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Review

Is phase angle an appropriate indicator of malnutrition in different disease states? A systematic review

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SUMMARY

Background & aims: Subjective Global Assessment (SGA) classifies malnutrition severity via a simple bedside assessment. Phase angle (PhA) is an indicator of cell integrity and has been suggested to be indicator of nutritional status.
Objective: To explore the relationship between PhA and SGA.
Methods: Relevant studies published through October 31, 2017 were identified using 7 electronic databases. Articles were included for review if they included comparison data between SGA and PhA within adult disease populations. Evidence quality was assessed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) guidelines and methodological quality was assessed using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool.
Results: 33 articles within four disease states (liver, hospitalization, oncology and renal) met inclusion criteria for review. Results were limited by restricting the database search to articles published in English only, and by the inherent difficulty of comparing 2 methods which are both influenced by the operator.
Conclusion: Based on GRADE guidelines, evidence quality received a grade of Low. Based on QUADAS-2, 61% of studies had high risk of bias in the index test (PhA), while all other domains had low risk. It is not possible to conclude that PhA is an accurate independent indicator of malnutrition. PROSPERO no. CRD42016050876.

1. Introduction

Malnutrition is a common concern in both chronic and acute disease with significant implications on survival, quality of life, medical complications, and other socioeconomic issues [1–3]. There is a broad range of methods for nutrition assessment available to clinicians [4]. Subjective Global Assessment (SGA) is a nutritional assessment method which classifies malnutrition severity via a bedside assessment [5]. It is the gold standard method to identify malnutrition [6], and has been validated in many disease states and clinical settings [2,7–12]. SGA combines dietary, weight, functional, gastrointestinal and disease history with a physical examination to arrive at a category ranking. SGA-A represents a well-nourished state, SGA-B represents moderate malnutrition or suspected of being malnourished and SGA-C represents severe malnutrition [5].

Since its initial development, SGA has been adapted by various groups. Hasse et al., 1993 developed an adapted-SGA for liver disease, which accounts for additional clinical conditions such as encephalopathy, infection, kidney function, and varices [13]. The CANADA-USA Peritoneal Dialysis Study Group (CANUSA)

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developed a 7-point modified SGA (7p-SGA) [14]. Kalantar-Zadeh and colleagues, proposed a quantitative scoring system known as the quantitative-SGA (QSGA), also referred to as Dialysis Malnutrition Score (DMS) [15]. The Patient-Generated SGA (PG-SGA) combines a patient-generated component with a professional assessment and is used most commonly in oncology and chronic catabolic conditions [16–19].

Whereas SGA evaluates nutritional status subjectively, phase angle (PhA) is strictly an objective measure. Unlike SGA which requires a comprehensive assessment by a trained evaluator, PhA measurement is a simple, quick and non-invasive technique. PhA is a measure of the resistance and reactance of a current as it passes through tissues of the body via bioelectrical impedance analysis (BIA) [20]. Resistance is affected by the amount of fluid in the tissues of the body, whereas reactance is affected by the type of body cells and their related permeability [21]. Age, sex, and BMI are the main biological factors affecting PhA [22]. PhA may also be affected by level of physical activity, fluid status, and body composition [22,23]. The calculation of a standardized phase angle (SPhA) aims to account for these confounding factors. A SPhA is calculated as a z-score which may be based on established population reference values stratified by a combination of age, sex, BMI, or ethnicity [24–28].

PhA has been suggested to be a prognostic, health, functional and nutrition indicator [29–31]. Generally, a low PhA indicates cell membrane breakdown and thus an altered ability to store energy and complete metabolic functions [22]. Conversely, a high PhA indicates intact cell membranes and high body cell mass [22]. Thus, as PhA reflects the quantity and types of tissues, such as muscle and fat mass, including hydration status, it is hypothesized that PhA could reflect nutritional status. It is thought that metabolic changes, such as those in cell membranes, are first affected by malnutrition [32]. Thus, PhA may be able to detect malnutrition at an early stage and may be useful in evaluating the effectiveness of nutrition therapy, before improvements in nutritional status can be detected by other assessment methods such as SGA. To this end, many studies have used PhA cut-off points to identify malnutrition [29,33]. Many of these PhA cut-off points were derived using survival as its reference standard [34–38]. Thus, the reliability of these cut-offs to identify malnutrition is unknown.

Therefore, the aim of this study is to evaluate the relationship between bioelectrical phase angle and malnutrition severity as measured by the Subjective Global Assessment in acute or chronically ill adults $\geq$18 years through a systematic review of cross-sectional and/or retrospective studies.

2. Methods

The systematic review protocol was registered on PROSPERO (no. CRD42016050876). The current systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Studies were selected using the following inclusion criteria: 1) original research published in English, 2) assessment of malnutrition using SGA and its adapted versions, with comparison to PhA or SPhA, and 3) individuals >18 years with acute or chronic disease/illness.

2.1. Data sources

Relevant studies were identified by searching 7 electronic bibliographic databases: Scopus, CINAHL, PubMed, ProQuest Nursing and Allied Health, Medline, Cochrane, and ProQuest Dissertation and Thesis. Search terms used were 'phase angle' AND ('subjective global assessment' OR SGA), including their MeSH terms. The search was limited to human studies published in English through October 31, 2017. Reference lists of all relevant studies, and relevant reviews were examined for other relevant studies, although none were identified. Two investigators independently reviewed titles and abstracts to select potentially eligible articles for document screening. If discordance existed between the 2 reviewers, a decision was made by a third reviewer (see Fig. 1).

2.2. Data extraction and synthesis

One reviewer independently extracted study information and then verified by a second reviewer. Data was organized in an excel spreadsheet which included authors, year of publication, country of origin, study objective, study population (clinical setting, sample size, sex and age), subjective method(s) of nutritional assessment, BIA model used, PhA cut-off, analyses between PhA and SGA and limitations of the study. A meta-analysis was not preformed as a variety of previously derived cut-off values were used which did not allow for agreement statistics. Data were synthesized by disease group to allow for more direct comparison between study results. Within each disease group, differences in findings were compared and reasons for these differences such as heterogeneity, study design, size and population were identified.

2.3. Data evaluation and quality assessment

The articles were evaluated by two reviewers using two quality assessment tools: the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) guidelines [39] and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool [40]. The GRADE approach provides a quality rating of scientific evidence ranging from Very Low to High. This approach is widely used in systematic reviews and meta-analyses in the development of clinical practice guidelines and health care recommendations [39]. Although the GRADE approach is a highly regarded tool, a second quality assessment tool designed specific for diagnostic accuracy was also used to assess methodological quality. The QUADAS-2 tool is recommended for use in systematic reviews involving diagnostic accuracy studies. QUADAS-2 evaluates the risk of bias and applicability within four domains observed in diagnostic accuracy studies: patient selection, index test, reference standard and flow and timing. QUADAS-2 does not generate a quality score, instead it allows the user to summarize the number of studies found at low, high or unclear risk of bias and applicability across domains. To indicate an overall utility of PhA or SPhA as a nutritional indictor in disease, quality assessment using the GRADE approach and the QUADAS-2 tool was completed within each disease group separately and across all studies. Both researchers involved in data extraction (SR and JM) were trained in the use of GRADE guidelines and the QUADA-2 tool.

For the purposes of data extraction, articles with reported κ coefficients (kappa) were interpreted as previously recommended by Altman [41]: $\kappa < 0.20$ (poor agreement); $0.21 \leq \kappa \leq 0.40$ (fair agreement); $0.41 \leq \kappa \leq 0.60$ (moderate agreement); $0.61 \leq \kappa \leq 0.80$ (good agreement); $\kappa > 0.80$ (very good agreement).

3. Results

Database searches resulted in 298 articles. All articles were exported into a reference management system and merged to remove duplicates, with 153 articles retained for screening. A final 33 articles were identified as relevant and reviewed further. Publication years ranged from 1993 to 2017. Study characteristics are displayed in Table 1. Study results are displayed in Table 2.

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Table 1
Study characteristics of the literature on the comparison between PhA and SGA in malnutrition assessment.

Author, Year	County	Participant characteristics	Sample size (% male)	Age (years) mean ± SD medium (range)	BIA device
Liver Disease					
Wagner, 2011 [44]	Austria	Years after Tx: *Group A*: <5 *Group B*: 5–10 *Group C*: >10	*Group A*: n = 11 *Group B*: n = 19 *Group C*: n = 41 Sex not specified	*Group A*: 58 ± 8 *Group B*: 59 ± 6 *Group C*: 58 ± 10	RJL-101
Bakshi, 2016 [45]	India	ESLD patients admitted to hospital for liver Tx	n = 54 (n = 20 underwent BIA) Sex not specified	48.3 ± 10.2	MC-180MA (Tanita)
Peres, 2012 [46]	Brazil	CLD	n = 66 (57.6%M)	59 (41–79)	RJL-101
Liboredo, 2015 [47]	Brazil	Liver Tx	n = 18 (83%M)	59 (41–79)	RJL Quantum X
Hospitalized Patients					
Barbosa-Silva, 2003 [48]	Brazil	Preoperative elective GI surgery	n = 279 (31%M)	50.4 years	RJL Quantum 101
Cardinal, 2010 [50]	Brazil	Preoperative elective GI surgery	n = 125 (46.4%M)	M: 50.8 F: 51.0	Biodynamics model 310
Meireles, 2012 [49]	Brazil	Preoperative elective GI surgery	n = 124 (43.5%M)	52.26 ± 14.95	Biodynamics model 310e
Scheunemann, 2011 [51]	Brazil	Preoperative elective GI surgery	n = 98 (32.7%M)	46.3 ± 13.6	Biodynamics model 310e
Kyle, 2012 [52]	Switzerland	Medical, surgical, trauma patients	*Patients*: n = 649 (59%M) *Controls*: n = 649 (59%M)	*Patients*: M: 39.8 ± 12.7 F: 38.6 ± 14.1 *Controls*: M: 39.7 ± 12.6 F: 38.4 ± 13.6	RJL-101
Kyle, 2013 [53]	Switzerland	Medical, surgical, trauma and cancer patients	*Patients:* n = 983 (53%M) *Controls:* n = 983 (53%M)	*Patients:* M: 49.8 ± 19.7 F: 56.4 ± 23.2 *Controls:* M: 49.6 ± 19.6 F: 56.2 ± 22.9	RJL-101
Guerra, 2015 [54]	Portugal	Long and short LOS hospitalized patients	*Short LOS*: n = 311 (45.2%M); *Long LOS*: n = 371 (54.8%M)	*Short LOS*: 55 (IQR 24) *Long LOS*: 61 (IQR 19)	Biodynamics 450
Norman, 2008 [55]	Germany	Hospitalized gastro-enterology, hepatology and endocrinology patients	n = 242 (50%M)	*SGA-A*: 60.3 (IQR 42.1–68.3) *SGA-B*: 57.1 (IQR 33.5–66.4) *SGA-C*: 56.2 (IQR 39.3–67.6)	Nutriguard M (Data Input)
Stobaus, 2012 [56]	Germany	Cardiology, general surgery, hepatology, endocrinology and GI patients	n = 777 (47%M)	53.6 ± 16.7	Nutrigard M (Data Input)
Oncology					
Gupta, 2004 [57]	USA	Stage IV pancreatic cancer	n = 58 (60.3%M) *SGA completed in n = 51	At diagnosis: 56.2 ± 1.5	RJL-101Q
Gupta, 2008 [58]	USA	Advanced CRC	n = 73 (50.6%M)	At diagnosis: 56 ± 11.4	RJL-101Q
Vicente 2013 [59]	Brazil	*Group 1*: Active gastric or CRC *Group 2*: treatment follow-up patients, tumor free >3 months	*Group 1*: n = 75 (48%M) *Group 2*: n = 62 (45.2%M)	*Group 1*: 60.2 ± 12.2 *Group 2*: 61.3 ± 11.6	Biodynamics 450
Mauricio, 2013 [60]	Brazil	CRC	n = 70 (44.3%M)	M: 60.1 ± 14.0 F: 60.7 ± 14.8	RJL Quantum X
da Silva, 2013 [61]	Brazil	Patients with esophageal and stomach cancer	n = 43 (60.5%M);	Not reported	Not reported
Malecka-Massalska, 2016 [62]	Poland	Newly diagnosed HNC	n = 75 (89.3%M)	At diagnosis: 56.88 ± 8.21	SFB7 BioImp v1.55
Wladysiuk, 2016 [63]	Poland	Presurgical, treatment-naïve, HNC	n = 75 (89.3%M)	56.88 ± 8.21	SFB7 BioImp v1.55

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Table 1 (*continued*)

Author, Year	County	Participant characteristics	Sample size (% male)	Age (years) mean ± SD medium (range)	BIA device
Mulasi, 2016 [64]	USA	HNC patients after 3 months of chemo-radiotherapy	n = 19 (94.7%M)	59 ± 7	QuadScan 4000
Maasberg, 2017 [65]	Germany	Neuro-endrocrine neoplasia	n = 203 (48.3%M)	Mean: 63.4	Nutriguard M (Data Input)
Norman, 2010 [66]	Germany	Solid or hematologic tumor disease	n = 399 (52.1%M)	63.0 ± 11.8	Nutriguard M (Data Input)
Motta, 2015 [67]	Brazil	Pre-radiotherapy cancer patients	n = 93 (72%M)	62 ± 12.74	Biodynamics 450
Renal Disease					
Guerra, 2015 [68]	Brazil	Pre-dialysis patients with Stage II-CKD	n = 75; Sex not specified.	64.8 ± 11.6	Biodynamics 450
Passadakis, 1999 [69]	India	CAPD	n = 47 (55.3%M)	M: 58.9 ± 14.6 F: 56.2 ± 18.3	Not reported
Gu, 2008 [70]	China	CAPD	n = 124 (41.1%M)	59.9 ± 12.8	Hydra analyzer (Xitron Tech)
Enia, 1993 [71]	Italy	HD and CAPD	n = 59 (64.4%M); n = 36 HD, n = 23 CAPD	58 (25–80)	RJL-101
Santin, 2017 [72]	Brazil	HD	n = 104 (70.2%M)	70.9 ± 6.9	Biodynamics 450
Maggiore, 1996 [73]	Italy	HD	*Patients*: n = 131 (49.6%M); *Controls*: n = 272 (50%M)	*Patients*: 61.6 ± 14.5 *Controls*: 62.5 ± 13.6	RJL-101 *Measured post HD
Rimsevicius, 2016 [74]	Lithuania	HD	n = 99 (58.7%M)	58.7 ± 14.38	Biospace InBody S10
Vannini, 2009 [75]	Brazil	HD	n = 52 (67.3%M)	55 ± 13.6	Biodynamics 450
Oliveira, 2010 [76]	Brazil	HD	n = 58 (47.3%M)	49.22 ± 14.85	Not specified

CAPD: continuous ambulatory peritoneal dialysis; CKD: chronic kidney disease; CLD: chronic liver disease; CRC: colorectal cancer; ESLD: end-stage liver disease; F: female; GI: gastrointestinal; HD: hemodialysis; HNC: head and neck cancer; LOS: length of stay; M: male; Tx: transplantation.

3.1. Liver disease

Four studies included participants with liver disease, two in chronic liver disease, one in pre-transplant (Tx) patients and one in post-Tx patients. Two additional studies were identified which assessed both SGA and PhA, however, all patients were assessed as SGA-A which did not allow for any direct comparison between SGA-score and PhA. Thus, these two articles were not included in this systematic review [42,43].

Two studies aimed to identify malnutrition using predetermined PhA cut-offs. Wagner et al. [44] found a PhA cut-off of <5° in individuals post liver Tx did not correlate with SGA, and malnutrition was underestimated by SGA compared with PhA cut-offs. While Bakshi et al. [45] reported a moderate agreement between SGA and a PhA cut-off of <4.4° in hospitalized, end-stage liver disease patients (ESLD). Additionally, Peres et al. [46] PhA was significantly higher ($p = 0.005$) in well-nourished patients compared to malnourished patients with CLD. Whereas, in a small study of eligible transplant patients with cirrhosis, no significant difference ($p > 0.05$) was found between the mean PhA of well-nourished and malnourished patients [47]. In summary, an association between PhA and SGA within liver disease patients is not clear. Although a trend toward decreasing PhA with worsening malnutrition exists, most studies found no correlation between PhA and SGA.

3.2. Hospitalized patients

Nine studies involved hospitalized patients with a variety of clinical conditions. In preoperative GI patients, Barbosa-Silva et al. [48] found a moderate agreement ($\kappa = 0.39$) between SGA and a PhA cut-off of <5.0°, however, optimal cut-offs of 6.3° and 5.9° in males and females, respectively, had the best balances of sensitivity and specificity. Using a SPhA cut-off of <−1.65 SD, Meireless et al. [49] found a weak agreement in females and a moderate agreement in males between SGA and SPhA. Two studies used a SPhA of <−0.8 SD. Cardinal et al. [50] found a moderate agreement between SGA and SPhA, while Scheunemann et al. [51] found weak agreements in the total sample and each sex-group. As well, Scheunemann et al. [51] determined an optimal SPhA cut-off of <−0.63 SD.

In medical, surgical and trauma patients, Kyle et al., 2012 [52] determined an optimal PhA cut-off of <5.0° for men and <4.6° for women. Using these cut-offs, Kyle et al., 2013 [53] found that the relative risk of low PhA increased with worsening malnutrition and Guerra et al. [54] reported a 60.5% agreement with PG-SGA in both long and short stay hospitalized patients. In GI, hepatology, endocrinology, cardiology and general surgery patients, Norman et al., 2008 [55] found that PhA was significantly reduced with worsening nutrition status ($p < 0.05$). Stobaus et al. [56] found reduced SPhA with worsening nutrition status. Overall, the body of research in hospitalized patients shows a significant reduction in PhA and/or SPhA with worsening malnutrition assessed using SGA. Despite this, agreement between the two methods ranged from weak to moderate as a variety of different PhA and SPhA cut-offs were used.

3.3. Oncology

Eleven studies were identified in oncology patient populations. Diagnoses included pancreatic cancer, gastric (GC) and colorectal cancer (CRC), neuroendocrine neoplasia, and head and neck cancers (HNC). In patients with pancreatic cancer, Gupta et al., 2004 [57] found a non-significant weak negative correlation between PhA and SGA ($r = -0.26$, $p = 0.10$). Gupta et al., 2008 [58] found that

Table 2
Study results of the literature on the comparison between PhA and SGA in malnutrition assessment.

Ref #	SGA	PhA/SPhA cut-off	Results	Agreement Analysis	Interpretation
Liver Disease					
[44]	Adapted SGA	<5.0°	Prevalence of malnutrition: Group A: 18.2% (SGA), 81.2% (PhA) Group B: 10.5% (SGA), 31.6% (PhA) Group C: 4.8% (SGA), 31.7% (PhA)	–	No correlation between SGA and PhA
[45]	SGA	<4.4° normal, 4.4–5.4° borderline, >5.4° abnormal	Prevalence of malnutrition: 75% (PhA), 88.9% (SGA-B + C)	$\kappa = 0.44$ (90% agreement) Sensitivity: 94.4%; Specificity: 50%	Moderate agreement between PhA and SGA
[46]	Adapted SGA	median PhA (5.18°)	Total: 5.18° (range: 1.86°–8.40°) SGA-A: 5.31° (range: 3.45°–7.42°) SGA-B + C: 4.35° (range: 1.86°–6.73°), $p = 0.005$	–	No significant difference between sexes ($p = 0.59$). PhA was significantly reduced in malnourished patients.
[47]	Adapted SGA	<5.44°	Prevalence of malnutrition: 50% (PhA), 66.7% (SGA). Total: 5.3° (range: 2.2°–6.9°); SGA-A: 6.0° (range: 4.2°–6.9°); SGA-B + C: 4.8° (range: 2.2°–6.1°), NS	–	Median PhA was not significantly correlated with any clinical parameter. No significant difference in PhA between SGA groups.
Hospitalized Patients					
[48]	SGA	<5.0°	Male: SGA-A: 6.65° [95% CI (6.33°–6.98°)] SGA-B: 6.13° [95% CI (5.75°–6.50°)] SGA-C: 4.70° [95% CI (4.03°–5.36°)], $p < 0.001$ Female: SGA-A: 6.36° [95% CI (6.23°–6.50°)] SGA-B: 5.14° [95% CI (4.82°–5.46°)] SGA-C: 4.22° [95% CI (3.02°–5.43°)], $p < 0.001$	$\kappa = 0.39$ [95% CI (0.26–0.51)] Male: $\kappa = 0.27$ [95% CI (0.07–0.47)] Sensitivity: 31%; Specificity: 97% Female: $\kappa = 0.46$ [95% CI (0.31–0.61)] Sensitivity: 47%; Specificity: 94%	PhA significantly decreased with worsening level of malnutrition for the total sample and within each sex group. Fair agreement between SGA and PhA in all participants and males, and moderate agreement in females. Optimal PhA cut-off could not be obtained. Cut-off with best balance of sensitivity and specificity was 6.3° (AUC: 0.72) for males and 5.9° (AUC: 0.83) for females.
[49]	SGA	<−1.65 SD	Prevalence of malnutrition: 31.5% (SGA-B), 4% (SGA-C) 4.8% (PhA)	Total: $\kappa = 0.038$ [95% CI (−0.068–0.144)] Male: $\kappa = 0.041$ [95% CI (−0.135–0.216)] Female: $\kappa = 0.029$ [95% CI (−0.092–0.150)]	SPhA was significantly reduced in malnourished versus well-nourished patients. Moderate agreement between PhA and SGA in males, and fair in all participants and females.
[50]	SGA	<−0.8 SD	Total: SGA-A: 0.3 ± 0.1 SD; SGA-B + C: −0.8 ± 0.2 SD, $p < 0.001$ Male: SGA-A: 0.3 ± 0.2 SD; SGA-B + C: −0.7 ± 0.3 SD, $p = 0.001$ Female: SGA-A: 0.3 ± 0.1 SD; SGA-B + C: −1.0 ± 0.5 SD, $p = 0.018$	$\kappa = 0.45$ [95% CI (0.25–0.65)]	SPhA was significantly reduced in malnourished versus well-nourished patients in the total group and in each sex group. Moderate agreement between SPhA and SGA.
[51]	SGA	<−0.8 SD	Total: SGA-A: 0.0 SD [95% CI (−0.2–0.3)] SGA-B + C: −0.7 SD [95% CI (−1.2–0.2)], $p = 0.001$ Male: SGA-A: 0.1 SD [95% CI (−0.4–0.6)] SGA-B + C: −1.2 [95% CI (−1.8–0.6)], $p = 0.002$ Female: SGA-A: 0.0 [95% CI (−0.3–0.3)] SGA-B + C: −0.5 [95% (CI −1.9–0.1)], NS	Total: $\kappa = 0.27$ [95% CI (0.06–0.48)] Sensitivity: 82.6% Specificity: 40.6% Male: $\kappa = 0.39$ [95% CI (0.04–0.73)] Female: $\kappa = 0.21$ [95% CI (−0.04–0.47)]	Significant difference in SPhA between malnourished and well-nourished groups in all patients and male patients, but not in female patients. Optimal SPhA cut-off obtained was −0.63 SD with 72.4% sensitivity and 68.1% specificity.

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Table 2 (*continued*)

Ref #	SGA	PhA/SPhA cut-off	Results	Agreement Analysis	Interpretation
[52]	SGA	<4.6° F, <5.0° M	Patients: Male: 6.6° ± 1.1° Female: 5.8° ± 0.96°, p < 0.001 Controls: Male: 7.55° ± 0.95° Female: 6.5 ± 0.08°, p < 0.001	Male: $\kappa = 0.489$, p < 0.001 AUC 0.83 Sensitivity: 73.3%; Specificity: 76.6% Female: $\kappa = 0.412$, p < 0.001 AUC 0.8 Sensitivity: 64.5%; Specificity: 76.1%	PhA was significantly greater in controls versus patients for both sexes. Moderate agreement between PhA and SGA in males and females. Optimal PhA cut-offs were determined to be < 4.6° for females and <5.0° for males.
[53]	SGA	<4.6° F, <5.0° M[52]	Patients: Male: 6.0° ± 1.4° Female: 5.0° ± 1.3°, p < 0.05 Controls: Male: 7.1° ± 1.2° Female: 6.0 ± 1.2°, p < 0.05 SGA-A: RR 1.4 [95% CI (1.0–2.1)], p = 0.046 SGA-B: RR 3.8 [95% CI (2.9–4.9)], p < 0.001 SGA-C: RR 7.2 [95% CI (5.7–9.0)], p < 0.001	–	PhA was significantly greater in controls versus patients for both sexes. Patients with moderate malnutrition were 3.8 times more likely to have a low PhA than healthy subjects. Patients classified with severe malnutrition were 7.2 times more likely to have a low PhA than healthy subjects.
[54]	PG-SGA	<4.6° F, <5.0° M[52]	Prevalence of malnutrition: Short LOS, Long LOS 6.5%, 16.7% (PhA) 30%, 14% (SGA-B) 30%, 13% (SGA-C)	$\kappa = 0.17$ (60.5% agreement)	Poor agreement between PhA and SGA in both short and long LOS.
[55]	SGA	N/A	SGA-A: 5.39° (IQR 4.72°–6.05°) SGA-B: 5.02° (IQR 4.42°–5.65°) SGA-C: 4.17° (IQR 3.50°–5.20°) SGA-A vs SGA-B, p = 0.033 SGA-B vs SGA-C, p < 0.0001 SGA-C vs SGA-A, p < 0.001	–	PhA significantly decreased with worsening level of malnutrition.
[56]	SGA	N/A	Total: 4.91° ± 1.17° (range, 1.62°–8.51°; −7.2–2.5 SD) PhA Linear regression: SGA-B: β = −0.538 (12.6% estimate of effect) p < 0.0001 SGA-C: β = −0.935 (26.5% estimate of effect) p < 0.0001 SPhA Linear regression: SGA-B: β = −0.743 (27.2% estimate of effect) p < 0.0001 SGA-C: β = −1.307 (58.2% estimate of effect) p < 0.0001	–	PhA was significantly greater in males. PhA and SPhA were significantly lower in malnourished versus well-nourished patients. Moderate and severe malnutrition were significant determinants of PhA and SPhA.
Oncology Patients					
[57]	SGA	median PhA (5.0°)	Correlation: r = −0.26, p = 0.10	–	No significant correlation between PhA and SGA.
[58]	SGA	Optimal cut-off determined	Median PhA: SGA-A: 6.12° SGA-B + C: 5.18°, p = 0.005 Correlation: ρ = 0.33, p = 0.004	AUC = 0.7 [95% CI (0.57–0.820)], p = 0.005 ROC curves: PhA / Sensitivity / Specificity <5.2° / 51.7% / 79.5% <5.3° / 55.7% / 68.2% <5.5° / 58.6% / 65.9% <5.7° / 69.0% / 56.8% <6.0° / 82.8% / 54.5%	PhA was significantly reduced in malnourished versus well-nourished patients. Fair agreement between PhA and SGA. PhA cut-off 5.9° in males with progressive disease had the best balance of sensitivity (100%) and specificity (73.3%)

[59]	PG-SGA validated Portuguese version	<25th percentile (5.1°)	Prevalence of malnutrition: Group 1: 66.6% (PG-SGA); 36% (PhA) Group 2: 30.9% (PG-SGA); 14.5% (PhA)	Group 1: Sensitivity: 44%; Specificity: 80% Group 2: Sensitivity: 38.4%; Specificity: 91.2%	Significant association between PhA and PG-SGA in Group 1 ($p = 0.041$) and Group 2 ($p = 0.006$)
[60]	SGA	Not specified	SGA-A: 5.5° ± 0.6° SGA-B: 5.4° ± 1.0° SGA-C: 4.9° ± 1.1°, *$p < 0.05$ between SGA-A and SGA-C	$\kappa = 0.11$, $p < 0.05$	PhA was significantly reduced in severely malnourished versus well-nourished patients only. Poor agreement between PhA and SGA.
[61]	SGA°	<5th percentile (−1.65 SD)	SGA-B: 5.1° (3.8−6.0)° SGA-C: 4.5° (2.6−6.4)° SGA-A: vs SGA-C, *$p < 0.05$* SGA-A vs SGA-B, *$p < 0.05$* SGA-B vs SGA-C, NS	κ<0.20	PhA was significantly reduced in malnourished versus well-nourished patients. Poor agreement between SGA and PhA.
[62]	SGA	Optimal cut-off determined	Total: 5.04° ± 0.88°, SGA-A: 5.25° ± 0.76°, SGA-B + C: 4.73° ± 0.96°, $p = 0.0009$	Optimal cut-off point (4.733°): AUC = 0.7 [95% CI (0.57−0.82)], $p = 0.005$ Sensitivity: 80%; Specificity: 56%	PhA was significantly reduced in malnourished versus well-nourished patients. Optimal PhA cut-off point was <4.733°.
[63]	SGA	median PhA (4.733°)	SGA-A: 5.25° ± 0.76°; SGA-B + C: 4.73° ± 0.96°, $p = 0.0009$ Correlation: $r = -0.35$, $p = 0.0022$	–	PhA was significantly reduced in malnourished versus well-nourished patients. PhA was negatively correlated with worsening SGA score.
[64]	PG-SGA	N/A	PG-SGA-A: 5.5° ± 0.96° PG-SGA-B + C: 5.3° ± 0.84°, $p = 0.62$ Correlation: $r = -0.35$, $p < 0.01$	–	No significant difference in PhA between well-nourished and malnourished patients. PhA was negatively correlated with worsening SGA score.
[65]	SGA	N/A	Total: SGA-A: 5.3° SGA-B + C: 4.2°, $p < 0.001$ Male: SGA-A: 5.4° ± 1.0° SGA-B + C: 4.5° ±1.1°, $p < 0.05$ Female: SGA-A: 5.1° ± 0.8° SGA-B + C: 4.0° ±1.1°, $p < 0.05$	–	PhA was significantly reduced in malnourished versus well-nourished patients.
[66]	SGA	PhA <5th percentile	Total: 4.59° ± 1.12° Male: 4.70° ± 1.17°, Female: 4.47° ± 1.04°, $p < 0.043$ Multinomial logistic regression: SPhA and SGA-B: OR 0.633 [(95% CI (0.504−0.794)], $p < 0.0001$ SPhA and SGA-C: OR 0.449 [(95% CI (0.337−0.597)], $p < 0.0001$	–	Patients with a high SPhA had a 1.5 times lower odds of being classified as moderately malnourished and 2.2 times lower odds of being classified as severely malnourished than the odds of being identified as well-nourished.
[67]	PG-SGA; PG-SGA categorical	<−1.65 SD; Optimal cut-off determined	*Median PhA/SPhA*: 5.95° ± 1.00°; −1.04 ± 0.98 SD *Median PG-SGA score*: 4 ± 4	*PhA and PG-SGA (5.9°):* κ=0.25 AUC=0.72 [95% CI (0.61−0.83)] *PhA and PG-SGA categorical (5.4°):* κ=0.26 AUC=0.84 [95% CI (0.69−0.99)]	Fair agreement between SPhA and PG-SGA, and SPhA and PG-SGA categorical. Optimal PhA cut-off points using PG-SGA and PG-SGA categorical as gold standard were <5.9° and <5.4°, respectively.
[68]	SGA	N/A	SGA-A: 6.4° ± 0.7° SGA-B: 5.6° ± 0.9° SGA-C: 5.3° ± 0.6°, $p < 0.01$ SGA-A versus SGA-B, $p < 0.05$ SGA-A versus SGA-C, $p < 0.05$ SGA-B versus SGA-C, NS	–	PhA was significantly reduced in mildly and severely malnourished patients as compared to well-nourished patients, but, there was no significant difference between mildly and severely malnourished patients.

(*continued on next page*)

Table 2 (*continued*)

Ref #	SGA	PhA/SPhA cut-off	Results	Agreement Analysis	Interpretation
[69]	SGA	N/A	Male: PhA = 5.06° ± 1.3° Females: 4.79° ± 1.4°, p = 0.56 SGA-A: 5.41° ± 1.15°, SGA-B: 4.62° ± 1.21°, SGA-C: 3.5° ± 1.53° A versus B, p = 0.087 A versus C, p = 0.021 B versus C, p = 0.193 Spearman's rank test: R = 0.48, p = 0.0048	–	No significant difference in PhA between males and females. PhA was significantly reduced in mildly and moderately malnourished patients as compared to well-nourished patients, however, there was no significant difference in PhA between mildly and moderately malnourished patients. PhA was negatively correlated with worsening SGA-score.
[70]	SGA	N/A	SGA-A: 4.79° ± 1.04°; SGA-B + C: 3.83° ± 0.86°, p < 0.001	–	PhA was significantly reduced in malnourished versus well-nourished patients.
[71]	SGA	N/A	Male: SGA-A: 6.32° ± 1.37°; SGA-B + C: 4.56° ± 0.91°, p < 0.001 Female: SGA-A: 5.76° ± 1.26°; SGA-B + C: 4.02° ± 0.72°, p = 0.009 CAPD: SGA-A: 4.82° ± 0.78°; SGA-B + C: 4.05° ± 0.49°, p = 0.016 HD: SGA-A: 6.76° ± 1.06°; SGA-B + C: 4.76° ± 1.05°, p < 0.001 Univariate analysis: r = −0.58, p < 0.001	–	PhA was significantly reduced in malnourished versus well-nourished patients in each sex group and in CAPD and HD groups. In total sample, PhA was negatively correlated with worsening SGA-score.
[72]	7p-SGA	N/A	Linear regression coefficient of the repeated measures model in time: Male: β = 0.05 (0.02 SE), p = 0.03 Female: β = 0.39 (0.11 SE), p = 0.002 *adjusted for age and dialysis vintage	–	1-unit increase in 7p-SGA was significantly associated with an increase of 0.05° and 0.39° in PhA for males and females, respectively.
[73]	SGA	lower quartile and <10th percentile to identify SGA-C	Spearman's rank correlation coefficient: r = −0.43, p ≤ 0.01	–	PhA was negatively correlated with worsening SGA-score.
[74]	SGA	Optimal cut-off determined	*Multivariate analysis*: OR 3.69 [95% CI (1.59–8.62)], p = 0.002	*Optimal PhA cut-offs*: SGA-B: <25th percentile AUC 0.70 [95% CI (0.60–0.81)], p = 0.01) SGA-C: <15th percentile AUC 0.74 [95% CI (0.62–0.85)], p = 0.005)	Mild malnutrition was most accurately identified by PhA <25th percentile. Severe malnutrition was most accurately identified by PhA <15th percentile. Patients with a higher PhA had 3.68 times lower odds of being classified as malnourished than the odds of being identified as well-nourished.
[75]	7p-SGA	median PhA (<6.4°)	SGA-A: 6.76° ± 1.4° SGA-B + C: 6.2° ± 1.7°, p = 0.10 *Multivariate analysis*: OR = 0.42, p = 0.011	–	No significant difference between malnourished and well-nourished patients. Patients with a higher PhA had 2.4 times lower odds of being classified as malnourished than the odds of being identified as well-nourished.
[76]	SGA; Adapted-SGA(15); PG-SGA	<5.0°	Total: 6.19° ± 1.33° Male: 6.70° ± 1.23°; Female: 5.73° ± 1.27°, p = 0.005 Linear correlation: Adapted SGA and PhA: r = −0.533, p < 0.001 PG-SGA and PhA: r = −0.453, p < 0.001	SGA and PhA: $\kappa = 0.316$	PhA was significantly higher in males versus females. Moderate agreement between PhA and adapted SGA. PhA was negatively correlated with worsening adapted SGA and PG-SGA scores.

AUC: area under the curve; CAPD: continuous ambulatory peritoneal dialysis; HD: hemodialysis; NS: not significant; OR: odds ratio; PhA: phase angle; ROC: receiver operator characteristics; SE: standard error; SGA-A: well-nourished; SGA-B: mild-moderately malnourished; SGA-C: severely malnourished; SPhA: standardized phase angle.

median PhA of well-nourished patients was significantly greater ($p = 0.005$) than that of malnourished patients in advanced CRC patients. Authors were only able to determine an optimal PhA cut off of <5.9° in males. Vicente et al. [59] found a significant association between malnutrition identified using PG-SGA and a PhA cut-off of <5.1° ($p = 0.041$) in patients with active GC and CRC, and those tumor free for >3 months. Mauricio et al. [60] found a weak agreement between SGA and SPhA in CRC patients, and only a significant difference in SPhA between the well-nourished and severely malnourished group ($p < 0.05$). da Silva et al. [61] also found a weak agreement between SGA and a SPhA cut-off <−1.65 SD in esophageal and GC patients.

Three studies were completed in HNC patients. Malecka-Massalska et al. [62] found that PhA was significantly higher in well-nourished patients than in malnourished patients ($p = 0.0009$) and an optimal cut-off of 4.733° was determined. Wladysiuk et al. [63] also found significant difference between PhA in well-nourished and malnourished patients ($p = 0.0009$), and PhA was found to be negatively correlated with SGA ($r = -0.35$, $p = 0.0022$). Whereas, Mulasi et al. [64] found no significant difference between PhA in well-nourished patients and malnourished patients ($p = 0.62$) however, had a negative correlation of $r = -0.35$ ($p < 0.01$).

Maasberg et al. [65] assessed malnutrition in patients with neuroendocrine neoplasia using SGA and PhA. Mean PhA was significantly higher ($p < 0.001$) in the well-nourished group as compared to the malnourished group and continued to be significant when stratified by sex ($p < 0.05$). Norman et al., 2010 [66] studied the relationship between SPhA and SGA in patients with cancerous tumors. SPhA had a strong positive effect on SGA-B ($p < 0.0001$), and SGA-C ($p < 0.0001$). Using a SPhA cut-off <−1.65 SD, Motta et al. [67] found fair agreement between SPhA and PG-SGA, and SPhA and PG-SGA categorical. An optimal PhA cut-off of <5.9° was determined using PG-SGA as the reference method, and <5.4° using PG-SGA categorical as the reference method. Articles with a broad range of cancer diagnoses were identified in our search. Although studies reported significant agreements between PhA and/or SPhA with SGA, strengths of agreements ranged from fair to poor.

3.4. Renal disease

Nine studies included participants with renal disease, including predialysis chronic kidney disease (CKD), continuous ambulatory peritoneal dialysis (CAPD) patients and hemodialysis (HD). Guerra et al., 2015 [68], found a significant difference in PhA between well-nourished and malnourished groups ($p < 0.05$), but not between mildly and severely malnourished groups ($p > 0.05$) in pre-dialysis patients with Stage II-CKD. Two studies evaluated PhA in patients on CAPD. One study by Gu et al. [70] found that PhA was significantly higher in well-nourished as compared to malnourished patients ($p < 0.001$). While Passadakis et al. [69] found that PhA was only significantly different between well-nourished and severely malnourished groups ($p = 0.021$) with a weak correlation ($r = 0.48$, $p = 0.0048$) between SGA and PhA. Enia et al. [71] found that PhA was significantly higher in well-nourished patients than in malnourished patients in both HD and CAPD patient groups with a significant negative correlation of $r = -0.58$ between SGA and PhA, ($p < 0.001$). In HD patients, Santin et al. [72] found that for every 1-unit increase in 7p-SGA PhA (improved nutritional status) was associated with an increase of 0.05° in males and 0.39° in females, respectively.

Four studies analyzed PhA cut-offs in HD patients. Maggiore et al. [73] found that a PhA cut-off of <25th percentile used to identify severe malnutrition had a 67% sensitivity and 78% specificity. However, a lowered cut-off of <10th percentile had an improved sensitivity of 91% but a reduced specificity of 33%. Rimsevicius et al. [74] found that moderately and severely malnourished patients were most accurately identified by adjusted PhA cut-offs of <25th and <15th percentile, respectively. Vannini et al. [75] used a PhA cut-off of <6.4° and found no significant difference between mean PhA of the well-nourished and malnourished groups ($p = 0.10$), but had an odds ratio of 0.42 ($p = 0.011$). Oliveira et al. [76], found that PhA had a significant negative linear relationship with QSGA and PG-SGA, and a moderate agreement with SGA using a PhA cut-off of <5.0°. Although no studies used SPhA in their analyses, the majority of studies in the renal disease population reported significant trends of decreased PhA with worsening malnutrition.

3.5. Quality assessment

Evidence quality was assessed by both GRADE Guidelines and the QUADAS-2 tool. Results of the quality assessment using the GRADE guidelines are shown in Table 3. Results of the quality assessment using the QUADAS-2 tool are shown in Fig. 2.

Table 3
Summary of findings.

Bioelectrical phase angle compared to Subjective Global Assessment as an indicator of malnutrition				
Patient or Population: acute or chronically ill adult patients Setting: inpatient and outpatient Intervention: Measurement of phase angle Comparison: Subjective Global Assessment				
	Outcome	Number of Participants (Studies)	Quality and Justification	
Liver Disease [44–47]	Relationship between PhA/SPhA and SGA	246 (4 cross-sectional studies)	●○○○ Very Low[a,b]	Overall: ●●○○ Low[a,b,d]
Hospitalized Patients [48–56]		3717 + 1632 controls (9 cross-sectional studies)	●●●○ Moderate[c,d]	
Oncology [57–67]		1238 (2 retrospective chart reviews + 9 cross-sectional studies)	●●●○ Moderate[c,d]	
Renal Disease [68–76]		749 + 272 controls (1 longitudinal + 8 cross-sectional studies)	●●○○ Low[b,d]	

[a] Inconsistency in results.
[b] Risk of bias: no sex comparison, minimal to no use of SPhA.
[c] Large magnitude of effect: significant difference in PhA between well-nourished and malnourished patients.
[d] Dose response – PhA significantly decreases with worsening malnutrition (SGA-B vs SGA-C).

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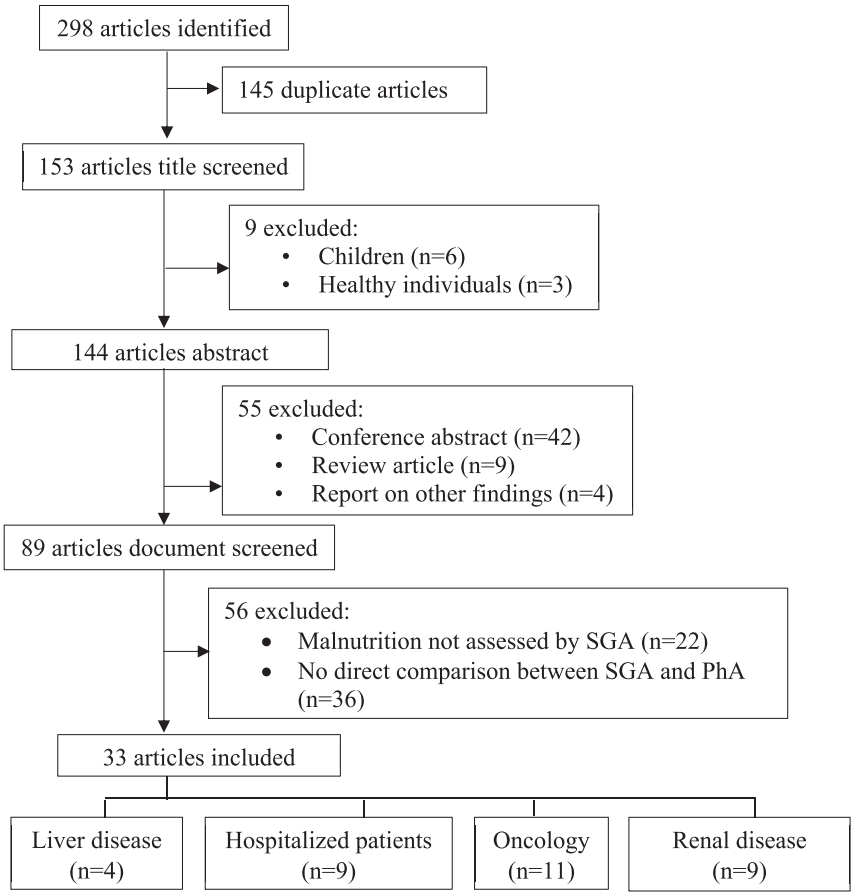

Fig. 1. Flowchart of selecting studies for the systematic review.

4. Discussion

This study aimed to evaluate the relationship between bioelectrical phase angle and malnutrition severity as measured by the Subjective Global Assessment in acute or chronically ill adults. Many studies used different PhA cut-offs, for example, sample median, lower quartile or cut-offs determined from previous studies which may not be translatable to all disease states. As the full biological meaning of PhA is not understood it would be difficult to predict how PhA may vary by disease even with controlling for confounding factors such as nutrition status, weight, age or gender. It is difficult to say with certainty that PhA cut-offs determined within one disease state, or based on non-nutritional parameters such as survival, are appropriate in all clinical situations. Therefore, the overall evidence quality determined in this systematic review received a grade of Low.

Many nutritional assessment tools exist; however, their use within specific disease populations can be limited. Within liver disease, complications such as fluid retention and hypoproteinemia associated with hepatic deterioration can confound nutritional assessment techniques such as BIA, biochemical markers, and BMI [23]. Use of SGA in CLD is recommended by the European Society for Parenteral and Enteral Nutrition (ESPEN) to screen for malnutrition in liver disease including alcoholic steatohepatitis, cirrhosis, surgery, and transplantation [77]. A recent review also identified SGA as a tool to use in nutritional assessment in liver cirrhosis [78]. Despite its acknowledged limitations in individuals with ascites, ESPEN recommends PhA to quantify undernutrition in cirrhosis, and in liver transplantation and surgery and PhA is said to be superior to anthropometry and 24 h creatinine excretion [77]. Interestingly, in these guidelines, the use of SGA in CLD received a evidence grade of C, while the use of PhA received a grade of B. Additionally, clinical practice guideline recommendations, evidence quality of the use of PhA in malnutrition assessment received the lowest grade.

Hospital malnutrition is a well-established issue [79], and has been associated with pressure ulcers, infection, impaired wound healing, increased length of hospital stay and readmission risk, all of which create a greater burden on health care costs and, ultimately, quality of life for patients [80]. The American Society for Parenteral and Enteral Nutrition (ASPEN) and ESPEN have recommended routine use of nutrition screening to identify malnutrition in hospitalized patients, including using SGA [11,81]. Currently, no published guidelines have identified the use of PhA in malnutrition screening or assessment.

Many elements of kidney disease such as fluid retention can complicate clinical assessments and jeopardize nutrition [76]. The utility of PhA and other BIA measures in dialysis patients is limited due to overhydration pre-dialysis and body water compartments not yet in steady state immediately post-dialysis. The National Kidney Foundation's (NKF) Kidney Dialysis Outcomes Quality Initiative (K/DOQI) clinical guidelines have identified the need for frequent nutrition assessment and recommend SGA as a valid and clinically useful tool in the overall nutritional assessment of non-dialyzed and dialyzed individuals [82]. NKF K/DOQI guidelines recommend CANUSA Study's 7p-SGA [14] as the preferred SGA technique. NKF K/DOQI identify valid methods of protein-energy malnutrition through anthropometric analysis, however, use of BIA in nutrition assessment is not mentioned in these guidelines. More recently, the 2010 Chronic Kidney Disease (CKD) Evidence-

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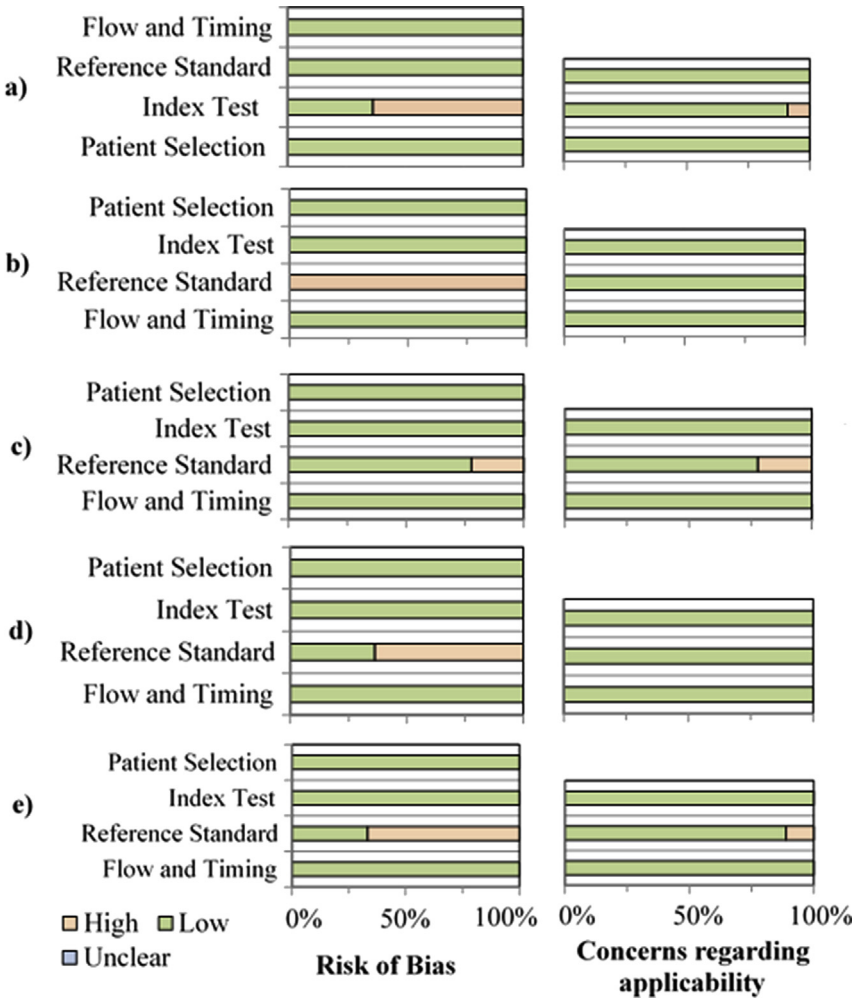

Fig. 2. QUADAS-2 Results. The proportion of studies with low, high and unclear risk of bias and concerns regarding applicability between the index test (PhA) and SGA are shown according to QUADAS-2 domains. **a)** Overall, 61% of studies had high risk of bias of the index test, PhA, and 9% of studies had high concerns for the applicability of the index test, **b)** Liver disease: Due to the lack of any PhA standardization methods, 100% of the articles reviewed had a high risk of bias of the index test, PhA. **c)** Oncology patients: 34% of studies had high risk of bias of the index test. **d)** Hospitalized patients: 64% of studies had high risk of bias in the use of PhA. Two studies (22% of studies) had concerns related to the applicability of the index test due to exclusion of participants where PhA measurement and SGA would have been appropriate. These studies excluded participants based on the inability to obtain anthropometric parameters due to patients being bedridden. **e)** Renal disease - Only a third of articles attempted to control for confounding factors through testing for sex differences or analyzing results by sex, therefore 67% of studies had high risk of bias of the index test. 11% of studies had concerns related to the applicability of the index test due to exclusion of participants where PhA measurement and SGA would have been appropriate.

Based Nutrition Practice Guideline [83] from Academy of Nutrition and Dietetics concluded that any valid measurement methodology including anthropometrics and body compartment estimates such as dual energy X-ray Absorptiometry (DEXA) or BIA, are appropriate in CKD. However, as no reference standard for assessing body composition in CKD patients has been established, no one test has been shown to be superior to another with respect to assessing body composition.

Nutrition status in oncology patients can be affected by surgery, radiation and chemotherapy treatment as well as the pathophysiology of cancer itself [84]. Prevalence of malnutrition is estimated to range between 50 and 80% depending on cancer diagnosis [84]. Clinical practice guidelines have recommended the use of SGA and PG-SGA in the oncology population [85,86]. As well, in their review of available tools within the adult oncology population, the Academy of Nutrition and Dietetics' Oncology Expert Work Group identified both the SGA and PG-SGA as valid and reliable tools in nutrition diagnosis within ambulatory and acute care settings [87]. No published guidelines have identified use of PhA in malnutrition screening or assessment.

Standardizing PhA with reference values for healthy populations may work to resolve this issue of PhA variation through accounting for individual variations from population norms [66]. Thus, SPhA allows for results that are translatable and comparable between studies and disease states. Of the 33 articles identified in this systematic review, only nine used SPhAs. Despite SPhA providing greater rigor than absolute values of PhA alone, variation can still exist based on the reference data used. For example, population norms determined in a German population [27] may be different than those determined in a Brazilian population [25]. Population norms can be standardized in a number of different ways. For instance, most published norms are presented in age- and sex-stratified groups, with fewer studies also including or ethnicity. Future research should make use of a SPhA, however, published data on PhA norms reflecting more diverse populations is needed. Thus, careful consideration is necessary when choosing appropriate reference values within existing population data.

Only six studies attempted to determine an ideal PhA or SPhA cut-off to diagnose malnutrition using SGA as the reference

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standard. Within hospitalized patients, one study identified a SPhA cut-off of <−0.63 SD [51], while two studies suggested gender-specific cut-offs of <6.3°in males and <5.9° in females [48], and <5.0° in males and <4.6°in females, respectively [53]. Within cancer patients, suggested PhA cut-off values included <4.733° [62], <5.9° [67], <5.4° [67], and <5.9° [58] in males with progressive disease. Although other PhA and SPhA cut-offs exist, it is important to note that other cut-offs present in the literature may have been determined using non-nutrition related reference standards limiting their ability to accurately identify malnutrition. Limitations of SGA-derived PhA or SPhA cut-offs, such as their diagnostic accuracy, should not be overlooked. Additionally, we acknowledge that including only articles published in English can bias the results found in this systematic review.

A limitation of using a single PhA or SPhA cut-off value is that it restricts an individual's nutrition status into two binary categories: well-nourished or malnourished. Rather, nutrition status exists on a spectrum. One small study (n = 20) identified in this review used two PhA cut-offs to classify patients into three categories; normal, borderline and abnormal [45]. However, no patients were identified as having borderline PhAs, therefore, comparison was made between comparable SGA-B and borderline PhA groups. Thus, in addition to controlling for confounding factors using a SPhA, and carefully choosing an appropriate cut-off value, future research should attempt to identify varying degrees of malnutrition using multiple SPhA cut-offs.

A major limitation of this review is attempting to find a meaningful relationship between two methodologies that may both be influenced by the operator. However, many studies have already used PhA as a nutritional marker to diagnose malnutrition despite its lack of validation. Therefore, it is important to comprehensively study the appropriateness of its use in both research and clinical practice. The current body of research indicates that PhA cannot independently identify malnutrition in disease, however, PhA or SPhA may show more promise in its use within nutrition monitoring. As an objective measure, SPhA may be able to detect more sensitive changes in nutrition status as compared to other nutrition assessment tools, which can be useful in assessing effectiveness of nutrition interventions. However, further research is needed to explore the relationship between nutrition status and PhA over time.

Conclusion

Early identification of malnutrition or the risk of malnutrition is vital in order to provide appropriate nutrition therapy as preventing worsening malnutrition or correcting nutritional deficiencies can help improve overall nutritional status and prognosis. Thus, the idea of a simple, quick and objective measure to identify malnutrition is appealing. Although the results of this systematic review are sufficiently encouraging to warrant further research in utilizing PhA, we are not able to conclude that PhA can independently identify malnutrition in disease.

Future research using PhA in nutritional assessment should focus on utilizing a standardized PhA. Additionally, further research should investigate the change in SPhA over time to determine if improvement or decline in nutritional status will affect SPhA. Within a clinical practice perspective, inclusion of SPhA in nutritional assessment can complement other nutrition assessment methods, as one method alone may not be sensitive enough to capture all factors that influence nutritional status.

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Conflict of interest

The authors have no relevant interests to declare.

CRediT authorship contribution statement

Sylvia Rinaldi: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Jason Gilliland:** Supervision, Methodology, Writing - review & editing. **Colleen O'Connor:** Supervision, Writing - review & editing. **Bert Chesworth:** Supervision, Writing - review & editing. **Janet Madill:** Supervision, Methodology, Validation, Writing - original draft, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2018.10.010.

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