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Marshall, Skye

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Protein-energy malnutrition in the rehabilitation setting: evidence to improve identification

Skye Marshall[a,b]

[a] BNutr&Diet(Hons), Accredited Practising Dietitian, PhD Scholar, Faculty of Health Sciences and Medicine, Bond University, Robina, Queensland, 4226, Australia.

[b] Corresponding author. Bond Institute of Health and Sport, Robina, Queensland, 4226, Australia. Telephone: +61 7 5595 5530, Fax: +61 7 5595 3524, skye_marshall@bond.edu.au

Abstract

Methods of identifying malnutrition in the rehabilitation setting require further examination so that patient outcomes may be improved. The purpose of this narrative review was to: 1) examine the defining characteristics of malnutrition, starvation, sarcopenia and cachexia; 2) review the validity of nutrition screening tools and nutrition assessment tools in the rehabilitation setting; and 3) determine the prevalence of malnutrition in the rehabilitation setting by geographical region and method of diagnosis. A narrative review was conducted drawing upon international literature. Starvation represents one form of malnutrition. Inadequate energy and protein intake are the critical factor in the aetiology of malnutrition, which is distinct from sarcopenia and cachexia. Eight nutrition screening tools and two nutrition assessment tools have been evaluated for criterion validity in the rehabilitation setting, and consideration must be given to the resources of the facility and the patient group in order to select the appropriate tool. The prevalence of malnutrition in the rehabilitation setting ranges from 14-65% worldwide with the highest prevalence reported in rural, European and Australian settings. Malnutrition is highly prevalent in the rehabilitation setting, and consideration must be given to the patient group when determining the most appropriate method of identification so that resources may be used efficaciously and the chance of misdiagnosis minimised.

Keywords: Malnutrition, Subacute Care, Rehabilitation, Nutrition Assessment, Aged / Aged 80 and over.

Abbreviations

AND, Academy of Nutrition and Dietetics

BMI, Body Mass Index

Kg, kilogram

m, meter

MNA, Mini Nutritional Assessment

MNA-SF, Mini Nutritional Assessment – Short Form

MST, Malnutrition Screening Tool

PG-SGA, Patient-Generated Subjective Global Assessment

SGA, Subjective Global Assessment

UK, United Kingdom

USA, United States of America

1. Introduction

Ever since Dr Charles Edwin Butterworth Jr's seminal 1974 article "The Skeleton in the Hospital Closet", there has been a positive movement in clinical health care to address "hospital malnutrition" [1]. However, in highly developed countries, such as Australia and the UK, malnutrition remains widespread in older adults, where prevalence is the highest in rehabilitation wards (30 – 50% of inpatients) [2]. In addition, there has been confusion in the literature and in clinical practice regarding malnutrition, starvation, sarcopenia and cachexia in older adults, which are conditions characterised by involuntary loss of lean tissue [3].

Nutrition screening and nutrition assessment are essential parts of the nutrition care process, as accurate identification and diagnosis of malnutrition is required in order for patients to be adequately treated, and for nutrition resources to be used efficaciously [4]. However, it is essential that the nutrition screening tools and nutrition assessment tools used to complete these steps have undergone adequate evaluation for validity so that the most appropriate tool can be selected for the patient group [2].

The prevalence of malnutrition in rehabilitation and the nutrition screening and assessment tools appropriate for use in rehabilitation have not been reviewed since 2009 [2]. Examining the validity of nutrition screening and assessment tools in rehabilitation will help practitioners select the most appropriate tool for their facility. Additionally, understanding the limitations of a particular tool in a particular setting is required so that appropriate steps can be taken to minimise the risk of misdiagnosis. For this reason, the method of diagnosis should be considered when reviewing the prevalence of malnutrition. The prevalence of malnutrition in rehabilitation has not been evaluated with consideration given to the method of diagnosis, nor the various settings in which it was measured, such as rural versus metropolitan prevalence or by country or region. Understanding the prevalence of malnutrition in these various settings

will help health care workers to understand the risk of malnutrition for particular patient groups and assist in the allocation of nutrition resources.

Therefore, the purpose of this narrative review was to: 1) examine the defining characteristics of malnutrition, starvation, sarcopenia and cachexia; 2) review the validity of nutrition screening tools and nutrition assessment tools in the rehabilitation setting; and 3) determine the prevalence of malnutrition in the rehabilitation setting by geographical region and method of diagnosis.

2. Methods

A narrative review was conducted which drew upon international literature published up until 15 August 2015. A review was conducted as part of the narrative review to identify the nutrition screening and assessment tools evaluated for validity in the inpatient rehabilitation facilities, as well as determine the prevalence of malnutrition. For this review, published English-language literature was searched on Google Scholar from 1980 – 15 August 2015. The search terms were ("MNA" OR "SGA" OR "PG-SGA" OR "ICD-10-AM" OR "Malnutrition Universal Screening Tool" OR "SNAQ" OR "NRS-2002" OR "nutrition screening tool") AND "Malnutrition" AND ("Rehabilitation" OR "Subacute"). The search strategy was complemented by a snowball search of literature cited by identified papers. Studies were included for the prevalence study only when malnutrition was diagnosed by a validated method.

3. Defining malnutrition

Protein-energy undernutrition, also known as protein-energy malnutrition, and frequently referred to simply as *malnutrition*, occurs when food and nutrient intake is unable to meet protein, energy and nutrient requirements over time leading to a disruption of homeostasis in lean tissues, body weight and physical function [5, 6]. Lean tissues include fat-free,

metabolically active tissues such as skeletal muscle, viscera, blood cells and the immune system. Lean tissues are the largest body component, comprising 35 – 50% of the total body weight of a healthy adult [6]. A decrease in lean tissue is the main cause of unintentional weight loss in most cases of malnutrition, although loss of fat mass may also be a contributing factor, and is caused by starvation or a combination of starvation and catabolic stress [6].

3.1 Malnutrition, starvation, sarcopenia or cachexia?

It has been widely recognised that muscle mass frequently decreases with age. Malnutrition, starvation, sarcopenia and cachexia are all conditions characterised by loss of lean tissue and typically occur in older adults, leading to confusion in the literature and in clinical practice [3].

Starvation is the loss of both fat-mass and fat-free mass as the result of a chronic inadequate intake of protein and energy [3]. Therefore, starvation may be a cause of malnutrition, as reflected by the Academy of Nutrition and Dietetics (AND) standardised set of diagnostic characteristics for malnutrition: a) starvation-related malnutrition, b) chronic-disease related malnutrition and c) acute disease or injury-related malnutrition [7]. The AND have defined starvation-related malnutrition as protein-energy malnutrition due to pure chronic starvation or anorexia nervosa [7]. Overall, starvation may be an important component of malnutrition in some clinical situations, but should be used with caution when discussing malnutrition in general.

Since being coined in 1989, the definition of “sarcopenia” has continued to evolve as the condition is further explored [8]. However, in 2009 and 2010 three separate groups of experts met to gain consensus for the definitions of sarcopenia. As each of these consensus definitions were slightly different, no definition is yet universally accepted and there still

remains confusion and inconsistency in the literature when describing and diagnosing this "geriatric syndrome" [9]. However, all three definitions agree that sarcopenia is characterised by the progressive age-related loss of lean muscle mass, muscle strength and physical function, and is associated with poor health outcomes [10-12]. One important development in the consensus of sarcopenia is the recognition that inadequate dietary intake and/or nutrient malabsorption is a possible factor in the aetiology of the syndrome (known as nutrition-related sarcopenia) by the European Working Group on Sarcopenia [10]. However, both the International Working Group on Sarcopenia and the Society for Sarcopenia, Cachexia and Wasting Disorders have not recognised inadequate nutrition as a potential cause in the multifactorial aetiology of the syndrome; though they did recognise that it has a role in the pathophysiology of sarcopenia [11, 12]. This may reflect the lack of strong research in exploring the nutritional mechanisms in sarcopenia along with the fact that it may be uncommon to find an older adult with sarcopenia who meets estimated energy and protein requirements [8]. However, there have not been enough well designed studies to conclude whether the severity or progression of sarcopenia is affected by dietary intervention. In addition, it may be possible for both malnutrition and sarcopenia to present as comorbidities, known as the malnutrition-sarcopenia syndrome (MSS); though it must be acknowledged a method of diagnosis for MSS has not yet been evaluated for validity or reliability [13].

Similar to disease-related malnutrition, cachexia is a complex syndrome associated with underlying illness, characterised by the loss of body weight, predominately skeletal muscle, which increases the risk of misdiagnosis [14]. Conditions which predispose to cachexia also increase the risk of malnutrition, including cancer, chronic infection, and chronic kidney disease [14]. However, unlike malnutrition, the loss of skeletal muscle in cachexia is a result of increased resting energy expenditure mediated by elevated levels of proinflammatory cytokines and a prolonged acute phase protein response [15]. Therefore, cachexia is

purported to not respond to dietary intervention, and states of malnutrition and sarcopenia have been described as a "pre-cachectic state", where nutritional intervention may have the most benefit [14]. However, emerging research has shown that nutrition intervention may impact upon the pathogenesis of cachexia, although nutrition intervention alone is insufficient to treat the condition [14, 16, 17].

Therefore, inadequate energy and protein intake leading to a loss of lean-tissues in older age may play a role in the pathogenesis sarcopenia and cachexia, but is a critical factor in the aetiology and prognosis of all forms of malnutrition, including starvation. The diagnostic criteria of malnutrition, sarcopenia and cachexia help to highlight both the unique characteristics and similarities of each condition, and are compared in table 1.

4. Identifying and diagnosing malnutrition

Due to the variable nature of the clinical presentation of malnutrition, there is no gold standard for diagnosing the condition. However, in Australian health care facilities, the *International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification* (sixth edition, ICD-10-AM) criteria are used to identify and code for malnutrition, and are therefore used to provide case-mix funding reimbursements [18]. The ICD-10-AM classification of malnutrition incorporate multiple criteria, including body mass index (BMI), weight loss, dietary intake and evidence of fat and/or muscle wasting [18]. However, prior to coding for malnutrition, a patient undergoes nutrition screening and nutrition assessment.

Nutrition screening acts as the trigger to engage a patient in the nutrition care process, which begins with nutrition assessment. Nutrition screening and nutrition assessment are often completed through the application of a nutrition screening tool and nutrition assessment tool [4]. However, the nutrition screening and assessment tools chosen should be validated for the

population to which they are applied. As there is no gold standard for identifying or diagnosing malnutrition, the criterion validity (comprising concurrent and predictive) must be established for nutrition screening and assessment tools [19]. Concurrent validity is determined by comparing the results of a new tool to the results of a well-established measurement for the same construct. When considering the concurrent validity of a nutrition screening or assessment tool, it is important to consider the well-established measurement used as a benchmark (or reference standard), and if this is a relevant benchmark for a particular patient group and condition. Predictive validity is established when the score of a particular measurement makes an accurate prediction about an important and related outcome.

4.1 Malnutrition screening tools

Nutrition screening tools should be quick and simple to implement and able to be used by any trained person or the patient themselves. Nutrition screening tools determine risk of malnutrition but cannot make a diagnosis of malnutrition. In the rehabilitation setting, eight nutrition screening tools have been evaluated for their criterion validity: the Mini Nutrition Assessment-Short Form (MNA-SF) [20], Malnutrition Screening Tool (MST) [21, 22], Malnutrition Universal Assessment Tool (MUST), Nutritional Form for the Elderly (NUFFE) [23], Rapid Screen [24], Short Nutritional Assessment Questionnaire (SNAQ) [25, 26], SNAQ Residential Care ($SNAQ^{RC}$) [25, 27] and the SNAQ for older adults ($SNAQ^{65+}$) [25, 28] . A description of their domains and criteria are described by Skipper et al. [29]. When evaluating the concurrent validity of a nutrition screening tool, sensitivity (those at risk of malnutrition correctly identified as such) is considered of higher importance than specificity (those not at risk of malnutrition correctly identified as such) and *a-priori* values of ≥80% for sensitivity and ≥60% for specificity are considered to indicate a good nutrition screening tool [22]. Table 2 compares the concurrent validity of nutrition screening tools in rehabilitation.

In the rehabilitation setting, only the MST, MUST, SNAQ and SNAQ^{65+} met *a-priori* values for sensitivity and specificity; however, of these, only the MST met *a-priori* values compared to a suitable multidimensional benchmark for malnutrition. The NUFFE did not report sensitivity, specificity nor a kappa statistic, and therefore no conclusions could be drawn about its suitability for the rehabilitation setting.

The moderate agreement of the MNA-SF with the full Mini Nutritional Assessment (MNA), reported by Kaiser et al. [30], is expected as the MNA-SF was designed using the six questions from the full MNA which had the strongest correlations with the total MNA score. However, the two subsequent studies found the MNA-SF may not be appropriate for use in geriatric rehabilitation, as it was found to significantly overestimate the risk of malnutrition when compared to a benchmark unrelated to the MNA [18, 21, 25]. The SNAQ^{RC} was also found to overestimate the risk of malnutrition. Overestimating risk of malnutrition may lead to increased burden on nutrition resources, as all patients identified as at risk of malnutrition will be referred to the dietitian for a nutrition assessment. Therefore, the MNA-SF may be appropriate for a well-resourced rehabilitation facility focussed on prevention [32-34]. The MNA-SF has displayed predictive validity for risk of institutionalisation and decreased physical function and quality of life in one study [35] and length of stay and poor participation in rehabilitation activities in a second study [36]. However, a two further studies found it was not able to predict length of stay, complications, physical function, rehospitalisation, institutionalisation, discharge location or mortality [21]. Apart from the MNA-SF, only the Rapid Screen displayed predictive validity, where it was able to predict discharge location [24]. The MST did not display predictive validity, whereas the MUST, NUFFE, SNAQ, SNAQ^{RC} and SNAQ^{65+} were not evaluated for predictive validity. Overall, although some nutrition screening tools are suitable for identifying risk of malnutrition, there is insufficient evidence to determine if they are suitable predictors of patient outcomes in

rehabilitation, which highlights the importance of following nutrition screening with a full nutrition assessment.

4.2 Nutrition assessment tools

The accuracy and reliability of global nutrition assessment tools in diagnosing malnutrition can be attributed to incorporating multiple criteria in their assessment, such as measures of anthropometry, medical status, physical function and dietary intake. The MNA and the Scored Patient-Generated Subjective Global Assessment (PG-SGA) have been evaluated for criterion validity in the rehabilitation setting [2]. Table 3 compares the concurrent validity of these nutrition assessment tools in rehabilitation facilities.

The two studies which evaluated the MNA as a continuous variable reported that it has good discriminatory power [37, 38]; however, when using the recommended score of <17 to identify malnutrition, the lower sensitivity indicates the MNA categories carry a risk of labelling a patient “at risk of malnutrition” instead of “malnourished” in rehabilitation [38]. The two-tiered process employed by Visvanathan et al [24], described in table 3, has improved the sensitivity of the MNA. This suggests that caution should be used when employing the MNA in geriatric rehabilitation, and that patients found “at risk of malnutrition” may require further evaluation. However, as the number of patients classified as “at risk of malnutrition” by the MNA is usually high, this may have negative impacts on nutrition resources [38]. These results suggest MNA may require further study to identify a more appropriate cut-off value to diagnose malnutrition in geriatric rehabilitation.

One study reported that the Subjective Global Assesment (SGA) ratings of nutrition status were associated with anthropometric measures and grip strength, and had good reproducibility when used by medical officers in rehabilitation [40]. Although the criterion validity of the SGA has not been evaluated, the Scored PG-SGA ratings of nutrition status are

analogous to the SGA ratings, and were found to have excellent concurrent validity when compared to the ICD-10-AM classification of malnutrition [38]. The Scored PG-SGA primarliy differs from the SGA by including a continuous numerical score for intervention triage. This score was found to be an "excellent test" [39] and also displayed strong concurrent validity when using a score of 7 or higher to indicate malnutrition in this geriatric population as opposed to 9 or higher currently recommended on the tool for adult populations [38]. Both the MNA and Scored PG-SGA have shown strong predictive validity when compared with institutionalisation, discharge location and rehospitalisation [38]. In addition, the MNA and Scored PG-SGA scores have been found to be sensitive to change in nutrition status during the course of rehabilitation admission [41, 42].

4.3 Body Mass Index

The BMI was first described by Adolphe Quetelet, a Belgian astronomer, mathematician, statistician and sociologist, between 1830 and 1850 [43]. The BMI, calculated by kg/m^2, has been classified into widely accepted categories of adiposity, where a BMI of $\leq 18.5 kg/m^2$ is considered "underweight" and has been used to diagnose chronic malnutrition for individuals [18]. However, there is strong emerging evidence to suggest that the BMI of $\leq 18.5 kg/m^2$ to indicate underweight is too low for older adults. In 2014, Winter et. al [44] published a meta-analysis which aimed to define BMI in community-dwelling older adults (≥65years, n=197,940 in total), and concluded that a BMI of $<23 kg/m^2$ may be considered underweight in community-dwelling older adults. However, it is important to acknowledge that malnutrition can occur in healthy weight or overweight/obese individuals [45]. Therefore, BMI may assist in the identification of chronic malnutrition in some patients, but should not be used as a sole method of screening or diagnosis.

5. Malnutrition prevalence in older adults admitted to rehabilitation

As suggested in the revision of the concurrent validity of nutrition assessment tools, the reporting of malnutrition prevalence can vary depending on the method used to diagnose the condition. For example, is the nutrition assessment method known to under- or overestimate malnutrition? Furthermore, prevalence of malnutrition in rehabilitation is likely to differ by geographical location, such as by rurality or country, reflecting the access to resources and the population profile of the particular patient group. Therefore, due to the importance of the diagnosis method and the participant characteristics, prevalence was only considered when reported by the MNA (score of <17 to indicate malnutrition), the SGA and Scored PG-SGA (ratings B or C to indicate malnutrition) or the ICD-10-AM criteria (E43, E44.0 or E44.1 to indicate malnutrition); and the patient group was described.

Seventeen studies were identified which reported the prevalence of malnutrition in the rehabilitation setting; two of which were in stroke rehabilitation [46, 47], with the remaining 15 in general rehabilitation facilities (table 4).

All malnutrition prevalence studies undertaken in the rehabilitation setting have had an older adult sample, however two studies did not describe the age of participants [55, 57]. No studies were identified reporting the malnutrition prevalence in rehabilitation in South America or Africa, and only one study reported the prevalence in North America [48]. Only two studies, both Australian, reported the prevalence of malnutrition in a rural population, where the prevalence was high but varied according to type of nutrition assessment (SGA=65% in one sample; ICD-10-AM criteria=46%, Scored PG-SGA=53%, MNA=28% in a second sample) [38, 56]. In two studies which also measured the prevalence of malnutrition in other settings, rehabilitation consistently had the highest prevalence [49, 55]. The MNA was the most popular choice internationally for the assessment of nutrition status (n=11 of 17 studies).

In metropolitan settings, the prevalence of malnutrition according to the MNA is inconsistent (0.06-68%), however when viewed by geographical location appears more consistent (33-53% in Europe and 14-24% in Asia and approximately 30% in Australia and North America). However, two studies reported outliers, 0.06% in Australia [35] and 68% in Italy [50]. It is unclear if these outliers in reported prevalence of malnutrition by the MNA are due to a real difference in the severity of malnutrition in each study or due to possible differences in how the tool was implemented. When considering the low sensitivity of the MNA to identify malnutrition in geriatric rehabilitation (table 3), the prevalence reported by the MNA may be underestimated generally [38]. The metropolitan prevalence of malnutrition according to the SGA was generally consistent according to studies from Australia and Sweden (32 – 49%).

6. Conclusion

The pathogenesis of malnutrition, including starvation-related malnutrition, is distinct from sarcopenia and cachexia; however, nutrition support may have a role in preventing or treating all conditions characterised by the loss of lean tissues. The MST has strong criterion validity; and the MUST, SNAQ and the SNAQ^{65+} may also be appropriate for use as nutrition screening tools in rehabilitation. However, the MNA-SF and SNAQ^{RC} may only be appropriate for well-resourced settings focussed on prevention. The Rapid Screen and NUFFE require further evaluation of their validity before being recommended as a screening tool in the rehabilitation setting. Overall, nutrition screening tools require further investigation regarding their predictive validity, reliability and accuracy when used in practice. The Scored PG-SGA is appropriate for use as a nutrition assessment tool in rehabilitation; however, the MNA and BMI carry a risk that a malnourished patient may not be identified and may therefore not be appropriate as sole methods of diagnosis. Further research examining the MNA is needed in geriatric rehabilitation, including the evaluation of a new cut-off value for diagnosing malnutrition. Although the SGA can be considered

appropriate for use, further evidence is needed regarding its criterion validity. Malnutrition in the rehabilitation setting is most prevalent in older adults, and ranges from <1 – 68% worldwide and is influenced by method of diagnosis, country and rurality. The highest prevalence of malnutrition has been reported in rural, European and Australian settings; however, further studies investigating the prevalence of malnutrition in North and South America and Africa, as well as studies reporting the prevalence in rural areas internationally, is required.

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Table 1: The diagnostic criteria of malnutrition, sarcopenia and cachexia

Malnutrition[a]	**Sarcopenia[e]**	**Cachexia[g]**
Diagnosis based upon criterion 1 or (criterion 2 plus criterion 3 plus criterion 4)	**Diagnosis based upon criterion 1 plus (criterion 2 or criterion 3)**	**Diagnosis based upon (criterion 1 or criterion 2) and (criterion 3, criterion 4 or criterion 5)**
Criterion 1: BMI[b] <18.5 kg[c]/m[d2]	Criterion 1: Poor physical functioning (gait speed <1m·s^{-1}[f])	Criterion 1: Unintentional weight loss (≥5%) in 12 months or less in presence of underlying illness
Criterion 2: Unintentional weight loss (≥5%)	Criterion 2: Whole body lean mass <20th percentile	Criterion 2: BMI <20kg/m^2
Criterion 3: Suboptimal intake	Criterion 3: Appendicular fat free mass ≤7.23kg/m^2 (men) or ≤5.67kg/m^2 (women)	Criterion 3: Fatigue
Criterion 4: Loss of fat and/or muscle		Criterion 4: Low fat-free mass (MUAMC[h] <10th percentile or appendicular skeletal muscle ≤7.25kg/m^2 (men) or ≤5.45kg/m^2 (women))
		Criterion 5: Abnormal biochemistry (albumin <32g[i]/L[j] (3.2 g/dL[k]), CRP[l] >5.0mg[m]/L or IL-6[n] >4.0pg[o]/ml[p], or Hb[q] <3.2g/dL)

[a] Diagnosis of malnutrition according to the *International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification* (sixth edition, ICD-10-AM) [18].
[b] BMI, body mass index
[c] kg, kilogram
[d] m, metre
[e] Diagnosis of sarcopenia according to the International Working Group on Sarcopenia [11]
[f] m·s^{-1}, meter per second
[g] Diagnosis of cachexia according to the Cachexia Consensus Working Group [14]
[h] MUAMC, mid upper arm muscle circumference
[i] g, gram

[j] L, litre
[k] dL, decilitre
[l] CRP, C-reactive protein
[m] mg, milligram
[n] IL-6, Interleukin-6
[o] pg, pictogram
[p] ml, millilitre
[q] Hb, haemoglobin

Table 2: Comparison of the concurrent validity of nutrition screening tools evaluated in the rehabilitation setting

Nutrition screening tool	**Benchmark used**	**Population**	**Sensitivity**	**Specificity**	**Kappa statistic**	**Kappa statistic classification[a]**
MNA-SF[b] - Kaiser et al. 2011 [30]	Full MNA[c]	n=99, μ74.9±6.2 years Rome, Italy	Not reported	Not reported	0.626	Substantial agreement
MNA-SF - Marshall et al. 2015 [21]	ICD-10-AM[d] classification	n=57, μ79.1±7.3 years NSW[e], Australia	100%	22.6%	0.210	Fair agreement
MNA-SF - Hertroijs et al. 2012 [25]	Low BMI[f] or weight-loss	n=366, μ55 years Netherlands	92%	37%	Not reported	Not reported
MST[g] - Marshall et al. 2015 [21]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	80.8%	67.7%	0.478	Moderate agreement
MUST[h] - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, μ55 years Netherlands	100%	97%	Not reported	Not reported
NUFFE[i] - Söderhamn & Söderhamn, 2002 [23]	BMI, MAC[j], CC[k] and MNA	n=114, μ78.0±6.3 years Western Sweden	Not reported	Not reported	Not reported	Not reported
Rapid Screen - Visvanathan et al. 2004 [24]	Standardised nutrition assessment	n=65, μ76.5-79.8 years SA[l], Australia	78.6%	97.3%	Not reported	Not reported
SNAQ[m]						

- Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, µ55 years Netherlands	96%	71%	Not reported	Not reported
SNAQ[RC,n] - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, µ55 years Netherlands	99%	48%	Not reported	Not reported
SNAQ[65+,o] - Hertroijs et al. 2012 [25]	Low BMI or weight-loss	n=366, µ55 years Netherlands	96%	77%	Not reported	Not reported

a Landis and Koch kappa statistic classification [31]
b MNA-SF, Mini Nutritional Assessment – Short Form
c MNA, Mini Nutritional Assessment
d ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification (sixth edition) classifications for protein-energy malnutrition in adults
e NSW, New South Wales
f BMI, body mass index
g MST, Malnutrition Screening Tool
h MUST, Malnutrition Universal Assessment Tool
i NUFFE, Nutritional Form for the Elderly; Spearman rank correlations used to determine concurrent validity with the BMI at admission (r_s -0.25, P=0.008), BMI at discharge (r_s -0.23, P=0.014), MAC (r_s -0.23, P=0.014), CC (r_s -0.25, P=0.008) and the MNA (r_s -0.74, P=0.000)
j MAC, mid arm circumference
k CC, calf circumference
l SA, South Australia
m SNAQ, Short Nutritional Assessment Questionnaire
n SNAQ[RC], Short Nutritional Assessment Questionnaire Residential Care
o SNAQ[65+], Short Nutritional Assessment Questionnaire for older adults

Table 3: Comparison of concurrent validity of nutrition assessment tools evaluated in the rehabilitation setting

Nutrition screening tool	**Benchmark used**	**Population**	**ROC AUC[a]**	**ROC AUC classification[b]**	**Sensitivity**	**Specificity**	**Kappa statistic**	**Kappa statistic classification[c]**
MNA[d] - Neumann et al. 2007 [37]	Body fat	n=34, median 84 (IQR[e], 78-88) years SA[f], Australia	0.74	Good test	Not reported	Not reported	Not reported	Not reported
MNA - Marshall et al. 2015 [38]	ICD-10-AM[g]	n=57, μ79.1±7.3 years NSW[h], Australia	0.85	Very good test	57.7%	96.8%	0.562	Moderate agreement
MNA[i] - Visvanathan et al. 2004 [24]	Standardised nutrition assessment	n=65, μ76.5-79.8 years SA, Australia	N/A[j,k]	N/A	89.5%	87.5%	Not reported	Not reported
Scored PG-SGA[l] ratings - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	N/A[k]	N/A	100%	87.1%	0.860	Almost perfect agreement
Scored PG-SGA score[m] - Marshall, et al. 2015 [38]	ICD-10-AM	n=57, μ79.1±7.3 years NSW, Australia	0.910	Excellent test	92.3%	83.9%	0.7555	Substantial agreement

a ROC AUC, Receiver Operating Characteristic Area Under the Curve
b ROC AUC classification for the discriminative power of a test [39]
c Landis and Koch kappa statistic classification [31]
d MNA, Mini Nutritional Assessment

e IQR, Interquartile range
f SA, South Australia
g ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems 10th Revision Australian Modification (sixth edition) classifications for protein-energy malnutrition in adults
h NSW, New South Wales
i Non-standard calculation of the MNA. A two-step process was used, where participants which were identified as “at risk of malnutrition” (score 17 – 23.5) underwent further nutritional assessment to re-classify as “malnourished” or “well-nourished”. Traditional scoring of the MNA considers a participant “malnourished” if they scored <17, and “well-nourished” if they scored 17 - 30, which includes participants “at risk of malnutrition”.
j N/A, Not applicable
k ROC AUC applies to continuous variables only
l PG-SGA, Patient-Generated Subjective Global Assessment
m A score of 7 or more used to indicate “malnutrition” in geriatric rehabilitation [38]

Table 4: International prevalence of malnutrition in the rehabilitation setting according nutrition assessment tools validated for the rehabilitation setting.

Study	Setting	Diagnosis method	Prevalence
MNA in North America			
Thomas et al. 2002 [48]	• St Louis, USA • n=104, µ75.8 years	MNA	29%
MNA in Europe			
Compan et al. 2000 [49]	• Nîmes, France • n=196, µ83.4±6.8 years	MNA	33%[a]
Donini et al. 2002 [50]	• Rome, Italy • n=167, µ79 – 83 years	MNA	68%
Kaiser et al. 2011 [30]	• Rome, Italy • n=99, µ74.9±6.2 years	MNA	41%
MNA in Asia			
Shum et al. 2005 [51]	• Regional Hong Kong • n=120, µ80.3±7.4 years	Chinese MNA[b]	17%
Tsai et al. 2009 [46]	• Wen-Hua District, Taiwan[c] • n=74, 82% were ≥60 years	MNA, MNA-TI (population specific)[d]	24% (MNA), 14% (MNA-TI)
MNA in Australia			
Visvanathan et al. 2004 [24]	• Adelaide, SA • n=65, µ76.5 – 79.8 years	MNA	29%
Neumann et al. 2005 [35]	• 3 Hospitals across SA • n=167, µ81±6 years	MNA	0.06%
Charlton et al. 2010 [52]	• Sydney, NSW • n=2076, µ80.6±27.7 years	MNA	33%
McDougall et al. 2015 [42]	• Melbourne, Victoria • n=114, 83±7 years	MNA	32%

Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	MNA	28%
SGA in Europe			
Westergren et al. 2001 [47]	• Metropolitan Sweden[e] • n=162, μ78.62 years	SGA[f]	32%
Westergren et al. 2002 [53]	• Metropolitan Sweden • n=520, μ81.0 years	SGA[f]	46%
Andersson et al. 2002 [54]	• South Sweden • n=237, μ78.5 – 78.6 years	SGA[f]	34%
SGA in Australia			
Beck et al. 2001 [55]	• Wollongong, NSW • n=344, age not described	SGA	49%[g]
Thomas, et al. 2014 [56]	• Ballarat, Victoria • n=20, "geriatric", age not described	SGA	65%
Breik, et al. 2015 [57]	• Metropolitan Victoria • n=69, age not described	SGA	49%
Scored PG-SGA in Australia			
Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	Scored PG-SGA	53%
ICD-10-AM classification of protein-energy malnutrition in Australia			
Marshall et al. 2015 [38]	• Rural NSW • n=57, μ79.1±7.3 years	ICD-10-AM	46%

CI, Confidence interval; ICD-10-AM, International Statistical Classification of Diseases and Health Related Problems, 10th Revision, Australian Modification; MNA, Mini Nutritional Assessment; SA, South Australia; PG-SGA, Patient-Generated Subjective Global Assessment; SGA, Subjective Global Assessment.

a Compan et al. [49] found that rehabilitation had a higher prevalence than acute care than those in acute care (24.5%) or long-term residential care (24.7%).

b Malnutrition is considered at an MNA score of <18.5 as opposed to the usual <17 in the modified Chinese MNA.

c Result reported from a combined community and inpatient stroke rehabilitation study sample as opposed to a general rehabilitation inpatient sample

d Cut-points for the modified MNA-TI not described by the authors.

e Results reported from a stroke rehabilitation study sample as opposed to a general rehabilitation inpatient sample

f The SGA used in Sweden has four ratings of nutrition status, A, B, C and D instead of the usual A, B or C. The authors report malnutrition prevalence comprising ratings B, C and D.

g Beck et al. [55] found that rehabilitation had the highest prevalence of malnutrition compared to other inpatient medical wards