chair stand tests; HGS, hand grip strength; gait speed, gait speed test; TUG, timed up-and go; KES, knee extension strength; NOS, Newcastle–Ottawa Scale; MN, malnourished; multi-component tests, mobility and physical performance tests spanning multiple domains; RMN, risk of malnutrition; SPPB, short physical performance battery; 6MWT, 6-min walking test.

*Association in subgroups only: an association is a) only found in the MN group, not in the RMN group or b) vice versa, or c) an association is only observed in RMN or MN groups, but only in men or in women, or d) associations differ in RMN/MN groups per gender.

...
FIGURE 2 Forest plot illustrating the mean difference of HGS (kg) between well-nourished versus malnourished groups. HGS, handgrip strength; MD, mean difference; MN, risk of malnutrition; WN, well-nourished.

![Forest plot illustrating the mean difference of HGS (kg)](image)

FIGURE 3 Forest plot illustrating the mean difference of HGS (kg) between well-nourished versus malnourished groups. HGS, handgrip strength; MD, mean difference; MN, malnourished; WN, well-nourished.

![Forest plot illustrating the mean difference of HGS (kg)](image)

HGS

For HGS, 13/30 (43.4%) studies showed an association with nutritional status and 8/30 (26.7%) showed an association in subgroups only. When only including studies of satisfactory quality, 7/15 (46.7%) studies report an association.

Twenty-three out of the 30 studies using HGS were included in the meta-analysis (Figures 2 and 3). WN groups had a significantly higher HGS compared with RMN groups (MD \( = 2.68 \text{ kg}; 95\% \text{ CI: 2.72, 4.30} \)) and the MN group \( = 2.57 \text{ kg} \).

| Study | Total Mean | SD | Total Mean | SD | Mean Difference | MD | 95% CI | Weight |
|-------|------------|----|------------|----|-----------------|----|--------|--------|
| Trombetta (69) | 491 ± 20.8 | 9.0 | 39.4 ± 20.8 | 9.0 | 91.7 | 2.68 | 2.72, 4.30 |
| Zheng (72) | 444 ± 17.0 | 3.0 | 44.1 ± 17.0 | 3.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Li (73) | 224 ± 24.9 | 9.0 | 22.4 ± 24.9 | 9.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Ramasamy (78) | 194 ± 26.7 | 9.0 | 19.4 ± 26.7 | 9.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Wang (79) | 159 ± 27.7 | 7.0 | 15.9 ± 27.7 | 7.0 | 2.1 | 0.34 | 0.03, 0.65 |
| de Vries (80) | 33.5 ± 10.2 | 2.0 | 3.3 ± 10.2 | 2.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Goldfarb (81) | 67.7 ± 27.0 | 10.0 | 6.77 ± 27.0 | 10.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Issac (82) | 91.4 ± 14.0 | 6.0 | 9.14 ± 14.0 | 6.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Lewin (83) | 147 ± 10.0 | 1.0 | 14.7 ± 10.0 | 1.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Chavoshi (84) | 147 ± 10.0 | 1.0 | 14.7 ± 10.0 | 1.0 | 2.1 | 0.34 | 0.03, 0.65 |
| Phanphanich (85) | 34 ± 20.3 | 8.0 | 3.4 ± 20.3 | 8.0 | 2.1 | 0.34 | 0.03, 0.65 |

Random effects model

![Random effects model](image)

CURRENT DEVELOPMENTS IN NUTRITION

Gait speed

Most studies measuring gait speed (8/14, 57.1%) reported an association with nutritional status, but this reduced to 3/8 (37.5%) when only including studies of satisfactory quality.

Seven of the 14 studies were included in the meta-analysis (Figures 4 and 5). WN groups walked significantly faster compared with RMN groups (MD = 0.09 m/s; 95% CI: 0.03, 0.16; \( P = 0.0038 \)) and MN groups (MD = 0.16 m/s; 95% CI: 0.05, 0.27; \( P = 0.0033 \)).

TUG

Half of all studies reporting the TUG test showed an association with MN (5/10) and was the same (3/6) when selecting only studies of satisfactory quality.

Eight of the 10 studies assessing TUG were included in the meta-analysis (Figures 6 and 7). WN groups were faster on the TUG compared with RMN groups (MD = –2.53 s; 95% CI: –4.42, –0.65; \( P = 0.0085 \)). However, sensitivity analyses showed that the study of Romero-Ortuno (62) affected the overall estimate considerably (results without this study: MD = –1.84 s; 95% CI: –3.53, –0.16; \( P = 0.032 \)). The difference was more pronounced for WN groups compared with MN groups (MD = –5.94 s; 95% CI: –8.98, –2.89; \( P < 0.001 \)).

CST

CST was the only measure of physical performance for which most studies (4/7, 57.1%) did not find an association with nutritional status. However, in studies of satisfactory quality 2/3 (66.7%) did find an association.

Seven studies reported on a type of CST, all using different effect estimates. Adly et al. (29) reported on 1-time impaired sit-to-stand time \( (>2 \text{ s}) \) for which the MN group had an OR of 0.491 (95% CI: 0.12–1.94) and the RMN group an OR of 0.35 (95% CI: 0.11–1.05) compared with WN. Chang et al. reported the number of times participants could rise from a chair in 30 s; for the WN group this was 16.74 ± 6.73 and for the RMN group 13.79 ± 7.15 times (33). Lim et al. reported on 5-times CST in points (max. 3), with the WN group scoring 2.88 ± 0.35 and the MN group 2.57 ± 0.57 (50). Misu et al. reported on the 5 times chair stand test (5CST) in seconds; the WN group had a mean of 8.80 ± 2.71s and the MN group of 8.86 ± 2.68 s (53). Ramsey et al. re-
FIGURE 4 Forest plot illustrating the mean difference of gait speed (m/s) between well-nourished versus at risk of malnutrition groups. MD, mean difference; RMN, risk of malnutrition; WN, well-nourished.

ported on the Z-scores of the natural logarithm (ZLN) 5CST in seconds, with $\beta = 0.53$ (95% CI: 0.19, 0.87) for MN compared with WN and an OR of 1.18 (95% CI: 0.56–2.46) for RMN compared with WN (68). Chatindiara et al. defined low 5-times CST as $\geq 17$ s, resulting in an OR of 0.76 (95% CI: 0.27, 2.11) in RMN compared with WN (34).

KES
All 3 studies reporting KES showed an association with MN, of which 1 was of satisfactory quality. Norman et al. reported a median KES of 10.3 kg (7.3–16.4) in WN people, 8.0 kg (5.0–12.0) in RMN, and 5.0 kg (3.0–7.0) in MN (54). Ogawa et al. reported KESs of 42.8 ± 10.9 Nm/kg in WN and 35.8 ± 7.29 in RMN (55). Pourhassan et al. reported a mean isometric KES of 17.5 ± 6.8 in WN and 12.4 kg ± 4.6 in MN participants (58).

6MWT
Two studies used the 6MWT, both of which were of satisfactory quality. One study showed an association with a mean of 421.2 ± 141.4 m in WN and 320.9 ± 132.0 m in RMN (55). Tramontano et al. defined poor 6MWT as $\leq 331$ m, for which MN showed an OR of 2.73 (95% CI: 1.06–7.45) compared with WN (59). Ramsey et al. looked at the 3 balance components of SPPB separately, calculating ORs for being unable to maintain 10 seconds for each of the 3 tests, comparing MN/MN with WN (side-by-side: OR 0.69 (95% CI: 0.23, 2.02), semi-tandem: OR 0.67 (95% CI: 0.31, 1.43), tandem: OR 1.02 (95% CI: 0.51, 2.04) (59).

Multicomponent test
Five studies used a multicomponent test spanning multiple domains, all of which showed an association with nutritional status. Three of these studies were of satisfactory quality. WN people scored a mean 25.20 ± 3.82 pts on the Tinetti performance-oriented mobility assessment compared with 22.15 ± 6.28 in RMN and 20.09 ± 6.29 in MN (47). Mobility scale scores were 86.14 ± 16.71 in WN and 66.29 ± 23.23 in MN (50). WN people scored a mean 18.9 ± 1.4 on Tinetti’s Elderly mobility scale, whereas the RMN group scored 18.2 ± 2.2 (66). Hegenдоров er et al. used a physical test for which the median value of WN people was 9 (6, 12) and for RMN/MN this was 6.5 (4, 7.9) (41). Lastly, Ferdous et al. used a 6-item performance test, scoring the percentage of limitation in any of the tasks. The RMN had an OR of 1.92 (95% CI: 1.07–3.45) and MN an OR of 4.24 (95% CI: 2.17–8.27) compared with WN (ORs are approximated due to missing values) (37).

FIGURE 5 Forest plot illustrating the mean difference of gait speed (m/s) between well-nourished versus malnourished groups. MD, mean difference; RMN, risk of malnutrition; WN, well-nourished.

FIGURE 6 Forest plot illustrating the mean difference of the TUG (s) between well-nourished versus at risk of malnutrition groups. MD, mean difference; RMN, risk of malnutrition; TUG, timed-up-and-go test; WN, well-nourished.
studies using KES, 6MWT, CST, and multicomponent tests showed that the majority of these studies reported lower physical performance in MN (or RMN) groups compared with WN groups as well. No studies reported an inverse association.

The remaining “other” tests are the only category for which most studies did not report a statistically significant association, although most effect estimates reported that MN people (or RMN people) had lower physical performance and the number of studies was low.

**Population**

Comparing studies performed in different healthcare settings, studies in hospitalized patients, outpatients, and community-dwelling people overall showed similar results in the narrative review, with approximately half of the studies confirming an association between malnutrition and physical performance. These results were similar when using all quality studies and when only studies of satisfactory quality were included. In contrast, studies in nursing home populations were mostly of poor quality and none of the studies of satisfactory quality reported an association.

The high prevalence of (risk of) malnutrition of ≥50% in the nursing home studies could have contributed to this difference (71, 54, 48), in line with previous results (91).

Secondly, none of the care home studies adjusted their analyses for confounders. Other factors that play an important role in malnutrition and physical performance are thus not accounted for, despite being highly prevalent in nursing home residents, such as comorbidities, polypharmacy (71), and sarcopenia (92).

**Malnutrition screeners and assessment tools**

In the included studies, 11 different screeners or assessment tools of malnutrition were used. These needed to be validated and address more than weight loss or a low BMI only. Although both weight loss and low BMI can be indicators of malnutrition and are part of the phenotypic side of malnutrition, the latest GLIM consensus paper of the global clinical nutrition community diagnoses malnutrition when etiologic as well as phenotypic factors are present (81). Etiologic factors consist of inflammation/disease burden or reduced food intake/absorption and are essential in selecting the right treatment. Many of the validated nutrition screeners and assessment tools (MNA-SF, NRS2002, MUST, ESPEN, SGA) measure weight reduction as well as disease burden and reduced food intake (81) and therefore, reflect the recent GLIM consensus better than assessing 1 aspect only. Only 1 included study in our review (58) used the actual GLIM criteria for diagnosis, with 10 other screening and assessment methods used by others. However, no single screening or assessment method can adequately screen and predict relating outcomes (93) and reported prevalence of malnutrition or RMN is dependent on the screener or assessment of choice (94, 95), likely contributing to differences between studies and withing studies that used multiple methods to identify malnutrition or malnutrition risk.

**Physical performance**

The outcome of interest for this systematic review, physical performance, had to be measured objectively, rather than self-reported measures or estimates to reduce reporting bias. We grouped these into 8 main categories of HGS, gait speed, TUG, CST, KES, 6MWT, multicomponent tests, and a category of “other.” There is no consensus on the best measure of physical performance; the European Society for Clinical and Economic Aspects of Osteoporosis and Osteoarthritis working group on frailty and sarcopenia advises the use of 4 m walking test and SPPB to measure physical performance and HGS for muscle strength (9). The European Working Group on Sarcopenia suggests the use of gait speed, SPPB, TUG, and the 400 m walking test and provides cut-off points (7). These tests were among the most used test in this systematic review, although individual studies used a myriad of different methods (e.g. average walking speed compared with maximum walking speed, or means compared with dichotomizing), units and cut-offs, reducing comparability even within a category. Additionally, this systematic review included studies using CST, KES, 6MWT, various multicomponent tests, and some others. Due to low study numbers and study quality, we could not compare the different measures of physical performance. In this systematic review, there seems to be no large differences between these methods in their association with malnutrition, but this should be studied in more detail in future.

**FIGURE 7** Forest plot illustrating the mean difference of the TUG (s) between well-nourished versus malnourished groups. MD, mean difference; WN, well-nourished.

**FIGURE 8** Forest plot illustrating the mean difference of the SPPB (points) between well-nourished versus at risk of malnutrition groups. MD, mean difference; RMN, risk of malnutrition; SPPB, short physical performance battery; WN, well-nourished.
Meta-analysis

Meta-analyses showed that MN groups had worse scores on HGS, gait speed, TUG, and SPPB compared with WN groups and that these results were also present in RMN people, but with a smaller effect. Since for multiple comparisons substantial statistical heterogeneity was present, results of the meta-analyses should be interpreted with care. Heterogeneity among studies originated from the way of classifying nutritional status (i.e. different tools/screeners and cut-off points) and small differences in measuring the outcome. An example of the latter is how HGS was determined in studies: taking the mean or maximum value and measuring the dominant hand or both hands. However, mean differences of the 4 outcomes were often at the same side of the spectrum, favoring the WN groups.

Additional heterogeneity in reporting and/or low numbers of studies, meant that not all studies were included in meta-analysis. Heterogeneity in reporting included different units of outcome that could not be translated, such as using m/s versus total distance, or different distances/number of repetitions. CSTs, KES, 6-min walking test, multi-component tests, and the remaining "other" tests were therefore only reviewed narratively.

Physical performance is a clinically meaningful outcome measure for sarcopenia and frailty (96). Clinically relevant changes need to be of such a size that a participant can perceive this or that it affects participation (96). Although this study included cross-sectional data, we suggest that the aforementioned, clinically relevant changes could give an indication of what differences between WN and MN or at-risk populations are relevant. The meta-analysis results showed a gait speed difference of 0.16 m/s for MN and 0.09 m/s for RMN groups compared with WN people and a 1.2 point and 1.3 point difference, respectively, on SPPB. Perera et al. reported that a decline of 0.1 m/s on 4 m gait speed or 1 point on SPPB per year increased the risk of 5-y mortality in observational and clinical populations, indicating these differences could be clinically relevant (97). This is in line with other studies showing that lower gait speed, SPPB, and CST can lead to disability in activities of daily living (25, 98, 99).

Notably, clinical relevance is dependent on context, perspective, and purpose (96). Considering the variation in the older population, relevant differences likely vary between subgroups such as community-dwelling, nursing home, and hospital populations. Regardless of subgroup, interventions should aim at clinically relevant improvements in physical performance through improvement of nutritional status.

Bias and quality

In this review and meta-analysis of observational, cross-sectional data, study quality was scored using a modified NOS and included studies of unsatisfactory and satisfactory quality. None of the included studies had a "good" NOS score. Using only satisfactory quality studies showed similar result for most categories of physical performance compared with using all studies, except for the category "other," which included a very low number of studies.

One of the contributors to the low NOS scores was that often the data on nutritional status and physical functioning used in this review were not the main analysis of the study, and were results of simple analysis, meaning confounders were not accounted for. Cognition, social support (100), intestinal permeability (101), physical activity, education, pain, depression (102), and multimorbidity (103) play an important role in physical performance and malnutrition (104). Not taking these into account might have changed the estimates and obscured differences between types of physical performance measures. A potential upside of nutritional status and physical performance not being the main focus of many articles is that the risk of publication bias might be limited.

Physiology

This systematic review and meta-analysis showed low-quality evidence that malnutrition and physical performance are associated. The 2 likely form a vicious cycle (105), with some suggesting the existence of a malnutrition-sarcopenia syndrome (20). On the one hand, moderate evidence exists that low physical performance is a determinant of malnutrition (5). On the other hand, malnutrition increases the risk of sarcopenia incidence (106). Sarcopenia severity is determined by physical performance (81) in the presence of low muscle mass and strength but cannot be explained by muscle mass loss alone (107). The pathophysiology is not fully understood, but protein and energy balance may play a key role. Muscles are a key metabolic site for glucose and protein storage, which are released to maintain the protein content of other organs when energy uptake does not meet demands, leading to muscle breakdown (108). Low energy and protein intake, low absorption, and/or disease-related inflammation all favor this catabolic state (109). Low intake of other nutrients such as vitamin D or antioxidants might also play a role, although their role in this remains unclear (105).

Intervention studies specifying MN populations (or at risk of) and measuring physical performance are scarce and showed mixed results. One systematic review in RMN adults showed no improvements in gait speed, balance, and HGS due to volunteer-delivered interventions (110). Other systematic reviews showed no effect on HGS (111) and TUG (14) after dietary counseling or oral nutritional supplementation, respectively. Interventions with combinations of supplementation with counseling or exercise were inconsistent (14). Some other intervention studies in MN or at-risk populations (14) show improvements in walking distance, but not HGS and SPPB (112), or performance improvements only in subgroups at 1 of 3 time points (113) in community-dwelling older adults.

Systematic reviews on related outcomes or in different populations of older adults are more numerous, but also show mixed results: in clinical muscle wasting populations (114), and frail and prefrail older adults (20, 115), certain dietary or physical performance interventions increased physical performance. In another systematic review in older adults using the European Working Group on Sarcopenia in Older People definition of sarcopenia (116), and an umbrella review of healthy aging outcomes (117), results on nutritional interventions and physical performance were ambiguous due to low numbers and heterogeneity.

We carried out this systematic review to study the underlying association and to provide some clarity that could help decipher the inconsistencies in the intervention studies. We aimed to reduce heterogeneity due to interventions and by clearly defining the nutritional (risk) status of the population and the outcome measure. Overall, as expected, it appears that malnutrition in older adults is associated with low physical performance, despite overall poor to moderate quality (no...
“good” NOS scores) of the studies. Perhaps the complexity and diversity in the origin of malnutrition and its relation to physical performance underlie the inconsistencies of intervention studies on this topic, and interventions should take into account the underlying etiology (81, 112). However, low study quality and remaining heterogeneity in measurements imply that strong conclusions cannot be drawn and corrections for confounders are mostly lacking. Future studies should focus on clearly defined MN populations, instead of grouping them together with frailty, sarcopenia, or other diseases, and standardization and clear reporting of physical performance would be welcomed. With this, high-quality interventions tailored specifically to the MN populations can be studied, since proof of high-quality evidence on effective interventions in treating malnutrition in older adults is still lacking (14).

Conclusion

This meta-analysis and narrative review provide low-quality evidence for the association between malnutrition or risk of malnutrition and low physical performance in older adults in studies in outpatient, hospital, nursing home, and community-dwelling settings. Although 11 different screeners or assessment tools of malnutrition and 8 main types of physical performance tests were used, an association between malnutrition and lower physical performance seems present among older adults. Without studies of “good” quality according to the NOS scale and with many methodological differences between the included studies regarding population, determination of malnutrition, the reported outcomes, and method of analysis, the overall results should be interpreted with care.

For future research, both observational and interventional, we recommend performing studies of high quality with clearly defined MN populations or at-risk populations and standardized outcomes and methods of testing. Malnutrition should be assessed according to standardized GLIM criteria (81) and physical performance should be measured in standardized ways, as recommended in the latest European Working Group on Sarcopenia in Older People number 2 consensus paper. Future studies could additionally focus on differences between the various physical performance tests and differences between subpopulations.

Good quality studies in clearly defined MN older adult populations are required to gain better insight into the relation between nutritional status and physical performance. This way interventions can be developed to improve physical performance specifically in the MN populations, while being careful to consider the underlying reasons of malnutrition.

Acknowledgments

The authors’ contributions were as follows—SB, IG, CSK, OvdR, and LCPGMdG: designed the research; SB and CSK: performed the systematic literature search, screened publications for inclusion; SB, IG, and CSK: extracted the data and scored the study quality; IG: performed the meta-analysis, and CSK: performed the remaining analyses; HHW, IG, and CSK: wrote the manuscript; and all authors: interpreted the results and had responsibilities for the final content and read and approved the final manuscript.

References

1. Wolters M, Volkert D, Streicher M, Kiesswetter E, Torbahn G, O’Connor EM, O’Keeffe M, Kelly M, O’Herlihy E, O’Bole PW, et al. Prevalence of malnutrition using harmonized definitions in older adults from different settings—a MaNuEL study. Clin Nutr 2019;38(5):2389–98.

2. Louie GH, Ward MM. Sex disparities in self-reported physical functioning: true differences, reporting bias, or incomplete adjustment for confounding? J Am Geriatr Soc 2010;58(6):1117–22.

3. Cederholm T, Barazzoni R, Austin P, Ballmer P, Biolo G, Bischoff SC, Compcher C, Correia I, Higashiguchi T, Holst M, et al. ESPEN guidelines on definitions and terminology of clinical nutrition. Clin Nutr 2017;36(1):49–64.

4. Volkert D, Kiesswetter E, Cederholm T, Donini LM, Egileer D, Norman K, Schneider SM, Ströbele-Benschop N, Torbahn G, Wirth R, et al. Development of a model on determinants of malnutrition in aged persons: a MaNuEL Project. Gerontol Geriatr Med 2019;5:23333721419858438. doi: 10.1177/2333721419858438.

5. O’Keeffe M, Kelly M, O’Herlihy E, O’Toole PW, Kearney PM, Timmons S, O’Shea E, Stanton C, Hickson M, Rolland Y, et al. Potentially modifiable determinants of malnutrition in older adults: a systematic review. Clin Nutr 2019;38(6):2477–98.

6. Streicher M, van Zwielen-Pot J, Bardon L, Nagel G, Teh R, Meisinger C, Colombo M, Torbahn G, Kiesswetter E, Flechtner-Mors M, et al. Determinants of incident malnutrition in community-dwelling older adults: a MaNuEL multicohort meta-analysis. J Am Geriatr Soc 2018;66(12):2335–43.

7. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, Cooper C, Landi F, Rolland Y, Sayer AA, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019;48(1):16–31.

8. Lusardi MM, Pellechiglia GL, Schulman M. Functional performance in community living older adults. Journal of Geriatric Physical Therapy 2003;26(3):14.

9. Beaudart C, Rolland Y, Cruz-Jentoft AJ, Bauer JM, Sieber C, Cooper C, Al-Daghri N, Araujo de Carvalho I, Baumsans I, Bernabei R, et al. Assessment of muscle function and physical performance in daily clinical practice: a position paper endorsed by the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO). Calcif Tissue Int 2019;105(1):1–14.

10. Reginster JY, Beaudart C, Al-Daghri N, Avouac B, Bauer J, Bere N, Bruyère O, Cerreta F, Cesari M, Rosa MM, et al. Update on the ESCEO recommendation for the conduct of clinical trials for drugs aiming at the treatment of sarcopenia in older adults. Aging Clin Exp Res 2021;33(1):3–17.

11. Tieland M, Trouwborst I, Clark BC. Skeletal muscle performance and ageing. Journal of Cachexia, Sarcopenia and Muscle 2018;9(1):3–19.

12. Hébuterne X, Bermon S, Schneider SM. Ageing and muscle: the effects of malnutrition, re-nutrition, and physical exercise. Curr Opin Clin Nutr Metab Care 2001;4(4):295–300.

13. Guest JF, Panca M, Baeyens JP, de Man F, Ljungqvist O, Pichard C, Wait S, Wilson L. Health economic impact of managing patients following a community-based diagnosis of malnutrition in the UK. Clin Nutr 2011;30(4):422–9.

14. Correa-Perez A, Abrahim I, Cherubini A, Collinson A, Dardevet D, Groot dl, Schuereh MAE, Hebestreit A, Hickson M, Jaramillo-Hidalgo J, et al. Efficacy of non-pharmacological interventions to treat malnutrition in older persons: a systematic review and meta-analysis. The SENATOR project ONTOP series and MaNuEL knowledge hub project. Ageing Res Rev 2019;49:27–48.

15. Trombetti A, Reid KF, Hars M, Herrmann FR, Pasha E, Phillips EM, Fielding RA. Age-associated declines in muscle mass, strength, power,
and physical performance: impact on fear of falling and quality of life. Osteoporos Int 2016;27(2):463–71.

16. van Leeuwen KM, van Loon MS, van Nes FA, Bosmans JE, de Vet HCW, Ket JF, Widdershoven GAM, Ostelo R. What does quality of life mean to older adults? A thematic synthesis. PLoS One 2019;14(3):e0213263.

17. Veronesi N, Stubbs B, Punzi L, Soysal P, Incalzi RA, Saller A, Maggi S. Effect of nutritional supplementations on physical performance and muscle strength parameters in older people: a systematic review and meta-analysis. Ageing Res Rev 2019;51:48–54.

18. Daniëls R, van Rossum E, de Witte L, Kempen GI, van den Heuvel W. Interventions to prevent disability in frail community-dwelling elderly: a systematic review. BMC Health Services Research 2008;8:1.278.

19. Dewansingh P, Melse-Boonstra A, Krijnen WP, van der Schans CP, Jager-Wittenaar H, van den Heuvel E. Supplemental protein from dairy products increases body weight and vitamin D improves physical performance in older adults: a systematic review and meta-analysis. Nutr Res 2018;49:1–22.

20. Kidd T, Mold F, Jones C, Ream E, Grossenver W, Sund-Ledervan M, Tingström P, Carey N. What are the most effective interventions to improve physical performance in pre-frail and frail adults? A systematic review of randomised control trials. BMC Geriatrics 2019;19(1):184.

21. Milne AC, Potter J, Vivanti A, Avenell A. Protein and energy supplementation in elderly people at risk from malnutrition. Cochrane Database Syst Rev 2009;2009(2):Cd003288.

22. Ligthart-Melis GC, Luiking YC, Kakourou A, Cederholm T, Maier AB, de van der Schueren MAE. Frailty, sarcopenia, and malnutrition frequently (co-)occur in hospitalized older adults: a systematic review and meta-analysis. J Am Med Dir Assoc 2020;21(9):1216–28.

23. Egleser D, Eminovic S, Lohrmann C. Association between sarcopenia and nutritional status in older adults: a systematic literature review. J Gerontol Nurs 2016;42(7):33–41.

24. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6(6):e1000097.

25. Wang DXM, Yao J, Zirek Y, Reijnierse EM, Maier AB. Muscle mass, strength, and physical performance predicting activities of daily living: a meta-analysis. J Cachexia Sarcopenia Muscle 2019. doi: 10.1002/jcsm.12502.

26. Margulis AV, Pladevall M, Riera-Guardia N, Varas-Lorenzo C, Hazell L, Berkmann ND, Viswanathan M, Perez-Guthmann S. Quality assessment of observational studies in a drug-safety systematic review, comparison of two tools: the Newcastle–Ottawa scale and the RTI item bank. Clinical Epidemiology 2014;6:359.

27. Modesti PA, Reboldi G, Cappuccio FP, Agyemang C, Remuzzi G, Rapi N, Martucci G, Lachapelle K, Noisieux N, Kim DH, et al. Malnutrition and mortality in frail and non-frail older adults undergoing aortic valve replacement. Circulation 2018;138(20):2202–11.

28. Gurina NA, Frolova EV, Degryse JM. A roadmap of aging in Russia: the prevalence of frailty in community-dwelling older adults in the St. Petersburg District – the “Crystal” Study. J Am Geriatr Soc 2011;59(6):980–8.

29. Hegenendorf E, Vanacker V, Vae B, Degryse JM. Malnutrition risk and its association with adverse outcomes in a Belgian cohort of community-dwelling adults aged 80 years and over. Acta Clin Belg 2020: 1–8.

30. Holst M, Yifter-Lindgren E, Surowiak M, Nielsen K, Mowé M, Carlsson M, Jacobsen B, Cederholm T, Fenger-Groen M, Rasmussen H. Nutritional screening and risk factors in elderly hospitalized patients: association to clinical outcome? Scand J Caring Sci 2013;27(4):953–61.

31. Inoue T, Misu S, Tanaka T, Sakamoto H, Iwata K, Chuman Y, Ono R. Pre-fracture nutritional status is predictive of functional status at discharge during the acute phase with hip fracture patients: a multicenter prospective cohort study. Clin Nutr 2017;36(5):1320–5.

32. Johansson Y, Bachrach-Lindström M, Carstensen J, Ek AC. Malnutrition risk in a home-living older population: prevalence, incidence and risk factors. A prospective study. J Clin Nurs 2009;18(9):1354–64.

33. Kaburagi T, Hirayama H, Yoshino H, Odaka Y, Satomi M, Nakano M, Fujimoto E, Kabasawa K, Sato K. Nutritional status is strongly correlated with grip strength and depression in community-living elderly Japanese. Public Health Nutr 2011;14(11):1893–9.

34. Kiesswetter E, Pohlhansen S, Ulhik K, Diekmann R, Lesser S, Heseker H, Stehle P, Sieber CC, Volkert D. Malnutrition is related to functional impairment in older adults receiving home care. The Journal of Nutrition, Health & Aging 2013;17(4):345–50.

35. Kocyigit SE, Soysal P, Ates Bulut E, Isik AT. Malnutrition and malnutrition risk can be associated with systolic orthostatic hypotension in older adults. The Journal of Nutrition, Health & Aging 2018;22(8):928–33.

36. Lecheta DR, Schierdercker MEM, de MELLO AP, Berkenbrock I, Cardoso NETO J, Maluf EMCP. Nutritional problems in older adults: a systematic review and meta-analysis. Nutr Res 2018;49:1–22.

37. Chatindiara I, Williams V, Sycamore E, Richter M, Allen J, Wham C. Associations between nutrition risk status, body composition and physical performance among community-dwelling older adults. Aust N Z J Public Health 2019;43(1):56–62.

38. Chevalier S, Saouf F, Gray-Donald K, Morais JA. The physical functional capacity of frail elderly persons undergoing ambulatory rehabilitation is related to their nutritional status. The Journal of Nutrition, Health & Aging 2008;12(10):721–6.

39. Dent E, Wright O, Hoogendijk EO, Hubbard RE. Nutritional screening and dietitian consultation rates in a geriatric evaluation and management unit nutritional screening in older patients. Nutrition & Dietetics 2018;75(1):11–6.

40. Lim EJ. Factors influencing mobility relative to nutritional status among elderly women with diabetes mellitus. Iran J Public Health 2018;47(6):814–23.
51. Mendes J, Borges N, Santos A, Padrão P, Moreira P, Afonso C, Negrão R, Amaral TF. Nutritional status and gait speed in a nationwide population-based sample of older adults. Sci Rep 2018;8(1):4227.

52. Mendes J, Afonso C, Moreira P, Padrão P, Santos A, Borges N, Negrão R, Amaral TF. Association of anthropometric and nutrition status indicators with hand grip strength and gait speed in older adults. Journal of Parenteral and Enteral Nutrition 2019;43(3):347–56.

53. Misu S, Asai T, Doi T, Sawa R, Ueda Y, Saito T, Nakamura R, Murata S, Suginoto T, Yamada M, et al. Association between gait abnormality and malnutrition in a community-dwelling elderly population. Geriatrics & Gerontology International 2017;17(8):1155–60.

54. Norman K, Smoliner C, Valentini L, Lochs H, Pirlich M. Is bioelectrical impedance vector analysis of value in the elderly with malnutrition and impaired functionality? Nutrition 2007;23(7–8):564–9.

55. Ogawa M, Iizawa KP, Satomi-Kobayashi S, Kitamura A, Ono R, Sakai Y, Okita Y. Poor preoperative nutritional status is an important predictor of the retardation of rehabilitation after cardiac surgery in elderly cardiac patients. Aging Clin Exp Res 2017;29(2):283–90.

56. Persson MD, Brismar KE, Katzarski KS, Nordenström J, Cederholm TE. Nutritional status using Mini Nutritional Assessment and Subjective Global Assessment predict mortality in geriatric patients. J Am Geriatr Soc 2002;50(12):1996–2002.

57. Pierik VD, Meskers CGM, Van Ancum JM, Numans ST, Verlaan S, Scheerteroek K, Kruizinga RC, Maier AB. High risk of malnutrition is associated with low muscle mass in older hospitalized patients – a prospective cohort study. BMC Geriatrics 2017;17(1):118.

58. Pourhassan M, Rommersbach N, Lueg G, Klimek C, Schnatmann M, Liermann D, Janssen G, Wirth R. The impact of malnutrition on acute muscle wasting in frail older hospitalized patients. Nutrients 2020;12(5):1387.

59. Ramsey KA, Meskers CGM, Trappenburg MC, Verlaan S, Reijnierse EM, Whittaker MC, Maier AB. Malnutrition is associated with dynamic physical performance. Aging Clin Exp Res 2020;32(6):1085–92.

60. Reijnierse EM, Trappenburg MC, Leter MJ, Blauw GJ, de van der Schueren MA, Meskers CG, Maier AB. The association between parameters of malnutrition and diagnostic measures of sarcopenia in geriatric outpatients. PLoS One 2015;10(8):0135933.

61. Rivetti N, Settati S, Laksmi PW, Abdullah M. Factors related with handgrip strength in elderly patients. Acta Med Indones 2017;49(3):215–9.

62. Romero-Ortuno R, Casey AM, Cunningham CU, Squires S, Prendergast D, Kenny RA, Lawlor BA. Psychosocial and functional correlates of nutrition among community-dwelling older adults in Ireland. The Journal of Nutrition, Health & Aging 2011;15(7):527–31.

63. Schrader E, Grosch E, Bertsch T, Sieber CC, Volkert D. Nutritional and functional status in geriatric hospital patients – MNA Short Form versus full MNA. The Journal of Nutrition, Health & Aging 2016;20(9):918–26.

64. Schrader E, Baumgartel C, Gueldenzoph H, Stehle P, Uter W, Sieber CC, Volkert D. Nutritional status according to Mini Nutritional Assessment is related to functional status in geriatric patients – independent of health status. The Journal of Nutrition, Health & Aging 2014;18(3):257–63.

65. Soundararajan AS, Mathew A, Narajanuddin R, Ganesh A. Association of geriatric syndromes with malnutrition among elderly. International Journal of Medical Research and Health Sciences 2017;6:14–8.

66. Suzana S, Boon PC, Chan PP, Normah CD. Malnutrition risk and its association with appetite, functional and psychosocial status among elderly Malays in an agricultural settlement. Malays J Nutr 2013;19(1):65–75.

67. Tian Q, Zhang M, Deng Y, Duan J, Tu Q, Cao Y, Zhu Q, Yu W, Lu’ Y. Does gait speed replace comprehensive geriatric assessment in the elderly? International Journal of Gerontontology 2016;10(4):232–6.

68. Tramontano A, Veronese N, Giantin V, Manzato E, Rodriguez-Hurtado D, Trevisan C, De Zaiacomo F, Sergi G. Nutritional status, physical performance and disability in the elderly of the Peruvian Andes. Aging Clin Exp Res 2016;28(6):1195–1201.

69. Turusheva A, Frolova E, Degryse JM. Age-related normative values for handgrip strength and grip strength usefulness as a predictor of mortality and both cognitive and physical decline in older adults in northwest Russia. J Musculoskeletal Neuronal Interact 2017;17(1):417–32.

70. Valhberg B, Zetterberg L, Lindmark B, Hellström K, Cederholm T. Functional performance, nutritional status, and body composition in ambulant community-dwelling individuals 1–3 years after suffering from a cerebral infarction or intracerebral bleeding. BMC Geriatrics 2016;16:48.

71. Wang YC, Liang CK, Hsu YH, Peng LN, Chu CS, Liao MC, Shen HC, Chou MY, Lin YT. Synergistic effect of low handgrip strength and malnutrition on 4-year all-cause mortality in older males: a prospective longitudinal cohort study. Arch Gerontol Geriatr. 2019;83:217–22.

72. Zhang XS, Liu YH, Zhang Y, Xu Q, Yu XM, Yang XY, Liu Z, Li HZ, Li F, Xue CY. Handgrip strength as a predictor of nutritional status in Chinese elderly inpatients at hospital admission. Biomedical and Environmental Sciences: BES 2017;30(11):802–10.

73. Zhou J, Wang M, Wang H, Chi Q. Comparison of two nutrition assessment tools in surgical elderly inpatients in northern China. Nutrition Journal 2015;14:1, 68.

74. Guigoz Y. The Mini Nutritional Assessment (MNA) review of the literature – what does it tell us? J Nutr Health Aging 2006;10(6):466–85; discussion 85–7.

75. Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the Short-Form Mini-Nutritional Assessment (MNA-SF). The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 2001;56(6):M366–M372.

76. Kruizenga HM, Seidell JC, de Vet HC, Wiersdama NJ, van Bokhorst-de van der Schueren MA. Development and validation of a hospital screening tool for malnutrition: the Short Nutritional Assessment Questionnaire (SNAQ). Eur J Clin Nutr 2005;24(1):75–82.

77. Bouillanne O, Morineau G, Dupont C, Coulombe I, Vincent JP, Nicolis I, Benazeth S, Cynober L, Aussel C. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. Am J Clin Nutr 2005;82(4):777–83.

78. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z. Nutritional Risk Screening (NRS 2002): a new method based on an analysis of controlled clinical trials. Clin Nutr 2003;22(3):312–36.

79. Cederholm T, Bosaeus I, Barazzoni R, Bauer J, Van Gossum A, Klek S, Mursactrollo N, Nyulasi I, Ockenga J, Schneider S. Diagnostic criteria for malnutrition – an ESPEN consensus statement. Clin Nutr 2015;34(3):335–40.

80. Posner BM, Jette AM, Smith KW, Miller DR. Nutrition and health risks in the elderly: the nutrition screening initiative. Am J Public Health 1993;83(7):972–78.

81. Cederholm T, Jensen GL, Correia M, Gonzalez MC, Fukushima R, Molenkampe S, van der Schueren MA, De Vets HC, Deeg DJ, Ferrucci L, Visser M. Development and validation of criteria for determining undernutrition in community-dwelling older men and women: the Short Nutritional Assessment Questionnaire 65+. Clin Nutr 2012;31(3):351–8.

82. Keller HH, Goy R, Kane SL. Validity and reliability of SCREEN II (Seniors in the community: risk evaluation for eating and nutrition, Version II). Eur J Clin Nutr 2005;59(10):1149–57.

83. Wijnhoef NA, Schiplj J, van Bokhorst-de van der Schueren MA, de Vet HC, Kruizinga HM, Deeg DJ, Ferrucci L, Visser M. Development and validation of criteria for determining undernutrition in community-dwelling older men and women: the Short Nutritional Assessment Questionnaire 65+. Clin Nutr 2012;31(3):351–8.

84. Elia, M The 'MUST' report. Nutritional screening of adults: a multidisciplinary responsibility. Development and use of the 'Malnutrition Universal Screening Tool' ('MUST') for adults British Association for Parenteral and Enteral Nutrition 2003:1 899467 70 X

85. Detsky AS, McLaughlin JR, Baker JP, Johnston N, Whittaker S, Mendelson RA, Jeejeebhoy KN. What is subjective global assessment of nutritional status? Journal of Parenteral and Enteral Nutrition 1987;11(1):8–13.

86. Podsiadlo D, Richardson S. The timed “Up & Go”: a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39(2):142–8.

87. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, Scherr PA, Wallace RB. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49(2):M85–M94.
88. Csuka M, McCarty DJ. Simple method for measurement of lower extremity muscle strength. Am J Med 1983;75(1):77–81.

89. Butland RJ, Pang J, Gross ER, Woodcock AA, Geddes DM. Two-, six-, and 12-minute walking tests in respiratory disease. BMJ 1982;284(6329):1607–8.

90. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. J Am Geriatr Soc 1986;34(2):119–26.

91. Cereda E, Pedrolli C, Klersy C, Bonardi C, Quarleri L, Cappello S, Turri A, Rondoni M. Caccialanza R. Nutritional status in older persons according to healthcare setting: a systematic review and meta-analysis of prevalence data using MNA®. Clin Nutr 2016;35(6):1282–90.

92. Papadopoulou SK, Tsintavis P, Potsaki P, Papandreou D. Differences in the prevalence of sarcopenia in community-dwelling, nursing home and hospitalized individuals. A systematic review and meta-analysis. The Journal of Nutrition, Health & Aging 2020;24(1):83–90.

93. van Bokhorst-de van der Schueren MA, Guatoli PR, Jansma EP, de Vet HC. Nutrition screening tools: does one size fit all? A systematic review of screening tools for the hospital setting. Clin Nutr 2014;33(1):39–58.

94. Raslan M, Gonzalez MC, Dias MC, Nascimento M, Castro M, Marques P, Segatto S, Torrinhas RS, Cecconello I, Waitzberg DL. Comparison of nutritional risk screening tools for predicting clinical outcomes in hospitalized patients. Nutrition 2010;26(7–8):721–6.

95. Kiesswetter E, Pohlhausen S, Diekmann R, Lesser S, Uter W, Heseker H, Stehle P, Sieber CC, Volkert D. Prognostic differences of the Mini Nutritional Assessment Short Form and Long Form in relation to 1-year functional decline and mortality in community-dwelling older adults receiving home care. J Am Geriatr Soc 2014;62(3):512–7.

96. Guralnik J, Bandeen-Roche K, Bhasin SAR, Eremenco S, Landi F, Muscedere J, Perera S, Register JY, Woodhouse L, Velas B. Clinically meaningful change for physical performance: perspectives of the ICFSR Task Force. J Frailty Aging 2020;9(1):9–13.

97. Perera S, Studenski S, Chandler JM, Guralnik JM. Magnitude and patterns of decline in health and function in 1 year affect subsequent 5-year survival. J Gerontol A Biol Sci Med Sci 2005;60(7):894–900.

98. Mijnarends DM, Luiking YC, Halfens RJG, Evers S, Segatto S, Cecconello I, Waizberg DL. Comparison of nutritional risk screening tools for predicting clinical outcomes in hospitalized patients. Nutrition 2010;26(7–8):721–6.

99. Lengelé L, Moehlinger P, Bruyère O, Beaudart C, Reginster JY, Locquet M. Malnutrition, physical and cognitive function: performance of a new Multimorbidity-Systematic review and meta-analysis. Eur J Public Health 2018;28(2):275–83.