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Evaluating the concurrent validity of body mass index (BMI) in the identification of malnutrition in older hospital inpatients

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SUMMARY

Background: Nutrition screening and assessment tools often include body mass index (BMI) as a component in identifying malnutrition risk. However, rising obesity levels will impact on the relevancy and applicability of BMI cut-off points which may require re-evaluation. This study aimed to explore the relationship between commonly applied BMI cut-offs and diagnosed malnutrition.
Methods: Data (age, gender, BMI and Subjective Global Assessment (SGA) ratings) were analysed for 1152 inpatients aged ≥65 years across annual malnutrition audits (2011–2015). The receiver operation characteristic (ROC) curve analysed the optimal BMI cut-off for malnutrition and concurrent validity of commonly applied BMI cut-offs in nutritional screening and assessment tools.
Results: Malnutrition prevalence was 36.0% (n = 372) using SGA criteria (not malnourished, moderate or severe malnutrition). Median age was 78.7 (IQR 72–85) years, median BMI 25.4 (IQR 21.8–29.7) kg/m^2; 52.1% male and 51.2% overweight/obese. ROC analysis identified an optimal BMI cut-off of <26 kg/m^2, 80.8% sensitivity and 61.5% specificity (AUC 0.802, 95% CI 0.773, 0.830; $p < 0.0001$). Commonly applied BMI cut-offs (between 18.5 and 23 kg/m^2) failed to meet the alpha-priori requirement of 80% sensitivity and 60% specificity. However, BMI <23 kg/m^2 had the highest agreement ($\kappa = 0.458$) with malnutrition diagnosed using the SGA.
Conclusions: Both malnutrition and overweight/obesity are common in older inpatients. Continuing increases in the prevalence of overweight and obesity will impact on the sensitivity of BMI as a screening component for malnutrition risk. The current study suggests tools developed over a decade ago may need to be revisited in future.

1. Introduction

The aetiology of malnutrition is complex and multi-factorial which makes its identification in the clinical setting challenging, particularly in older patients, as a result it often goes underdiagnosed and untreated [1]. Malnutrition in inpatients has been found to present both an economic and operational burden with malnourished patients experiencing significantly higher rates of emergency hospitalisation, prolonged durations of hospital stay and increased subsequent healthcare costs [2]. Therefore, identifying individuals at risk of malnutrition or diagnosing malnutrition, allowing the initiation of nutritional support is fundamental to the provision of safe and effective clinical care. The first step to the identification of malnutrition is purposeful routine nutritional screening to identify individuals at risk, leading to more in-depth nutritional assessment and appropriate nutritional intervention [3–5]. In order for nutritional screening to be embedded into routine clinical practice, it has to be quick and simple for busy clinical staff to carry out [4]. To safely identify those at risk of malnutrition, the screening tool used should have the appropriate degree of sensitivity to identify all patients at risk of malnutrition and have reasonable specificity to ensure a manageable number of patients are referred for additional assessment and dietetic input. Whilst nutrition screening sensitivity takes precedence (avoiding unidentified malnutrition) for clinical safety reasons, the focus of nutritional assessment shifts more to specificity

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with the view to only providing nutritional support to those individuals where it is clinically indicated [5]. There are over 100 tests or tools for the detection of malnutrition used in clinical practice around the world [6]. Some of the most commonly used screening tools in the clinical setting include the Malnutrition Screening Tool (MST) [7], Mini Nutritional Assessment – Short Form (MNA-SF) [8], the Malnutrition Universal Screening Tool (MUST) [9], Nutritional Risk Screening 2002 (NRS-2002) [10]. The MST and MUST are the most commonly applied screening tools across healthcare facilities throughout Australia [11] and United Kingdom [12]. However, no nutritional screening tool is considered to be the 'gold standard' [13] and there is inconsistency in the accuracy of these screening tools depending on the setting in which they were validated and are now used [14].

One of the most common components of nutrition screening tools is body mass index (BMI) due to it being a cheap, quick, simple and pragmatic measure with tools assigning a level of malnutrition risk according to descending BMI cut-offs. However, various BMI cut-off points from 18.5 kg/m^2 to 23 kg/m^2 are used [7–10,15], which influence the sensitivity and specificity of the tool in identifying those at risk depending on the target patient group's characteristics. Some tools have attempted to account for these difference by having a higher BMI cut-off for older patients for example the MNA-SF [8]. With an increasingly ageing population and the strong association between malnutrition risk and age, the ability to promptly identify malnutrition risk in this patient group is becoming of increasing clinical importance [16]. This presents a challenge to healthcare systems such as Australia, where there is both a growing ageing and obese population. In Australia, the prevalence of overweight and obesity has risen sharply over the last 20 years [17] and by 2025, it is predicted that 73% of the Australian population will be overweight or obese [18]. Many of the screening tools used in practice today were developed over a decade ago (between 2001 and 2004). However for those with a BMI component, these population changes could have an important clinical impact on their effectiveness in identifying malnutrition risk. Therefore, the aims of this study were to explore the sensitivity of BMI as a marker for malnutrition risk and the concurrent validity of commonly applied BMI cut-off points to identify malnutrition in older hospital inpatients.

2. Methods

2.1. Study design and participants

An observational inpatient population point prevalence audit used malnutrition prevalence surveillance data collected annually over a 5-year period (2011–2015) at The Prince Charles Hospital, Brisbane as part of the Queensland Patient Safety Bedside Audits (QBA) to explore the relationship between malnutrition status and BMI. The analysis was restricted to a convenience sample of older inpatients aged ≥65 years and who provided informed consent on the day of audit and had data available for the outcomes of interest (BMI, malnutrition status). Inpatients were primarily recruited from Orthopaedic surgery, General Medical, Cardiology and Thoracic wards. Ethics exemption had been obtained from The Prince Charles Hospital (HREC/17/QPCH/312) and Queensland University of Technology (1700000942) Human Research Ethics Committees and the project was approved as a Quality assurance project.

2.2. Data collection

Demographic data and clinical information were collected using standard templates by ward staff for all patients during the annual Queensland Bedside Audits. Data collected included age, gender, height, weight, BMI. Weights were measured on the day of audit, or the day prior, by ward staff. Hospital policy is for all clinical weighing scales to be routinely calibrated every 6 months and calibration occurred within 2 months prior to the annual audits. Malnutrition status was assessed by dietitians using the Subjective Global Assessment (SGA) and an overall nutritional status rating of not malnourished (A), moderately malnourished (B) or severely malnourished (C) was recorded for each inpatient. Where an SGA was unable to be completed, this was reported as missing data. SGA is the nutrition assessment tool used in routine clinical practice at the hospital site to diagnose malnutrition. It is a widely used diagnostic instrument that is based on features of the participant's anthropometric history, nutritional intake history and physical examination of fat and muscle stores [19] and has been validated in a variety of patient groups [20]. All nutrition assessments were undertaken on audit day unless an SGA had been completed within 7 days prior to audit by a staff member who had inter-rater reliability data available, if not another SGA was undertaken. To ensure data integrity, all dietitians involved attended an SGA and audit training workshop prior to the audit where they completed a minimum of 2 SGAs on patients paired with at least one other dietitian. Dietitians were blinded to each other's assessments and inter-rater reliability was compared with any disagreements in assessment reviewed and discussed prior to the audit. The inter-rater reliability of each audit was as followed: 90.2% (14 dietitians), 92% (16 dietitians), 100% (16 dietitians), 100% (14 dietitians) and 75% (15 dietitians) for the years of 2011–2015 respectively. Inter-rater reliability was observed to be lower in 2015 however, closer exploration of the cases revealed a difference in dietitian assessment in highly complex patients. These would be cases that would generally be discussed with dietetic colleagues and the wider multi-disciplinary team prior to confirming a diagnosis of malnutrition. Any missing data were collected retrospectively through medical chart reviews. Data for weight and SGA were only included if completed ± 7 days of the audit day.

2.3. Analysis

Patients identified with moderate (SGA B) or severe (SGA C) malnutrition were categorised as 'malnourished' while those with an SGA category A were classified as 'not malnourished'. BMI was classified according to the World Health Organisation criteria [21]: underweight BMI <18.5 kg/m^2, normal weight BMI 18.5–24.9 kg/m^2, overweight BMI 25.0–29.9 kg/m^2, obese BMI 30.0–39.9 kg/m^2 and morbidly obese BMI ≥40 kg/m^2. BMI cut-off points used within commonly used nutritional screening tools (Table 1) were compared with SGA diagnosed malnutrition.

Data were analysed using SPSS (Statistical Package for the Social Science, Version 23, 2015, Armonk, NY, USA). Descriptive analyses were presented as absolute numbers and percentages, mean (SD) or medium (IQR). Chi-square, t-test and/or their non-parametric equivalent tests were used to compare and identify any significance between patients who had full dataset and those with missing data. A p-value <0.05 was used to indicate statistical significance. The Receiver Operation Characteristic (ROC) analysis was applied to identify an optimally sensitivity and specific cut-off point for BMI with the area under the curve (AUC) interpreted as followed: poor 0.5–0.6, sufficient 0.6–0.7, good 0.7–0.8, very good 0.8–0.9 and excellent 0.9–1.0 [22]. To evaluate the concurrent validity of commonly applied BMI cut-off points used in screening tools, sensitivity, specificity, positive predictive values (PPV) and negative predictive values (NPV) were calculated against SGA diagnosed malnutrition using a 2 × 2 contingency table. Sensitivity was defined as the proportion of malnourished correctly identified

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Table 1
A summary of commonly applied nutrition screening tools and their BMI cut-off points.

Screening Tool	Year of development	Criteria	Specific groups or setting	BMI cut-off points used
'MUST' [9]	2003	BMI. % unintentional weight loss in 3–6 months, no intake for >5d (past or future). Alternative measures (for height and BMI) and subjective criteria provided when objective measures not possible	All settings, all adults.	<18.5 kg/m^2 18.5 – <20.0 kg/m^2
NRS 2002 [10]	2002	BMI, unintentional weight loss in 3 months, appetite, ability to eat and/or retain food, clinical and/or medical stress factors	Acute setting	<18.5 kg/m^2 18.5 – <20.5 kg/m^2
MNA-SF [8]	2001	BMI, declining food intake over 3 months, mobility, psychological stress and/or acute disease, neuropsychological problems	Initially developed for elderly patients. Now widely used across patient groups	21 – <23 kg/m^2 19 – <21 kg/m^2 <19 kg/m^2
Rapid Screen [15]	2004	BMI, % unintentional weight loss in 3 months, biochemistry markers (total lymphocyte count, serum albumin, total cholesterol level), nutritional impact symptoms	Sub-acute care facilities	<22 kg/m^2

This table is adapted from Stratton et al. (2004) [33].
Abbreviations: BMI – body mass index (kg/m^2); MUST - malnutrition universal screening tool; NRS, nutrition risk screening; MAN-SF, mini nutritional assessment – short form. NB: none of the nutrition screening tools included use BMI as a sole criterion for identifying malnutrition risk.

as malnourished. Conversely, specificity was defined as the proportion of well-nourished inpatients correctly identified. As the focus was on the validity of BMI as a component of nutrition screening, sensitivity was considered of higher importance than specificity [7]. An accepted *alpha-priori* definition of ≥80% for sensitivity and ≥60% for specificity was used to indicate a clinically appropriate nutrition screening tool [7,23]. The PPV was the proportion of patients who had a positive screen result and were malnourished whereas the NPV was the proportion of inpatients who had a negative screen result and were well-nourished. The Cohen's kappa statistics was used to measure the level of agreement between the BMI cut-off points and diagnosed malnutrition and interpreted using the criteria of Landis and Koch [24]: <0 indicating no agreement, 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial and 0.81–1 as substantial agreement. Missing data was excluded from all inferential statistics. The reporting of this paper is also in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations [25].

3. Results

Data from 1152 older inpatients were included in the analysis and patient characteristics are presented in Table 2; 52.1% of the cohort were male, 53.4% were overweight or obese and 36.0% were diagnosed as malnourished. Complete data were available on 88% of the 1152 cohort, some inpatients having missing data for SGA, BMI or both but there were no significant differences between those inpatients providing full data and those without (Age 79.0 versus 78.7 years; p = 0.801, gender: male 51.5% versus 56.2%; p = 0.825). ROC analysis was possible for 1009 inpatients (Fig. 1). The prevalence of malnutrition was 36.0% (30.3% SGA B; 5.7% SGA C). However, nearly a quarter (23.9%) of inpatients diagnosed as malnourished had a BMI of ≥25 kg/m^2. The AUC of the ROC curve analysis for BMI was 0.802, 95% CI 0.773–0.830; p < 0.0001 (Fig. 2), indicating very good discrimination between those patients who were malnourished and those who were not. Based on the ROC curve analysis for the current cohort, the optimal BMI cut-off point for predicting malnutrition was <26.0 kg/m^2.

Figure 2 illustrates the various BMI cut-off points within commonly used nutrition screening tools compared with the BMI distribution for the 360 malnourished patients in the current study. Across all patients, the sensitivity and specificity of various commonly applied BMI cut-off points ranged from 20.0% to

Table 2
Demographic characteristics of the population (n = 1152).

Variables	Value
Age (years)[a]	78.7 (IQR 72–85)
Gender	
Male	52.1% (n = 600)
Female	47.9% (n = 552)
BMI (kg/m^2)[a]	25.4 (IQR 21.8–29.7)
BMI Category[a,b]	
Underweight	7.8% (n = 87)
Normal weight	38.8% (n = 428)
Overweight	29.0% (n = 320)
Obese	24.4% (n = 269)
SGA Rating[c]	
SGA-A (Not malnourished)	64.0% (n = 662)
SGA-B (Moderate malnutrition)	30.3% (n = 313)
SGA C (Severe malnutrition)	5.7% (n = 59)
SGA B or C	36.0% (n = 372)

BMI - body mass index; SGA - Subjective Global Assessment.
[a] n = 1104.
[b] Based on WHO categorisation; Underweight: <18.5 kg/m^2, Normal weight: 18.5–24.9 kg/m^2, Overweight: 25.0–29.9 kg/m^2, Obese: ≥30.0 kg/m^2.
[c] n = 1034.

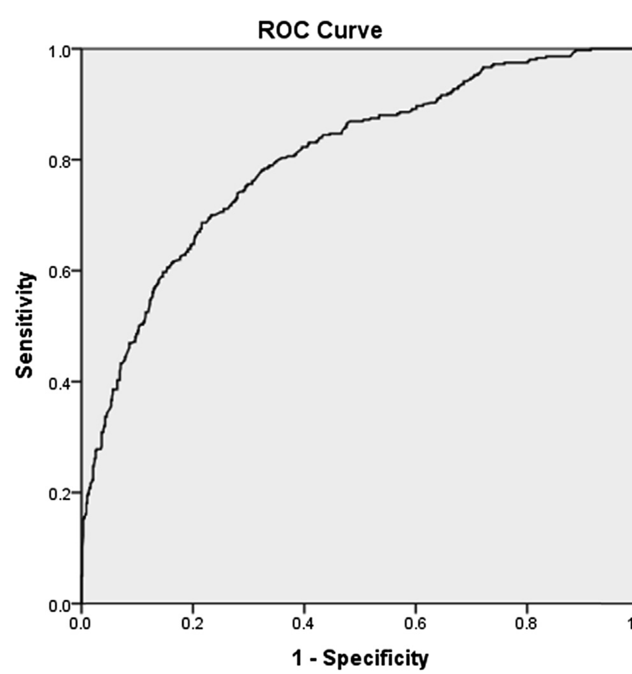

Fig. 1. Receiver operation characteristics (ROC) curve of BMI against SGA diagnosis of malnutrition. BMI – body mass index (kg/m^2); SGA – subjective global assessment.

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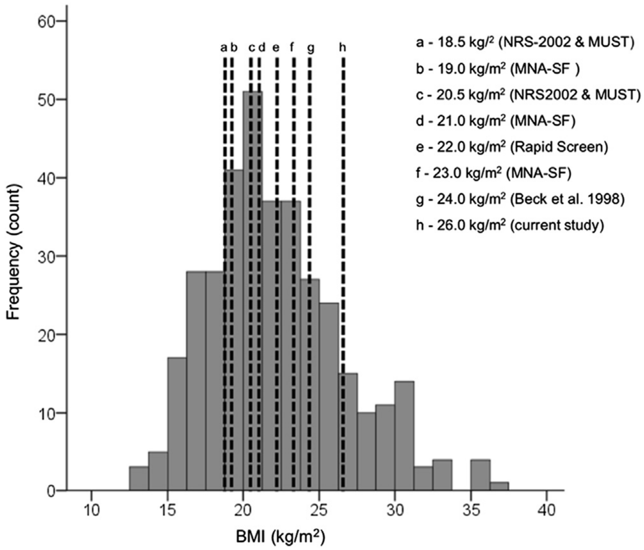

Fig. 2. Distribution of BMI amongst malnourished older inpatients and the BMI cut-off points [34]. 2 column fitting image. BMI – Body Mass Index (kg/m^2); NRS-2002 – Nutrition Risk Screening 2002; MUST – Malnutrition Universal Screening Tool; MNA-SF – Mini Nutritional Assessment Short Form.

80.8% and 61.5%–98.6% respectively, with a BMI cut-off point of <26 kg/m^2 having the highest sensitivity (80.8%) and a specificity (61.5%) that achieved the alpha-priori definition for appropriate screening (Table 3). The proportion of patients with a positive screen result (BMI <26 kg/m^2) and correctly identified as malnourished (PPV) was 53.8% and the proportion of patients with a negative screen result (BMI ≥26 kg/m^2) and correctly identified as well-nourished was 85.3% (Table 3). However, the BMI cut-off point of <23 kg/m^2, with a sensitivity of 61.4% and specificity of 83.5% (67.4% PPV, 79.6% NPV), had the highest agreement ($\kappa = 0.458$) with malnutrition diagnosis using SGA. All BMI cut-off points had only a fair to moderate agreement ($\kappa = 0.225$–0.458; $p < 0.0005$) with the SGA diagnosis of malnutrition.

4. Discussion

This study is the first involving a large representative sample of older inpatients to examine the concurrent validity of various BMI cut-offs included in many commonly used nutritional screening tools. The study found that whilst the mean BMI for the cohort was overweight, with over half classified as overweight or obese, malnutrition was common across all BMI categories and affected nearly 40% of the older inpatient cohort. Whilst BMI as a continuous variable was strongly associated with malnutrition in the inpatients, the BMI cut-off that achieved the target *alpha-priori* for sensitivity (≥80%) and specificity (≥60%) for a good marker of malnutrition risk was higher in the current cohort than in any previously validated screening tools (<26 kg/m^2). All other commonly applied BMI cut-off points, from <18.5 to 23 kg/m^2, failed to achieve the *alpha-priori* values of ≥80% sensitivity and ≥60% specificity and only had a fair to moderate agreement with SGA-diagnosed malnutrition. Even at the highest BMI cut-off point of <23 kg/m^2, sensitivity was 61.4%, suggesting that only approximately 2 in 3 older inpatients diagnosed with malnutrition would have scored as at risk for the BMI component. Considering the high prevalence of malnutrition in hospitalised older patients across all medical specialties, and the association with poorer patient outcomes, this degree of sensitivity might not be considered acceptable. The complexities and impact of malnutrition in older patients was recently demonstrated in a cohort of Australian patients with chronic obstructive pulmonary disease (COPD) where malnourished patients went on to experience poorer survival, increased hospitalisation, prolonged length of hospital stay and twice the healthcare costs [2]. In this study the COPD patients were identified and coded for malnutrition using the SGA. However, the mean BMI of the malnourished patients was above current common BMI cut-offs and also demonstrated wide variation (23.6 SD 5.4 kg/m^2). It is feasible that in the absence of more in-depth nutritional assessment using SGA, some of these malnourished patients would not have been identified using more simple nutrition screening techniques alone involving BMI. SGA does include a physical assessment component which identifies loss of muscle stores and it has been demonstrated in COPD patients that assessment of fat-free mass using bioelectrical impedance analysis, allowing interpretation of fat-free mass index, was more sensitive at predicting malnutrition risk than BMI [26]. Given the high prevalence of malnutrition risk and nutritional depletion in hospitalised older patients, it does raise important clinical questions around whether current routine nutritional screening methods are appropriate and whether more comprehensive nutritional assessment, such as the SGA, as routine practice is justified and feasible in certain high risk inpatient groups. The practicalities, feasibility, opportunity costs and effectiveness of routine assessment over screening in specific high risk groups needs to be supported with adequately powered prospective studies in these groups.

It is important to acknowledge that many of the nutrition screening tools routinely used in practice were developed and validated over a decade ago; MUST (2003), MNA (1994), NRS (2002), Rapid Screen (2004). Whilst all of these tools use BMI as a component for identifying malnutrition risk, there is little consistency with cut-offs ranging from <20 kg/m^2 [9] to <23 kg/m^2 [8] before a degree of malnutrition risk is attributed. Of the nutrition screening tools most commonly used in clinical practice, the MNA-

Table 3
Sensitivity, specificity, positive and negative predictive values and kappa for various BMI cut-off points commonly applied or recommended (n = 1009).

BMI cut-offs (kg/m^2)	Sensitivity	Specificity	PPV	NPV	Kappa[a]	Kappa discrimination
	%					
BMI <18.5	20.0	98.6	88.9	69.0	0.225	Fair
BMI <19	24.7	97.7	85.6	70.1	0.266	Fair
BMI <20.5	38.6	93.7	77.2	73.3	0.363	Fair
BMI <21	44.4	92.0	75.5	74.9	0.401	Fair
BMI <22	52.5	88.3	71.3	77.0	0.433	Moderate
BMI <23	61.4	83.5	67.4	79.6	0.458	Moderate
BMI <24	70.0	76.3	62.1	82.1	0.450	Moderate
BMI <26[b]	80.8	61.5	53.8	85.3	0.381	Fair

NPV, Negative Predictive Values; PPV, Positive Predictive Values.
[a] Approximate significance <0.0005.
[b] Achieved the *alpha priori* definition of ≥80% sensitivity and ≥60% specificity.

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SF has the highest BMI cut-off but was validated for use in older patients. The MNA-SF was validated in 2032 participants with a mean age of 82.3 years [8], slightly older than the current cohort of inpatients (78.7 years), and only included 127 participants from the hospital setting with the majority of the sample involving nursing home residents (n = 1346). Despite this, the findings from the current study suggest the MNA-SF might have particular utility in the identification of malnutrition in a predominantly overweight or obese older inpatient population even though further prospective studies are needed to confirm whether an upwards revision of BMI cut-off from <23 kg/m^2 to <26 kg/m^2 improves the sensitivity and specificity of the tool. The recommendation for an upwards revision of BMI cut-off to identify malnutrition risk in older patients is not unique, some 20 years ago Beck at al [27]. recommended a cut-off of <24 kg/m^2 for individuals aged >65 years old. More recently, researchers have also recommended a cut-off very similar to the current findings, <26.5 kg/m^2 [28]. It is likely the difference in recommendations relating to what BMI cut-off is the most appropriate to identify malnutrition risk in older patients has been driven by the relatively rapid population changes seen of the past two decades. These population changes are likely to have had an impact on previously validated nutrition screening tools particularly in countries such as Australia, where the changes have been considerable and present a challenge to healthcare systems where malnourished-obese patients present a unique clinical challenge. Australia has one of the highest life expectancies out of all Organisation for Economic Cooperation and Development (OECD) countries, ranking third with children born in 2008 expected to live on average to 81.5 years of age (OECD average 79.3 years) [29]. However, Australia also has one of the highest overweight and obesity rates in OECD countries with 74.3% (65–74 years), 73% (75–84 years) and 56.6% (>85 years) classified as overweight or obese [30]. This potentially has implications not only on BMI cut-offs used in this age group but on other components of nutritional assessment routinely included in screening tools (e.g. percentage unintentional weight loss over the previous 3–6 months). Whilst a BMI cut-off of <26 kg/m^2 had the highest sensitivity, the cut-off of <23 kg/m^2 had the highest agreement with SGA however sensitivity dropped to only 61.4%. This disparity between higher sensitivity at the expense of specificity when comparing BMI to dietitian diagnosed malnutrition (SGA) is not surprising given the changing population that many healthcare systems are facing, namely an increasingly ageing, multi-morbid, overweight and obese inpatient population. In addition to these challenges, there is also growing interest in the clustering and impact of malnutrition, frailty and sarcopenia, all of which can be masked by the presence of obesity and complicate nutritional assessment and treatment [31]. In order to ensure patients at nutritional risk continue to be identified and nutritional support initiated in a timely manner, it is likely components of nutritional screening tools, such as BMI, need to be revisited in order to ensure they remain fit for purpose in the population in which they are being used. It is hoped the findings of this study will encourage researchers to revisit, re-evaluate and potentially modify screening tools to ensure busy clinicians tasked with the nutritional management of patients are best equipped to identify those at risk.

Whilst the current study involved a large dataset that we feel is wholly representative of the inpatient population for that particular tertiary hospital, this study was a single site therefore consideration is needed when interpreting the findings. However, we feel a particular strength of the study is the sample was obtained over a 5-year period providing confidence in the representative nature of the study. A potential limitation of the current study relates to the earlier point made regarding different components of nutritional screening tools, BMI is rarely used to identify malnutrition risk in isolation and is often used alongside unintentional weight loss. The current study did not have access to accurate data on recent unintentional weight loss, this could have increasing clinical significance in patients of increased weight. It does often rely on recalled weight which might be an issue in some older patients however, with increased use of electronic medical records rapid access to historical measured data might improve. Finally, although there is currently no gold standard for the diagnosis of malnutrition, the SGA is often used as a reference and we feel the comparisons made following all assessors (dietitians) undergoing training and assessment of inter-rater reliability also adds confidence in the findings. This a particular strength in the current study design and has been recommended previously [32].

5. Conclusions

In conclusion, despite BMI having a strong significant association with malnutrition in older hospital inpatients, BMI cut-off points used in commonly applied nutrition screening tools demonstrated limited concurrent validity. In this predominantly overweight and obese older inpatient population, the optimal BMI cut-off point associated with malnutrition was <26 kg/m^2. However, due to lower specificity at this level, the impact of such a revision on the BMI component of a screening tool on issues, such as clinical workload, needs to be confirmed in future studies. Given the rate and magnitude of the population changes observed over recent decades, it is recommended that nutrition screening tools are regularly reevaluated to ensure the validation values stand true in the populations in which they are intended to be used.

Conflict of interest statement

There are no conflicts of interest to declare.

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Statement of Authorship

JJB conceived the study; JJB, PFC, WLN and DFH helped in refining the study design and research question; WLN and JJB collected the data, JJB, PFC and WLN analysed and interpreted statistical data, WLN wrote the first draft of the paper with the support of JJB and PFC. All authors critically reviewed and approved the manuscript prior to submission.

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