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Review

Potentially modifiable determinants of malnutrition in older adults: A systematic review

M. O'Keeffe [a], M. Kelly [a], E. O'Herlihy [b, c], P.W. O'Toole [b, c], P.M. Kearney [d], S. Timmons [e], E. O'Shea [e], C. Stanton [c], M. Hickson [f], Y. Rolland [g], C. Sulmont Rossé [h], S. Issanchou [h], I. Maitre [i], M. Stelmach-Mardas [j, k], G. Nagel [l], M. Flechtner-Mors [m], M. Wolters [n], A. Hebestreit [n], L.C.P.G.M. De Groot [o], O. van de Rest [o], R. Teh [p], M.A. Peyron [q], D. Dardevet [q], I. Papet [q], K. Schindler [r], M. Streicher [s], G. Torbahn [s], E. Kiesswetter [s], M. Visser [t], D. Volkert [s], E.M. O'Connor [a, c, u, *], on behalf of the MaNuEL consortium

[a] Department of Biological Sciences, University of Limerick, Limerick, Ireland
[b] School of Microbiology, University College Cork, Cork, Ireland
[c] Alimentary Pharmabiotic Centre Microbiome Irelan, University College Cork, Cork, Ireland
[d] School of Public Health, University College Cork, Cork, Ireland
[e] Centre for Gerontology and Rehabilitation, School of Medicine, University College Cork, Cork, Ireland
[f] Institute of Health & Community, University of Plymouth, England, UK
[g] Gérontopôle de Toulouse, Institut du Vieillissement, Centre Hospitalo-Universitaire de Toulouse (CHU Toulouse), UMR INSERM 1027, University of ToulouseIII, Toulouse, France
[h] Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRA, Université Bourgogne Franche-Comté, F-21000 Dijon, France
[i] GRAPPE USC 1422 INRA, Ecole supérieure d'Agricultures (ESA), Univ. Bretagne Loire, Angers, France
[j] German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany
[k] Poznan University of Medical Sciences, Poznan, Poland
[l] Institute of Epidemiology and Medical Biometry, Ulm University, Ulm, Germany
[m] Division of Sports and Rehabilitation Medicine, Medical Center, Ulm University, Ulm, Germany
[n] Leibniz Institute for Prevention Research and Epidemiology – BIPS, Bremen, Germany
[o] Division of Human Nutrition, Wageningen University & Research, Wageningen, the Netherlands
[p] Department of General Practice and Primary Health Care, The University of Auckland, Auckland, New Zealand
[q] Université Clermont Auvergne, Institut National de la Recherche Agronomique (INRA), Unité de Nutrition Humaine (UNH), Centre de Recherche en Nutrition Humaine (CRNH), Auvergne, 63000, Clermont-Ferrand, France
[r] Department of Medicine III, Medical University of Vienna, Vienna, Austria
[s] Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Nürnberg, Germany
[t] Department of Health Sciences, Vrije Universiteit Amsterdam, Amsterdam Public Health Research Institute, Amsterdam, the Netherlands
[u] Health Research Institute, University of Limerick, Limerick, Ireland

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SUMMARY

Background & aims: Malnutrition in older adults results in significant personal, social, and economic burden. To combat this complex, multifactorial issue, evidence-based knowledge is needed on the modifiable determinants of malnutrition. Systematic reviews of prospective studies are lacking in this area; therefore, the aim of this systematic review was to investigate the modifiable determinants of malnutrition in older adults.

Methods: A systematic approach was taken to conduct this review. Eight databases were searched. Prospective cohort studies with participants of a mean age of 65 years or over were included. Studies were required to measure at least one determinant at baseline and malnutrition as outcome at follow-up. Study quality was assessed using a modified version of the Quality in Prognosis Studies (QUIPS) tool. Pooling of data in a meta-analysis was not possible therefore the findings of each study were synthesized narratively. A descriptive synthesis of studies was used to present results due the heterogeneity of population source and setting, definitions of determinants and outcomes. Consistency of findings was assessed using the schema: strong evidence, moderate evidence, low evidence, and conflicting evidence.

* Corresponding author. Schrodinger Building, School of Natural Sciences, Department of Biological Sciences and Health Research Institute, University of Limerick, Room 1001, Ireland.
E-mail address: eibhlis.oconnor@ul.ie (E.M. O'Connor).

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Results: Twenty-three studies were included in the final review. Thirty potentially modifiable determinants across seven domains (oral, psychosocial, medication and care, health, physical function, lifestyle, eating) were included. The majority of studies had a high risk of bias and were of a low quality. There is moderate evidence that hospitalisation, eating dependency, poor self-perceived health, poor physical function and poor appetite are determinants of malnutrition. Moderate evidence suggests that chewing difficulties, mouth pain, gum issues co-morbidity, visual and hearing impairments, smoking status, alcohol consumption and physical activity levels, complaints about taste of food and specific nutrient intake are not determinants of malnutrition. There is low evidence that loss of interest in life, access to meals and wheels, and modified texture diets are determinants of malnutrition. Furthermore, there is low evidence that psychological distress, anxiety, loneliness, access to transport and wellbeing, hunger and thirst are not determinants of malnutrition. There appears to be conflicting evidence that dental status, swallowing, cognitive function, depression, residential status, medication intake and/or polypharmacy, constipation, periodontal disease are determinants of malnutrition.

Conclusion: There are multiple potentially modifiable determinants of malnutrition however strong robust evidence is lacking for the majority of determinants. Better prospective cohort studies are required. With an increasingly ageing population, targeting modifiable factors will be crucial to the effective treatment and prevention of malnutrition.

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1. Introduction

Malnutrition is defined as "a state of nutrition in which a deficiency of energy, protein and other nutrients causes measurable adverse effects on tissue and body form (body shape, size and composition) and function and clinical outcome" [1]. Protein-energy malnutrition in particular, is common, costly and increases with age, resulting in significant personal, social and economic burden [1,2]. Of most concern, it is an increasing health problem, mainly due to changes in worldwide population demographics. For instance, between 2010 and 2050, the global population over the age of 80 has been predicted to grow from 11.5% to 21.0% worldwide and from 9.0% to 19.0% in developed countries [3]. The prevalence of malnutrition in older adults varies significantly across different population subgroups; it is higher in older persons with higher disability levels, deteriorating health and multi-morbidities, deteriorating poor physical function, and dependence in activities of daily living (ADL) [4]. Malnutrition affects less than 10% of independently living older persons in the community. This prevalence is even lower when older adults are living at their home and attending senior centres [5,6]. However, the prevalence is reported to be 50% higher in nursing home and acute care settings; estimates ranging from 30 to 50% [7–9], displaying the importance of examining malnutrition across multiple settings. Although malnutrition is a prognostic factor associated with morbidity, mortality, and costs of care, nutritional problems in older adults often remain undetected or unaddressed [10]. This is a serious issue, as malnutrition is strongly associated with sarcopenia and frailty, two major public health issues among older adults [2,11]. Understanding the aetiology of malnutrition, and finding effective interventions and preventive strategies is therefore of utmost importance [12–14].

Several different definitions and criteria have been recommended for the diagnosis of malnutrition. These include different cut-off points for weight loss, body mass index (BMI), blood parameters (e.g. albumin) and assessment tools (e.g, the full Mini Nutritional Assessment (MNA)) [15–18]. The heterogeneity across definitions and diagnostic criteria in research and clinical practice makes it very difficult to generate meaningful data or comparisons on true malnutrition prevalence, incidence and treatment response across different countries and settings. Nevertheless, focussing on which factor contribute to the development of malnutrition may aid the development of effective interventions.

Multiple factors have been correlated with malnutrition in older adults and then suspected to be determinants including reduced appetite, female sex, social resources, poor physical function, poor-self related health, sensory function, chewing and swallowing problems, physical and cognitive impairment, depression, polypharmacy, low-grade inflammation, low socioeconomic status and loneliness, lack of food choices, lack of dietary advice/education, and older age [2,6,15–20]. However, most of the available studies in this area are cross-sectional with limited ability to make causal inference. Less emphasis has focussed on prospective studies and on determinants that could be considered potentially modifiable. Achieving consensus on what determinants may be modifiable, and generating strategies to modify these may be useful for future prevention and treatment of malnutrition.

Several studies and narrative reviews describe determinants of malnutrition. To date, three systematic reviews [14,21,22] have been completed in this area. One of these systematic reviews [21] investigated the determinants of malnutrition in community adults only, and only up to January 2013. This review consisted of mainly cross-sectional studies; it excluded certain tools for measuring malnutrition, and was limited to studies conducted in Western countries. The second [14] of the three reviews investigated determinants of malnutrition in nursing home patients only, from January 1990 to 2013 (16 cross-sectional studies). The third review [22] assessed determinants using prospective cohort studies which were published between January 2000 and March 2015. This review which had strict inclusion criteria based on sample size, measures of malnutrition, and methods of statistical analysis and, included six studies. No systematic review of malnutrition in older people has searched all years up to 2017, included all settings, was not restricted based on definitions or outcome measures used, and was focussed on modifiable determinants, which are arguably the most important for prevention and treatment of malnutrition. It is necessary to examine all of the available evidence to achieve a better understanding of the determinants, and effectively inform the design of future studies to generate better data and outcomes. Therefore, the objective of this systematic review was to examine the potentially modifiable determinants of malnutrition in older adults, across all settings, using information from prospective studies.

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2. Methodology

2.1. Search strategy

This review was registered on the PROSPERO database (CRD42017070383) and has been reported in accordance with the PRISMA statement [23]. Relevant prospective cohort studies meeting the inclusion criteria were identified by a computer aided search of the MEDLINE, CINAHL, Academic Search Complete, AMED, SPORTDiscus, PsycINFO, Biomedical Reference Collection, PsycARTICLES, and Web of Science databases during February 2017 from the period of inception (See Fig. 1 for search keywords). The reference lists of the included manuscripts were searched for additional papers by two independent reviewers. The search was restricted to include all studies that involved humans and were published in English, French, Dutch or German only. The reference lists of the selected articles were also manually searched for any further relevant articles.

Two reviewers (MOK and MK) screened the articles independently. The strategy had two components which were combined: (1) nutrition AND (2) old. The terms were searched using title and abstract. The exact search strings utilized are shown in Fig. 1.

2.2. Inclusion/exclusion criteria

2.2.1. Study design

Only reports of completed prospective cohort studies published in peer-reviewed journals were included. Only prospective studies that looked at the impact of determinants on the evolution of malnutrition were included.

2.2.2. Population

Study participants were required to be 65 years or older (if a combined population was described, the mean age had to be $\geq$ 65 years [24]. All settings (nursing home, community-dwelling, geriatric rehabilitation setting, acute care setting) were included. Studies examining specific patient groups (e.g. cancer patients) were not excluded based on the presence of these specific co-morbidities, as co-morbidity is a known determinant of malnutrition.

2.2.3. Potential determinants

Studies were required to examine one or more determinants of malnutrition. Studies examining determinants that the authors of this review deem as potentially modifiable by the older adult or by a carer-physician were included. Decisions on the potential modifiability of determinants were based on consensus within the author group. Factors considered non-modifiable, like age and genetics, were excluded. Attempts were made not to be too strict on what constituted non-modifiable, as it remains unclear whether certain factors within particular settings, are modifiable or not. Where it was unclear whether the factor was modifiable or non-modifiable (e.g. vision. cognitive state), the study was included.

2.2.4. Clinical outcomes

Studies had to report results from an outcome measure in the domain of malnutrition. Examples include BMI, and weight loss percentage. Since there is no gold standard definition or criteria for malnutrition, no study was excluded based on the outcome measure used for malnutrition. This means that studies that assessed malnutrition by screening or assessment tools (e.g. MNA and MUST) that include risk factors of malnutrition were included. Differences in definitions and criteria used for malnutrition were recorded. No restriction was placed on the time of follow-up.

A previous review [21] excluded studies that assessed malnutrition by screening or assessment tools that include determinants of malnutrition (such as the MNA and the MUST). Therefore, we also completed a descriptive synthesis without these studies to see if their removal would change the results.

2.3. Study selection

A standard protocol was followed for study selection and data extraction. After the removal of duplicates, two authors (MOK and MK) independently screened the titles and abstracts from the articles found, and excluded articles not meeting the eligibility

Nutrition* OR nutrient* OR undernutrition OR “under nutrition” OR undernourish* OR “under nourish*” OR under-nutrition OR malnutrition OR malnourish* OR "body composition" OR body-composition OR “underweight* OR “under weight” OR “weight loss” OR weight-loss OR underfed* OR “under fed” OR starv* OR weight* OR thinness OR sarcopeni* OR "energy intake" OR “food intake” OR anorexia* OR fasting* OR underfeeding OR hunger* OR BMI OR "body mass index" OR cachexia* OR ”wasting syndrome” OR protein-energy OR protein-calorie OR “protein calorie” OR “protein energy” OR slimness OR diet* OR appetite* (Title and Abstract)
AND
old* OR elder* OR elderly OR geriatric* OR senior* OR aging* OR aged OR “old age” OR “nursing home” OR nursing-home OR "community dwell*" OR “community-dwell*” OR “home care” OR home-care OR domiciliary OR free-living OR "free living" OR “over age 65” OR “65 and over” OR “living at home” OR "home nurs*" OR "home living" OR home-living OR "home help” OR home-help OR “home health” OR home-health OR “long-term care” OR “long term care” OR “community care” OR “domestic care ” OR “residential care” OR long-stay OR “long stay” (Title and Abstract)

Fig. 1. Search keywords.

criteria. If no abstract was available, or when it was not clear if the study should be included, full-text articles were retrieved in order to determine inclusion or exclusion. Both reviewers kept a record of their reasons for the inclusion or the exclusion of articles. The full-text version of an article was obtained if the title and abstract seemed to fulfil the inclusion criteria, or if the eligibility of the study was unclear. If any disagreements on study eligibility took place, the planned procedure was to hold a consensus meeting with another author (EOC). Original study authors were emailed, where required, to provide clarity on methodology.

2.4. Risk of bias assessment and overall quality

Two reviewers assessed the methodological quality of the studies independently and discrepancies were resolved by consensus. If necessary, a third author helped to reach consensus. The methodological quality was assessed by the Quality in Prognosis Studies (QUIPS) tool, which has been recommended by the Cochrane Prognosis Methods Group [25]. The QUIPS was modified to judge bias in relation to determinants, instead of the original tool's focus on prognostic factors. The modified version has been used in a previous systematic review [26]. The following six domains were considered: 1) study participation, 2) study attrition, 3) measures of risk factors, 4) measurement of, and controlling for confounding variables, 5) outcome measures, 6) analysis and reporting. Each domain was assessed as having high, moderate or low risk of bias (ROB) The overall ROB was also assessed. We considered a study to be of high quality when the ROB was rated low on at least four of the six domains and was rated low for both study attrition and study confounding. This approach has been used for systematic reviews in other fields [26].

2.5. Data extraction and data analysis

Data regarding each study were extracted by one author (MOK) and cross-checked by a second author (MK). The following data were extracted from each study:

- Characteristics of the determinant: domain, study and determinant examined
- Characteristics of the participants: setting, country, sample size, sex, age
- Characteristics of the outcome: malnutrition outcome measure and length of follow-up
- Results: for example, odds ratios, hazard ratio, risk ratio, 95% confidence intervals, p-values
- Study quality: overall rating on the QUIPs
- Strength of evidence: Low, Moderate, or High.

Due to substantial heterogeneity across studies, in terms of determinants examined, measurement of determinants, definition of malnutrition, malnutrition measurement, and length of follow-up, pooling of data in a meta-analysis was not possible. A descriptive synthesis [27] of studies was instead used to explore heterogeneity due to population source and setting, definitions of determinants and outcomes. Consistency of findings was assessed using the following schema.

- **Strong evidence**: consistent findings (defined as > 75% of studies showing the same direction of effect) in multiple high-quality (defined as low ROB in all domains) studies.
- **Moderate evidence:** consistent findings in multiple low quality (moderate to high ROB in 4 of 6 domains) studies and/or at least one low risk of bias/high-quality study.
- **Low evidence:** findings from one study only of moderate to high ROB (low or moderate quality).
- **Conflicting evidence:** inconsistent findings across studies of any risk of bias/quality.

3. Results

3.1. Literature search

Study identification is summarised in Fig. 2. The literature search of databases yielded **30,891** potentially relevant articles. 11,336 duplicates were removed and **19,555** titles and abstracts were scanned. Sixty five full-text studies were retrieved with 42 studies being excluded as they did not meet the eligibility criteria. Searching the reference lists of these articles did not yield any further articles. The major reasons for exclusion were cross-sectional design, mean age <65 years, and examined the association of malnutrition with mortality. Twenty three articles met the selection criteria. Two authors were emailed to obtain further information for clarification, of whom one replied.

3.2. Quality assessment

The majority of studies were rated as low quality on the QUIPS tool (n = 18) [24–45]. Five studies [46–49] were rated as moderate quality on the QUIPS tool. Common methodological limitations identified across studies were attrition rates, study confounding, and statistical analysis and reporting. Common methodological strengths were description of study participants and explanation of potential determinant and outcome measurements. The quality assessment scores for all studies are shown in Table 1.

3.3. Participants and follow-ups

Table 2 shows the characteristics of the 23 included studies in this review. The follow-up period of studies varied from 24 weeks to 12 years. All studies were performed in a mixed sample of males and females. Studies were conducted in the USA (n = 5) [28,29,39,42,50], Canada (n = 4) [43,46,48,49], Sweden (n = 4) [34,35,40,47], the Netherlands (n = 2) [38,44], Japan (n = 2) [33,41], Spain (n = 2) [31,45], Denmark (n = 1) [30], Israel (n = 1) [37], Finland (n = 1) [36], and Taiwan (n = 1) [32]. Studies involved participants from community-dwelling setting only (n = 15) [28,29,34,35,39–45,47–50], nursing home only (n = 3) [30,33,38], acute hospital only (n = 3) [31,32,37], and a combination of community-dwelling and nursing home settings (n = 2) [36,46]. The mean (SD) age across all studies was 74 (±12) years.

3.4. Definitions and measurement of malnutrition

Table 2 shows the outcome measures used for malnutrition in the 23 included studies in this review. Type and cut-off for measures of malnutrition significantly varied across studies. Four studies [30,38,40,44] used low BMI as a measure of malnutrition. However, the BMI cut off for being defined as malnourished varies across the four studies: one study [38] had no cut off; one study [30] defined <18.5 as malnourished; one study [40] defined <22 as malnourished, and one study [44] defined <20 as malnourished. Eight studies defined malnutrition by weight loss. Four studies [39,46,48,50] used >5% loss of body weight as a measure of malnutrition, but the time period of weight loss varied from one to two years across studies. Two studies [42,49] used >10% loss of body weight as a measure of malnutrition. One study [28] used >10 pounds loss of body weight over a one-year period. One study [29] used weight loss measured by DEXA as a measure of malnutrition.

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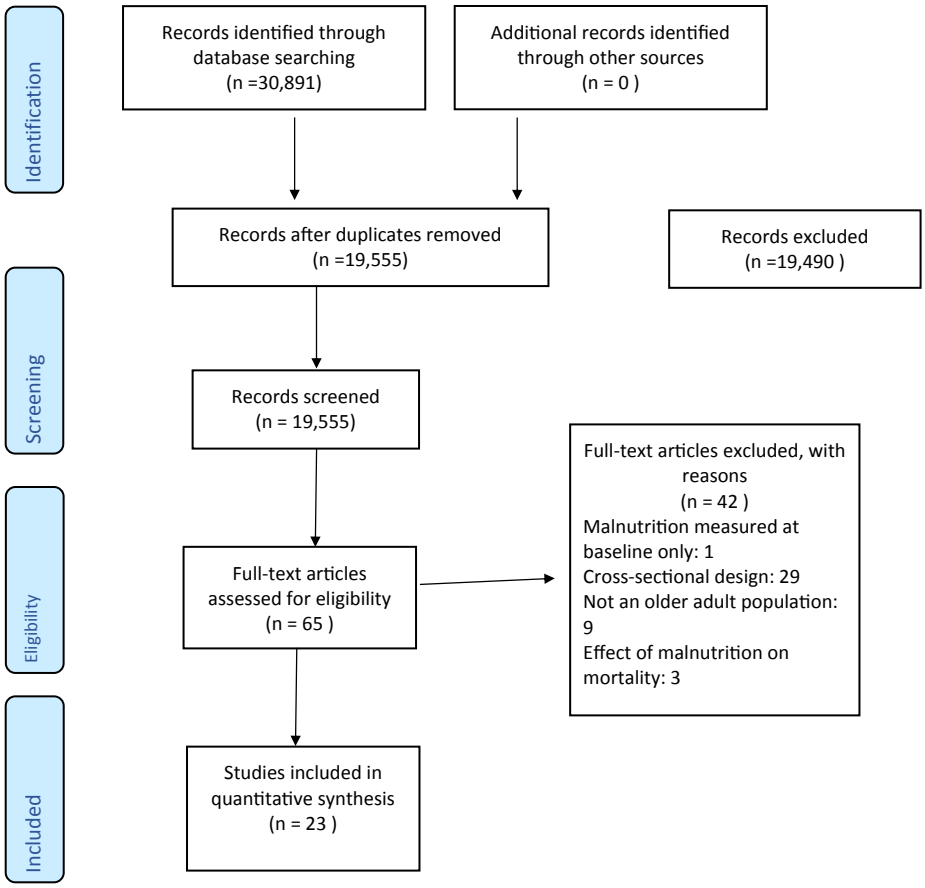


Fig. 2. Flowchart.

Table 1
Risk of bias/quality scores.

Study	1	2	3	4	5	6	Final quality rating
Agostini et al., 2004 [28]	Low	Low	Low	Low	Moderate	Low	Moderate
Alley et al., 2010 [29]	Low	High	Low	High	Low	Low	Low
Beck et al., 2015 [30]	Low	High	High	Low	High	High	Low
Carrión et al., 2015 [31]	Low	High	Low	Low	High	High	Low
Chen et al., 2009 [32]	Low	High	High	Low	High	High	Low
Izawa et al., 2014 [33]	Low	High	Low	Low	Low	Low	Low
Johansson et al., 2009a [34]	Low	High	Low	Low	High	Low	Low
Johansson et al., 2009b [35]	Low	Moderate	Low	Low	High	High	Low
Jyrkkä et al., 2011 [36]	Low	High	Low	Low	High	Low	Low
Kagansky et al., 2005 [37]	Low	Moderate	Low	Low	High	High	Low
Knoops et al., 2005 [38]	Low	Moderate	High	Low	High	Low	Low
Lee et al., 2004 [39]	Low	Moderate	High	Low	High	High	Low
Mamhidir et al., 2006 [40]	Low	High	High	High	High	High	Low
Okabe et al., 2015 [41]	Low	Moderate	Low	Low	Low	Low	Moderate
Ritchie et al., 2000 [42]	Low	Moderate	Low	Low	Low	Low	Moderate
Roberts et al., 2007 [43]	Low	High	Low	Low	Low	Low	Low
Schilp et al., 2011 [44]	Low	Moderate	Low	Low	Low	Low	Moderate
Serra-Prat et al., 2012 [45]	Low	High	Low	Low	High	Low	Low
Shatenstein et al., 2001 [46]	Low	Moderate	Low	Low	High	High	Low
Söderström et al., 2015 [47]	Low	Moderate	Low	Low	High	High	Low
St-Arnaud McKenzie et al., 2010 [48]	Low	Moderate	Low	Low	Low	Low	Moderate
Stephen and Janssen 2010 [49]	Low	High	Low	Low	High	Yes	Low
Weyant et al., 2004 [50]	Low	Moderate	Low	Low	High	Low	Low

High quality: risk of bias was rated low on at least four of the six domains and was rated low for both study attrition and study confounding (shaded).
Moderate quality: risk of bias was rated low or moderate on at least four of the six domains and was rated moderate for both study attrition and study confounding (shaded).
Low quality: risk of bias was rated high on at least four of the six domains and/or was related high for study attrition and study confounding (shaded).
Studies with high risk of bias for study attrition or study confounding were rated as low quality.
1 = Study Participation; **2** = Study Attrition; **3** = Risk Factor Measurement; **4** = Outcome Measurement; **5** = Study Confounding; **6** = Statistical Analysis and Reporting.

Two studies [40,44] used combinations of low BMI and weight loss to measure malnutrition. Seven studies [31,32,34,35,37,45,47] used the long form MNA (MNA-LF). One of these [45] defined <23.5 as malnourished, another [47] defined <17 as malnourished. Three

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Table 2
Description of studies.

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
Oral	**Dental status**					Conflicting
	Knoops et al., 2005 [38]	Nursing home. Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low	
	Lee et al., 2004 [39]	Community-dwelling. USA N = 3075 52% female Mean age: unclear, ranged from 70 to 79	Weight loss ≥5% of body weight in 1 year Follow-up: 1 year	NS	Low	
	Mamhidir et al., 2006 [40]	Community-dwelling. Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	
	Okabe et al., 2016 [41]	Community-dwelling. Japan N = 197 Mean age: unclear	MNA- Short Form <7 Follow-up: 1 year	NS	Moderate	
	Ritchie et al., 2000 [42]	Community-dwelling. USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	Edentulousness effect on 4% weight loss: OR (95% CI): 1.63 (1.09,2.43); P < 0.05. Edentulousness effect on 10% weight loss OR (95% CI): 2.03 (1.05, 3.96); p < 0.05	Moderate	
	Roberts et al., 2007 [43]	Community-dwelling. Canada N = 839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	
	Chewing					Moderate
	Beck et al., 2015 [30]	Community-dwelling. Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low	
	Izawa et al., 2014 [33]	Nursing home. Japan N = 392 77.7% female Mean age: 84.3 (7.2)	MNA-Short Form <7 Follow-up: 2 years	NS	Low	
	Knoops et al., 2005 [38]	Nursing home. Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low	
	Lee et al., 2004 [39]	Community-dwelling. USA N = 3075 52% female Mean age: unclear, ranged from 70 to 79	Weight loss ≥5% of body weight in 1 year Follow-up: 1 year	NS	Low	
	Mamhidir et al., 2006 [40]	Community-dwelling. Sweden N = 503	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	

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	72% female Mean age: 86.2 (5.5)				
Ritchie et al., 2000 [42]	Community-dwelling. USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
Schilp et al., 2011 [44]	Community-dwelling. Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
Mouth Pain					Moderate
Lee et al., 2004 [39]	Community-dwelling. USA N = 3075 52% female Mean age: unclear, ranged from 70 to 79	Weight loss ≥5% of body weight in 1 year Follow-up: 1 year	NS	Low	
Mamhidir et al., 2006 [40]	Community-dwelling. Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	
Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
Gum issues					Conflicting
Beck et al., 2015 [30]	Community-dwelling. Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low	
Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
Weyant et al., 2004 [39]	Community-dwelling USA N = 1053 50.3% female Mean age: 72.7 (2.8)	Weight loss ≥5% of body weight over 2 years Follow-up: 2 years	Extent of sites with ≥ 6 mm periodontal probing depth OR (95% CI): 1.53 (1.32−1.77); p < 0.05.	Low	
Swallowing					Conflicting
Beck et al., 2015 [30]	Community-dwelling. Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low	
Carrión et al., 2015 [31]	Acute hospital Spain N = 1662 61.7% Female Mean age: 85.1 (6.23)	MNA<17 Follow-up: 6 months and 1 year	OR (95% CI): 12.6 (7.49, 21.12); p < 0.001	Low	
Knoops et al., 2005 [38]	Nursing home The Netherlands N = 108	BMI Follow-up: 24 weeks	NS	Low	

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Table 2 (*continued*)

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
		83% female Mean-age: 82.1 (7.6)				
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	
	Okabe et al., 2016 [41]	Community-dwelling Japan N = 197 Mean age: %female unclear	MNA- Short Form <7 Follow-up: 1 year	RR (95% CI): 5.21 (1.65, 16.43); p = 0.005.	Moderate	
	Serra-Prat et al., 2012 [45]	Community-dwelling Spain N = 254 46.5% female Mean age: 78	MNA<23.5 Follow-up: 1 year	NS	Low	
Psychosocial	**Cognitive function**					Conflicting
	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	B (SE): 0.17 (0.01), 95% CI (0.43, 0.60); p < 0.001	Low	
	Johansson et al., 2009a [34]	Community-dwelling Sweden N = 579 % female Mean age: unclear	MNA<17 Follow-up: 6 years	NS	Low	
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female: unclear Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	For men: OR (95% CI): 12.9 (2.9, 56.7); p < 0.01 For women: NS	Low	
	Kagansky et al., 2005 [37]	Acute hospital Israel N = 414 65.7% female Mean age: 84.8 (6.1)	MNA<17 Follow-up: 2 years	OR (95% CI): 3.85 (1.55, 9.59); P = 0.004.	Low	
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or 10% of total body weight Follow-up: 1 year	OR (95% CI): 1.844 (1.267, 2.683); P = 0.001	Low	
	Okabe et al., 2016 [41]	Community-dwelling Japan N = 197 %female unclear Mean age: unclear	MNA- Short Form <7 Follow-up: 1 year	NS	Moderate	
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
	Roberts et al., 2007 [43]	Community-dwelling Canada N = 839	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	

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	68.7% female Mean age: 79.6				
Depression and depressive symptomology					**Conflicting**[a]
Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	β (SE): −0.35 (0.03), 95% CI (−0.41,-0.29); p < 0.0001	Low	
Johansson et al., 2009a [34]	Community-dwelling Sweden N = 579 % female: unclear Mean age: unclear	MNA<17 Follow-up: 6 years	OR (95% CI): 1.522 (1.185, 1.954); p = 0.001	Low	
Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or 10% of total body weight Follow-up: 1 year	NS	Low	
Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
Shatenstein et al., 2001 [46]	Community-dwelling and institutionalised Canada N = 584 59.6% female Mean age: unclear, ranged from 70 to 90	Weight loss ≥5% of body weight Follow-up: 5 years	Loss of interest in life For institution: β (SE): −0.63 (0.29) 95% CI (0.30, 0.93); P = 0.027 For community-dwelling β (SE): −0.58 (0.25) 95% CI (0.34, 0.90); p = 0.017	Low	
Psychological distress					Low
Roberts et al., 2007 [43]	Community-dwelling Canada N = 839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	
Anxiety					Low
Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
Social support					Low
Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: six months	NS	Low	
Roberts et al., 2007 [43]	Community-dwelling Canada N = 839	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	

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Table 2 (*continued*)

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
		68.7% female Mean age: 79.6				
	Residential status					Conflicting
	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: six months	NS	Low	
	Johansson et al., 2009a [34]	Community-dwelling Sweden N = 579 % female Mean age:	MNA<17 Follow-up: 6 years	NS	Low	
	Jyrkkä et al., 2011 [36]	Community-dwelling and nursing home Finland N = 294 69% female Mean age: 81.9	MNA- Short Form <11 Follow-up: 1,2, 3 years	B (SE): −1.89 (0.25), 95% CI -2.38-(-1.39); P < 0.001	Low	
	Schilp et al., 2011 [44]	Community-dwelling The Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
	Transport					Low
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	NS	Low	
	Loneliness					Low
	Schilp et al., 2011 [44]	Community-dwelling The Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
	Wellbeing					Low
	Johansson et al., 2009a [34]	Community-dwelling Sweden N = 579 % female: unclear-Mean age: unclear	MNA<17 Follow-up: 6 years	NS	Low	
	Meals on wheels					Low
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	For men: OR (95% CI): 11.6 (2.0, 67.8); p < 0.01 For women: OR (95% CI): 18.0 (1.8, 182.7); p < 0.05.	Low	
Medication and care	**Medication and polypharmacy**					Conflicting
	Agostini et al., 2004 [28]	Community-dwelling USA N = 885 72% female Mean age: 81.0 (5.2)	Weight loss ≥10 pounds in 1 year Follow up: 1 year	1-2 medications: NS 3-4 medications: OR (95% CI): 1.96 (1.08, 3.54); p < 0.05 ≥5 medications: 2.78 (1.38, 5.60); p < 0.05	Moderate	

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	Beck et al., 2015 [30]	Nursing home Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low
	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	β (SE)-0.08 (0.02), 95% CI (−0.13, −0.04); p = 0.0002	Low
	Jyrkkä et al., 2011 [36]	Community-dwelling and nursing home Finland N = 294 69% female Mean age: 81.9	MNA- Short Form <11 Follow-up: 1,2, 3 years	Excessive polypharmacy (10 or more drugs): β (SE): −0.62 (0.18); 95% CI -0.98-(-0.27); p = 0.001 Polypharmacy (6–9 drugs): NS	Low
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate
	Hospitalisation				**Moderate**[b]
	Alley et al., 2010 [29]	Community-dwelling USA N = 2690 50.8% female Mean age: 73.5 (2.9)	Weight loss per year in total body mass (DEXA scan) per year Follow-up: 1 year	For men: β (95% CI): −0.79 (−1.04, −0.54); p < 0.001 For women: β (95% CI): −0.79 (-1.07, −0.51)' p < 0.001	Low
	Izawa et al., 2014 [33]	Nursing home Japan N = 392 77.7% female Mean age: 84.3 (7.2)	MNA- Short Form <7 Follow-up: 2 years	OR (95%CI): 1.80 (1.09, 2.97); P = 0.023	Low
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female: unclear Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	For men: NS For women: OR (95% CI): 5.9 (1.1, 31.5); p < 0.05.	Low
Health	**Co-morbidities**				Moderate
	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	NS	Low
	Izawa et al., 2014 [33]	Nursing home Japan N = 392 77.7% female Mean age: 84.3 (7.2)	MNA- Short Form <7 Follow-up: 2 years	NS	Low

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Table 2 (*continued*)

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
	Jyrkkä et al., 2011 [36]	Community-dwelling and nursing home Finland N = 294 69% female Mean age: 81.9	MNA- Short Form <11 Follow-up: 1, 2, 3 years	NS	Low	
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low	
	Okabe et al., 2016 [41]	Community-dwelling Japan N = 197 Mean age:unclear %female unclear	MNA- Short Form <7 Follow-up: 1 year	NS	Moderate	
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
	Roberts et al., 2007 [43]	Community-dwelling Canada N = 839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	
	Functional health status					Conflicting
Constipation	Beck et al., 2015 [30]	Nursing home Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low	
Vision & hearing	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	Both NS	Low	
Constipation	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	OR (95% CI): 2.490 (1.185, 4.964); p = 0.015	Low	
Vision & hearing	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	Both NS	Moderate	
	Eating dependency/ difficulty feeding					Moderate
	Beck et al., 2015 [30]	Nursing home Denmark	BMI<18.5 Follow-up: 6 months and 1 year	OR (95% CI): 2.16 (1.27, 3.67); p < 0.05	Low	

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		N = 441 80% female Mean age: 85.2 (7.5)			
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	OR (95% CI): 2.257 (1.676, 3.038); p = 0.001	Low
	Shatenstein et al., 2001 [46]	Community-dwelling and nursing home Canada N = 584 59.6% female Mean age: unclear, ranged from 70 to 90	Weight loss≥5% of body weight Follow-up: 5 years	β (SE): 4.24 (1.07); p = 0.000	Low
	Self-perceived health				**Moderate**[c]
	Johansson et al., 2009a [34]	Community-dwelling Sweden N = 579 % female: unclear Mean age: unclear	MNA<17 Follow-up: 6 years	OR (95% CI): 0.443 (0.289, 0.676); p < 0.001	Low
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female: unclear Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	For men: OR (95% CI): 3.9 (1.4, 10.8); p < 0.01. For women: NS	Low
	Jyrkkä et al., 2011 [36]	Community-dwelling and nursing home Finland N = 294 69% female Mean age: 81.9	MNA- Short Form <11 Follow-up: 1,2,3 years	Poor self-perceived health: β (SE): −1.05 (0.17), 95% CI -1.38-(-0.73); p < 0.001	Low
	Roberts et al., 2007 [43]	Community-dwelling Canada N = 839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6–13) Follow-up: 1 year	OR (95% CI): 3.30 (1.42, 7.67)	Low
Physical function	**ADL, performance or strength**				Moderate
	Chen et al., 2009 [32]	Acute hospital Taiwan N = 306 53.27% female Mean age: 71.75 (5.62)	MNA<17 Follow-up: 6 months	B (SE): 0.17 (0.01), 95% CI 0.15,0.19); P < 0.001	Low
	Izawa et al., 2014 [33]	Nursing home Japan N = 392 77.7% female Mean age: 84.3 (7.2)	MNA Short-Form <7 Follow-up: 2 years	ADL score of 20–50 points: OR (95%CI): 2.62 (1.47, 4.69); P = 0.001 ADL score of 0–15 points: OR (95% CI): 2.02 (1.10, 3.72); P = 0.024	Low
	Johansson et al., 2009b [35]	Community-dwelling Sweden N = 258 % female: unclear Mean age: 74.2 (2.55)	MNA<17 Follow-up: 12 years (3 times with 4 year intervals)	For men: OR (95% CI): 7.5 (2.8–20.4); p < 0.001. For women: OR (95% CI): 3.3 (1.2, 9.2); p < 0.05	Low

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Table 2 (*continued*)

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	β (95% CI): −0.11 (−0.21, −0.01); p = 0.39.	Low	
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	OR (95% CI): 1.793 (1.163, 2.765); p = 0.008	Low	
	Okabe et al., 2016 [41]	Community-dwelling Japan N = 197 Mean age: unclear %female: unclear	MNA-Short Form <7 Follow-up: 1 year	NS	Moderate	
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	Dependent in one or more ADLs effect on 10% weight loss: OR (95% CI): 2.27 (1.08, 4.78); p < 0.05 NS for 4% weight loss	Moderate	
	Roberts et al., 2007 [43]	Community-dwelling Canada N = 839 68.7% female Mean age: 79.6	Elderly Nutrition Screening (6–13) Follow-up: 1 year	NS	Low	
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	Difficulty walking stairs, aged <75 HR (95% CI): 1.91 (1.14, 3.22) Difficulty walking stairs ≥ 75 years: NS Limitation of normal activities due to a health problem: NS Physical performance test score: NS	Moderate	
	Serra-Prat et al., 2012 [45]	Community-dwelling Spain N = 254 46.5% female Mean age: 78	MNA<23.5 Follow-up: 1 year	NS	Low	
	St Arnaud-McKenzie et al., 2010 [48]	Community-dwelling Canada N = 1497 52.3% Female Mean age: unclear. Ranged from 67 to 84	Weight loss ≥5% of body weight over 2 years Follow-up: 2 years	Worse baseline physical function predicted both weight loss and weight gain	Moderate	
Lifestyle	**Smoking**					Moderate
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate	
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate	

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	Alcohol				Moderate
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss ≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate
	Physical activity				Moderate
	Ritchie et al., 2000 [42]	Community-dwelling USA N = 563 57.9% female Mean age: unclear, range 70 and over	Weight loss≥10% of body weight in 1 year Follow-up: 1 year	NS	Moderate
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	NS	Moderate
	Stephen and Janssen 2010 [49]	Community-dwelling. Canada N = 4512 57.1% female Mean age: unclear	Weight loss ≥10% of body weight Follow-up: Every year over a 8 year period	NS	Low
Eating	**Appetite/leaves food on plate**				Moderate
	Beck et al., 2015 [30]	Nursing home Denmark N = 441 80% female Mean age: 85.2 (7.5)	BMI<18.5 Follow-up: 6 months and 1 year	OR (95% CI): 2.36 (1.07, 5.18); p < 0.05	Low
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	β(95% CI): −2.16 (−4.32, −0.01); p = 0.49	Low
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or 10% of total body weight Follow-up: 1 year	NS	Low
	Schilp et al., 2011 [44]	Community-dwelling Netherlands N = 1120 51.% female Mean age: 74.1 (5.7)	Weight loss ≥5% of body weight in 6 months Follow-up: every 3 years over a 9 year period	HR (95% CI): 1.63 (1.02, 2.61); p < 0.05	Moderate
	Shatenstein et al., 2001 [46]	Community-dwelling and nursing home Canada N = 584 59.6% female Mean age: unclear, ranged from 70 to 90	Weight loss ≥5% of body weight Follow-up: 5 years	Community-dwelling: β (SE): −1.52 (0.33), 95% CI 0.12, 0.42); P = 0.000	Low
	Complaints about taste of food				Moderate
	Beck et al., 2015 [30]	Nursing home Denmark	BMI<18.5 Follow-up: 6 months and 1 year	NS	Low

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Table 2 (*continued*)

Domain	Study and determinant examined	Setting, country and participants	Malnutrition measure and length of follow-up	Results	Quality	Strength of evidence
		N = 441 80% female Mean age: 85.2 (7.5)				
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	
	Nutrient intake and modified texture diets					Moderate
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	Fat intake at baseline β (95% CI): 0.07 (0.01, 0.13); p = 0.027	Low	
	Okabe et al., 2016 [41]	Community-dwelling Japan N = 197 Mean age: unclear %female unclear	MNA- Short Form <7 Follow-up: 1 year	NS	Moderate	
	Söderström et al., 2015 [47]	Community-dwelling Sweden N = 725 51.6% Female, Mean age 66.7	MNA<17 Follow-up: 10 years	BMI of <25 kg/m^2 at baseline: Fat intake: OR (95% CI): 1.106 (1.020, 1.199); P = 0.015.	Low	
	Hunger					Low
	Mamhidir et al., 2006 [40]	Community-dwelling Sweden N = 503 72% female Mean age: 86.2 (5.5)	BMI<22 and weight of 5% or10% of total body weight Follow-up: 1 year	NS	Low	
	Thirst					Low
	Knoops et al., 2005 [38]	Nursing home Netherlands N = 108 83% female Mean-age: 82.1 (7.6)	BMI Follow-up: 24 weeks	NS	Low	

OR = Odds ratio, HR = Hazard ratio, RR = Risk ratio, NS: Non-significant, CI: confidence interval, BMI: body mass index, MNA: Mini Nutritional Assessment, DEXA: Dual-energy X-ray absorptiometry, ADL: Activities of Daily Living.

[a] When studies using the MNA are removed from the analysis, the conflicting evidence for depression being a determinant of malnutrition changes to moderate evidence that depression is not a determinant of malnutrition.

[b] When studies using the MNA are removed from analysis, the moderate evidence for hospitalisation being a determinant of malnutrition changes to limited evidence that hospitalisation is a determinant of malnutrition.

[c] When studies using the MNA are removed from the analysis, the moderate evidence for self-perceived health being a determinant of malnutrition changes to limited evidence that self-perceived health is a determinant of malnutrition.

studies [33,36,41] used the short form MNA (MNA-SF). Two of these studies [33,41] defined <7 as malnourished, while one study [36] defined <11 as malnourished. One study [43] used the Elderly Nutrition Screening Tool.

3.5. Potentially modifiable determinants

Thirty determinants categorised into seven domains shown in Table 3. The results will be discussed according to these domains for ease of clarity.

3.6. Oral domain

A total of 13 studies [30–33,38–45,50] studies examined 5 potential determinants in the oral domain.

3.6.1. Dental status

Dental status (denture use, having teeth) was assessed by six studies [38–43]. Measurement of dental status varied significantly across studies. Five studies [38–40,42,43] used single item yes/no questions: One study [40] used a yes/no response to some or all natural teeth lost and not using dentures; one study [38] assessed whether dental status was complete or incomplete; one study [39] assessed if participants had any remaining natural teeth; one study [43]assessed the presence or absence of dental problems. One study [42] scored participants based on number of dentures, no teeth or presence of natural teeth.

3.6.2. Chewing difficulties

Chewing difficulties was assessed by seven studies [30,33,38–40,42,44]. Five studies [30,38–40,42] used single item yes/no questions on able or unable to chew or presence or absence of chewing problems. One study [33] categorised chewing difficulties into three categories: difficulty chewing even soft food items (poor), difficulty chewing harder foods (fair), and no difficulty chewing harder foods (good). Only one study [44] assessed biting and chewing with a question 'Are you able to bite or chew hard food?' and categorised participants into 'almost never', 'some of the time', no problem, 'often' or 'most of the time'.

Table 3
Domains of potentially modifiable determinants.

Domain name	Included determinants (n = 30)
Oral	1. Dental status
	2. Chewing
	3. Mouth pain
	4. Gum issues
	5. Swallowing
Psychosocial	6. Cognitive function
	7. Depression/depressive symptomology
	8. Psychological distress
	9. Anxiety
	10. Social support
	11. Residential status
	12. Transport
	13. Loneliness
	14. Wellbeing
	15. Meals on wheels
Medication and care	16. Medication and polypharmacy
	17. Hospitalisation
Health	18. Co-morbidities
	19. Functional health status
	20. Eating dependency/difficulty feeding
	21. Self-perceived health
Physical function	22. Activities of daily living, performance or strength
Lifestyle	23. Smoking
	24. Alcohol
	25. Physical activity
Eating	26. Appetite/leaves food on plate
	27. Complaints about taste of food
	28. Dietary factors – nutrient intake and modified texture diets
	29. Hunger
	30. Thirst

3.6.3. Mouth pain

Mouth pain was assessed by three studies [39,40,42] using a single item yes/no question on the presence or absence of mouth pain.

3.6.4. Gum issues

Gum issues (inflammation, bleeding, periodontal disease) were assessed by three studies [30,42,50]. One study [30] used a single item yes/no answer question to the presence or absence of inflamed, swollen or bleeding gums. One study [42] assessed the number of participants with gum bleeding, and percentage of sites with this bleeding.

Two studies assessed the effect of periodontal disease [42,50]. One study [50] measured mean depth and attachment loss, percentage of pockets with at least 6 mm probing depth. The other study [42] used a single item yes/no question to assess the presence or absence of periodontal disease.

One study [32] assessed a combination of oral health factors together and could not be categorised under any one determinant. This study used the 12-item General Oral Health Assessment Index to assess oral health.

3.6.5. Swallowing

Swallowing was assessed by six studies [30,31,38,40,41,45]. Measurement of swallowing varied significantly across studies. Two studies [31,45] used the volume viscosity test. Three studies [30,38,40] used single item yes/no questions from The Resident Assessment Instrument - Minimum Data Set (RAI-MDS) to the presence or absence of swallowing problems. One study [41] used cervical auscultation to assess swallowing problems.

There is conflicting evidence that dental status, periodontal disease and swallowing are determinants of malnutrition.

There is moderate quality evidence that chewing difficulties, mouth pain and gum issues are not determinants of malnutrition.

3.7. Psychosocial domain

A total of ten studies [32,34–37,40–44,46] examined ten determinants in the psychological domain.

3.7.1. Cognitive function

Cognitive function was assessed by eight studies [32,34,35,37,40–43]. Four studies [32,34,35,43] used a Mini-Mental State Examination (MMSE) measure to assess cognitive capacity, one study [46] used the modified MMSE (3MS); one study [32] used the 11-item MMSE, two studies [34,35] used the full MMSE; one study [43] used the Adult Lifestyle and Function Interview MMSE (ALFI-MMSE). The Clinical Dementia Rating Scale and Cognitive Performance Scale were used by two studies [40,41], respectively. One study [37] used a single item yes/no question on the presence of dementia, and the MNA 2 subscore on cognitive status. Another study [42] assessed mental status subjectively by getting the interviewer to judge the participants' presence or absence of mild confusion. Memory impairment affecting ADL function was assessed by one study [34] using a single item yes/no question; "Do you believe you are having memory problems that have an impact on your daily life?".

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3.7.2. Depression and depressive symptomology

Depression and/or depressive symptomology was assessed by six studies [32,40,42,44,46]. Measures of depression varied significantly across studies. One study [40] used the Depression Rating Scale. One study [32] used the Geriatric Depression Scale Short-Form. One study [42] used the Geriatric Depression Long-Form. One study [44] used the Center for Epidemiological Studies Depression Scale while another [46] used the Cambridge Mental Disorders of the Elderly Examination questionnaire and a single item yes/no question on loss of interest in life. Only one study [42] used a single item question "How often have you felt downhearted and blue?".

3.7.3. Psychological distress

Psychological distress was assessed by one study [43] using L'Indice de détresse psychologique de Santé Québec (IDPESQ-14) questionnaire.

3.7.4. Anxiety

Anxiety was assessed by one study [44] using the anxiety subscale of the Hospital Anxiety and Depression Scale.

3.7.5. Social support

Social support was assessed by two studies [32,43]. One study [32] used the six-item Social Support Questionnaire-Short Form. The second study [43] used a single item yes/no question on satisfaction with social support.

3.7.6. Residential status

Residential status was assessed by four studies [32,34,36,44]. Two studies [32,34] used a single item yes/no question on living alone or not. One study [36] assessed whether participants were living at home or in sheltered accommodation. The final study [44] assessed whether participants were independent in living, receiving home care, or not independent (including institutionalised).

3.7.7. Transport

Use of special transport services was assessed by one study [35] using a single item yes/no question on the use of special transport services.

3.7.8. Loneliness

Loneliness was assessed by one study [44] using the Dutch validated loneliness scale.

3.7.9. Wellbeing

Wellbeing was assessed by one study [34] using the Philadelphia Geriatric Centre Multilevel Assessment Instrument.

3.7.10. Meals on wheels

Meals on wheels was assessed by one study [35] using a single item yes/no question on use of meals and wheels.

There is conflicting evidence that cognitive function, depression and residential status are determinants of malnutrition.

Low evidence suggests that loss of interest in life and access to meals and wheels are determinant of malnutrition.

There is also low evidence showing that psychological distress, anxiety, residential status, loneliness, access to transport and wellbeing are not determinants of malnutrition. Furthermore, there is low evidence that access to meals and wheels is a determinant of malnutrition.

3.8. Medication and care domain

A total of ten studies [28–30,32–34,36,38,40,44] examined two determinants in the medication and care domain.

3.8.1. Medication and/or polypharmacy

Medication and/or polypharmacy was assessed by seven studies [28,30,32,36,38,40,44]. One study [30] assessed prescription medications, and polypharmacy was defined as the consumption of over five prescription medications per day. The second study [36] defined excessive polypharmacy as the use of ten or more drugs, polypharmacy as the use of six to nine drugs, and non-polypharmacy as the use of five or less drugs concomitantly. A third study [28] recorded all medication reported taken by participants on a regular basis, and categorised participants into no medication use, 1 or 2, 3 or 4, or 5 or more drugs taken daily. The fourth study [40] assessed the number of medications reported taken in the last seven days. One study [44] assessed medication through three categories: no medication use; the use of one or two medications; and the use of three or more medications. Another study [32] assessed the number of prescriptions and over the counter medication that were taken currently by participants. Finally, one study [38] assessed the frequency of medication use and type of medicines reported taken.

3.8.2. Hospitalisation

Hospitalisation was assessed by three studies [29,33,35]. Two studies used a single item yes/no question to hospitalisation over a 2-year period [33], and hospital stay during the last 2 months [35]. One study [29] assessed total days hospitalized in a given year and categorised participants into no hospitalisation, 1–3 days hospitalised, 4–7 days hospitalised, or 8 or more days hospitalised.

There is conflicting evidence that medication intake and/or polypharmacy is a determinant of malnutrition while moderate evidence suggests that hospitalisation is a determinant of malnutrition.

3.9. Health domain

A total of twelve studies [30,32–36,38,40–44] examined four determinants in the health domain.

3.9.1. Co-morbidities

Co-morbidity was assessed by eight studies. Two studies [33,41] used the Charlson Comorbidity Index. Four studies [32,38,42,44] assessed number and type of diagnosis/disease. One study [43] used the chronic disease score while another study [36] used the Functional Comorbidity Index.

3.9.2. Functional health status

Visual and hearing impairments were individually assessed by two studies [32,44]. Two categories were created: 'none' and 'one or two items with some difficulty'. Constipation was individually assessed by two studies [30,40] using a single item yes/no question on the presence of constipation.

3.9.3. Eating dependency/Difficulty feeding

Eating dependency was assessed by four studies [30,38,40,46]. Two studies [30,40] used the single item yes/no question on eating dependency (whether the person was classified as independent in eating and drinking) from the Resident Assessment Instrument-Minimum Data Set (RAI-MDS). One study [38] used a single item yes/no question on able/not able to bring food to mouth. The last

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study [46] categorised ability to eat unaided into, completely unable, with some help, or without help.

3.9.4. Self-perceived health

Self-perceived health was assessed by four studies [34–36,43]. Two studies [34,35] used the Nottingham Health Profile. One study [36] used a five-point scale and classified participants into three health status categories: good (very good/good), moderate and poor (fairly poor). One study [43] assessed current health status by getting participants to rate their own health as very good, excellent or poor, and their current health status (worse, same, better) compared to their own health one year earlier.

There is moderate evidence that co-morbidity, visual and hearing impairments are not determinants of malnutrition.

There is also moderate evidence that eating dependency and poor self-perceived health are determinants of malnutrition.

Conflicting evidence suggests constipation is a determinant of malnutrition.

3.10. Physical function domain

Physical function was assessed by 13 studies [32–34,36,38,40–46,48]. Measures focused on ADL, performance, and strength. Three studies [33,34,46] used the 0-100 ADL Index. One study [40] used a 4-18 ADL score. Another study [38] used the Zorg index (Care Index Questionnaire). A third study [43] summed the number of reported physical problems in the past year (problems with balance, feet, ankles). Finally, one study [36] used an eight-point instrumental ADL tool.

One study [42] used a single yes/no question on independent/dependent in ADLs of walking, bathing, dressing, toileting, transferring, and getting outside. Three studies [32,41,45] used the Barthel Index. Two studies [44,48] used a series of performance tests. One study [44] used three performance tests (chair stands, tandem stand, walk tests, and difficulty walking stairs), and rated performance on a scale, and the other study [48] used eight performance tests: handgrip, bicep strength, quadriceps strength, chair stand test, two gait speed tests, timed up and go test, and the one leg stand test.

There is moderate evidence that physical function is a determinant of malnutrition.

3.11. Lifestyle domain

A total of three studies [42,44,49] examined three determinants in the lifestyle domain.

3.11.1. Smoking

Smoking status was assessed by two studies [42,44]. One study [42] used a single item yes/no question to the smoking or chewing of tobacco, and categorised participants into current smoker, former smoker or those who had never smoked. The second study [44] categorised participants into 3 categories: current smoker, former smoker, or never a smoker.

3.11.2. Alcohol

Alcohol use was assessed by two studies [42,44]. One study [44] assessed alcohol use on the number of days per week drinking alcohol, and the number of alcohol consumptions each time, and categorised participants into four categories: no alcohol, light, moderate, and (very) excessive use of alcohol. The second study [42] assessed alcohol use using a yes or no single item yes/no question on drinking alcohol 5 or more days per week.

3.11.3. Physical activity

Physical activity was assessed by three studies [42,44,49]. One study [42] defined physical activity by whether participants walked one or more blocks each day. A second study [44] assessed physical activity in the previous two weeks using the Longitudinal Ageing Study Amsterdam Physical Activity Questionnaire which included information on frequency and duration of walking, cycling, household activities, and sport activities. The third study [49] asked participants whether they had engaged in common leisure activities in the previous 2 weeks, including walking, hiking, jogging, cycling, dancing, aerobics, bowling, golfing, calisthenics, and swimming. Each activity was assigned a per-minute caloric expenditure value, which was summed over all minutes of activity over the week.

There is moderate evidence that smoking status, alcohol consumption and physical activity levels are not determinants of malnutrition.

3.12. Eating domain

A total of eight studies [30,34,38,40,41,44,46,47] examined five determinants in the eating domain.

3.12.1. Appetite/leaves food on plate

Appetite/leaving food on plate was measured by five studies [30,38,40,44,46]. Four studies [30,38,40,46] used a single item yes/no question on loss of appetite/leaves 25% of food on plate or not. The other study [44] used the question 'I did not feel like eating, my appetite was poor' from the Center for Epidemiologic Studies Depression Scale, and participant had to rate on a 4-point scale.

3.12.2. Complaints about taste of food

Complaints about taste was assessed by two studies [30,40]. Both studies used the single item yes/no question on complaint/no complaint about taste of food from the RAI-MDS.

3.12.3. Dietary factors: nutrient intake and modified texture diets

Two studies [38,47] assessed energy and/or nutrient intake. One study [38] recorded participant food and beverage consumption in diaries, and energy and nutrient intake (protein, fat, carb) was calculated using the Dutch food composition database. The second study [47] used a questionnaire assessing dietary intake, with a particular focus on fat, and the different types of fat.

One study [41] assessed the effect of a modified texture diet (whether the diet was minced into small pieces, pureed, or mixed in a blender).

3.12.4. Hunger

Hunger was assessed by one study [40] using a single item yes/no question from the RAI-MDS on feeling hungry or not.

3.12.5. Thirst

Thirst was assessed by one study [38] by asking participants whether their thirst was increased, normal or diminished.

There is moderate evidence that poor appetite is a determinant of malnutrition.

Moderate evidence suggests that complaints about taste of food and specific nutrient intake are not determinants of malnutrition.

There is also low evidence that modified texture diets is a determinant of malnutrition.

Low evidence suggests that hunger and thirst are not determinants of malnutrition.

3.12.5.1. Results when studies using the MNA are removed. Removing the ten studies [31–37,41,45,47] which used the MNA as a indicator of malnutrition changed the results for certain domains,

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because potential determinants are included as part MNA. The conflicting evidence for depression changed to moderate evidence that depression is not a determinant. The current moderate evidence for self-perceived health and hospitalisation being determinant changed to limited evidence for both. The evidence for the other potential determinants stayed the same.

4. Discussion

This systematic review provides moderate evidence that hospitalisation, eating dependency, poor self-perceived health, poor physical function and poor appetite are determinants of malnutrition.

There is moderate quality evidence that chewing difficulties, mouth pain, gum issues co-morbidity, visual and hearing impairments, smoking status, alcohol consumption and physical activity levels, complaints about taste of food and specific nutrient intake are not determinants of malnutrition.

Low evidence suggests that loss of interest in life, access to meals and wheels, and modified texture diets are determinants of malnutrition.

Furthermore, low evidence suggests that psychological distress, anxiety, loneliness, access to transport and wellbeing, hunger and thirst are not determinants of malnutrition.

There is conflicting evidence that dental status, swallowing, cognitive function, depression, residential status, medication intake and/or polypharmacy, constipation, periodontal disease are determinants of malnutrition. The findings of this systematic review are broadly in line with previous systematic reviews conducted on determinants of malnutrition in older adults [14,21,22], but vary on the quality assessment of studies and the balance of evidence for certain determinants. Two of these reviews [14,22] state that certain factors, for example, depression, swallowing, excessive polypharmacy are determinants of malnutrition, whereas we have found that there is conflicting evidence for these potential determinants.

The results of this systematic review should be interpreted with caution due to the identified limitations of the included studies. While prospective cohort studies are regarded as Level 1a evidence, observational studies are often flawed by residual and unmeasured confounding. The definitions and criteria used for malnutrition varied across studies, even within the same domain (e.g. oral domain). Using the MNA as an outcome measure of malnutrition could potentially lead to an overestimate of the impact of certain factors which are already in the MNA. This aspect does not seem to be considered by authors of the included studies. We examined if removal of the MNA studies would change the results and found that the items which are part of the MNA (e.g. cognition, depression, physical function) were overestimated in terms of their impact on determining malnutrition.

There is still no consensus on whether low BMI, malnutrition screening tools instead of MNA, and percent weight loss, are equally valid and sensitive for measuring malnutrition [51–54]. It is imperative that future research examines these considerations carefully, as a better understanding of the best definition, is likely to significantly progress the quality of our studies, and the overall malnutrition field [9,55].

There is strong evidence that the prevalence of malnutrition varies across settings [2,5,6]. The vast majority of studies included in this review focus on the community setting. Due to the paucity of literature focussing on the nursing home and acute hospital setting, it is difficult to state with any certainty if different determinants of malnutrition are more relevant in specific settings. Studies that examine the same determinants across multiple setting are needed to enable any conclusions about setting-specific determinants.

Measurement of determinants across available studies varied significantly. Although subjective complaints may be more relevant with regards to eating problems, most studies poorly described the assessment of their determinants, and used single-item subjective questions of questionable validity to measure determinants which may warrant objective measurement (e.g. oral health, physical activity). Similar to the definition of malnutrition, there is no consensus on what best defines cut-offs for certain determinants; for example, good oral health, polypharmacy, cognitive function, etc. Research needs to better examine what are the best definitions and measurements of these individual determinants.

There is a paucity of literature on certain determinants like hunger, physical activity, anxiety, loneliness, social support, etc. with only one to two studies examining these factors; this limited data means we cannot draw inference on these factors and malnutrition.

While we are interested in progressing our knowledge of malnutrition in older adults, focussing on older adults with a mean age of 74 is also a significant limitation. Participants in the included studies had high levels of co-morbidities at baseline, and the possibility that malnutrition could have been present at baseline cannot be ruled out. Fifty years of age and older has been defined as the new age bracket for older adults by some groups, so potentially we need future research in older adults earlier in this range to track determinants and malnutrition more closely over regular follow-ups, to give us a clearer understanding of the true determinants of malnutrition in this population. Results may also be influenced by the type of participants. We compared cohorts of different age, different settings, and different health status so the determinants could change depending on the group under investigation. Long term prospective studies are need recruiting participants from young old group before they become malnourished to truly identify determinants of malnutrition. Future research in specific age brackets, different settings and health status need to be conducted with appropriate follow-ups to advance our understanding of the determinants of malnutrition in different subgroups and settings as certain determinants are more relevant/specific depending on the setting they are assessed in.

Analysing the effect of single determinants in isolation may have limitations. The emerging international consensus on malnutrition is that it is a complex multidimensional problem where determinants from different domains (e.g. oral, psychosocial, physical, lifestyle, health, and eating) interact with each other, may vary from individual to individual, or over time depending how strong the determinant is [56–60]. Treatments targeting a range of these factors seem promising [61]. If determinants are not mutually exclusive, the utility of further prospective studies analysing one determinant in isolation should be called into question. Studies measuring the cumulative risk of different determinants may provide us with better insights. Interactions between determinants should also be explored (for example, lack of cooking skills might only be a determinant of malnutrition in older community-dwelling men when they are recently widowed) which may be pertinent in different settings/genders. Further research into multidimensional screening tools that measure cumulative risk across multiple domains may be a useful way forward. It may then be worth examining if stratifying or individualizing care based on the dominant modifiable determinants for each individual can provide superior outcomes over one size fits all usual care approaches for malnutrition.

Strengths of this review are that it was systematically performed by two independent reviewers, and only prospective cohort studies were included. We acknowledge some limitations. (1) Our definition of a potentially modifiable determinant is open

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to interpretation. Currently, we lack the data to confirm which determinants are modifiable. For example, cognitive status, hospitalisation, medication, for a number of reasons, may not be modifiable. We also do not know what underlying determinants influence the success of an [nutritional] intervention, e.g. dental condition, ability to masticate and swallow food with ease and mediate treatment response. However, placing more attention on factors that are likely to be more modifiable, and treatable malnutrition, are important research and clinical priorities (2). The way we categorised domains and determinants is subjective in nature. Certain determinants (e.g. swallowing, self-reported health, dependency) are multifaceted in nature, and so could also be placed in a different domain, as we do not understand the factors that underlie these individual determinants. However, a previous review on this topic used a similar categorisation approach [21]. We included studies with a wide variety of settings, determinants, definitions, follow-up periods, and measurements, so it is difficult to synthesize this heterogeneous evidence. However, we did use a descriptive synthesis [27] to give a best evidence approach. Furthermore, definitions and measurements vary widely in clinical practice. Lastly, the total number of presently available studies, especially when taking into account the substantial heterogeneity between studies together with their inconsistent results, is too limited to draw firm conclusions.

5. Conclusion

This systematic review of prospective studies provides moderate evidence that hospitalisation, eating dependency, poor self-perceived health, physical function, poor appetite are determinants of malnutrition. Moderate quality evidence suggests that chewing difficulties, mouth pain, gum issues co-morbidity, visual and hearing impairments, smoking status, alcohol consumption and physical activity levels, complaints about taste of food and specific nutrient intake are not determinants of malnutrition. The review displays low evidence that loss of interest in life, access to meals and wheels, and modified texture diets are determinants of malnutrition, and low evidence that psychological distress, anxiety, loneliness, access to transport and wellbeing, hunger and thirst are not determinants of malnutrition. Finally, there is conflicting evidence that dental status, swallowing, cognitive function, depression, residential status, medication intake and/or polypharmacy, constipation, periodontal disease is a determinant of malnutrition. Overall multiple factors contribute to malnutrition. However, strong robust evidence is lacking for many determinants. Better prospective cohort studies are required. With an increasingly aging population, targeting modifiable factors will be crucial to the effective treatment and prevention of malnutrition.

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Statement of authorship

MV, DV and EMOC conceived the idea for the review. MOK and MK performed the database searches and analyses. MOK wrote the manuscript. All authors edited the manuscript. All authors have read and approved the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

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