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RESEARCH

Mid-upper arm circumference (MUAC) as a feasible tool in detecting adult malnutrition

E Van Tonder[a], L Mace[b], L Steenkamp[c], R Tydeman-Edwards[d], K Gerber[e] and D Friskin[f]

[a]*Department of Dietetics, Nelson Mandela University, Port Elizabeth, South Africa*
[b]*Dietetics Department, Department of Health, Tayler Bequest Hospital, Matatiele, South Africa*
[c]*Dietetics Department, Department of Health, Settlers Hospital, Grahamstown, South Africa*
[d]*Dietetics Department, Department of Health, Port Elizabeth Provincial Hospital, Port Elizabeth, South Africa*
[e]*Nursing Department, Nelson Mandela University, Port Elizabeth, South Africa*
[f]*Department of Statistics, Nelson Mandela University, Port Elizabeth, South Africa*
**Corresponding author, email: esmarie.vantonder@mandela.ac.za*

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Objectives: This study aimed to expand on the limited South African malnutrition prevalence data and investigate the feasibility of mid-upper-arm circumference (MUAC) as a malnutrition screening tool.
Design: A cross-sectional, multi-centre, descriptive design was adopted.
Setting: The study was undertaken in three tertiary public hospitals in the same urban area within the Eastern Cape of South Africa.
Subjects: Adult hospitalised patients volunteered to participate ($n = 266$).
Methods: Data were collected using interviewer-administered questionnaires; obtaining anthropometric measurements; and consulting medical files. For maximum accuracy of various MUAC cut-off points, receiver operating characteristic curves were generated and area under the curve determined.
Results: Both body mass index (BMI) and MUAC identified 21% of participants as underweight or malnourished, and 39% as overweight or obese. The Malnutrition Universal Screening Tool (MUST) found 23% at increased malnutrition risk. Nurses or doctors detected and referred only 19% of underweight patients (BMI < 18.5 kg/m^2), to dietetics services. Direct measurements of BMI and MUST were unobtainable in 38% and 43% of patients respectively, whilst MUAC was obtainable in 100%.
A statistically significant relationship ($p < 0.001$) exists between MUAC, BMI and MUST to detect malnutrition or malnutrition risk. MUAC cut-offs for undernutrition were determined at < 23 cm (BMI < 16 kg/m^2) and < 24 cm (BMI < 18.5 kg/m^2), respectively, for the study's population groups.
Conclusion: Malnutrition prevalence was high in this study, but often unidentified, with only a fifth referred to dietetic services. MUAC is a feasible method to identify adult malnutrition and should be considered as a malnutrition screening tool and key nutritional status indicator in South African public hospitals.

Keywords: adults, hospitalised, malnutrition, mid-upper arm circumference, MUAC, referral rates, screening

Introduction and objectives

The unfavourable effects of malnutrition on healthcare costs, as well as patient quality of life, are well established.[1] A recent study conducted in the Eastern Cape, South Africa,[2] shows a high prevalence of malnutrition in three public hospitals. The Malnutrition Universal Screening Tool (MUST) found 27% of participants to be underweight, 48% at high malnutrition risk and 33% overweight or obese.

A well-established system across the continuum of care is necessary to minimise malnutrition risk, through efficient implementation of prevention and treatment measures, including: malnutrition screening; triaging of nutrition care; and an evidence-based nutrition intervention.[1]

Nursing staff usually obtain information regarding appetite and feeding requirements on admission, and have the ideal opportunity to screen patients. In low resource areas, the lack of staff, skills, equipment and time can collectively hinder or inhibit the screening process.[2–5] Currently, nutritional screening is not mandatory in South African public hospitals, with reported low incidences of weighing patients or measuring of height reported on admission or thereafter.[2,6] The most frequently cited reason for this is understaffing.[2] Nurses also report low confidence levels in calculating parameters such as body mass index (BMI) and percentage weight loss,[2] which often form part of malnutrition screening. The decision to refer a perceived malnourished patient to dietetic services may therefore be purely subjective, lacking substantiated parameters such as low BMI or significant unplanned weight loss.

An uncomplicated method to identify malnourished patients for nutritional intervention is needed in South African public hospitals. Mid-upper-arm circumference (MUAC) may be a feasible option as it is relatively easy to measure,[7] requires little equipment and calculations, and is transportable and inexpensive.[7] Its diagnostic value in determining malnutrition among children is already a globally accepted practice, including in South Africa.[8] However, global MUAC cut-offs for adult malnutrition classification have not yet been established.[7] Namibia, Ethiopia, Uganda and Zambia have developed their own cut-offs to screen for programme eligibility. However, the optimal cut-off values are unconfirmed.[7] In pregnancy, MUAC correlates strongly with BMI up to 30 weeks' gestation, and could

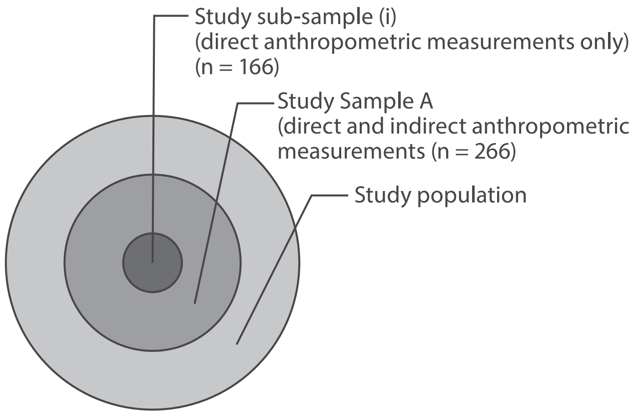

Figure 1: Method of sample selection

substitute for BMI estimation.[9] MUAC measurement has been included in the Maternal Care Record nationally in South Africa.[9] MUAC is also recommended for patients with ascites or oedema in the legs or trunk, to gauge dry weight and BMI.[10]

This article therefore proposes to expand MUAC as an adult malnutrition screening tool, thereby improving malnutrition detection rates and nutritional intervention referrals.

Methods

Study design and participants

A cross-sectional, multi-centre investigation using an exploratory descriptive research design was conducted in three Eastern Cape tertiary public hospitals within the same urban area. The study consisted of Phase 1, which entailed an initial screening phase determining malnutrition prevalence and existing dietetic service referral rates; and Phase 2, which determined MUAC's feasibility as a malnutrition screening tool and applicable cut-off values.

Participants

An initial study sample A was recruited to determine malnutrition prevalence in the Eastern Cape, including participants on whom either direct or indirect (i.e. immobile patients) anthropometric measurements could be obtained. A sub-sample (*i*) was then extracted to contain only those participants from whom direct anthropometric measurements were obtained and who were between 18 and 65 years of age (Figure 1).

Study sample A

Two trained dietetic interns collected data via interviewer-administered questionnaires, anthropometric measurements and consulting medical files. The questionnaires included: demographic and anthropometric information; disease condition; and dietitian referral status during the current admission. The face and content validity of the interviewer-administered questionnaire were tested in a pilot study, involving six participants in one of the hospitals' urology wards, after which no changes were required. All patients who met the inclusion criteria ($\geq$ 18 years of age, not pregnant, able to provide informed consent and without psychiatric illness) in the pre-selected wards were invited to participate in the study. Consecutive purposive sampling was used in the following number of in-patient adult wards: surgical ($n = 2$), medical ($n = 7$), orthopaedic ($n = 2$), oncology ($n = 2$), haematology ($n = 1$), cardiothoracics ($n = 1$) and neurology ($n = 1$). All paediatrics ($n = 10$), antenatal ($n = 2$) and postnatal ($n = 2$), some surgical ($n = 2$), some medical ($n = 2$), burns ($n = 2$), urology ($n = 1$), psychiatric ($n = 1$), critical care ($n = 1$), and high-care ($n = 2$) wards were excluded from the study. The critical care and burns wards were excluded due to the difficulty in obtaining accurate anthropometric measurements and the urology ward formed part of the pilot study. Some medical wards were excluded due to time constraints.

Anthropometric measurements and nutritional screening

A calibrated SECA scale (Seca GmbH, Hamburg, Germany), SECA stadiometer, and a non-stretchable measuring tape were used to obtain anthropometric measurements,[11] including: weight; height; and MUAC. BMI, MUAC and MUST scores were used to identify malnutrition risk.[7,12,13] Body mass index (< 18.5 kg/m^2) and MUAC (< 23 cm),[14,15] were used to determine malnutrition prevalence and MUST to determine malnutrition risk prevalence. Demi-span or ulna length was used to determine height for non-ambulatory patients, using validated formulae.[11,12] Body mass index was then estimated, from which the current weight was extrapolated.[11,12] To improve intra-observer reliability, dietetic interns were trained in relevant measuring techniques by a registered biokineticist, after which an acceptable level of technical error of measurement (TEM) was obtained.[11]

The use of a validated screening tool (MUST) further improved the validity of the data.

Statistical analysis

Statistica® (version 13) (www.statsoft.com) was used to analyse the data. Descriptive statistics were used for categorical data, and means, standard deviations and ranges for continuous data. Groups were compared by means of chi-square tests[16] with a p-value < 0.05 considered as statistically significant.

Receiver operating characteristic (ROC) curves were generated and area under the curve (AUC) calculated[17] to determine global accuracy measurements for MUAC cut-off points to classify BMI classes (sub-sample *i* only). Youden's[18] index was used to obtain optimal MUAC cut-off point accuracy.

Ethical considerations

Permission was granted by the Nelson Mandela University Research Ethics Committee (Human) (H15-HEA-DIET-005), the Eastern Cape Department of Health, as well as the CEO of each participating hospital.

The Helsinki declaration guidelines were followed, including voluntary written informed consent and maintenance of confidentiality.[19]

Results

Study sample A

Study sample A consisted of $n = 266$ patients with a mean age of 47.11 ± 15.4 years with a relatively even distribution of males (52%) and females (48%). The ethnic distribution was 68% ($n = 181$) black, 26% ($n = 69$) coloured, 6% ($n = 15$) white and < 1% ($n = 1$) Indian patients.

The sample distribution according to disease-specific wards was as follows: surgical 17% ($n = 45$), medical 43% ($n = 114$), orthopaedic 15% ($n = 39$), oncology/haematology 12% ($n = 31$), cardiothoracic 10% ($n = 26$) and neurology 4% ($n = 11$).

Table 1: Malnutrition prevalence and risk according to nutrition-related indicators

Prevalence of malnutrition according to BMI		
	n	**Percentage (%)**
Underweight (< 18.5 kg/m^2)	57	21.4
Normal weight (18.5–24.9 kg/m^2)	105	39.5
Overweight (25.0–29.9 kg/m^2)	45	16.9
Obesity (30.0–39.9 kg/m^2)	49	18.4
Morbidly obese (≥ 40 kg/m^2)	10	3.8
Total	266	100
Prevalence of malnutrition according to mid-upper arm circumference (MUAC) cut-offs		
	n	Percentage (%)
Normal (MUAC > 23 cm)	208	78.2
Malnutrition (MUAC ≤ 23 cm)	58	21.8
Total	266	100
Prevalence of malnutrition according to MUST score		
Malnutrition risk	***n***	**Percentage (%)**
Low Risk (Score = 0)	89	33.5
Medium Risk (Score = 1)	19	7.1
High Risk (Score ≥ 2)	43	16.2
Unable to determine	115	43.2
Total	266	100

BMI: body mass index; MUST: Malnutrition Universal Screening Tool.

Outcomes of the nutritional status indicators (MUAC, BMI and MUST) of study sample A are summarised in Table 1. Some 21% ($n = 57$) of participants were classified as underweight (BMI < 18.5 kg/m^2), whilst 39% ($n = 104$) were classified as either overweight (BMI 25–29.9 kg/m^2) or obese (BMI > 30 kg/m^2). MUAC measurements showed that 22% ($n = 58$) of the sample were malnourished with a measurement of ≤ 23 cm. According to MUST, 23% ($n = 158$) of patients were at increased malnutrition risk (MUST score ≥ 1), with 16% at high risk (MUST score ≥ 2).

Referral to dietetics services

As shown in Table 2, only 19% of underweight patients according to BMI, 22% of malnourished patients according to MUAC and 21% of patients with a MUST score of ≥ 2 were referred to dietetics services. Similarly, only 14% of overweight or obese patients were referred.

Factors limiting malnutrition screening

Malnutrition screening was limited to mobility of participants for direct measurements of weight and height to calculate BMI. Of the 266 participants, 37.6% of BMIs had to be estimated, which is reliant on advanced clinical skills, in which non-nutritional health professionals are not specifically trained. A further challenge was to obtain patients' usual weight in order to calculate percentage weight loss, an important parameter for determining a patient's malnutrition risk.[20] The latter was due to patients' weights not routinely being documented in their medical files, and many patients not knowing their usual weight. Consequently, 43.2% of participants' MUST scores could not be calculated. Conversely, MUAC was obtainable in 100% of the sample, which made it a more feasible screening tool for non-nutritional healthcare professionals such as nurses.

Table 2: Referral rates to dietetics services based on nutritional status or risk

Factor	**Referred to a dietitian**		**Not referred to a dietitian**	
	n	**Percentage (%)**	***n***	**Percentage (%)**
BMI < 18.5 kg/m^2	11	19	46	81
BMI ≥ 24.9 kg/m^2	15	14	89	86
MUAC ≤ 23 cm	13	22	45	78
MUST ≥ 2	9	21	34	79

BMI: body mass index; MUAC: mid-upper arm circumference; MUST: Malnutrition Universal Screening Tool.

Study sub-sample (i)

Direct anthropometric measurements were obtained in 181 participants from study sample A, which was included in sub-sample (*i*). Fifteen of these patients were > 65 years of age, and were excluded. Therefore 166 participants were included in sub-sample (*i*), to statistically compare MUAC values with BMI and MUST, and to determine MUAC cut-off values (see Figure 1).

MUAC as a feasible screening tool

The performance of MUAC as a screening tool to classify participants as malnourished, was further explored (based on data from sub-sample (*i*)) for feasibility and accessibility, in comparison with the barriers experienced with both BMI and MUST. The mean age of sub-sample (*i*) ($n = 166$) was 41.72 ± 12.8 years with a relatively even distribution of males (52%) and females (48%). Sub-sample (*i*) consisted of 71% ($n = 118$) black, 25% ($n = 42$) coloured, 3% ($n = 5$) white and <1% ($n = 1$) Indian patients. The ability of MUAC to accurately detect patients with malnutrition or malnutrition risk was statistically compared with BMI and MUST respectively.

A statistically significant relationship (chi-square = 66.816; $df = 4$; $p < 0.001$) existed between MUAC and BMI in classifying undernourished patients, with Cramer's $V = 0.634$, indicating large practical significance.

Mid-upper arm circumference showed a significant strong correlation with BMI ($r = 0.93$, $p < 0.001$). The relationship is illustrated in Figure 2.

Similarly, a statistically significant relationship was found between MUAC and MUST (chi-square = 38.816; $df = 2$; $p < 0.001$) with Cramer's $V = 0.623$, also indicating large practical significance.

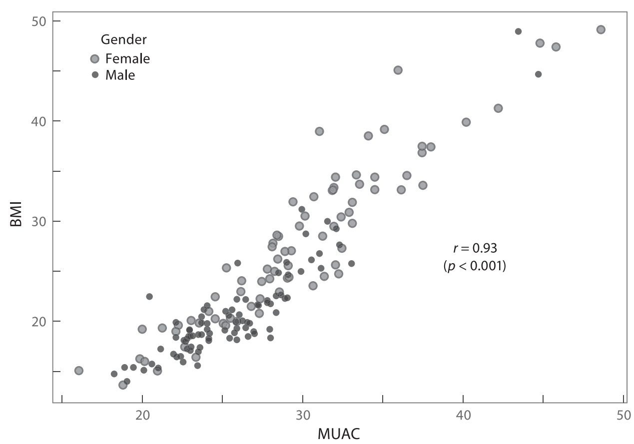

Figure 2: Relationship between body mass index (BMI) and mid-upper arm circumference (MUAC) according to gender

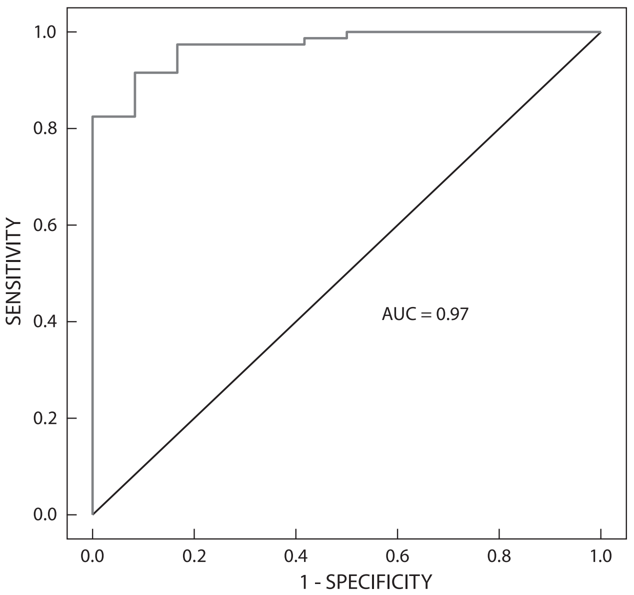

Figure 3: ROC curve for MUAC classification of BMI < 16 kg/m^2 (Sub-sample *i) ROC: Receiver operating curve, MUAC: mid-upper arm circumference*

Table 3: Optimal MUAC cut-offs to detect malnutrition based on study sub-sample (*i*)

BMI (kg/m^2)	MUAC (cm)	AUC	Sensitivity (%)	Specificity (%)
< 16 Severely underweight	22.6	0.97	91.6	91.7
< 18.5 Underweight	23.7	0.92	89.3	82.9
≥ 25 Overweight	28.1	0.96	94.9	86.9
≥ 30 Obese	29.4	0.97	100	87.2

BMI: body mass index; MUAC: mid-upper arm circumference; AUC: area under the curve.

MUAC cut-offs to identify malnutrition risk

Receiver operating curves (ROC) were plotted and area under the curve (AUC) was calculated to determine global accuracy measurements for using MUAC cut-off points to classify BMI classes. Figure 3 provides an example of the ROC for using MUAC to classify a BMI of < 16 kg/m^2.

Based on the coordinates of the curve, Youden's index was used to determine the optimal cut-off points (highest combined sensitivity and specificity) to classify BMI's of < 16 kg/m^2, < 18.5 kg/m^2, ≥ 25 kg/m^2 and ≥ 30 kg/m^2 (Table 3).

The MUAC values derived for the whole sample population were rounded off to < 23 cm, < 24 cm, > 28 cm and > 29 cm and colour coded for ease of classification purposes in the form of a MUAC tape, similar to what has previously been developed by the United Nations International Children's Emergency Fund (UNICEF) to identify malnutrition in children (see Table 4).

Table 4: Proposed MUAC tape for nutritional screening

	BMI category (kg/m^2)				
	< 16	< 18.5	18.5–24.9	≥ 25	> 29.9
MUAC (cm)	< 23.0	< 24.0	24.1–27.9	> 28.0	> 29.0

BMI: body mass index; MUAC: mid-upper arm circumference; MUST: Malnutrition Universal Screening Tool.

Table 5: Predicted MUAC cut-offs for the detection of malnutrition according to gender

BMI (kg/m^2)	MUAC (cm)	AUC	Sensitivity (%)	Specificity (%)
Males:				
< 16 Severely underweight	< 22.6	0.96	91	88.9
< 18.5 Underweight	< 23.7	0.88	86.4	78.6
≥ 25 Overweight	> 29.0	0.97	92.3	95.9
≥ 30 Obese	> 29.9	0.97	100	91.6
Females:				
< 16 Severely underweight	< 21.1	0.99	96.1	100
< 18.5 Underweight	< 23.5	0.98	93.1	100
≥ 25 Overweight	> 28.0	0.94	95.7	81.8
≥ 30 Obese	> 29.4	0.96	100	82

BMI: body mass index; MUAC: mid-upper arm circumference; AUC: area under the curve.

In addition to the proposed MUAC cut-off values for undernutrition, which were similar to the results of Ferro-Luzzi and James,[14] Chakraborty *et al.*[20] and Sultana *et al.*,[21] the current study predicted MUAC cut-off values for the overweight population as well.

MUAC cut-offs according to gender and race

The MUAC cut-off points with the highest sensitivity and specificity to correspond with BMIs of < 16 kg/m^2, < 18.5 kg/m^2, ≥ 25 kg/m^2 and ≥ 30 kg/m^2, were also determined according to gender and race. The proposed cut-off values for each corresponding BMI value are summarised in Tables 5 and 6. These cut-off values were again rounded off for practical purposes and colour coded for ease of use (Table 7).

Table 6: Predicted MUAC cut-offs for the detection of malnutrition according to race

BMI (kg/m^2)	MUAC (cm)	AUC	Sensitivity (%)	Specificity (%)
Black				
< 16 Severely underweight	< 23.5	0.97	85.5	100
< 18.5 Underweight	< 23.7	0.92	90.7	85.7
≥ 25 Overweight	> 28.1	0.95	92.9	85.5
≥ 30 Obese	> 29.9	0.98	100	89.2
Coloured				
< 16 Severely underweight	< 22.6	0.96	0.868	100
< 18.5 Underweight	< 22.9	0.92	0.964	78.6
≥ 25 Overweight	> 28.1	0.99	100	93.3
≥ 30 Obese	> 29.4	0.99	100	94.4

BMI: body mass index; MUAC: mid-upper arm circumference; AUC: area under the curve.

Table 7: Proposed MUAC cut-off values according to gender and race

	BMI category (kg/m²)				
MUAC (cm)	**< 16**	**< 18.5**	**18.5–24.9**	**≥ 25**	**> 29.9**
Males	<23	<24	24.1–28.9	>29	>30
Females	<21	<24	24.1–27.9	>28	>29
Black	<24	<24	24.1–27.9	>28	>30
Coloured	<23	<23	23.1–27.9	>28	>29

BMI: body mass index; MUAC: mid-upper arm circumference.

The insufficient number of white and Indian patients was a limitation of the study, which inhibited the prediction of MUAC cut-offs for these groups. Further research is needed in these groups.

Discussion

Nutritional status of the sample

The world is faced with a double burden of disease encompassing both spectrums of malnutrition (undernutrition and overnutrition) within the same communities.[22] The current study illustrated that the double burden of disease also exists in the hospitalised population that was studied. On screening, 21% were classified as underweight (BMI < 18.5 kg/m^2), whilst 23% were at increased malnutrition risk (score ≥ 1) by MUST. According to BMI, a staggering 39.1% of participants were overweight or obese. The malnutrition prevalence rates found in this study agree with previously reported global prevalence of hospital malnutrition, varying between 13 and 78%[23], as well as a recent study in the Eastern Cape (2016) in the same study population.[2]

Referral to dietetic services

Only approximately 20% of underweight and high malnutrition risk patients were referred to dietetic services, and even fewer overweight or obese patients. This is lower than an Australian study (2011) that found 36% of malnourished patients were referred to a dietitian in a tertiary teaching hospital.[24] Since the current lack of human resources in the public health service impedes the establishment and implementation of blanket malnutrition screening and referral policies or procedures, many patients in the three public hospitals who required at least some form of nutrition intervention remained undetected.

By proposing the MUAC measurement as a malnutrition screening method in South African public hospitals, many more patients could be screened, detected and referred to a dietitian for a more thorough assessment and nutritional intervention. This can lead to multiple benefits for both the patient and institution,[25] but will also need a larger nutrition workforce to cope with an increased patient load.

Although there has been progress in the development of South African national policies[26,27] and guidelines[28] that emphasise nutrition screening, more collaboration with other professional societies and organisations is needed in terms of screening, management and referral pathways of malnourished or nutritionally at-risk patients.

Relationship of MUAC with BMI and MUST

The use of the MUAC as a screening tool to assess adult nutritional status, especially in low resource areas, has steadily increased since its first application in the late 1900s.[7,14,15] The current study confirms previous findings [7–9,14,15,20,21,29–32] that MUAC correlated well with BMI, and could be used to identify patients as underweight and overweight. In addition, the current study also demonstrated that MUAC correlated well with the validated malnutrition screening tool (MUST),[10] albeit to a lesser extent than BMI. Therefore, MUAC may be a feasible nutritional screening tool to be used in both clinical and other settings, especially where frontline professions (e.g. nurses) do no not routinely use nutritional indicators, e.g. weight, height, BMI and percentage weight loss.

Inhibiting factors to malnutrition screening methods

A limitation to the current study was that more than a third of patients in the initial study, sample A were not ambulant, therefore direct measures of weight or height could not be measured. BMI had to be estimated in such circumstances and could have impacted on the accuracy of the findings. Some 43% of participants in study sample A were unable to recall their usual body weight. The data were also unavailable from the medical file, which made accurate calculation of percentage weight loss impossible, thereby inhibiting MUST score calculations in a large sample of patients. The current study's challenges compared with those experienced by Powell-Tuck and Hennesy,[29] where BMI was obtainable in only 44% of their study population, and recent percentage weight loss in only 33%, but MUAC in 95% of their patients.

From the above data it can be seen that the use of screening tools, where more advanced anthropometric skills and calculations may be required, is not currently feasible in South African public hospitals. Undergraduate and in-service training of frontline workers (e.g. nurses) will have to be up-skilled first. Additional inhibiting factors are the time constraints and availability of nursing staff and equipment,[2,3,5] thereby reinforcing the need for a relatively easy and quick malnutrition risk screening tool in the acute setting, such as MUAC.[10]

Since MUAC is already used as a screening tool in children under five years old and pregnant women in South Africa, it may be easier for nursing staff to adopt this method of blanket nutritional screening of adult patients.[9] Mid-upper arm circumference is not without its limitations, and does not account for recent significant unplanned weight loss, an important indicator of nutritional risk.[33] However, even after taking the above-mentioned inhibiting factors into consideration, MUAC remains feasible as a stepping stone towards nutritional screening in South African public hospitals.

Predicting MUAC cut-offs

The strong correlation between BMI and MUAC allowed for optimal MUAC cut-offs to be derived for identifying malnourished patients. Depending on a facility's resources, a MUAC cut-off of either < 23 cm (corresponding to a BMI of < 16 kg/m^2) or < 24 cm (corresponding to a BMI < 18.5 kg/m^2) is proposed (see Table 3). More specific cut-offs have been proposed that consider demographic characteristics (see Table 6), again depending on facilities' preferences and resources.

The current study's cut-offs are similar to those proposed by Chakraborty *et al.*[20] (< 24 cm in males as an indicator of malnutrition and illness), Sultana *et al.*[21] (< 25 cm in males and < 24 cm in females to correspond to a BMI < 18.5 kg/m^2), Brito et al.[13] (≤22.5 cm to correspond highly to a BMI of <18.5 kg/m^2 and Ferro-Luzzi and James[14] (< 23 cm for men and < 22 cm for women based on a BMI < 18.5 kgm^2)[7].

Sultana *et al.*[21] (n = 1373) and Chakraborty *et al.*[20] (n = 205) both used ROC and Youden's index, similar to the current study, to determine optimal MUAC cut-offs, whilst Ferro-Luzzi and James[14] analysed and extrapolated anthropometric data from adults with normal nutritional statuses across nine adult surveys from Asia, Africa and the Pacific.

The current study was further able to determine MUAC cut-offs for overweight and obese patients, due to the high prevalence in the population group. Cut-offs of > 28 cm or > 29 cm (corresponding to a BMI of ≥ 25 and 29.9 kg/m^2 respectively) are proposed (see Table 3), again depending on facilities' preferences and resources. Gender and race specific cut-offs have also been determined (see Table 6).

Conclusion

The high prevalence of malnutrition, both as underweight and overweight, illustrated that the double burden of disease was also endemic in this study population. Patients falling in either of these categories were often unidentified and untreated for malnutrition, with only a fifth being referred to dietetic services. Further research is recommended to validate the proposed MUAC cut-offs in hospitalised patients, but also to extend it to other settings, e.g. community clinics and long-term care settings. As the selection of patients was not randomised, the results could not be generalised to all hospitalised patients. Research on larger samples of the white and Indian populations are needed, to develop MUAC cut-offs for these groups.

The use of MUAC should be considered as a first step to mandatory nutritional screening and a key nutritional status indicator in South African public hospitals and other settings.

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