Assessment of Severe Malnutrition Among Hospitalized Children in Rural Kenya
Comparison of Weight for Height and Mid Upper Arm Circumference

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S EVERE MALNUTRITION HAS A HIGH mortality rate among hospitalized children in sub-Saharan Africa.[1,2] The World Health Organization (WHO) gives clear guidelines for the management of children with severe malnutrition,[3] and where standardized management protocols have been followed, mortality has been reduced.[4,5] However, recent reports suggest that there are problems in initially identifying severely malnourished children at hospital admission.[5,6] The WHO defines severe malnutrition requiring hospital admission as weight-for-height z scores (WHZs) of less than or equal to –3 or as less than or equal to 70% of the reference median using US National Center for Health Statistics (NCHS)/WHO reference values (severe wasting)[3] or symmetrical edema involving at least the feet (edematous malnutrition, kwashiorkor).[3]

There are several reasons why screening by WHZ is potentially problematic and is frequently not undertaken in practice in sub-Saharan Africa. First, height

Context Severe malnutrition has a high mortality rate among hospitalized children in sub-Saharan Africa. However, reports suggest that malnutrition is often poorly assessed. The World Health Organization recommends using weight for height, but this method is problematic and often not undertaken in practice. Mid upper arm circumference (MUAC) and the clinical sign "visible severe wasting" are simple and inexpensive methods but have not been evaluated in this setting.

Objectives To evaluate MUAC and visible severe wasting as predictors of inpatient mortality at a district hospital in sub-Saharan Africa and to compare these with weight-for-height z score (WHZ).

Design, Setting, and Participants Cohort study with data collected at admission and at discharge or death. Predictive values for inpatient death were determined using the area under receiver operating characteristic curves. Participants were children aged 12 to 59 months admitted to a district hospital in rural Kenya between April 1, 1999, and July 31, 2002.

Main Outcome Measure MUAC, WHZ, and visible severe wasting as predictors of inpatient death.

Results Overall, 4.4% (359) of children included in the study died while in the hospital. Sixteen percent (1282/8190) of admitted children had severe wasting (WHZ $\leq$ –3) (n=756), kwashiorkor (n=778), or both. The areas under the receiver operating characteristic curves for predicting inpatient death did not significantly differ (MUAC: 0.75 [95% confidence interval, 0.72-0.78]; WHZ: 0.74 [95% confidence interval, 0.71-0.77]) (P=.39). Although sensitivity and specificity for subsequent inpatient death were 46% and 91%, respectively, for MUAC less than or equal to 11.5 cm, 42% and 92% for WHZ less than or equal to –3, and 47% and 93% for visible severe wasting, the 3 indices identified different sets of children and were independently associated with mortality. Clinical features of malnutrition were significantly more common among children with MUAC less than or equal to 11.5 cm than among those with WHZ less than or equal to –3.

Conclusions MUAC is a practical screening tool that performs at least as well as WHZ in predicting subsequent inpatient mortality among severely malnourished children hospitalized in rural Kenya. Visible severe wasting is also a potentially useful sign at this level, providing appropriate training has been given.

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is difficult to measure accurately in children at any time but especially so in a busy ward and when children are ill or distressed. The measurement of weight depends on the presence of properly calibrated and functioning scales, which often are not available.[7] The actual weight-for-height determination depends on correctly recording 2 separate values and then looking up a third value on a chart, which must be readily available.

In contrast, mid upper arm circumference (MUAC) is a simple, low-cost, objective method of assessing nutritional status. The MUAC is generally as good as, or better than, other anthropometric measures in predicting subsequent mortality in community-based studies (reviewed by Pelletier[8]). In Uganda, for example, MUAC was the strongest predictor of subsequent death of any anthropometric index among 3748 village children.[9] Among hospital admissions, MUAC was found to be as effective as other nutritional indices in predicting death in a study of 352 children with diarrhea in Bangladesh.[10] During famine, MUAC performed as well as body mass index among adults admitted to a feeding center in Sudan.[11]

The clinical sign of "visible severe wasting" is a component of the WHO Integrated Management of Childhood Illness evaluation that accounts for the likelihood that measuring facilities are not available at the primary care level in this setting. Given the challenges to the assessment of weight for height at the secondary (referral) level, evaluation of malnutrition is commonly performed by observation only, often without formal training. Despite being inexpensive, convenient, and apparently effective in other settings, MUAC and visible severe wasting have not been evaluated as predictors of mortality among hospitalized children in sub-Saharan Africa.

Since 1998, we have conducted detailed clinical surveillance of all children admitted to Kilifi District Hospital in Kenya. Using data collected at admission and at discharge or death, we have previously reported that a small number of clinical features, including neurologic status, respiratory signs, temperature, and weight for age effectively predicted inpatient deaths despite a variety of underlying etiologies.[12] Our principal aim in this analysis was to examine the predictive value for inpatient death of MUAC compared with WHZ among children aged 12 to 59 months. We also sought to determine whether there are any differences in the children identified by the 2 methods. Furthermore, we aimed to evaluate both the clinical sign of visible severe wasting as a predictor of subsequent inpatient death and also MUAC as an indicator of the presence of the current WHO standard definition of severe wasting, ie, WHZ less than or equal to –3.

METHODS
Location
The study was conducted at Kilifi District Hospital, located in a rural, malaria-endemic area on the Kenyan coast. The hospital serves a population of more than 200 000 people who are mainly rural farmers. Approximately 10% of women attending the hospital antenatal clinic were infected with human immunodeficiency virus (HIV) in 2000.[13] Antiretroviral therapy was not in routine use at the time of the study. The Kenya Medical Research Institute Centre for Geographic Medicine Research (coast) is located at the hospital.

Patients and Clinical Methods
Data were prospectively collected from all pediatric admissions as part of an ongoing surveillance study, and details of the clinical data collection have been described elsewhere.[12] Approval was given by the Kenya Medical Research Institute national ethical and scientific review committees. Parents or guardians of individual study participants gave written informed consent in their own language. For this analysis we examined data from all children aged 12 to 59 months admitted between April 1, 1999, and July 31, 2002. Trained clinical assistants measured MUAC with a nonstretch cloth measuring tape, weight with an electronic scale (Weylux, Lon-

don, England) that was checked for consistency weekly, and length using a measuring board of standard design (for children younger than 2 years) or height using a wall-mounted scale (for those aged 2 years or older). From September 1, 1999, onward, clinicians were trained to recognize visible severe wasting, and data on this sign were subsequently collected. Clinicians were taught to look for muscle loss, manifested as a wasting of the gluteal area and as the presence of a bony prominence over the chest wall.[3,14] Children with a clinical diagnosis of severe malnutrition were treated with broad-spectrum antibiotics, vitamin and mineral supplements, F75 and F100 milk, and careful attention to fluid and electrolyte intake. Other treatments were according to WHO guidelines[3] and local protocols. Inpatient deaths were confirmed on clinical examination by research clinicians.

Statistical Methods
We calculated WHZ, weight-for-age z score (WAZ), and height-for-age z score (HAZ) using the NCHS reference standards[3] with EpiInfo version 6.04 (Centers for Disease Control and Prevention, Atlanta, Ga). Complete nutritional assessment, especially for height, were sometimes omitted when children arrived in extremis. Thus, to avoid bias, only children with complete data for all 3 indices were included in the main analysis. To determine the predictive value for inpatient death, we calculated the area under the receiver operating characteristic (ROC) curves with 95% confidence intervals (CIs) using the *roctab* and *roccomp* (a χ^2 test) commands in STATA version 8.0 (Stata Corp, College Station, Tex). We also examined the sensitivities and specificities of commonly used cutoff values and examined the clinical data for differences between children identified as severely malnourished by the MUAC and WHZ methods. Sensitivity was defined as the number of inpatient deaths among children with anthropometric measures equal to or below a cutoff value, divided by the total number of inpatient deaths. Specificity was de-

Table 1. Number of Admissions and Inpatient Deaths, by Nutritional Index

	Nutritional Indices Reported as *z* Scores								
	WHZ		WAZ		HAZ		MUAC		
z Score	No.	Died (%)	No.	Died (%)	No.	Died (%)	Circumference, cm	No.	Died (%)
≤−4	197	60 (30.5)	755	158 (20.9)	645	91 (14.1)	≤11	691	149 (21.6)
−3.99 to −3	559	91 (16.3)	1206	68 (5.6)	826	66 (8.0)	11.1 to 11.5	182	17 (9.3)
−2.99 to −2	1898	91 (4.8)	2377	70 (2.9)	1625	76 (4.7)	11.6 to 12.5	922	59 (6.4)
−1.99 to −1	3036	72 (2.4)	2346	37 (1.6)	2213	66 (3.0)	12.6 to 13.5	1477	44 (3.0)
>−1	2498	45 (1.8)	1504	26 (1.7)	2897	60 (2.1)	>13.5	4946	90 (1.8)

Abbreviations: HAZ, height-for-age *z* score; MUAC, mid upper arm circumference; WAZ, weight-for-age *z* score; WHZ, weight-for-height *z* score.

fined as the number of children discharged alive with anthropometric measures above a cutoff value, divided by the total number of children discharged alive.

Since the WHO recommends that children be treated for severe malnutrition if they have severe wasting or kwashiorkor, we also evaluated the positive and negative likelihood ratios for death for each of MUAC, WHZ, and visible severe wasting combined with (and/or) kwashiorkor. These were calculated as follows: positive likelihood ratio=sensitivity/(1−specificity), and negative likelihood ratio=(1−sensitivity)/specificity.[15] We used the χ^2 test, or the Fisher exact test where appropriate, to compare categorical data. We used the Kruskal-Wallis test to compare the distributions of age and length of history between groups, which were not normally distributed. To determine the independent associations of different nutritional indices with mortality, we used multivariable logistic regression in a model that included age, sex, visible severe wasting, WHZ, and MUAC. To determine the clinical features that differed between children identified by MUAC and WHZ, we used backward stepwise multivariable logistic regression. We evaluated the performance of the resulting models using the Hosmer-Lemeshow goodness-of-fit test. All analyses were performed using STATA version 8.0, and *P*<.05 was used to determine statistical significance.

RESULTS

There were 8500 children aged 12 to 59 months admitted during the study period

(1999-2002). Anthropometric data were incomplete in 3.6% (310) of children, who were mostly admitted in extremis: weight was missing in 0.2% (21), height in 2.8% (235), and MUAC in 1.4% (126). Among these 310 children, the median age was 27 months (interquartile range, 20-39 months), and 27.4% (85) died. These 310 were excluded, leaving 8190 children in the main analysis. The mean anthropometric values were −1.54 for WHZ, −2.15 for WAZ, −1.59 for HAZ, and 13.7 cm for MUAC. Severe wasting (WHZ ≤−3) was present in 9.2% (756) and kwashiorkor in 9.5% (778); 15.6% (1282) had 1 or both of these features. Severe wasting in admitted children was more common among boys than girls (10.1% [446/4426] vs 8.2% [310/3764], respectively; *P*<.001), while kwashiorkor was less common among boys (8.4% [370/4422] vs 10.8% [408/3763], *P*<.001). Overall, 4.4% (359) of children included in the study died while in the hospital.

Prediction of Inpatient Mortality

The distribution of nutritional indices within admissions and numbers of deaths at commonly used cutoffs are shown in **TABLE 1**. The areas under the ROC curves for MUAC, WHZ, and WAZ in predicting inpatient death did not significantly differ: 0.75 (95% CI, 0.72-0.78) for MUAC and 0.74 (95% CI, 0.71-0.77) for WHZ (*P*=.39) (**FIGURE**). The area under the ROC curve for WAZ was 0.76 (95% CI, 0.73-0.79) and for HAZ was 0.69 (95% CI, 0.66-0.72). The sensitivity and specificity for inpatient death were 46.2% (166/359) and 91.0% (7122/7829), respectively, for MUAC

less than or equal to 11.5 cm, and 41.8% (150/359) and 92.4% (7233/7829) for WHZ less than or equal to −3.

The case fatality rate among admitted children with WHZ less than or equal to −3 was 19.9% (151/756). The case fatality rate among admitted children with MUAC less than or equal to 11.5 cm was 19.0% (166/873) and did not significantly vary with age (**TABLE 2**).

Visible severe wasting was present in 9.0% (608) of 6727 children assessed. The median age of children with visible severe wasting was 24 months (interquartile range, 18-35 months) and did not differ significantly from that in children without this sign. Of the 608 children with visible severe wasting, 22.5% (137) died, compared with 2.5% (153/6117) without this sign (sensitivity, 47%; specificity, 93%). The positive and negative likelihood ratios for death for WHZ less than or equal to −3 and/or kwashiorkor were 4.36 (95% CI, 3.95-4.84) and 0.47 (95% CI, 0.41-0.53), respectively; those for MUAC less than or equal to 11.5 cm and/or kwashiorkor were 5.12 (95% CI, 4.49-5.84) and 0.59 (95% CI, 0.54-0.65); and those for visible severe wasting and/or kwashiorkor were 5.31 (95% CI, 4.71-5.97) and 0.46 (95% CI, 0.40-0.53). A multivariable logistic regression model adjusted for age and sex showed that MUAC, visible severe wasting, and kwashiorkor were all independently associated with inpatient death (**TABLE 3**).

Predicting the Current WHO Criterion for Severe Wasting

For detecting the WHO standard criterion for severe wasting (WHZ ≤−3),

the sensitivity and specificity of MUAC less than or equal to 11.5 cm were 65.1% (486/746) and 94.8% (7057/7444), respectively, and of visible severe wasting were 52.6% (320/608) and 95.3% (5831/6119) (P<.001). Of 608 children with WHZ less than or equal to –3, 29.3% (178) did not have visible severe wasting or MUAC less than or equal to 11.5 cm (**TABLE 4**).

Differences in Children Identified by MUAC and WHZ

Although the sensitivity and specificity for death of MUAC less than or equal to 11.5 cm, visible severe wasting, and WHZ less than or equal to –3 appeared roughly similar, the sets of children identified by these nutritional indices differed, with only partial overlap (Table 4). Comparing children with MUAC less than or equal to 11.5 cm with children with WHZ less than or equal to –3 by univariate analysis, children with MUAC less than or equal to 11.5 cm were more likely to be stunted, female, and to have a longer history of illness, cough, diarrhea, subcostal indrawing, visible severe wasting, kwashiorkor, moderate anemia, and bacteremia (**TABLE 5**). They also were less likely to have a history of seizures or to be unable to localize a painful stimulus. Although the median ages appeared similar, the distribution of ages significantly differed between the 2 groups (Table 5). Multivariable analysis showed that skin/hair changes associated with recent kwashiorkor, bipedal edema associated with current kwashiorkor, stunting, subcostal indrawing, no history of seizures, female sex, and younger age were independent associations of having MUAC less than or equal to 11.5 cm rather than WHZ less than or equal to –3 (**TABLE 6**).

COMMENT

In a large study of children admitted to a district hospital in sub-Saharan Africa, MUAC performed as well as WHZ in predicting inpatient mortality. Since MUAC is inexpensive, more commonly available, does not require a chart to calculate, and is easier to measure than WHZ, it may be a useful screening tool for such children. However, there were differences in the groups of children identified by these methods, and they independently predicted inpatient death. The observation that the sets of children identified by these methods of assessment do not

Figure. Receiver Operating Characteristic Curves for MUAC and WHZ as Predictors of Inpatient Mortality
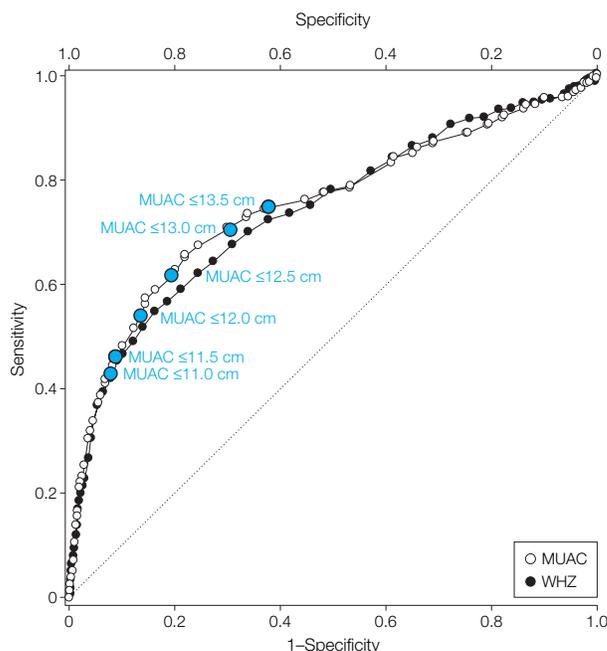
MUAC indicates mid upper arm circumference; WHZ, weight-for-height *z* score. Large blue circles indicate the performance of various cutoff points for MUAC

Table 2. Case Fatality Rates by Age Among Admitted Children With Mid Upper Arm Circumference (MUAC) ≤11.5 cm and >11.5 cm

	No. of Deaths/Total (%)				
	Age 12-23 mo	Age 24-35 mo	Age 36-47 mo	Age 48-59 mo	Total
All admissions*	161/3688 (4.4)	106/2355 (4.5)	57/1336 (4.3)	35/811 (4.3)	359/8190 (4.4)
MUAC, cm					
≤11.5†	94/495 (18.9)	44/237 (18.6)	19/100 (19.0)	9/41 (22.0)	166/873 (19.0)
>11.5‡	67/3193 (2.1)	62/2118 (2.9)	38/1236 (3.0)	26/770 (3.4)	193/7317 (2.6)

*$\chi^2_3 = 0.133$, P = .99.
†$\chi^2_3 = 0.261$, P = .97.
‡$\chi^2_3 = 6.81$, P = .08.

Table 3. Multivariable Logistic Regression Analysis of the Independent Associations of MUAC, WHZ, Visible Severe Wasting, Sex, and Age With Subsequent Inpatient Death*

Clinical Feature	Adjusted Odds Ratio (95% CI)	P Value
MUAC ≤11.5 cm	1.76 (1.18-2.62)	.005
WHZ ≤–3	2.57 (1.81-3.66)	<.001
Visible severe wasting	4.81 (3.34-6.92)	<.001
Female sex	1.02 (0.79-1.31)	.90
Age, per 1 y	1.13 (0.99-1.28)	.06

Abbreviations: CI, confidence interval; MUAC, mid upper arm circumference; WHZ, weight-for-height *z* score.
*Hosmer-Lemeshow goodness-of-fit test: $\chi^2 = 8.90$ (10 groups), P = .18.

entirely overlap has been previously reported in 2 African studies, both conducted outside the hospital setting and involving only children.[16,17] In both of these studies, the differences were attributed to age, with low MUAC values identifying younger children but not older children with a low WHZ. We found that there were statistically significant, independent associations of age and sex and identification by MUAC alone compared with WHZ alone when adjusted for the effects of other variables (Table 6). However, the case fatality rate for MUAC less than or equal to 11.5 cm was consistently high (19.0%) at all ages (Table 2), suggesting that an unadjusted MUAC may be clinically useful in this setting.

There are 2 other potentially important reasons why MUAC, visible severe wasting, and WHZ might identify different children. First, while all of these measures reflect bone, fat, and muscle mass, WHZ is also influenced by total body water. The WHZ may therefore be potentially lowered by acute dehydration. While this is unlikely to be a significant problem in community-based studies, children admitted to hospitals in sub-Saharan Africa are commonly dehydrated. Dehydration does not only occur with gastroenteritis[4,18] but also may occur in other common conditions such as severe malaria.[19,20] To evaluate the potential for severe dehydration to influence WHZ, we examined the changes in

Table 4. Numbers of Admissions and Deaths Among Children With MUAC ≤11.5 cm, WHZ ≤−3, or Visible Severe Wasting*

	MUAC >11.5 cm and WHZ >−3	MUAC ≤11.5 cm Only	MUAC ≤11.5 cm and WHZ ≤−3	WHZ ≤−3 Only
No visible severe wasting				
Admissions, No.	5682	147	110	178
Deaths, No. (%)	116 (2.0)	14 (9.5)	15 (13.6)	8 (4.5)
Visible severe wasting				
Admissions, No.	150	138	274	46
Deaths, No. (%)	24 (16.0)	17 (12.3)	81 (29.6)	15 (32.6)

Abbreviations: MUAC, mid upper arm circumference; WHZ, weight-for-height z score.
*Results are presented for the 6727 admitted children from whom data on visible severe wasting were systematically collected.

Table 5. Clinical Features of Children Admitted With and Without MUAC ≤11.5 cm and/or WHZ ≤−3*

Clinical Feature	MUAC >11.5 cm and WHZ >−3 (n = 7050) No. (%)	P Value†	MUAC ≤11.5 cm Only (n = 384) No. (%)	P Value†	MUAC ≤11.5 cm and WHZ ≤−3 (n = 489) No. (%)	P Value†	WHZ ≤−3 Only, No. (%) (n = 267)
Girls	3250 (46.1)	.05	204 (53.1)	.001	203 (41.5)	.70	107 (40.1)
Age, median (IQR), mo	26 (18-37)	.09	22 (15-30)	<.001	22 (16-30)	<.001	22 (18-35)
Days of illness, median (IQR)	3 (2-4)	<.001	7 (3-23)	<.001	12 (4-20)	<.001	3 (2-7)
History of fever	6048/7047 (85.8)	.002	299 (77.8)	.72	351/488 (71.9)	<.001	211 (79.0)
History of cough	2776/7047 (39.4)	.33	225 (58.6)	<.001	285/488 (58.4)	<.001	113 (42.3)
History of diarrhea (≥3 episodes in 24 h)	1197/7047 (17.0)	<.001	149 (38.8)	.03	275/488 (56.4)	<.001	81 (30.3)
History of seizures during the current illness	2193/7046 (31.1)	.01	28 (7.3)	<.001	22/488 (4.5)	<.001	64 (23.9)
Impaired consciousness‡	433/7045 (6.2)	<.001	11 (2.9)	<.001	16/488 (3.3)	<.001	32 (12.0)
Subcostal indrawing	889/7045 (12.6)	.81	76 (19.8)	.03	73/488 (15.0)	.49	35 (13.1)
Deep breathing (Kussmaul respiration)	381/7045 (5.4)	<.001	29 (7.6)	.19	47/488 (9.6)	.07	28 (10.5)
Sunken eyes§	350/5828 (6.0)	<.001	35/283 (12.4)	.10	109/386 (28.2)	.003	40/228 (17.5)
Visible severe wasting§	150/5829 (2.6)	<.001	136/283 (48.1)	<.001	276/386 (71.5)	<.001	46/229 (20.1)
Bipedal edema	388/7046 (5.5)	<.001	146 (38.0)	<.001	207/488 (42.4)	<.001	37 (13.9)
Skin/hair changes of kwashiorkor	351/7046 (5.0)	<.001	188 (49.0)	<.001	331/488 (67.8)	<.001	76 (28.5)
Stunting (HAZ ≤−3)	854 (12.1)	.02	254 (66.1)	<.001	298 (60.9)	<.001	45 (16.9)
Hyperthermia (axillary temperature ≥39°C)	2334/7049 (33.1)	<.001	53 (13.8)	.67	40 (8.2)	.003	40 (15.0)
Hypothermia (axillary temperature <36°C)	191/7049 (2.7)	.93	26 (6.8)	.02	43 (8.8)	.001	7 (2.6)
Moderate anemia (hemoglobin 5-8 g/dL)	2026/7029 (28.8)	.93	150/383 (39.2)	.007	159/488 (32.6)	.26	76/266 (28.6)
Severe anemia (hemoglobin <5 g/dL)	668/7029 (9.8)	.047	64/383 (16.7)	.23	70/488 (14.3)	.65	35/266 (13.2)
Malaria slide-positive‖	4342/7023 (61.8)	<.001	153/383 (40.0)	.23	149/487 (30.6)	<.001	118/264 (44.7)
Bacteremia¶	236/6097 (3.9)	.007	43/332 (13.0)	.04	68/409 (16.6)	.001	17/230 (7.4)
Died	166 (2.4)	<.001	42 (10.9)	.74	124 (25.4)	<.001	27 (10.1)

Abbreviations: HAZ, height-for-age z score; IQR, interquartile range; MUAC, mid upper arm circumference; WHZ, weight-for-height z score.
*Denominators lower than N indicate missing data.
†For comparison with WHZ ≤−3, by χ² tests, except age and days of illness (Kruskal-Wallis test).
‡Inability to localize a painful stimulus.
§Systematically collected from September 1999 only.
‖Defined as asexual forms of *Plasmodium falciparum* evident on microscopic examination of blood.
¶Children with contaminated blood cultures were excluded from the denominator.

Table 6. Multivariate Logistic Regression Analysis of Clinical Features Found in Children With MUAC ≤11.5 cm Only vs Those With WHZ ≤−3 Only*

Clinical Feature	Adjusted Odds Ratio (95% CI)	P Value
History of seizures during the current illness	0.45 (0.28-0.80)	.007
Subcostal indrawing	1.91 (1.13-3.21)	.02
Bipedal edema	2.15 (1.26-3.65)	.005
Skin/hair changes of kwashiorkor	2.34 (1.43-3.82)	.001
Stunting (HAZ ≤−3)	8.08 (5.33-12.3)	<.001
Female sex	2.05 (1.38-3.02)	<.001
Age, per 1 y	0.74 (0.60-0.91)	.005

Abbreviations: CI, confidence interval; HAZ, height-for-age z score; MUAC, mid upper arm circumference.
*Hosmer-Lemeshow goodness of fit test: $\chi^2 = 6.90$ (10 groups), $P = .55$.

z score with respect to NCHS standards for a hypothetical 1-year-old child with severe dehydration (10% loss of body weight). If such a child's usual WHZ was zero, then 10% dehydration would have reduced the WHZ by approximately 1 z score. If the child's usual WHZ was −3, then the WHZ would be reduced by approximately 0.6 z scores. However, examining the clinical features of the groups of children with MUAC less than or equal to 11.5 cm only and WHZ less than or equal to −3 only, there were no significant differences in the prevalence of deep breathing (indicating severe metabolic acidosis), sunken eyes, or malaria parasitemia. Furthermore, diarrhea was more commonly present among those with MUAC less than or equal to 11.5 cm only than in those with WHZ less than or equal to −3 only. It is possible that some children with very severe hypovolemia were excluded from the analysis because they were in extremis on admission. However, we have previously reported that low weight for age did not predict deaths within the first 4 hours after admission but was predictive of later inpatient deaths.[13] Thus, our findings suggest that dehydration does not have a significant confounding effect in the hospital setting.

Second, although small physical size due to stunting may contribute to a low MUAC measurement, stunting is not reflected by a low WHZ value. The prevalence of stunting in children with MUAC less than or equal to 11.5 cm was greater than in those with WHZ less than or equal to −3 (Tables 5 and 6). Although wasting has generally been the focus of acute inpatient management, stunting has been reported to be associated with a poor outcome from diarrhea and lower respiratory tract infection. However, the evidence is relatively weak, since it is based on a very small number of studies (reported by Rice et al[21]). Our data show that even mild stunting (HAZ −1.99 to −1) is associated with inpatient death (age and sex–adjusted odds ratio, 1.45 [95% CI, 1.02-2.07]) (Table 1) compared with no stunting (HAZ >−1), having excluded those in extremis on arrival. Since stunting is not altered by acute illness, it is the most likely to be an actual risk factor rather than simply an association. In practice, measurement and calculation of HAZ shares some of the same disadvantages as WHZ. However, MUAC measurement incorporates elements of both stunting and wasting. A number of other clinical characteristics, including bipedal edema associated with current kwashiorkor and skin/hair changes associated with recent kwashiorkor, among children with MUAC less than or equal to 11.5 cm suggest MUAC may be a better indicator of severe malnutrition than WHZ in this setting.

Because of the recognized difficulties of measuring weight for height, the WHO Integrated Management of Childhood Illness program for primary-level care makes use of the clinical sign of visible severe wasting.[14] Our results suggest that there is little difference in the sensitivity and specificity of visible severe wasting and the single cutoff points of MUAC less than or equal to 11.5 cm and WHZ less than or equal to −3. When combined with the identification of kwashiorkor, the positive likelihood ratio for death of visible severe wasting was actually greater than for WHZ less than or equal to −3. This supports the use of visible severe wasting as a bedside test for acutely ill children at the district hospital level, provided appropriate training has been given. The observation that clinical assessment may be as useful as anthropometry in hospitalized patients in developed country settings has previously been reported.[22] However, visible severe wasting is a subjective, binary assessment. Where possible, an objective measure with more than 1 cutoff point, such as MUAC, is preferable to allow standardization between centers and classification of the degree of malnutrition. Furthermore, as a predictor of the presence of WHZ less than or equal to −3, visible severe wasting did not perform as well as MUAC less than or equal to 11.5 cm, suggesting that MUAC may be better in identifying less–severely ill children in need of nutritional rehabilitation.

Limitations

The main limitations of this study are that it was performed at only 1 site, and data from areas of differing malaria transmission and HIV prevalence would be valuable. There was a lack of individual data on HIV infection, which may potentially cause wasting and influence fat distribution. In addition, no laboratory assessment of nutritional status, such as measurement of serum albumin levels, was routinely performed. Finally, no systematic follow-up was made to identify deaths occurring after hospital discharge.

Conclusions

In summary, MUAC and visible severe wasting performed as well as the WHO-recommended assessment method in predicting inpatient death. Our findings, as well as considerations of cost and practicality, suggest that MUAC may be more appropriate than WHZ for identifying severe malnutrition in children aged between 1 and 5 years who are admitted to an African district hospital. However, an as-

sessment that includes MUAC, WHZ, and visible severe wasting increases the number of at-risk children who are identified on admission and highlights those in overlapping groups who are at the greatest risk of dying. Further studies are needed to evaluate MUAC and visible severe wasting in other operational settings and other situations in which anthropometric assessment is difficult to perform.

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