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Malnutrition assessment methods in adult patients with tuberculosis: a systematic review

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ABSTRACT

Objectives Malnutrition is associated with a twofold higher risk of dying in patients with tuberculosis (TB) and considered an important potentially reversible risk factor for failure of TB treatment. The construct of malnutrition has three domains: intake or uptake of nutrition; body composition and physical and cognitive function. The objectives of this systematic review are to identify malnutrition assessment methods, and to quantify how malnutrition assessment methods capture the international consensus definition for malnutrition, in patients with TB.

Design Different assessment methods were identified. We determined the extent of capturing of the three domains of malnutrition, that is, intake or uptake of nutrition, body composition and physical and cognitive function.

Results Seventeen malnutrition assessment methods were identified in 69 included studies. In 53/69 (77%) of studies, body mass index was used as the only malnutrition assessment method. Three out of 69 studies (4%) used a method that captured all three domains of malnutrition.

Conclusions Our study focused on published articles. Implementation of new criteria takes time, which may take longer than the period covered by this review. Most patients with TB are assessed for only one aspect of the conceptual definition of malnutrition. The use of international consensus criteria is recommended to establish uniform diagnostics and treatment of malnutrition.

PROSPERO registration number CRD42019122832.

Strengths and limitations of this study

- PubMed, CINAHL and EMBASE were systematically searched for studies in the last decade, to prevent older studies describing outdated supportive care strategies to be eligible for inclusion.
- As there is no instrument for 'risk of bias assessment' of studies on diagnosis (eg, malnutrition assessment), we evaluated risk of bias by scoring the presence of essential components required for adequate assessment and reporting of malnutrition.
- To report on how malnutrition was assessed in studies on tuberculosis (TB), we quantified how malnutrition assessment methods capture the international consensus definition for malnutrition, in patients with TB.
- Implementation of new criteria in study protocols takes time. This implementation might take longer than the time period used in this review.

BACKGROUND

In 2019, tuberculosis (TB) was the worldwide leading cause of death from a single infectious agent, with 10 million new patients, and 1.2 million deaths.[1] TB prevalence is up to 20 times higher among people living in low-income countries compared with high-income countries.[2] TB, poverty and malnutrition are closely linked. Prevalence of malnutrition in patients with TB is studied to be 50% to 57%, and malnutrition is associated with a twofold risk of dying.[3–9]

As hunger-related malnutrition caused by food-insecurity impacts the immune system,[1 10 11] malnutrition is an important risk factor for re-activation of TB, with a reported 27% attributable risk.[1 12] Malnutrition is considered an important, potentially reversible risk factor for treatment failure.[13] Therefore, a better understanding in assessing malnutrition in patients with TB is urgently needed.[14]

The European Society for Clinical Nutrition and Metabolism (ESPEN) defines malnutrition as 'a state resulting from lack of intake or uptake of nutrition that leads to altered body composition (decreased fat-free mass) and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease'.[10] In patients with TB, two types of malnutrition may coexist: malnutrition without disease[10]; and disease-related malnutrition once active disease has developed. The latter is often driven by a combination of loss of appetite, malabsorption and/or inflammation-driven catabolism.[10 11] A low

body mass index (BMI) is a characteristic for chronic malnutrition.[15] However, since malnutrition leads to loss of fat-free mass in all individuals, including those who are overweight or obese, patients with either a normal or high BMI may be malnourished as well.[10] In 2015, ESPEN published their first consensus on diagnostic criteria for malnutrition,[15] followed by the Global Leadership Initiative on Malnutrition (GLIM) criteria in 2018, which were established by ESPEN, the American Society for Parenteral and Enteral Nutrition, la Federación Latino Americano de Terapia Nutriconal, Nutricion Clinica y Metabolismo and the Parenteral and Enteral Nutrition Society of Asia.[16]

It was not until 2013 that the WHO presented their first guideline on nutritional care and support for patients with TB. In this guideline, the WHO stressed that all patients with active TB receive individualised nutritional assessment and management, including dietary counselling and nutritional interventions, to improve nutritional status and consequently, prevent TB treatment failure.[17] Nutritional assessment is a necessary step in the 'nutritional care process', enabling the professional to design a treatment plan together with the patient.[18] However, the 2013 WHO guideline only refers to BMI as a method of assessing malnutrition for adults. The important issue of lack of consistency and understanding of how malnutrition can be assessed in patients with TB results from, the complexity of TB being on the one hand strongly associated with malnutrition and on the other by the vertical and siloed nature of TB programmes.

The primary aim of this review is to identify malnutrition assessment methods that are used in adult patients with TB. The secondary aim is to quantify how malnutrition assessment methods capture the international consensus definition for malnutrition in this population.

METHODS

The protocol for this review was registered at PROSPERO with number CRD42019122832. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used.[19]

Search strategy

In September 2020, PubMed, CINAHL and EMBASE were systematically searched for studies in any language. The search term consisted of a domain describing 'malnutrition' and a domain describing 'tuberculosis', while excluding in vitro, animal and paediatric studies. Details of the search strategy can be found in online supplemental material 1.

Inclusion and exclusion criteria

Studies in the English language that aimed to assess malnutrition and described a method for assessment of malnutrition in patients with microbiologically confirmed or clinically diagnosed TB, published between 1 January 2009 and 18 September 2020 were considered eligible for inclusion. Since the aim of the review is to identify how malnutrition is assessed in current research, 2009 was chosen as a starting point. Restricting the search to the last decade will prevent older studies describing outdated supportive care strategies to be eligible for inclusion.

Only studies that focused on adult patients with TB were included, because the assessment of malnutrition in children requires different methods than in adults as children are growing, and the criteria for measuring their nutritional status differ per by age.[20]

Reviews and study protocols were excluded since they do not present original data. Case reports and abstracts/posters were also excluded since the information provided on methods used in this type of publication is considered too limited.

Study selection

Screening of title and abstract was done independently by two authors using the Rayyan web application.[21] Evaluation of the screening of the first 10 articles was used to define the criteria that determine which studies were eligible for final inclusion. Final inclusion was based on an independent judgement of the full text of both authors. Disagreements about inclusion were resolved through discussion and if consensus was not reached, a third author was consulted, which resulted in consensus in all cases.

Patient and public involvement

No patient involved

Data collection

Data collection was performed by two authors independently. The following characteristics were extracted from each study: citation, first author, country, years of publication and data collection, aim of the malnutrition assessment, number of included patients, number of HIV coinfected patients, disease location, drug susceptibility of the *Mycobacterium tuberculosis* isolate.

Data analysis

To report on how malnutrition was assessed in studies on TB, we determined the extent of capturing of the three domains of malnutrition, malnutrition included in the ESPEN conceptual definition of malnutrition, that is, intake or uptake of nutrition (Domain A), body composition (Domain B), and physical and cognitive function (Domain C).[10 22 23]

Domain A was considered to be covered to some extent (+) if the method addressed nutritional intake or uptake at all. It was considered to be covered extensively (++) if the method addressed nutritional intake or uptake in depth. For domain B, weight change, BMI and anthropometric measurements, such as skinfold measurements were considered covering domain B to some extent (+). It was considered extensively addressed (++) if the method

included identification of muscle mass, lean mass or fat-free mass. Domain C was considered to be covered to some extent (+) if functionality was addressed. Domain C was considered extensively covered (++) if physical (eg, handgrip strength), mental and cognitive function tests were performed, or questions about activities of daily living were addressed.

As micronutrient or trace elements in serum are not representative for intake or uptake of protein or energy,[10] laboratory tests were not considered to attribute to any of the malnutrition domains. Serum albumin and C reactive protein are parameters for inflammation but are not related to parameters of protein/energy intake or functionality, nor do they represent body composition and were therefore not taken into consideration. In addition, while prealbumin (ie, transthyretin) is sensitive for changes in protein and energy intake, this marker is influenced by inflammation activity.[10]

As there is no instrument for 'risk of bias assessment' of studies on diagnosis (eg, malnutrition assessment), we evaluated risk of bias by scoring the presence of essential components required for adequate assessment and reporting of malnutrition. The risk of bias in included studies was assessed by rating the following four characteristics:

- Rationale for the assessment of malnutrition.
- Malnutrition was assessed and clear cut-off points were described in the method section. For example: 'malnutrition was assessed as BMI <18.5 kg/m^2.
- Malnutrition was reported in the results section.
- The results with regard to malnutrition were reflected on in the discussion section.

The characteristics were graded for quality of the study. Risk of bias was rated by - (meaning high risk of bias), + (medium risk of bias), or ++ (low risk of bias). The scores were added and the total was translated into very low (≥7 plusses), low (5–6 plusses), medium (3–4 plusses) or high risk of bias (≤2 plusses).

RESULTS

The search resulted in 2175 studies after removal of duplicates. After screening by title and abstract, 272 studies were selected for a full text eligibility check. Review of the full text resulted in inclusion of 69 studies.[3 24–91] A flow diagram of the selection process is visualised in figure 1.

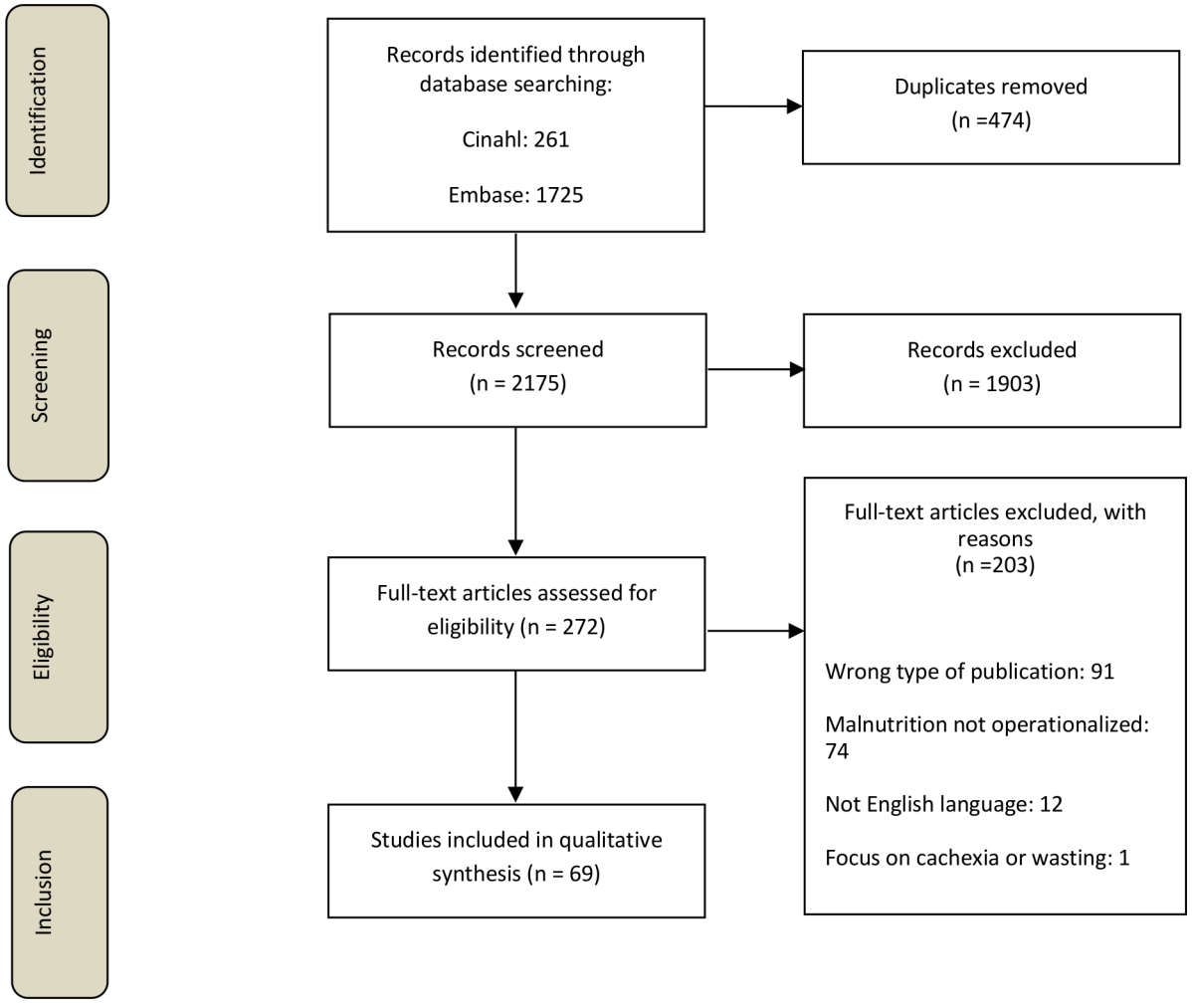

Figure 1 Flow diagram of the selection process of studies describing assessment in the context of malnutrition.

Table 1 Cut-off values BMI exclusively used

Cut-off value	Studies using only BMI for assessment of malnutrition n=53
≤20.0 kg/m^2	1
<20.0 kg/m^2	2
<18.5 kg/m^2	34
≤18.5 kg/m^2	3
<18.49 kg/m^2	1
<18.4 kg/m^2	1
<17.0 kg/m^2	2
<16.0 kg/m^2	2
No clear cut-off value described in study	7

BMI, body mass index.

In total, among 69 studies, 17 different methods were used to assess malnutrition. Four studies used multiple (ie, two to four) methods to assess malnutrition. Four studies used multiple criteria but integrated these together into one method to perform an assessment. In 53/69 (77%) of the studies, BMI was used as single assessment method. Among these studies eight different cut-off points were used, 34/53 studies (64%) used BMI <18.5 kg/m^2. In seven studies, no cut-off values for BMI were described. Table 1 shows all the cut-off values of BMI used as single method.

Capturing of the domains of malnutrition

Table 2 presents the capturing of the domains of malnutrition per assessment method.[3 24–91] Uptake or intake of nutrition (A) was addressed to some extent by four methods that were used in five of the 69 studies. Body composition (B) was addressed to some extent by all but two studies, 67/69 (97%). Two methods did not address domain B, as these were methods that used self-reporting of diet quality and a food frequency questionnaire as assessment methods. Physical and/or cognitive functionality (C) was addressed to some extent by only 3/69 studies (4%).

Only 2 of the 17 different assessment methods that were used in the 69 studies captured all three domains of the definition, that is, the Subjective Global Assessment was used in two studies and the Mini Nutritional Assessment was used in one study. Forty-one studies (59%) assessed malnutrition for the purpose of their primary aim. The three studies that used a method that captured all three domains of the definition, had a primary aim related to malnutrition.

Table 2 Comparison of 17 different assessment methods by malnutrition domain capturing

Domains	A	B	C	
Description of domain	Intake or uptake of nutrition	Body composition	Physical and cognitive function	Total
PIBW, BMI, albumin, TLC, cholesterol, Hb	–	+	–	+
Weight change	–	+	–	+
BMI & MUAC	–	+	–	+
Self-report of diet quality	+	–	–	+
MNA	++	+	++	+++++
MUST	+	+	–	++
AMA	–	++	–	++
BMI/albumin	–	+	–	+
BMI, MUAC, TSF, MAMC, Hb, Ht, albumin, total protein, globulin, iron fixation capacity, retinol, tocopherol Zn, SE, Fe	–	+	–	+
MAMC	–	++	–	++
Underweight	–	+	–	+
TSF/TST	–	+	–	+
SGA	++	++	++	++++++
BMI	–	+	–	+
BIA: (body fat%)	–	+	–	+
MUAC	–	+	–	+
FFQ	++	–	–	++

AMA, arm muscle area; BIA, bio-electrical impedance analysis; BMI, body mass index; Fe, iron; FFQ, Food Frequency Questionnaire; Hb, haemoglobin; Ht, haematocrit; MAMC, mid arm muscle circumference; MNA, mini nutritional assessment; MUAC, mid upper arm circumference; PIBW, percent ideal body weight; SE, selenium; SGA, subjective global assessment; TLC, total lymphocyte count; TSF, triceps skin fold ; TST, triceps skinfold thickness; Zn, zinc.

Table 3 Subanalysis of malnutrition assessment methods

Year of start data collection	No of studies (n=69)	BMI as the only assessment method N %	Use of an assessment method that attributes to three domains %
2000–2004	9	9 89	–
2005–2009	12	7 58	–
2010–2014	14	13 93	–
2015–2019	19	15 79	–
No available data on year of data collection	15	10 67	3 20
Total	69	53 77	3 4

A descriptive subanalysis, as shown in table 3, was performed to compare studies regarding their use of assessment tools, by their period of data collection.[3 24–91] No differences were found between 5-year periods regarding the use of BMI as the only assessment method. The studies that used methods that capture all three domains of the ESPEN definition of malnutrition did not describe when their data was collected Of the 69 included studies, 18 studies (26%) were on inpatients, 26 studies (38%) on outpatients, 7 (10%) on both type of patients and in 18 studies (26%) the type of patients was not described.

Risk of bias assessment

Online supplemental material 2 shows the risk of bias assessment and details of the 69 included studies.[3 24–91] Twenty-one of the 69 studies (30%) did not describe the rationale for the assessment of malnutrition. Fifteen of the 69 studies (22%) described their assessment method without clear cut-off values. Risk of bias was very low in 24 studies (35%), low in 20 studies (29%), medium in 20 studies (29%) and high in five studies (7%).

DISCUSSION

This review showed that most patients with TB are assessed for only one aspects of the construct of malnutrition. BMI is often used assessment method for malnutrition in studies with patients with TB, even though it only partly covers just one malnutrition domain (domain B). In addition, while some studies did not report a cut-off value for BMI, in other studies different cut-off values for BMI were used, therefore making it difficult to compare these studies. The use of BMI could be justified from a public health perspective, since a low BMI is a characteristic of chronic malnutrition that involves loss of both fat and muscle tissue.[15] However, the use of BMI alone for assessing malnutrition in this population is debatable. In clinical settings, disease-related malnutrition is the predominant type of malnutrition. Disease-related malnutrition is a (sub)acute condition, in which loss of weight and muscle/fat-free mass does not automatically result in a low BMI, while loss of weight and fat-free mass are related to poor clinical outcomes including increased morbidity and mortality.[15 92] With the current global overweight and obesity epidemic, patients with catabolic diseases such as TB may lose more than 20% of their weight and muscle mass within 3–6 months, and still show BMI values at or above normal range.[93] When assessing malnutrition in patients with TB solely based on BMI, these patients will not be identified when they are malnourished, despite the therapeutic and prognostic implications of malnutrition.[94]

This review indicates that the international criteria for the assessment of malnutrition have not yet found their way into studies with patients with TB. The 2013 WHO guideline on nutritional care only refers to BMI as a method of assessing malnutrition for adults, which may contribute to the status quo. BMI is by far the most frequently used assessment method for malnutrition (77%) in studies with patients with TB. Only a few (4%) of the studies that reported on the assessment methods addressed all domains of the conceptual definition of malnutrition. For the studies performed after the ESPEN criteria of 2015[95] and the GLIM criteria of 2018,[16] this may be explained by the fact that the WHO does not yet refer to these criteria in their communications. The GLIM criteria have been developed for global use and is therefore recommended to be used in any setting for all patients with TB. The GLIM framework does not include the domain of functionality as criterion.

There are some limitations in our study. First, our study focused on published articles and not on the underlying study protocol. In some cases, detailed information on the assessment and operationalisation of malnutrition might be available in the study protocol, however, it was not addressed in the article making it unavailable to the public domain. Second, implementation of new criteria in study protocols takes time. This implementation might take longer than the time period used in this review. Third: research and clinical practice are different settings and the results from our review are not a reflection of clinical practice. Nevertheless, we postulate that BMI is used the most commonly used method in clinical practice since the WHO recommends that BMI is the method to assess undernutrition/malnutrition.

Awareness of the presence of malnutrition and concept of malnutrition assessment in healthcare professionals working with patients with TB needs improvement. Future studies regarding malnutrition assessment in patients with TB should aim at implementation of international consensus criteria regarding malnutrition assessment. Using the same terminology for malnutrition may make a difference to our patients, improve outcomes as well as reduce chronic sequelae and help to end TB.

It should be stressed that we need to agree on using standardised methods for malnutrition assessment and

interventions. However, malnutrition assessment should always be preceded by malnutrition screening with a validated tool (online supplemental material 3).[16]

In conclusion, most studies in adult patients with TB did not describe their assessment method for malnutrition. Most patients with TB are assessed for only one or two aspects of the conceptual definition of malnutrition. Various methods for assessing of malnutrition have been used, and only a very small proportion of the published studies on TB used an assessment method that fully reflects the definition of malnutrition. The use of international consensus criteria is recommended to establish systematic and uniform diagnostics and treatment of malnutrition.

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Supplement material 1 - Details of search strategy

Embase

('malnutrition'/exp OR 'nutritional status'/exp OR Malnutrition:ab,ti OR Malnourish*:ab,ti OR 'Nutritional Deficienc*':ab,ti OR Undernutrition:ab,ti OR Undernourish*:ab,ti OR 'Nutritional Status':ab,ti OR 'Nutrition Status':ab,ti)

AND

('tuberculosis'/exp OR Tuberculosis:ab,ti OR TB:ab,ti OR tuberculoses:ab,ti) NOT ('animal'/exp NOT 'human'/exp) NOT 'child'/exp NOT 'review'/exp

Pubmed

("Malnutrition"[Mesh] OR Malnutrition [tiab] OR Malnourish* [tiab] OR Nutritional Deficienc* [tiab] OR Undernutrition [tiab] OR Undernourish* [tiab] OR "Nutritional Status"[Mesh] OR Nutritional Status [tiab] OR Nutrition Status [tiab])

AND

("Tuberculosis"[Mesh] OR Tuberculosis [tiab] OR TB [tiab] OR tuberculoses [tiab]) NOT ("animals"[MeSH] NOT "humans"[MeSH]) NOT "Child"[Mesh] NOT "Review" [Publication Type]

Cinahl

((MH "Malnutrition" OR MH "Nutritional Status" OR TI (Malnutrition OR Malnourish* OR Nutritional Deficienc* OR Undernutrition OR Undernourish* OR Nutritional Status OR Nutrition Status) OR AB (Malnutrition OR Malnourish* OR Nutritional Deficienc* OR Undernutrition OR Undernourish* OR Nutritional Status OR Nutrition Status)) AND ((MH "Tuberculosis+" OR TI (tuberculosis OR tb OR tuberculoses) OR AB (tuberculosis OR tb OR tuberculoses))

Supplement material 2. Details of included studies and risk of bias assessment

First author	**Year of publication**	**Year(s) of data collection**	**Country**	**Rationale**	**Aim of malnutrition assessment**	**Assessment method**	**Clear cut-off**	**Maln* in results**	**Maln* in discussion**	**Risk of bias**	**Number of in/out patients**	**HIV coinfection**	**Susceptibility**	**Type of TB**
Martins[24]	2009	2005-2006	Timor-Leste	+	Secondary, part of clinical outcome	BMI < 18.5 kg/m^2	-	+	+	medium	270 outpatients	unknown	unknown	pulmonary
Pakasi[25]	2009	unknown	Indonesia	++	Primary, prevalence and association	BMI < 18.5 kg/m^2	++	++	++	very low	121 outpatients	unknown	unknown	pulmonary
Ulasli[26]	2009	2001-2006	Turkey	+	Secondary, association	BMI < 20.0 kg/m^2	++	+	+	low	24 inpatients	unknown	unknown	pulmonary and/or extra pulmonary
Kim[27]	2010	2005-2006	South-Korea	++	Primary, malnutrition etiology	PIBW, BMI, Albumin, TLC, Cholesterol, Hb	++	++	++	very low	23, unknown type of patients	unknown	unknown	pulmonary
Khoharo[28]	2010	2007-2008	Pakistan	-	Secondary, risk factor	BMI < 18.5 kg/m^2	++	+	++	low	350, unknown type of patients	unknown	unknown	pulmonary
Pakasi[29]	2010	2004-2005	Indonesia	+	Secondary, part of clinical outcome	BMI (no clear cut-off)	-	+	+	medium	300 outpatients	unknown	unknown	pulmonary
Gambhir[30]	2010	2006-2009	India	-	Secondary, risk factor	BMI <18.5 kg/m^2	++	+	+	medium	95 inpatients	no	unknown	pulmonary and/or

														extra pulmonary
Singla[31]	2010	2004-2009	India	+	Secondary, risk factor	BMI < 18.5 kg/m^2	+	+	+	medium	175 in- and outpatients	no	unknown	pulmonary and/or extra pulmonary
Mupere[32]	2010	2002-2008	Uganda	++	Primary, association	BMI < 18.5 kg/m^2	+	+	+	low	445, unknown type of patients	115	unknown	pulmonary
Warmelink[33]	2010	2005-2008	Nederland	+	Primary, risk factor	Change in body weight	-	+	+	medium	192 inpatients	15	MDR patients included	pulmonary and/or extra pulmonary
Podewils[34]	2011	2000-2004	Latvia	++	Primary, association	BMI < 18.5 kg/m^2	++	++	+	very low	995 in- and outpatients	32	only MDR patients	pulmonary
De Jong[35]	2011	unknown	Gambia	-	Secondary, part of clinical outcome	BMI < 16 kg/m^2	++	+	+	medium	692, unknown type of patients	56	unknown	pulmonary
Kawai[36]	2011	2000-2005	Tanzania	+	Primary, follow-up of malnutrition	BMI < 18.5 kg/m^2	++	+	+	low	887 outpatients	471	unknown	pulmonary
Miyata[37]	2011	unknown	Japan	++	Primary, prognostic factor	SGA	++	++	++	very low	39 inpatients	unknown	unknown	pulmonary

Mupere[38]	2012	unknown	Uganda	-	Primary, association	BMI < 18.5 kg/m^2	++	+	+	medium	747 outpatients	539	unknown	pulmonary
Piva[39]	2013	2008-2009	Brazil	++	Primary, prevalence	BMI < 18.5 kg/m^2	++	++	++	very low	34 in- and outpatients	unknown	unknown	pulmonary
Islam[40]	2013	2010-2011	Bangladesh	++	Primary, prevalence	BMI < 18.5 kg/m^2 and MUAC < 22 cm	++	+	++	very low	1068, unknown type of patients	unknown	unknown	pulmonary
Chittoor[41]	2013	unknown	Mexico	-	Secondary, association	Self-reported estimate of diet quality	-	+	+	high	75 outpatients	unknown	unknown	pulmonary
Miyata[42]	2013	unknown	Japan	+	Primary, prognostic factor	MNA < 17	++	+	+	low	53 inpatients	unknown	unknown	pulmonary
Bhargava[3]	2013	2004-2009	India	++	Primary, prevalence and association	BMI < 18.5 kg/m^2	++	++	++	very low	1695 in- and outpatients	39	unknown	pulmonary
Bakari[43]	2013	2009-2010	Tanzania	++	Primary, prevalence and follow-up of malnutrition	BMI < 18.5 kg/m^2	++	+	+	low	43 outpatients	43	unknown	pulmonary
Ismawati[44]	2013	2011-2012	Indonesia	+	Secondary, part of clinical outcome	BMI (no clear cut-off)	-	+	+	medium	30, unknown type of patients	unknown	unknown	pulmonary
Miyata[45]	2013	unknown	Japan	++	Primary, prognostic factor	MUST	++	+	+	low	57 inpatients	unknown	unknown	pulmonary

Maeda[46]	2014	2007-2009	Vietnam	-	Secondary, association	BMI ≤ 18.5 kg/m^2	++	+	+	medium	465 outpatients	38	Including different types of resistance	pulmonary
Oliveira[47]	2014	2007-2010	Brazil	++	Secondary, association	TST AMA	+	++	++	very low	166 inpatients	31	unknown	pulmonary
Tian[48]	2014	2000-2001	China	-	Secondary, risk factor	BMI < 18.5 kg/m^2 and/or serum albumin < 30 g/L	++	+	+	medium	160 in- and outpatients	43	unknown	pulmonary
Kumar[49]	2014	2011-2014	India	+	Primary, prognostic factor	BMI (no clear cut-off)	-	+	+	medium	376 outpatients	unknown	Only MDR	pulmonary
Bacelo[50]	2015	2008-2013	Brazil	++	Primary, follow-up of malnutrition intervention	Multiple anthropometric and biochemical biomarkers	++	++	++	very low	68, unknown type of patients	22	unknown	Pulmonary and extra pulmonary
Golemba[51]	2015	2011-2014	Argentina	-	Secondary, association	BMI ≤ 20 kg/m^2	++	+	+	medium	75 inpatients	0	unknown	pulmonary
Te Brake[52]	2015	unknown	Indonesia	++	Primary, prognostic factor	BMI < 18.5 kg/m^2	++	+	++	very low	36 outpatients	0	unknown	pulmonary
Medellin-Garibay[53]	2015	unknown	Mexico	-	Secondary, association	BMI < 18.49 kg/m^2	+	+	+	medium	48, unknown type of patients	0	unknown	Pulmonary and extrapulmonary
Ezeamama[54]	2015	2004-2008	Uganda	++	Secondary, association	BMI < 18.5 kg/m^2	++	++	++	very low	208 outpatients	208	unknown	pulmonary

McLachlan[55]	2016	2014	South Africa	-	Secondary, association	BMI < 18.5 kg/m^2	++	-	+	medium	105 inpatients	74	Susceptible and MDR	Pulmonary and extrapulmonary
Gebrecherkos[56]	2016	2015	Ethiopia	+	Secondary, risk factor	BMI < 18.5 kg/m^2	++	+	+	Low	15 outpatients	4	No rifampicin resistance	pulmonary
Araújo-Mariz[57]	2016	2007-2012	Brazil	-	Secondary, prognostic factor	BMI < 18.5 kg/m^2	++	+	+	medium	173, unknown type of patients	173	unknown	unknown
Buntoro[58]	2016	unknown	Indonesia	+	Primary, part of clinical outcome	BMI <18.5 kg/m^2	++	++	++	very low	72 outpatients	unknown	unknown	pulmonary
Pandit[59]	2016	2012-2013	India	-	Secondary, prognostic factor	BMI <20.0 kg/m^2	-	+	+	high	148, unknown type of patients	unknown	unknown	pulmonary
Abdelbary[60]	2017	2006-2013	Mexico	-	Secondary, risk factor	Underweight	-	++	-	high	8431 outpatients	447	Susceptible and MDR	pulmonary and extrapulmonary
Bhat[61]	2017	2013	India	+	Secondary, association	BMI < 18.5 kg/m^2	++	+	+	low	267 outpatients	0	unknown	pulmonary
Hochberg[62]	2017	2014-2016	India	-	Primary, prevalence	BMI < 18.5 kg/m^2	++	++	++	low	409 outpatients	1	Only normal susceptible	pulmonary
Piparva[63]	2018	2014-2015	India	-	Secondary, part of clinical outcome	BMI < 18.5 kg/m^2	++	++	++	low	108 inpatients	5	only MDR	pulmonary

Gurung[64]	2018	2016	Nepal	++	Primary, prevalence	BMI (no clear cut-off)	-	++	++	low	133 outpatients	1	unknown	pulmonary and extrapulmonary
Pande[65]	2018	2015-2016	India	-	Secondary, prevalence and association	BMI < 18.4 kg/m^2	+	+	+	medium	728 inpatients	53	unknown	pulmonary and extrapulmonary
Rao[66]	2018	2013-2014	India	-	Secondary, risk factor	BMI (no clear cut-off)	-	+	++	medium	220 outpatients	unknown	unknown	pulmonary
Sattler[67]	2018	unknown	4 continents, 26 study sites	+	Primary, association	BMI < 18.5 kg/m^2	-	+	+	medium	51, unknown type of patients	51	unknown	pulmonary
Kirchmann Lazzari[68]	2018	unknown	Brazil	++	Primary, prevalence	BMI TSF MAMC SGA	+	++	++	very low	108 inpatients	44	unknown	pulmonary
Cheng[69]	2019	2013-2016	China	-	Secondary, part of clinical outcome	BMI < 18 kg/m^2	+	+	-	high	85 inpatients	0	unknown	intestinal
Cavalheiro Skupien[70]	2019	unknown	Brazil	-	Secondary, association	BMI ≤ 18.5 kg/m^2	-	+	+	high	35 inpatients	unknown	unknown	pulmonary

Abdullahi[71]	2019	2012 - 2016	Kenya	+	Primary, association	BMI < 18.5 kg/m^2	++	++	-	low	10717 outpatients	3163	unknown	Pulmonary and extrapulmonary
Benzekri[72]	2019	2016 - 2017	Senegal	-	Primary, part of clinical outcome	BMI (no clear cut-off)	-	++	+	medium	26 outpatients	26	Susceptible	pulmonary
Chebrolu[73]	2019	unknown	USA	++	Primary, inclusion criterion	BMI < 16 kg/m^2	++	+	+	low	27, unknown type of patients	0	unknown	Pulmonary and extrapulmonary
Da Silva[74]	2019	2017 – 2018	Brazil	+	Primary, association	BMI < 18.5 kg/m^2 TSF MUAC MAMC BIA FFQ	+	++	++	low	35, unknown type of patients	14	unknown	Pulmonary
Feleke[75]	2019	2015 - 2018	Ethiopia	++	Primary, prevalence	BMI < 18.5 kg/m^2	++	++	+	very low	1681, unknown type of patients	595	unknown	Pulmonary and extrapulmonary

Gashaw[76]	2019	2015 – 2017	Ethiopia	++	Primary, prevalence	BMI ≤ 18.5 kg/m^2 MUAC ≤ 23 cm (men) MUAC ≤ 22 cm (women)	++	++	++	very low	384, unknown type of patients	unknown	unknown	Pulmonary and extrapulmonary
Hoyt[77]	2019	2015 – 2017	India	++	Primary, part of clinical outcome	BMI < 18.5 kg/m^2	++	++	++	very low	173, unknown type of patients	unknown	unknown	pulmonary
Hussien[78]	2019	2017 – 2018	Ethiopia	++	Primary, prevalence	BMI < 18.5 kg/m^2	+	++	++	very low	372 inpatients	42	unknown	pulmonary
Lee[79]	2019	2016 – 2017	Philippines	++	Primary, prognostic factor	BMI< 17 kg/m^2 MUAC ≤ 20.5 cm (men) MUAC ≤ 18.5 cm (women)	++	++	++	very low	348 inpatients	22	31 MDR	unknown
Mailu[80]	2019	2013-2017	Kenya	-	Primary, prevalence	BMI < 18.5 kg/m^2	++	++	+	low	421409 outpatients	134776	unknown	Pulmonary and extrapulmonary

Rashak[81]	2019	2010-2014	Mexico	++	Primary, prevalence and association	BMI < 18.5 kg/m^2 (or BMI ≤ 18.5 kg/m^2, not clearly described)	-	++	++	low	5508 , unknown type of patients	224	unknown	Pulmonary and extrapulmonary
Ren[82]	2019	2015 – 2017	China	++	Primary, prevalence	BMI < 18.5 kg/m^2	++	-	++	low	300 in- and outpatients	unknown	unknown	pulmonary
Wardani[83]	2019	2016	Indonesia	+	Secondary, risk factor	BMI ≤ 18.5 kg/m^2	++	+	-	medium	311 outpatients	unknown	unknown	pulmonary
Wessels[84]	2019	2015	South Africa	++	Secondary, association	BMI < 18.5 kg/m^2 (underweight)	-	++	+	low	100 inpatients	68	unknown	unknown
White[85]	2019	2016 – 2017	Philippines	++	Primary and secondary, validation of tool and prognostic factor	BMI < 17 kg/m^2	++	++	++	very low	348 inpatients	22	31	unknown

Ma'rufi[86]	2020	2017	Indonesia	++	Primary, follow-up of malnutrition	BMI < 18.5 kg/m^2	++	++	++	very low	200 outpatients	0 (excluded)	0 (excluded)	pulmonary
Musuenge[87]	2020	unknown	Burkino Faso	++	Primary, prevalence and association	BMI < 18.5 kg/m^2	++	++	++	Very low	302 outpatients	23	unknown	pulmonary
Seid[88]	2020	2019	Ethiopia	++	Primary, prevalence and prognostic factor	BMI < 18.5 kg/m^2	+	++	++	Very low	284 in- and outpatients	51	Unknown	Pulmonary and extrapulmonary
Edwards[89]	2020	2017	Phillipines	+	Primary, prevalence	BMI < 17.0 kg/m^2	+	++	++	Very low	446 outpatients	68 (28%)	Susceptible	Unknown
White[90]	2020	2017	Phillipines	++	Primary, prevalence and association	BMI < 18.5 kg/m^2	+	++	++	Very low	637 outpatients	74 (24%)	Unknown	Unknown

Mollah[91]	2020	2018	India	++	Primary, prevalence	BMI < 18.5 kg/m^2 MUAC <23 (m) & <22 (f)	++	-	++	Low	113, unknown type of patients	Unknown	Unknown	Pulmonary and extrapulmonary

Abbreviations *PIBW: Percent Ideal Body Weight; BMI: Body Mass index; TLC: Total Lymphocyte Count; Hb: Haemoglobin; MUAC: Mid Upper Arm Circumference; MNA: Mini Nutritional Assessment; AMA: Arm Muscle Area; MAMC: Mid Arm Muscle Circumference; TSF: Triceps Skin Fold ; TST: Triceps Skinfold Thickness; SGA: Subjective Global Assessment; BIA: Bio-electrical Impedance Analysis; FFQ: Food Frequency Questionnaire*

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Supplement Material 3: Overview of validated malnutrition screening tools available in English language[1]

Screening- tool	Characteristics	Target group
MUST[2]	BMI, weight loss and acute disease effect	All adult patients
PG-SGA Short Form[3]	Weight loss, food intake, nutrition impact symptoms, physical activity	All adult patients
SNAQ[4]	Weight loss, appetite, use of supplements/tube feeding	Adult hospitalized patients
MNA-SF[5]	Food intake, weight loss, mobility, psychological stress/acute disease, dementia or depression, BMI	Elderly patients
SNAQ 65+ [6]	Weight loss, MUAC, appetite, functionality	Elderly patients and/or rehabilitation care
SNAQ RC[7]	Weight loss, dependence, appetite, BMI	Elderly patients in residential care
Nutric Score[8]	Age, comorbidity, days from hospital to ICU admittance, APACHE score, SOFA score	Adult intensive care

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