

Development of a Photographic Figure-rating Scale for Detection of Wasting Among Infants 9-12 Months in Buyende, Uganda

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ABSTRACT

Wasting among infants and young children remains a significant public health concern, and accurate identification of infants with severe undernutrition is crucial for ensuring timely intervention and prevention of adverse health outcomes. For mothers with low literacy levels, detection using conventional anthropometric measures can be difficult due to interpretation challenges, leading to delayed maternal care-seeking, and poor health outcomes for the child. This study aimed to develop a photographic figure-rating scale based on WHO weight-for-height z-scores for infants and young children (9-12 months), to empower mothers prevent childhood wasting in the rural communities of Buyende District, Uganda. A cross-sectional study was conducted involving 210 mother-infant pairs. A culturally appropriate 5-point figure-rating scale was developed, depicting infant body sizes matching WHO z-scores from -2 to +2. The developed scale showed moderate accuracy (67%) CI: 60.4% - 73.0%; with a sensitivity and specificity value of 64.4% (CI: 57.9% - 70.9) and 77.8% (CI 72.1% - 83.5%); respectively. A positive predictive value of 93.3% (CI: 87.06 - 99.60) demonstrates that most positive results (56/60 were true positives. In conclusion, a 5-point photographic figure-rating scale developed was moderately accurate in detecting wasting in children.

Keywords: Wasting, Infants, Photographic Figure-Rating Scale, Buyende, Uganda.

INTRODUCTION

Childhood wasting has profound and enduring implications, encompassing compromised psychomotor and cognitive development, as well as diminished productive capacity in adulthood [1]. This issue persists as a significant public health challenge among infants in Uganda, particularly in rural regions where healthcare access and nutritional assessment tools are scarce. Timely identification of wasting is essential to avert health complications in infants. On a global scale, numerous infants under five years of age experience wasting [2,3], with 19 million afflicted by severe

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acute malnutrition (SAM) [3]. A considerable proportion of these affected infants are found in South Asia and Africa [1], with a substantial annual mortality rate attributed to malnutrition [4].

In Busoga sub-region of Uganda, where Buyende district is located, the prevalence of stunting among infants aged 6-23 months is alarmingly high at 29.0%, surpassing the national average of 26% [5,6]. Paradoxically, malnutrition is seldomly the primary impetus for maternal healthcare visits; rather, infants are typically presented due to comorbidities. This phenomenon highlights a critical issue in the healthcare-seeking patterns of families in the region, particularly in monitoring infant growth and development. While conventional methodologies employing anthropometric measurements plotted on standardized growth charts are crucial for detection of growth faltering [7], the interpretation of these charts necessitates a level of literacy that is often lacking among low literate mothers [8]. Research demonstrates that literacy profoundly influences the ability to comprehend these charts, which is vital for monitoring infant growth and preventing malnutrition. It has been reported that literate mothers achieved an average score of 4.5 in growth chart interpretation, whereas their illiterate counterpart scored 3.2, underscoring a significant comprehension disparity [9]. Systematic reviews have further indicated that between one-third and three-quarters of caregivers in developing nations struggle with growth chart comprehension, with literacy serving as a primary determinant [10]. This knowledge deficit frequently results in delayed healthcare-seeking for the malnourished infants until severe symptoms or comorbidities manifest.

The efficacy of pictorial representations in health communication has been extensively documented [11-13]. Addressing malnutrition necessitates not only increased awareness but also accessibility to methods for assessing infant growth that can be comprehended by low literacy caregivers in rural areas. The implementation of health

literacy initiatives, such as the application of this novel photographic Figure-rating Scale (FRS), can significantly enhance maternal empowerment, leading to improved health outcomes for infants [14].

Initially developed by Stunkard [15], the FRS serves as a visual tool for assessing body image and perceived body size, and has been adapted for various applications in body image assessment and eating disorder research [16,17]. Currently, over 40 instruments or scales exist for measuring body image [18]. These are classified into three distinct categories: figure preferences [19-22], video projection techniques [23,24], and questionnaires [25-29]. These instruments have been developed using a combination of traditional and contemporary methodologies, varying in image quantity (typically 9-images), facial characteristics, gender representation, and development techniques. [30-34]. In the field of child nutrition, similar visual scales could offer a more accessible approach for low literate mothers to evaluate their infants' nutritional status and monitor growth. This study aimed to develop visual photographic FRS for infant wasting screening based on WHO weight-for-height standards for Infants and Young Children, thereby; thereby empowering mothers to improve maternal health seeking behavior.

MATERIALS AND METHODS

A cross-sectional study was conducted in six sub-counties of Buyende district, Eastern Uganda, including; Kidera, Nkondo, Buyende Town Council, Buyende, Bugaya, and Kagulu, from April to June 2023. The study population comprised of biological mothers of infants (boys and girls) aged 9-12 months. Calculation of the desired minimum sample size using G*Power 3 [38], yielded a sample size of 236. Two hundred and ten (210) mother-infant pairs gave consent and participated within the period of the study. The obtained power ($1-\beta$) from the post-hoc analysis (Table 1) was above 80%, indicating an adequate sample size for the study.

Table 1. Post-hoc Power Analysis

Characteristic	Sensitivity		Specificity		Accuracy	
	Lower CI 95%	Upper CI 95%	Lower CI 95%	Upper CI 95%	Lower CI 95%	Upper CI 95%
Effect size	0.0579	0.209	0.2208	0.3348	0.104	0.23
α -value	0.05	0.05	0.05	0.05	0.05	0.05
Sample size	210	210	210	210	210	210
Constant proportion	0.5	0.5	0.5	0.5	0.5	0.5
Obtained power ($1-\beta$)	0.717	0.999	0.999	1.000	0.910	0.999

Convenience sampling during routine immunization visits was used to select the eligible mothers who were the primary caregivers of the children. The study was conducted in four phases. Phase 1 involved participant selection; phase 2, anthropometry and FRS development; phase 3, assessment of maternal perceptions and satisfaction on use of the scale; and phase 4, FRS field use. A pilot study was conducted before conducting the phased study, and this was done outside the study area, to test the validity and reliability of the study tools. This paper reports the data for Phases 1, 2, and 4.

Participant Selection

All mothers from the six selected sub-counties of Buyende district, who brought their infants (9-12 months) to the health center on the due date for immunization within the study period, were eligible to participate in the study as long as the infants were brought entirely for immunization, and not for treatment of illnesses. Because of the short duration of the study and logistical issues, the researchers were able to recruit 210 mother-infant pairs in the study. All ethical guidelines were followed in the recruitment of mother-infant pairs, and research assistants with a health and nutrition background were properly trained on the methods of data collection.

Data Collection

Phase 1 involved the collection of data using a content validated semi-structured questionnaire conducted by research assistants in the local language (Lusoga). The semi-structured questionnaire collected socio-demographic and food consumption data from the mothers.

Development of the Photographic Figure-Rating Scale (FRS)

Development of the FRS followed a review process of the 9-FRS developed by Mutale [39]. This scale was reviewed for relevance, clarity and representativeness of images by a panel of four experts (3 from Makerere University, and 1 from the Ministry of Health) in Uganda. This was done by classifying

images based on body size categories, aligning the categories with established anthropometric cut offs (WHO weight-for-age z-scores for children), and expert validation to confirm that the images accurately represented body size variations. Expert validation used a Likert scale (1 = Not relevant, 4 = Highly relevant) to rate each image. All the 4 experts agreed they were relevant and suitable for adaptation to the Ugandan context, and developed 7-graphic dummies of the infant FRS for boys and girls (Figures 1 a and b; respectively), to guide the development of the photographic FRS.

Phase 2 of the study was the anthropometric measurements (weight, length/height) of all the recruited 210 infants using a digital weighing scale (SECA 877, GmbH & Co. KG (Germany), calibrated to the nearest 0.1kg. To obtain the infant weight, measurements were taken without clothes. Similarly, to obtain the height, measurements were performed following standard procedures, with a length/height board (SECA 213, GmbH & Co. KG, Germany); calibrated to the closest 0.1cm. Three measurements were taken and mean obtained. The measurements were transferred to ANTHRO plus software, to obtain the weight-for-height z-scores based on the WHO standards [40].

The mother of an infant whose Z-scores fell at exactly -2.0, -1.0, 0, + 1.0, and + 2.0 z-scores was requested to sign consent for photography, and subsequently photographed. During photography, the infant was dressed in diapers only, and with support from their mother, made to lie on the surface of the measuring board. He/she was then photographed with a high-resolution camera and with the help of a graphic designer, the respective photographs were converted into pictorials (i.e. one per z-score for each BMI-for-age category), for the respective sex groups. Numerous photographs were taken for each category, of which only the best (five for boys and five for girls) were selected to represent others in the development of the photographic FRS. Despite the fact that infants measuring +3 z score of the WHO scale was available in the community, it was not possible to find matching infants for -3 z score to complete a 7-point FRS as was intended.

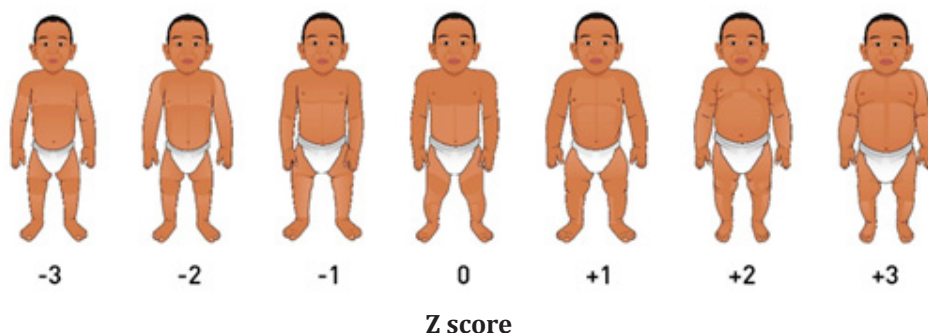


Figure 1a. A dummy infant figure-rating scale for boys.

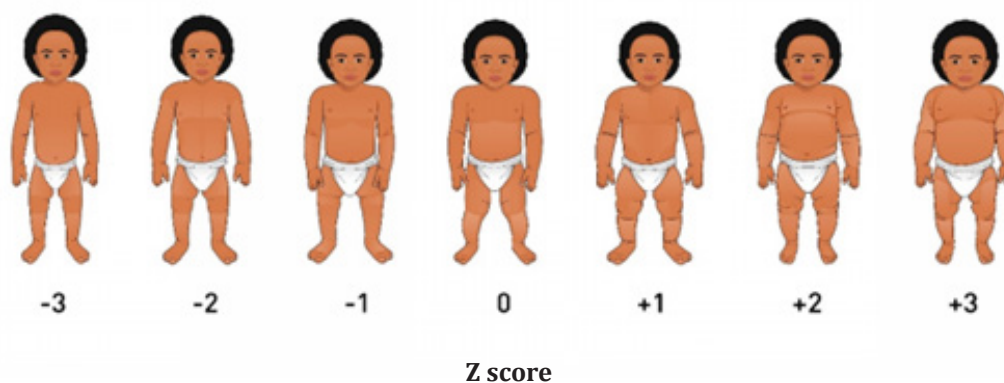


Figure 1b. A dummy infant figure-rating scale for girls.

Determination of Accuracy of the Photographic FRS

Determination of accuracy (Phase 4) included a sub-sample of mother-infant pairs ($n=105$). Systematic sampling was done where a mother-infant pair was picked after every one pair, contributing to 50 percent of the study group. To determine accuracy, mothers were given the developed photographic FRS (-2, -1, 0, +1, +2), unaware of the reference measurements and asked to identify the photograph to which the index child conformed.

Responses were recorded as 1) true positive, 2) true negative, 3) false positive and 4) false negative (Table 1). The respective responses were then used in a confusion

matrix to calculate common performance metrics (accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the scale.

Data analyses

Quantitative data were analyzed using STATA/SE version 14 to generate the necessary descriptive statistics.

Reliability of the photographic FRS was analyzed using a confusion matrix (Table 2). The ability of the mothers to match the picture to the correct size of the index infant (up to 70% and above) indicated consistency and good performance of the FRS [41,42].

Table 2. Calculation of sensitivity and specificity ($n=105$)

Sensitivity = $\frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$		Specificity = $\frac{\text{True Negatives}}{\text{True Negatives} + \text{False Positives}}$	
PPV = $\frac{\text{True Positives}}{\text{True Positives} + \text{False Positives}}$		NPV = $\frac{\text{True Negatives}}{\text{True Negatives} + \text{False Negatives}}$	
Accuracy = $\frac{\text{True Positives} + \text{True Negatives}}{\text{True positives} + \text{False Positives} + \text{False Negatives} + \text{True Negatives}}$			

Where:

- True Positives: Infants correctly identified as wasted by the FRS.
- True Negatives: Infants correctly identified as not wasted by the FRS.
- False Positives: Infants incorrectly identified as wasted by the FRS (false alarm).
- False Negatives: Infants incorrectly identified as not wasted by the FRS (missed cases).
- PPV: Positive Predictive Value

NPV: Negative Predictive Value

Post hoc Analysis

The post hoc power analysis was done on the confidence intervals of the obtained sensitivity (64.37, CI 95%: 57.9-70.9%), specificity (77.78, 95% CI:72.08%-83.48%) and accuracy (66.67%, 95% CI:60.4%, 73.0%) using G*Power version 3.1.9.7 following Zhang [43]. A medium effect size (Cohen's $h = 0.5$) was anticipated [44,45], Table 1.

Likelihood Ratios for detection of Positive and Negative Cases of wasting

From the sensitivities and specificities, the likelihood ratios for detecting positive and negative cases of wasting (LR^+ and LR^-) were also calculated using the formulae below, to understand the probability that the scale possesses to detect positive and negative cases [45].

*Positive Likelihood Ratio = Sensitivity/(1-Specificity);

*Negative Likelihood Ratio = (1- Sensitivity)/specificity.

Thresholds; $LR^+ > 10$ = Strong diagnostic evidence (significantly increases the probability of disease); LR^+ between 5 and 10 = Moderate evidence; LR^+ between 2 and 5 = Weak evidence; LR^+ close to 1 = No diagnostic value (test does not change probability significantly) for the positive likelihood ratio, and;

$LR^- < 0.1$ = Strong diagnostic evidence (significantly decreases

probability of disease); LR^- between 0.1 and 0.2 = Moderate evidence; LR^- between 0.2 and 0.5 = Weak evidence; LR^- close to 1 = No diagnostic value (test does not rule out disease effectively) for the negative Likelihood Ratio.

Ethical approval

Ethical approval was obtained from the Makerere University School of Social Sciences, Research and Ethics Committee (MakSSREC; REC003219.01.) and the Uganda National Council for Science and Technology (UNCST; HS2137ES). The clearance to conduct the study in Buyende District was obtained from the chief executive officer. Informed consent was obtained from all the participants. Additionally, participants in the study were first consulted and their consent was obtained before they were enrolled and registered.

RESULTS

Demographic characteristics of the mothers

The study reports data for 210 mother-infant pairs (Table 3). The mean age of the mothers was 26.3 years ($SD \pm 5.7$), with all mothers having either received primary education (Grade 1-7 (primary school)) or no formal education. The mean age of the infants was 10.2 months ($SD \pm 1.1$), with 52.4% female and 47.6% male infants. Of the participating mothers, 54.3% reported being employed, in the informal sector.

Table 3. Socio-demographic data of the study participants (n=210)

Variable	Frequency (n=210)	Percentage (%)
Mothers' age		
17-20	56	26.7
21-30	124	59.1
30-max	30	14.3
Infant's Gender		
Male	100	47.6
Female	110	52.4
Infants age		
09-10	150	71.4
11-12	60	28.6
Level of Education		
No formal education	12	5.7
Grade 1-7 (primary school)	198	94.3
Grade 1-4 (Lower secondary school)	0	0
Grade 5-6 (Higher secondary school)	0	0
Grade 7 and above (Post- secondary education)	0	0
Employment status		
Yes	114	54.3
No	96	45.7

The Developed Figure-rating Scale (FRS)

The 5-point photographic FRS (-2, -1, 0, +1, +2) for boys and girls are presented (Figures 2a and 2b; respectively).



Figure 2a. A 5-point photographic (weight-for-height z scores) FRS for boys.

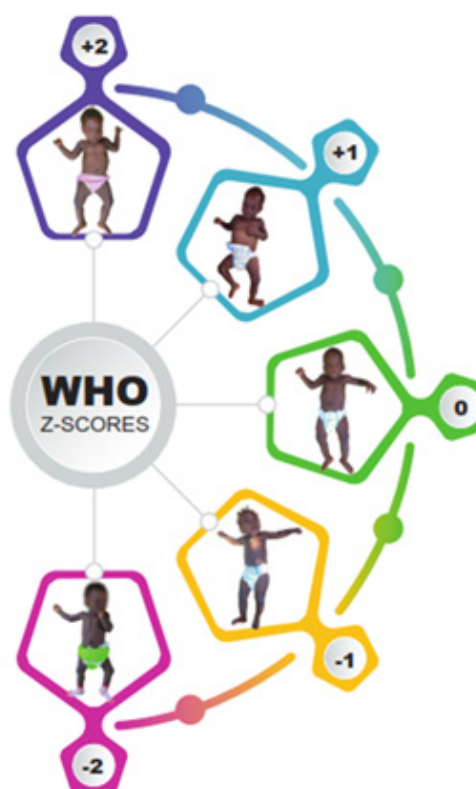


Figure 2b. A 5-point photographic (weight-for-height z scores) FRS for girls.

Accuracy, Sensitivity and Specificity of the developed FRS

The accuracy (66.7%) of the photographic FRS was found to be modest (PPV: 93.3; NPV: 31.1) while the sensitivity and specificity (Table 4) were moderately and relatively high (64.4% and 77.8%; respectively). The FRS scale

demonstrated a specificity of over 70% and a positive predictive value (PPV) exceeding 90%. Its accuracy ranged from 60% to 73%, while sensitivity varied between 57% and 70%. However, the scale showed a low negative predictive value (NPV), remaining below 50%.

Table 4. Sensitivity and Specificity measures of the Figure-rating Scale (n=105)

Measures (TPs, TNs, FPs, FNs)	Value (Percent)	95% CI (Lower - Upper)
Sensitivity (TP 56, FP 31)	64.37	57.9 – 70.90
Specificity (TN 4, FN 14)	77.78	72.08 – 83.48
PPV (TP 56, TN 4)	93.33	87.06 – 99.60
NPV (TN 31, FN 14)	31.11	17.56 – 44.66
Accuracy (54, 4/54, 14, 31, 4)	66.67	60.40 – 73.01

Standard Error (SE) = $\sqrt{p * (1 - p) / n}$, Margin of Error = $z (1.96) * SE$, CI = Value $\pm$ Margin of error

Likelihood Ratios for the detection of Positive and Negative Cases of wasting

Table 5 indicates the likelihood ratios obtained for the sensitivity and specificity of the figure-rating scale. Both

the LR+ (2.8) and LR- (0.47) show that the scale provides weak evidence (R+ between 2 - 5; and LR- between 0.0 - 0.5), in its likelihood of separating children into the respective categories.

Table 5. Likelihood ratios for sensitivity and specificity measures of the photographic Figure-rating scale

Positive Likelihood Ratio (LR+)	Negative Likelihood Ratio (LR-)
0.64	1 - 0.64
$\frac{0.64}{1-0.77}$	$\frac{0.77}{0.77}$
2.8	0.47

DISCUSSION

Development of the FRS

The photographic Figure-rating Scale (FRS) serves as an effective tool for assessing body image and dissatisfaction, proving its usefulness among various groups, including adults, children, and other minority groups [46]. Various approaches have been used in creating Figure-rating Scales (FRS) [47], including figural drawings, silhouettes, and photographic methods (photographic techniques, video techniques, or computer software). The use of photography in developing figure-rating scales is well-established [48,49], especially in body image evaluations, consistently demonstrating the reliability and validity of photographic methods for capturing subjective assessments. In a recent study, Ralph-Nearman et al. [50] introduced and validated two new scales: the “Female Body Scale (FBS)” for the

thin-ideal and the “Female Fit Body Scale (FFITBS)” for the muscularity-ideal, both of which proved reliable and valid in measuring different aspects of body dissatisfaction in women. Unfortunately, all these figure-rating scales were developed for adult but not infant use.

This study successfully created a 5-photographic FRS for infant boys and girls aged 9-12 months (ranging from -2 to +2 z-scores), (Figure 2a & 2b), using similar photographic techniques. The FRS does not definitely compare to the scales reported in the literature because of differing age groups. The shift from a 9- to a 5- FRS in this study was guided by WHO reference standards [40], which employs a 7-rating scale (+3 to -3z scores). The initial plan of the study was to develop a 7-figure-rating scale in line with WHO growth charts, but this was not achieved due to the inability to find children on the -3 z score of the FRS.

The reasons for inability are not well understood, having been a short study. However, one possible explanation suggested by some authors [52] is that infants in this age group may not have reached severe undernutrition (-3 z-score) due to continued breastfeeding. This hypothesis aligns with another study indicating that breastfeeding can protect infants against severe wasting [53]. Another hypothesis is that severely malnourished infants are more likely to be admitted to referral hospitals for specialized care, resulting in their absence from the study population. In this case, given the life-threatening nature of wasting, these infants are likely to have been identified by community health extension workers (CHEWS) and removed from the community for urgent medical care before reaching such an extreme state of wasting. Nevertheless, the successful creation of this 5-photographic FRS for infants marks a significant advancement in health and nutrition, offering a context-specific tool for evaluating growth patterns and nutritional well-being of infants. With further refinement, this FRS, alongside the newly introduced family-led mid-upper arm circumference tape (family MUAC) [51], could potentially improve infant growth monitoring.

Accuracy, Sensitivity and Specificity of the FRS

The accuracy, sensitivity, and specificity of photographic figure-rating scales are crucial for reliable assessments, especially in medical fields like nutrition, but there is limited direct information about their relationship and nutrition. In an earlier study, the FRS consisting of nine schematic figures of varying size, was found to have good test-retest reliability and moderate correlations with measures of body image dissatisfaction and eating disturbance [54]. The accuracy, sensitivity and specificity of the current photographic FRS (Table 4) demonstrate the potential of the scale as a tool for assessing wasting in infants aged 9-12 months. The developed FRS successfully classified the degree of wasting in approximately two-thirds of the infants, which highlights a notable strength in its performance. Diagnostic accuracy of such rating scales has been evaluated in several studies [49], and have showed promising results for assessing body image disturbance and related conditions. Aside of nutrition, research on validity of photographic FRS have demonstrated strong psychometric properties, showing high test-retest reliability and convergent validity, which are essential for accurate assessments [49], with correlation coefficients exceeding 0.87. Interestingly, a similar measure on 9- schematic figures [54], demonstrated good test-retest reliability and moderate correlations with other measures of

body image dissatisfaction, eating disturbance, and overall self-esteem, comparing well with the findings of this study. High sensitivity ensures that the scale accurately identifies individuals with wasting, while high specificity confirms that it correctly identifies those without [55]. The specificity of the scale, exceeding 70%, is a positive aspect as it indicates a low rate of false positive classifications. Authors [56-58], state that this high specificity, combined with the high positive predictive value (PPV), indicates that the tool is both effective at correctly identifying non-wasted individuals and accurately predicting those who are wasted. These findings underscore the potential utility of the developed photographic FRS as a screening tool for infant wasting, particularly in a resource-limited setting like the one we worked with, where more complex assessment methods may not be feasible.

However, considering that about 33% of wasted infants might be missed by the developed FRS is a concern that warrants further investigation and potential refinement of the scale. But the implications of the findings from this study suggest that, the FRS could serve as a valuable initial screening tool, allowing for identification of infants who may require further assessment or intervention before its late. Furthermore, the study's findings open avenues for future research. There is definitely a clear need to explore modifications to the developed FRS that could improve its sensitivity for infants in the 9-12month age range. Additionally, longitudinal studies could also provide valuable insights into the predictive value of the FRS over time. By tracking infants assessed with the FRS and comparing outcomes with those identified through other methods like a MUAC tape, researchers could gain a better understanding of the scale's long-term utility in nutrition assessments.

Predictive values and Likelihood ratios

In this study, the positive predictive value (PPV) exceeding 90%, comparable to Cardinal et al [59], was identified as a significant strength of the FRS. It is recommended [60,61] that effective screening tools should generally exhibit sensitivity and specificity within the 70-80% range, although the prioritization of one metric over the other may be required depending on the specific context. In the realm of infant malnutrition, failing to identify a true case of wasting (low-sensitivity) can have severe repercussions. Therefore, maintaining high sensitivity and PPV, as obtained in this study, is essential to ensure that infants who could benefit from nutrition interventions are not left out [62,63].

Limitations

The study did not do a proper validation of the tool by conducting a comparison of its findings and methods against the MUAC (Mid-Upper Arm Circumference) – a tool that is commonly used in the assessment of wasting, which was a limitation. Essentially, due to time and resource constraints, the authors acknowledge this as a limitation and recommend a further study to inform this gap and validate the results of the FRS tool.

CONCLUSIONS

The Figure-rating scale (FRS) was developed to detect wasting among infants (9-12 months). It demonstrated acceptable specificity and high positive predictive value (PPV), indicating its potential effectiveness in identifying cases of wasting. The overall accuracy of the FRS suggests that it could be a valuable addition to existing diagnostic tools, enhancing the screening process for child wasting. However, it is not intended for use in isolation, but rather in conjunction with other established methods. Although the initial results are promising, further research is necessary to fully understand the capabilities and limitations of the FRS. Future studies should focus on examining diagnostic accuracy, sensitivity, and specificity across diverse populations and settings, comparing the FRS to existing screening tools to determine its relative effectiveness, and identifying any unique advantages that the FRS may offer in clinical practice.

Future research directions should include longitudinal studies to evaluate the FRS in terms of its predictive value over time, comparative analyses with other screening tools, and assessments of the FRS's performance across diverse populations and settings. Key areas include conducting longitudinal studies to assess the predictive value and performing comparative analyses with other screening tools. Future research should also focus on integration into existing protocols, which will necessitate evaluating compatibility with current growth monitoring practices, assessing the feasibility of incorporation into routine health checkups, developing training programs for health care professionals, engaging stakeholders for feedback, and addressing ethical considerations, all of which are important steps in the research process. Finally, cultural adaptations to diverse settings are necessary to ensure the applicability of the FRS across different contexts. Collectively, these efforts aim to improve the validity and effectiveness of the FRS in

predicting child wasting.

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AUTHOR CONTRIBUTIONS

"Conceptualization, H.A. and R.K.; methodology, H.A., R.K, M.M, R.B., E.B; software, R.K, M.M; validation, H.A., R.K, R.B., E.B.; formal analysis, H.A., R.K. M.M; investigation, H.A., R.K; data curation, R.K., H.A., M.M. R.B; writing—original draft preparation, H.A., R.K., E.B., M.M.; writing—review and editing, H.A. and R.K. R.B.; project administration, H.A., and R.K.; All authors have read and agreed to the published version of the manuscript."

CONFLICT OF INTEREST

The author(s) declare no conflict of interest.

INSTITUTIONAL REVIEW BOARD STATEMENT

"The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board and of Uganda National Council for Science and Technology (UNCST, HS2137ES, 03/May 2022)."

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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