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Towards identifying malnutrition among infants under 6 months: a mixed-methods study of South-Sudanese refugees in Ethiopia

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Abstract

Objectives: To determine (i) whether distinct groups of infants under 6 months old (U6M) were identifiable as malnourished based on anthropometric measures and if so to determine the probability of admittance to GOAL Ethiopia's Management of At Risk Mothers and Infants (MAMI) programme based on group membership; (ii) whether there were discrepancies in admission using recognised anthropometric criteria, compared with group membership and (iii) the barriers and potential solutions to identifying malnutrition within U6M.

Design: Mixed-methods approaches were used, whereby data collected by GOAL Ethiopia underwent: factor mixture modelling, χ^2 analysis and logistic regression analysis. Qualitative analysis was performed through coding of key informant interviews.

Setting: Data were collected in two refugee camps in Ethiopia. Key informant interviews were conducted remotely with international MAMI programmers and nutrition experts.

Participants: Participants were 3444 South-Sudanese U6M and eleven key informants experienced in MAMI programming.

Results: Well-nourished and malnourished groups were identified, with notable discrepancies between group membership and MAMI programme admittance. Despite weight for age *z*-scores (WAZ) emerging as the most discriminant measure to identify malnutrition, admittance was most strongly associated with mid-upper arm circumference (MUAC). Misconceptions surrounding malnutrition, a dearth of evidence and issues with the current identification protocol emerged as barriers to identifying malnutrition among U6M.

Conclusions: Our model suggests that WAZ is the most discriminating anthropometric measure for malnutrition in this population. However, the challenges of using WAZ should be weighed up against the more scalable, but potentially overly sensitive and less accurate use of MUAC among U6M.

Keywords
Infants under 6 months
Malnutrition
Mid-upper arm circumference
Weight for age z-scores
Weight-for-length
Management of At Risk Mothers and Infants

A primary contributor to the global burden of disease[1], malnutrition accounts for 53 % of under 5 mortality[2]. Large-scale efforts to assess the outcomes of children enrolled in nutrition programmes have identified higher rates of acute malnutrition (AM) or wasting, the result of recent rapid weight loss or the failure to gain weight[3], among infants under the age of 6 months (U6M), compared with those aged from 6 to 59 months[4]. This represents an increased vulnerability for malnutrition among U6M, which, if not addressed, could result in severe and irreversible adverse health outcomes.

A number of inter-connected factors contribute to the increased vulnerability of U6M. First, U6M have unique physiology[5] including active immune suppression in early infancy[6] which can correspond to increased risk, frequency, duration and severity of infection[3]. The immune system response during nutrient shortage and adipose tissues role in nutrient uptake are interrelated processes[7].

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Furthermore, infections may lead to an increased demand for energy exacerbating malnutrition[8]. These interrelated factors can create a cycle of malnutrition and worsening illness[3].

Second, considering U6M's complete dependence on caregivers' decisions regarding feeding practices[9], certain cultural beliefs can contribute to malnutrition. Restrictive practices around breast-feeding, food taboos and misconceptions that the colostrum is dangerous or 'dirty' for infants have been identified as important global determinants of infant malnutrition[10,11]. While international efforts to curb child malnutrition have emphasised the importance of exclusive breast-feeding (EBF), U6M have long been considered less vulnerable to malnutrition due to the assumption that infants are exclusively breastfed. However, infants U6M are vulnerable to AM regardless of breast-feeding status[4]. Moreover, although effective EBF can protect against early malnutrition, it is only practiced with an estimated 40 % of all U6M[12]. Consequently, millions of infants are exposed to contaminated water, pre-lacteals and inappropriate foods annually, potentially causing illness and further malnutrition[13,14].

Due to these misconceptions, infants are commonly overlooked in community screenings for malnutrition and standard nutrition surveys[15] and are often excluded from nutritional recommendations and interventions[4]. Often programmes for the identification and treatment of AM in 'infants and children' refer exclusively to those 6–59 months[16]. Furthermore, it has been found that even when admitted to therapeutic feeding programmes, U6M had more missing anthropometric data than their 6–60 months counterparts[17].

As a preventative strategy, infant and young child feeding practices have the greatest potential to improve child survival[18]. The potential of infant and young child feeding has been acknowledged by the international community through numerous inter-sectoral campaigns focusing exclusively on nutrition including *The Decade*[19] and *The Scaling Up Nutrition Movement*[20]. Here again, however, there is a conspicuous absence of U6M within these campaigns and programmes. Taken together, the above not only demonstrates that U6M are at a greater risk of malnutrition compared with their older counterparts but they are also indirectly at risk, due to the widespread exclusion of this age group from current child malnutrition literature, policy and diagnostic guidelines. This dearth of evidence has a cascading effect, with policy makers reluctant to ratify policies to identify and treat AM in U6M without substantial rationale. Subsequently, practitioners and humanitarian workers face a notable lack of guidance when they encounter infants U6M whom appear to be malnourished. Furthermore, despite the WHO stating outpatient care should be available for U6M with AM this is not reflected in national protocols, thus leaving inpatient treatment as the only option for high-risk cases[21]. There are also concerns that inaccurate assessments amongst small but healthy infants could be counterproductive by undermining and/or interrupting EBF[4,22].

Unfortunately, the paucity of malnutrition research conducted among U6M has resulted in a dearth of guidelines and protocols for how to best measure and identify AM for this age group[23]. As a result, at the time of data collection, there was an overreliance on tools and methods developed and tested for children aged 6–59 months being applied to the identification of AM for U6M. Among children aged 6–59 months, AM is most often measured and identified using weight-for-age (WAZ), weight-for-height or weight-for-length (WLZ) *z*-scores and/or a measure of mid-upper arm circumference (MUAC)[24]. However, inconsistencies between these tools are well documented within the literature[25]. Given the availability of different anthropometric indicators of malnutrition (i.e. WLZ, WAZ, MUAC) and the absence of evidence regarding which of these is best to assess malnutrition among U6M, an alternative approach may be used to determine if there are unique groups of U6M characterised by similar patterns of malnutrition across these different measures.

Aims and objectives

The identification of malnutrition within U6M is necessary to mitigate the physiological, socio-cultural and political factors which can contribute to an increased risk of malnourishment within this population. We conducted a study of infants aged 0–6 months residing in two refugee camps in Ethiopia. Our objectives were to determine (i) whether distinct groups of malnourished U6M were identifiable based on multiple anthropometric measures; and if so, to determine the probability of admittance to GOAL Ethiopia's Management of At Risk Mothers and Infants (MAMI) programme based on one's group membership; (ii) whether there were discrepancies in admission to MAMI, using anthropometric criteria internationally recognised at the time of data collection as best practice (i.e. MUAC < 110 mm, MUAC < 115 mm, WLZ < –3·0, WAZ < –3·0), compared with admission based on group membership and (iii) the key barriers, and possible solutions, to the challenge of identification of malnutrition within U6M, from the perspective of global child nutrition experts.

Methods

Participants and procedures

The first two objectives used data collected by GOAL Ethiopia's MAMI programme as part of the routine, monthly programme collection. Screening was linked to blanket supplementary feeding distribution and maternal, infant and young child nutrition education as part of a wider nutrition support programme run in collaboration with

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the United Nations High Commissioner for Refugees and the Ethiopian Administration for Refugee and Returnee Affairs. At the time of commencing this study, there were data on 3444 infants U6M. Thus, participants were 3444 South-Sudanese U6M (51·9 % female, mean age = 2·98 months, SD = 1·34) seeking refuge in Ethiopia and residing in either Kule or Tierkidi camps. The data were collected between 22 February 2016 and 2 January 2017.

The third objective made use of non-probability, snowball sampling procedures to recruit key informants with extensive experience with MAMI implementation and programming[26]. The key informant interviews consisted of nine females and two males, all over 18 years of age. Participants were recruited from multiple humanitarian and academic organisations including: Action Against Hunger, Save the Children UK and US, Brixton Health, the WHO, the Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) and the London School of Hygiene and Tropical Medicine. All interviews were conducted by the lead author in English over Skype and lasted an average of 24·7 min. Written informed consent was gained prior to the interviews.

Measurement tools

Weight was measured using 25 kg salter scales with 100 g increments, while length was measured using a solid height board laid flat on the ground. MUAC measurements were taken using a standard UNICEF specification colour coded MUAC tape. Mothers/carers were asked age of the infant in months. All data were collected in a clinic setting by trained nurses or health extension agents on paper forms and entered into a database by the nutrition programme manager. Consistent with international guidelines[21,27], the following cut-offs for severe acute malnutrition were employed to assess malnutrition in U6M: (i) WLZ < –3·0 and (ii) WAZ < –3·0. In addition, (iii) MUAC < 110 mm and (iv) < 115 mm were utilised based on the cut-offs for children aged 6–59 months[21,28] as there is currently no internationally recognised MUAC cut-off for U6M. In line with these internationally recognised definitions, GOAL's MAMI protocol specified that admission at the time should be based on anthropometric measurements of MUAC < 115 mm and WLZ < –2, also recent weight loss, failure to gain weight or visible wasting. This was decided by nursing staff, supported by community outreach agents. These decisional factors, outside anthropometry, were not recorded in the data set.

The interview schedule was designed based on the above review of the literature, with input from GOAL's nutritional advisor. The final schedule included open-ended questions designed to solicit responses and opinions on the factors that facilitate and prohibit the identification of malnutrition in U6M (see Appendix 1). The schedule was piloted with a nutrition expert prior to use, leading to minor changes to clarify the language in the interview guide. The lead author performed the interviews. These were audio recorded and transcribed verbatim immediately following each interview. Following this, the transcriptions were crosschecked with the audios for accuracy and for additional notes.

Data analysis

Z-scores in the dataset were recorded using look-up tables. Factor mixture modelling was used to determine whether empirically distinct groups of U6M were identifiable within this population based on their scores across three anthropometric measures (WAZ scores, WLZ scores and MUAC *z*-scores[1]). Factor mixture modelling is a latent variable modelling technique that combines confirmatory factor analysis with latent profile analysis in a simultaneous process[29]. First, the associations between scores on the three anthropometric measures were modelled as observed indicators of a single latent dimension of malnutrition (confirmatory factor analysis component). Second, variation in levels of nutrition was held constant, and the optimal number of groups (or 'latent classes') of U6M was determined (latent profile analysis component). Latent profile analysis is well suited to this study as it is an exploratory, data-driven technique that makes no *a priori* assumptions regarding the number of groups that exist in the population[30].

Four-factor mixture models were tested that included one factor (nutrition) and one to four latent classes. All models were estimated using the robust maximum likelihood estimator[31], and missing data were managed using full information maximum likelihood. To avoid solutions based on local maxima, 500 random sets of starting values were used, followed by 50 final-stage optimisations. The relative fit of the models was compared using three information theory-based fit statistics: the Akaike Information Criterion[32], the Bayesian Information Criterion[33] and the sample size adjusted Bayesian Information Criterion[34]. In each case, the model with the lowest value is considered to be the best, and Nylund, Asparouhov and Muthen[35] demonstrated that the BIC is the best information criterion for identifying the correct number of classes. In addition, the Lo–Mendell–Rubin adjusted likelihood ratio test[36] was used to compare models with increasing numbers of latent classes. A non-significant value ($P > 0{\cdot}05$) suggests that the model *with one less class* should be accepted. These analyses were conducted using Mplus 7·11[37].

Next, bivariate associations between group membership and the likelihood of MAMI admission, as well as WHO cut-offs for malnourishment and likelihood of MAMI admission, were assessed using χ^2 analysis. Group membership was defined by the results of the factor mixture model. Given high rates of missing data on the MAMI admission variable, differences between U6M who had no information on admittance (i.e. missing cases),

[1]MUAC scores were transformed to z-scores for the purposes of Factor Mixture Modelling so that all measures were equally scaled.

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those admitted and those who were not admitted for MAMI on measures of MUAC, WAZ and WLZ were assessed using a one-way between groups ANOVA. Logistic regression analysis was conducted to determine the associations between each anthropometric measures and admittance for MAMI, controlling for sex (0 = male, 1 = female) and age.

The challenges with identifying malnutrition within U6M, as perceived by global child malnutrition experts, were identified through key informant interview. Interviews were transcribed verbatim immediately following each interview, and transcriptions were crosschecked with the audios for accuracy and for additional notes (i.e. pauses). Data were analysed using inductive approaches, via open coding. Generated codes were then categorised through axial coding whereby original codes were subsumed under broader categories[38]. Finally, selective coding was applied to identify key emergent themes in the creation of key concepts[38].

Results

Descriptive statistics

From the total sample of 3444 U6M (51·9 % female, mean age = 2·98 months, SD = 1·34), 5·9 % (*n* 202) were admitted to GOAL Ethiopia's MAMI programme, 59·2 % were not admitted and 34·9 % had no record of whether they were admitted or not admitted. With respect to the different anthropometric measures of malnutrition, 8·3 % (*n* 286) of U6M met the criteria for malnutrition based on MUAC scores < 115 mm; 3·7 % (*n* 129), based on MUAC scores < 110 mm; 5·1 % (*n* 177), based on WAZ scores < –3·0 and 3·9 % (*n* 133) and based on WLZ scores < –3·0 (Table 1).

Missing data analysis

Significant differences between those with missing data on admittance, those who were admitted and those who were not admitted were identified across all three anthropometric measures ($P < 0.001$). Post hoc analysis suggested no differences between U6M who had no information on admittance and those not admitted to MAMI. Differences were found, however, on those who were admitted for MAMI, whereby those who were admitted were recorded as having lower WAZ, WLZ and MUAC scores. This suggests that the reason why no record of admittance was made in certain cases is possibly due to the absence of the U6M meeting any of the cut-off criteria for malnutrition.

Table 1 Prevalence of infants under the age of 6 months (U6M) meeting the criteria for malnourishment according to international cut-offs, the results of the factor mixture model and as per programme admittance

Criteria	Malnourished		Nourished	
	n	%	*n*	%
Traditional cut-offs				
WAZ	177	5·1	3273	95·0
WLZ	133	3·9	3311	96·1
MUAC < 115 mm	286	8·3	3158	91·7
MUAC < 110 mm	129	3·7	3315	96·3
MAMI Programme Admittance	202	9·0	2039	91·0
Factor mixture model	196	5·7	3248	94·3

WAZ, weight for age *z*-scores; WLZ, weight for length *z*-score; MUAC, mid-upper arm circumference; MAMI, Management of At Risk Mothers and Infant.

Objective 1

The factor mixture modelling results identified two distinct groups of U6M in this population (Table 2). The first group included 94·3 % (*n* 3248) of U6M, with infants in this group characterised by normative scores on each anthropometric measures of nutrition (WAZ = –0·10, WLZ = –0·22, and mean MUAC = 132·29). The second group included 5·7 % (*n* 196) of U6M, and these infants were characterised by WAZ scores of –3·86, WLZ scores of –1·61 and mean MUAC scores of 114·80 mm, thus reflecting a group of U6M experiencing malnutrition (Table 3). The profile plots for both groups are represented in Fig. 1.

The association between group membership and admission for MAMI was statistically significant ($\chi^2 = 226.39$, df = 1, $P < 0.001$), whereby individuals in the malnourished group were 10·79 times more likely to be admitted for therapeutic intervention than those in the well-nourished group (OR = 10·79, 95 % CI = 7·47–15·60). Only 43·2 % of U6M in the malnourished group were admitted for MAMI; and of all U6M who were admitted for MAMI, only 31·7 % belonged to the malnourished group.

Objective 2

The results of the bivariate and multivariate associations between admittance for MAMI and meeting internationally recognised criteria for AM are presented in Table 4. Admittance to MAMI was most strongly associated with MUAC scores < 115 mm (OR_{adj} = 366·03), followed by WLZ scores < –3·0 (OR_{adj} = 2·89) and WAZ scores < –3·0 (OR_{adj} = 2·12). Cross-tabulations indicated that 82·9 % of U6M with MUAC scores < 115 mm were admitted for MAMI, 30·7 % of U6M with WAZ scores < –3·0 were admitted for MAMI and 26·7 % of U6M with WLZ scores < –3·0 were admitted for MAMI.

Objective 3

A number of key themes emerged with regard to barriers to the identification of AM within U6M: (i) health care workers (HCW) misconceptions surrounding the existence and cause of AM in this age group, (ii) a dearth of evidence and (iii) issues with the current identification protocol, especially with measures of WLZ. Misconceptions regarding the nature of AM in U6M described as a 'stigma' (P1) and one of the 'biggest hindrances' (P4) was mentioned frequently (*n* 7) and in length. Namely, the lack of awareness and recognition that AM can and does exist in U6M was seen as an important barrier, as explained by Participant 4: 'The biggest challenge has been the assumption that there is no malnutrition within this age group ... because then if

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Table 2 Fit indices from the factor mixture models (*n* 3444)

Classes	Log likelihood	AIC	BIC	ssaBIC	LMR-A	*P*	Entropy
1	−16 933	33 884	33 939	33 911	–		–
2*	−16 879	33 780	33 848	33 813	101	0·002	0·80
3	−16 870	33 767	33 847	33 806	16	0·409	0·85
4	−16 864	33 758	33 850	33 802	12	0·248	0·81

AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; ssaBIC, sample size adjusted BIC; LMR-A, Lo-Mendell-Rubin Adjusted Test.
*Best fitting model.

Table 3 Mean, SD and confidence intervals (95 %) for the two-class solution

Class	*n*	Mean	SD	95 % CI
Nourished				
WAZ	3248	−0·10	1·29	−0·15, −0·06
WLZ	3248	−0·22	1·53	−0·27, −0·16
MUAC (*z*-score)*	3248	132·29 (0·08)	0·93	0·05, 0·11
Malnourished				
WAZ	196	−3·86	0·91	−3·99, −3·73
WLZ	196	−1·61	2·01	−1·90, −1·33
MUAC (*z*-score)	196	114·8	1·16	−1·46, −1·14

WAZ, weight for age *z*-scores; WLZ, weight for length *z*-score; MUAC, mid-upper arm circumference.
*MUAC scores were transformed to *z*-scores for the purposes of Factor Mixture Modelling so that all measures were equally scaled.

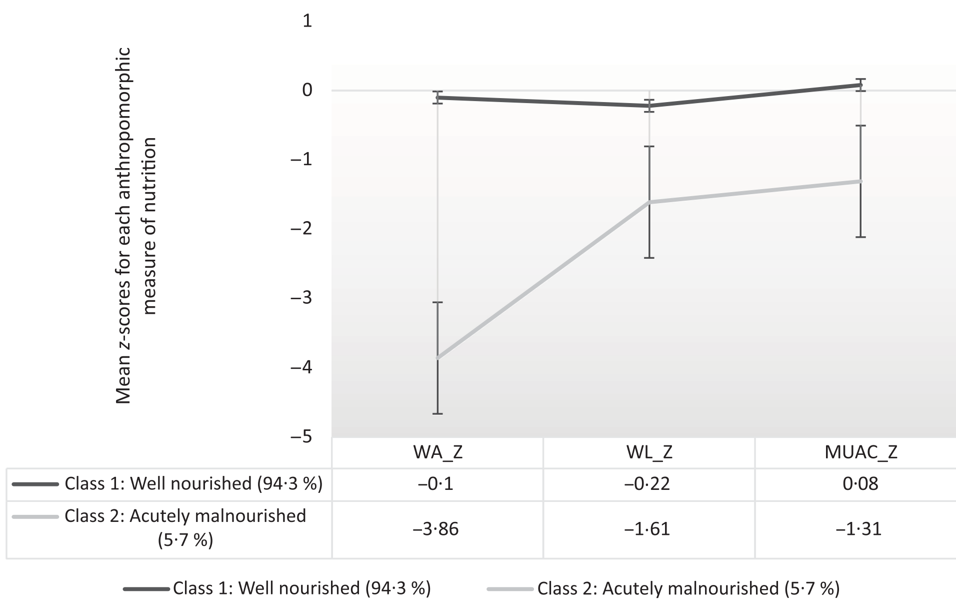

Fig. 1 Mean *z*-scores for each anthropomorphic measure of nutrition

you don't think there is a problem you don't look for it'. Misconceptions further included the belief among field-workers that AM is 'impossible' in U6M (*n* 3), with some rationalising this with the fallacy that U6M are protected from AM due to EBF (*n* 2). It was suggested that this lack of awareness contributes to a lack of effort to identify AM among U6M (P11).

Ubiquitous across each interview was the second theme of a lack of evidence regarding the identification of AM in U6M. Described by P8 as the 'black hole in terms of data', with standard surveys focusing on 6–59 months, a systematic exclusion of U6M infants (*n* 3) has led to a lack of longitudinal data on MUAC for U6M (P4). As explained by Participant 2: 'The number of AM children U6M is not a figure or a measure that we see very often in reports, so people have a tendency, I think, of thinking that it's quite rare and therefore it's never something that is necessarily prioritised'. With insufficient research on the issue, one is unable to demonstrate need and consequently incite adequate action (*n* 2). It was proposed that the systematic measurement of MUAC for this age group will, in itself, generate data (P5).

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Table 4 Bivariate and multivariate associations between admittance for Management of At Risk Mothers and Infants (MAMI) and international criterion guidelines for acute malnutrition

	χ^2/B	P	OR	95 % CI
Bivariate associations				
WAZ < –3·0	229·23	< 0·001	8·26	6·06, 11·26
WLZ < –3·0	117·39	< 0·001	5·16	3·74, 7·13
MUAC < 115 mm	1639·45	< 0·001	538·28	301·15, 962·14
Gender (0 = Male, 1 = Female)	7·55	0·006	1·51	1·12, 2·03
Multivariate associations				
Logistic regression model	957·54	< 0·001	–	
WAZ < –3·30	0·75	0·025	2·12	1·01, 4·09
WLZ < –3·0	1·06	0·004	2·89	1·41, 5·92
MUAC < 115 mm	5·90	< 0·001	366·03	196·82, 680·74
Gender (0 = Male, 1 = Female)	0·46	0·123	1·58	0·88, 2·84
Age	–0·23	0·044	0·80	0·64, 0·99

WAZ, weight for age *z*-scores; WLZ, weight for length *z*-score; MUAC, mid-upper arm circumference.
B = unstandardised beta value; *P* = statistical significance value; all comparisons have 1 df; logistic regression model has 5 df.

All eleven interviewees mentioned the current WLZ case definition as a barrier to identification of AM in U6M, with the criteria being described as 'very rigid' and 'legalistic' (P3). Issues with WLZ arose at each stage of the WLZ process. First, obtaining the anthropometric measurements of weight and length was considered difficult due to the poor availability of equipment (*n* 2), with procurement of equipment being a particularly big barrier in rural settings (P9). The reliability of the equipment was also mentioned in terms of the accuracy of weighing scales (*n* 2) and the difficulty of measuring the physicality of U6M equating to a larger margin of error in terms of measurement (P2). Where equipment was available, the physical measurement itself can be inconsistent, i.e. removal of infant's clothes before weighing (P10), with difficulties obtaining U6M height being described as 'particularly challenging' (P2), and requiring more resources, including more staff, 'at least 2 people, ideally 3, whom are a higher capacity of health worker' (P5) and time (*n* 2), whereby 'realistically people won't have time to do it in practice in the field, it won't be done'. Finally, the majority of participants expressed that even when WLZ is performed well it is not an ideal measurement for U6M (*n* 9). Issues with WLZ being 'not necessarily reliable or accurate' (P4) for U6M included WLZ being superimposed from the 6 to 59 month age group without much supporting evidence (P4) and not accounting for low birth weight infants or those small for gestational age (*n* 2).

Although considered a 'very poor prognostic indicator of mortality' (P3), the transition from WLZ to another measure was flagged as difficult: 'I think it's fetishized in a way . . . people really, really stick to this (WLZ) . . . no matter how much evidence you give to people they will still go out and use weight for height' (P3). There appeared to be a further barrier in the way of overcoming this, as other feasible options such as MUAC are not supported with official guidance and thus its use is prevented (*n* 2), one participant even considered this the 'biggest barrier' to the identification of AM in U6M (P5).

To address these barriers, a number of possible solutions were acknowledged, including using a more appropriate tool for identification, whereby the majority of participants named MUAC as the preferred option. MUAC was described as 'the only way forward really' (P1), with its perceived advantages being its simplicity, efficiency, low cost and ease of transport and use (*n* 2), in addition to possibly increasing access to screening and increasing the number of detected cases (*n* 2). As participant 11 stated: 'I think the evidence is becoming stronger and stronger that MUAC is the way forward for this group as, and will, is the one thing that will revolutionise their management'. Furthermore, MUAC and WAZ were flagged as more practical (P1), easier to use (P10) and better predictors of mortality (P4) in comparison with WLZ. However, all of those that did explicitly mention MUAC discussed the need to use appropriate cut-offs (*n* 6).

Although breast-feeding was mentioned by ten of the eleven participants, it was expressed as both a potential facilitator (*n* 4) and barrier (*n* 6) to the identification of AM in U6M. Breast-feeding emerged as a facilitator to identification of AM, particularly where there is a lack of equipment for WLZ measures, 'the only thing that they can do is assess if there is any breastfeeding problem . . . so they need to be trained on that simple, simple rapid assessment of breastfeeding problem'. HCW available and already trained to assess breast-feeding practices in combination with clinical signs of AM were also perceived to be facilitators to the identification of AM in U6M (*n* 4). Numerous interviewees expressed that they felt breast-feeding assessment should be used for identification in collaboration with anthropometry (*n* 3), while some suggested the case definition of AM in U6M should include risk factors such as breast-feeding practices (*n* 2).

Breast-feeding was also portrayed as a potential barrier to the identification of AM. As participant 11 explained: 'I think there's that false logic that infants should be breastfed and therefore malnutrition is rare in that age group'.

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The assumption that U6M are exclusively breastfed and thus are protected from AM was described as a key barrier (*n* 2), and breast-feeding and infant and young child feeding practices are an additional challenge particular to this cohort of children (P10). Subsequent treatment related to breast-feeding following the diagnosis of AM was also suggested to be a barrier to identification as it disincentivised HCW:

> *Identification would kind of have to be accompanied by treatment and because with infants under 6 months that would have to be a lot about breast-feeding and kind of counselling the mother and kind of supporting the mother … that's also a kind of barrier for even starting the identification because of the treatment that's implied (P10)*

Finally, the lack of evidence of breast-feeding benefits for rehabilitating malnourished infants was suggested to further disincentivise HCW to perform the initial identification (P4), with the idea of treating a malnourished infant U6M with anything other than the breast being described as 'taboo' (P3). It was noted that a 'kneejerk reaction' by influential breast-feeding advocates, referred to by one participant as 'breast fundamentalists,' could potentially hinder progress in the identification of AM in U6M.

Discussion

U6M are routinely excluded from malnutrition prevalence rates and nutrition interventions globally, prompting MAMI experts and a number of international agencies to call for a stronger evidence base for efficient management of AM in infants[21,39,40]. Part of this is due to misconceptions regarding the existence and causes of malnourishment in U6M, including the assumption that U6M are inherently protected from malnourishment by breast-feeding. There is some overlap between our key informant interview findings, regarding perceived causes of AM in U6M and breast-feeding practices, and similar key informant interviews within the literature[41]. In light of the current absence of an agreed upon method by which to most effectively identify malnutrition among U6M, we applied novel statistical methods (factor mixture modelling) that used information from WAZ, WLZ and MUAC scores to determine whether there were two distinct groups within this population. One group, representing 94·3 % of the population, was characterised by normative WAZ (–0·10) and WLZ (–0·22) scores and a mean MUAC score of 132·29 mm. These anthropometric measures are consistent with international guidelines for healthy levels of nourishment. The second group, representing the remaining 5·7 % of the population, was characterised by extremely low WAZ scores (–3·86), low WLZ scores (–1·58) and a mean MUAC score of 114·80 mm. Consistent with recognised cut-off criteria for 6–59 months, including WAZ of < –3·0 and for MUAC scores of < 115 mm, as well as others who found non-negligible levels of wasting among U6M[4], we therefore found evidence of the existence of malnourishment among this age group. Further, and also consistent with previous findings[42], our results suggest that malnourished children can be most effectively differentiated from their nourished counterparts by the WAZ anthropometric measure. Our results also support the use of MUAC < 115 mm as an appropriate cut-off to identify malnutrition in this population, a finding that is consistent with the most recent revisions made to MUAC cut-offs by the WHO[21].

Among the total population of U6M, 5·9 % were recorded as having been admitted for MAMI. Our findings suggest the possibility that a large number of U6M belonging to the well-nourished group were admitted for MAMI. Conversely, more than half of U6M belonging to the malnourished group were excluded from MAMI programming. These results highlight the possible consequences of the lack of availability of clear protocols and guidelines around the identification and admission criteria for U6M, a theme which also emerged as a perceived barrier to the identification of AM in U6M within the qualitative interviews. Specifically, the absence of evidence-based guidelines will inevitably result in the misallocation of scarce resources, the exclusion of vulnerable U6M from life-saving interventions and the unnecessary inclusion of U6M and their caretakers in what amounts to time- and resource-intensive therapeutic interventions.

In relation to the study's second objective, results of the bivariate and multivariate analyses indicated that admittance to MAMI, in practice, was most strongly associated with the use of the MUAC criterion of scores < 115 mm. Although amongst the literature, MUAC is recognised as a reliable measure among children aged 6–59 months valued for its simplicity, accuracy, reproducibility and affordability[25,43,44], it has also been criticised for its strong association with gender, age and stunting therefore negatively affecting its validity[25]. Consistent with internationally recognised guidelines, U6M that met this criterion (MUAC < 115 mm) were 366 times more likely to be admitted than those that did not, controlling for sex, age and all other anthropometric measures. In contrast, despite WAZ emerging as the most discriminating anthropometric measure, approximately 70 % of U6M that satisfy this criterion (WAZ < –3·0) are not being admitted for treatment for malnutrition.

There is therefore a clear disconnect between the anthropometric measure that most clearly distinguishes U6M in the malnourished group and those in the well-nourished groups (i.e. WAZ scores) and the anthropometric measure that was most strongly associated with MAMI admission (i.e. MUAC scores < 115 mm). As gleaned from the qualitative interviews, however, this is likely due to the simplicity, affordability and ease of use of the MUAC over more onerous and time-consuming methods, where

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equipment (i.e. weighing scales) is not always available or reliable[25,43]. Therefore, while a greater reliance on WAZ scores for the identification of malnutrition should lead to improved access to treatment for those U6M most in need of care, this needs to be considered in light of the practicality of other, more sensitive methods. Furthermore, although this study explored admittance to MAMI not mortality, among 1–6-month-olds, Mwangome et al.[42] found that WAZ and MUAC were better predictors of mortality than WLZ. Consistent with others suggesting the best cut-off for MUAC to be < 110 mm[21,42], Mwangome et al.[42] found this to be a greater predictor of mortality among 1–6-month-olds than WLZ scores < –3·0.

A stronger emphasis on the use of WAZ is consistent with international guidelines of growth monitoring among children under 2 years of age. However, the challenge remains in weighing the additional financial and human resource costs of using WAZ against the more scalable, but potentially overly sensitive and less accurate, use of MUAC scores. Aligned with the results of the factor mixture modelling, interviewed international nutrition experts identified WAZ and MUAC scores as the most practical methods to identify malnutrition, compared with WLZ. Unanimously, WLZ was reported as a barrier to the identification of AM by MAMI experts, concerns consistent with the literature such as the exclusion of smaller infants < 45 cm from WLZ plotting[17,45] were noted.

Furthermore, the efficiency of MUAC in the field over WLZ based on the reliability of measurements taken by HCW is also reflected within the literature[43]. As noted by Kerac et al. in addition to the reliability of WLZ being questionable, there is limited evidence of its validity and accuracy in U6M[46]. Practically, WLZ is a less favoured indicator given the challenges associated with measuring the length of an infant. Consequently, and as Grijalva-Eternod *et al.* noted, length is often missing in admission data for U6M[17]. Specifically, in terms of practical use, it was found that procurement and reliability of equipment for measuring weight/height and inconsistencies during the measurement process are perceived barriers to the identification of malnutrition. This is concurrent with literature detailing barriers such as fears of harming the infant, unfamiliarity with taking weight and height measurements for such a young age group and the use of differing scales[4] noted as negative aspects to the standard anthropometric measurements.

Limitations

The current study is not without limitations. First, this being a cross-sectional study, there is an absence of outcome criteria (i.e. infant mortality) with which to compare the different anthropometric criteria. As such, we cannot infer which anthropometric criterion is most effective to predict mortality. Similarly, the absence of confounding factors such as maternal age and education, number of other children in the household and the presence of disease or pitting oedema among infants, as additional factors that could have influenced programme admittance, is another limitation of this study. Third, as the data were manually transcribed from paper forms to the data base there are potential for transcription errors. Fourth, as the sample was U6M refugees, whom, as discussed, present a particular vulnerability to malnutrition, the findings may not be generalisable to other infants U6M.

Conclusions

The lack of a standardised identification tool for malnutrition in U6M potentially equates to the exclusion of many vulnerable U6M from potentially life-saving MAMI programmes while a proportion of healthy U6M are unnecessarily enrolled for resource-intensive inpatient therapeutic interventions. This study shows a clear disconnect between the most discriminant anthropometric measurement WAZ and the anthropometric measurement with the most associated admissions to therapeutic intervention (WLZ). The statistically driven results are consistent with expert opinions that MUAC is a preferred method of anthropometric measurement to identify malnutrition in U6M in the field. However, the scalability, ease of use and reduced human and time resources associated with MUAC need to be considered against the specificity and reliability of WAZ. Further research is required for future predictions of morbidity and mortality outcomes based on the use of the different anthropometric measurements.

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and discussion. Ethics of human subject participation: Approval to access the de-identified secondary data was obtained from GOAL. GOAL also acted as a gatekeeper, linking the lead author to the MAMI special interest group. Potential informants were initially invited to participate by email, and both verbal and written consent were obtained prior to the start of the interview. Ethical approval to perform the study was obtained by HPM/Centre for Global Health Ethics Committee, Trinity College Dublin.

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