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Anthropometric indicators and risk of death[1–3]

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ABSTRACT Six anthropometric indicators based on weight, height, arm circumference (AC), and age were examined to predict mortality risk of children aged 12–59 mo in a rural area of Teknaf, Bangladesh. In the period 1981–85, 9861 measurements at 6-mo intervals were made on 2449 children. For all indices mortality risk was greater in the first 3 mo than in the second 3 mo in severely malnourished children. Mortality discriminating power of the indicators in terms of sensitivity and specificity was highest for AC and AC for age and lowest for weight-for-height. Logistic regression analysis showed that the predictive power of weight-, height-, and age-based indicators improved after adding AC whereas predictive power of AC did not improve after adding weight-based indicators. The relative risk of death in children with ACs measuring ≤ 120 mm was 12 times higher than in those whose ACs measured > 140 mm. *Am J Clin Nutr* 1989;49:884–8.

KEY WORDS Child mortality, risk of death, anthropometric indicators, Bangladesh

Introduction

The efficiency of anthropometric indices in defining malnutrition rests on their ability to show a direct relationship with morbidity and mortality (1). To discriminate those children at a high mortality risk, several measures were investigated (2–4). Chen et al (4) found that the mortality discriminating efficiency in 2-y-old children in a 2-y period was highest for weight-for-age (WA) and arm circumference-for-age (ACA), intermediate for height-for-age (HA) and arm circumference-for-height (ACH), and lowest for weight-for-height (WH). Arm circumference (AC) has been proposed as a simple age-independent measure of nutritional status (5–7) and the high mortality predicting power of ACA prompted exploring the usefulness of AC for this purpose. In reanalyses of the previously published works (2, 4) done on chronically malnourished children in Matlab, Bangladesh, AC performed better in identifying children with a high mortality risk than did ACH (8) and WH and performed similar to ACA, WA, and HA (9). The present study examines the adequacy of AC by using a shorter follow-up period (6 mo) in a population that has an average prevalence of malnutrition lower than that in Matlab.

Different anthropometric indices represent different types of malnutrition and it is believed that death might be better predicted by using a combination of several of these indices. However, combinations of different indices did not improve the prediction of death of patients with diarrhea admitted to a hospital (10). Therefore, the objectives of this paper are to study the prediction of death by using a single anthropometric index and combinations of different indices.

Methods

The anthropometric data of this study were recorded as part of the health impact assessment of a 5-y water and sanitation intervention project in Teknaf at the southeastern tip of Bangladesh. People in this region generally have no education and are employed mainly in fishing and agriculture. Most women are housewives and give birth to an average of eight children. Anthropometric measurements on children aged 12–59 mo were taken at six monthly intervals at their homes from January 1981 to July 1985 by a female research officer who was assisted by a male and a female field worker. Body weight was measured to the nearest 10 g on Salter scales, (Salter Industrial Measurement Ltd, West Boomwich, UK) checked for accuracy before each weighing session. Body length to the nearest millimeter was recorded by use of locally constructed measuring boards while the young children were supine and while the older children (aged 24–59 mo) were standing. Left midupper AC was measured by oil-cloth tailor's tapes, also to the nearest millimeter. Anthropometric indices used in this study were calculated as a percentage of the National Center for Health Statistics (NCHS) reference standards (11). The study was approved by the ICDDR,B Ethical Review Committee.

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[2] This paper utilized the anthropometry data of the ICDDR,B's water and sanitation project and mortality and migration data of the Demographic Surveillance System in Teknaf funded by the International Development Research Centre, Canada (IDRC) and the Canadian International Development Agency (CIDA), respectively.

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TABLE 1
Anthropometric indices of children who survived and those who emigrated and died after nutritional assessment*

Indices	Survived (n = 9801)	Emigrated (n = 176)	Died (n = 60)
Arm circumference (cm)	13.8 ± 1.1	13.8 ± 1.0	12.6 ± 1.8†
Arm circumference-for-age (%)	84.4 ± 6.5	83.8 ± 5.9	77.3 ± 10.4†
Arm circumference-for-height (%)	89.8 ± 6.4	88.9 ± 5.7	84.4 ± 9.9†
Height-for-age (%)	89.0 ± 4.2	88.9 ± 4.7	85.7 ± 5.7†
Weight-for-height (%)	90.5 ± 7.7	89.9 ± 6.3	87.1 ± 10.1†
Weight-for-age (%)	74.2 ± 8.9	73.4 ± 8.7	66.1 ± 12.7†

* $\bar{x} \pm$ SD.
† $p < 0.001$ (compared between survived and died).

Child survival status was determined by matching anthropometric records with death and emigration information and was recorded in monthly home visits by the Health Assistants of the Teknaf Demographic Surveillance System (DSS). The DSS has been collecting information on all vital events and migration in a larger area since 1976. Age of the children is precisely known from birth records or from in-migration records.

Data analysis

The performance of anthropometric indices in identifying children with a high risk of mortality was compared by means of their sensitivity and specificity and of their predictive power estimated from logistic regression models. Whether the use of several anthropometric indices improved the mortality predicting power was tested by the likelihood ratio test comparing the difference of the log likelihood statistics of two logistic regression models (where one is a special case of the other) (12). The goodness of fit of each model was tested by Hosmer-Lemeshow chi-square (C*) (13).

Results

During 10 nutritional surveys, 10 037 anthropometric measurements were taken from 2625 children aged 12–59 mo. **Table 1** shows the mean ± SD of six nutritional indices by child survival status. The nutritional status of children who died was significantly lower for each index than that of those who survived. Because the nutritional status of the children who survived and of those who emigrated from the study area was comparable, the emigration records were excluded from the analysis.

Of the 60 deaths recorded, 30 deaths occurred during the first 3 mo and 30 during the second 3 mo after anthropometric measurement, which resulted in mortality rates 3.06 and 3.07/1000 child-periods, respectively. However, mortality rates were substantially higher in the first 3 mo than in the second 3 mo in severely malnourished children with a marked difference in those classified as wasted (< 80% of WH) children (**Tables 2 and 3**). The risk of death declined with improvement of nutritional status as measured by all indices, although to different extents. The relative risk of death among severely malnourished children in the subsequent 6 mo was 12–20 times higher for AC and WA, 8–9 times higher for ACA and ACH, and 3–4 times higher for HA and WH compared with relatively well-nourished children. However, this may be sensitive to the particular

TABLE 2
Mortality rate per 1000 child-periods by anthropometric indices based on arm circumference

Indices	Number of measurements	Number of deaths in 6 mo	Mortality rate			Relative risk*		
			1–3 mo	4–6 mo	Total	1–3 mo	4–6 mo	Total
Arm circumference (mm)								
<121	599	22	23.4	13.4	36.7	16.7	7.9	11.8
121–130	1729	12	2.9	4.0	6.9	2.1	2.4	2.2
131–140	3317	13	1.5	2.4	3.9	1.1	1.4	1.3
141+	4216	13	1.4	1.7	3.1	1.0	1.0	1.0
Percent of median arm circumference-for-age								
<75	727	21	17.9	11.0	28.9	10.5	6.5	8.5
75–79	1583	14	3.2	5.7	8.8	1.9	3.4	2.6
80–84	2890	9	1.4	1.7	3.1	0.8	1.0	0.9
85+	4661	16	1.7	1.7	3.4	1.0	1.0	1.0
Percent of median arm circumference-for-height								
<80	592	14	15.2	8.4	23.6	10.1	5.6	7.9
80–84	1560	12	3.8	3.8	7.7	2.5	2.5	2.6
85–89	2966	20	2.7	4.0	6.7	1.8	2.7	2.2
90+	4743	14	1.5	1.5	3.0	1.0	1.0	1.0

* Relative risk = mortality rate divided by that of the highest category.

TABLE 3
Mortality rates per 1000 child-periods by weight-, height- and age-based anthropometric indices

Indices	Number of measurements	Number of deaths in 6 mo	Mortality rates			Relative risk*		
			1-3 mo	4-6 mo	Total	1-3 mo	4-6 mo	Total
Percent of median weight-for-age								
<60	507	16	19.7	11.8	31.6	24.6	14.8	19.8
60-69	2591	17	3.1	3.5	6.6	3.9	4.4	4.1
70-79	4333	23	2.3	3.0	5.3	2.9	3.8	3.3
80+	2430	4	0.8	0.8	1.6	1.0	1.0	1.0
Percent of median height-for-age								
<85	1496	23	9.4	6.0	15.4	7.8	2.5	4.3
85-89	4220	22	2.6	2.6	5.2	2.2	1.1	1.4
90+	4145	15	1.2	2.4	3.6	1.0	1.0	1.0
Percent of median weight-for-height								
<80	733	11	13.6	1.4	15.0	5.4	0.5	2.8
80-89	3983	21	1.8	3.5	5.3	0.7	1.2	1.0
90+	5145	28	2.5	2.9	5.4	1.0	1.0	1.0

* Relative risk = mortality rate divided by that of the highest category.

cutoff used for a given anthropometric index. To avoid this, sensitivity and specificity analysis was done.

Figure 1 shows the sensitivity values for a wide range of specificity by using five anthropometric indices to identify children who would die in the subsequent 6 mo. Sensitivity was highest for AC; intermediate for WA, HA, and ACH but at a high level of specificity only; and lowest for WH. The sensitivity of ACA was similar to AC.

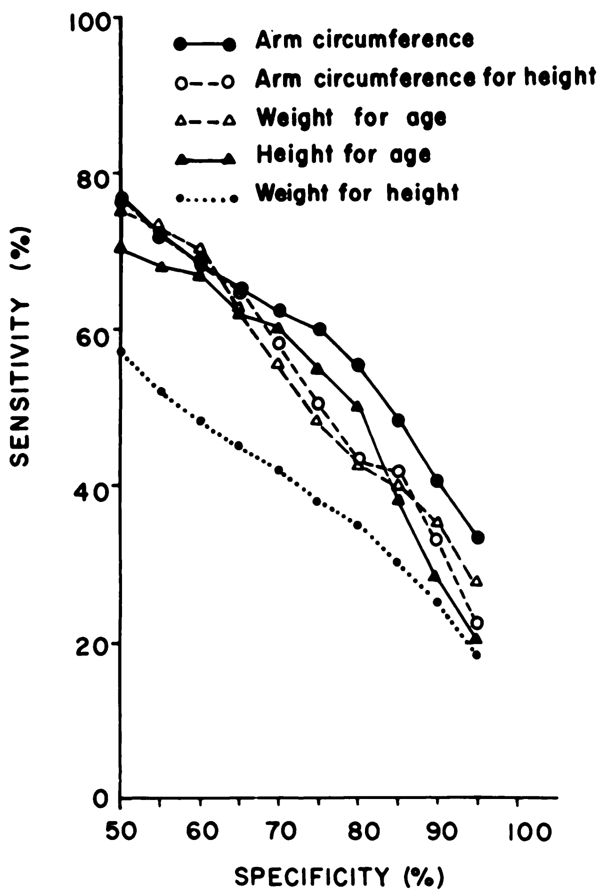

FIG 1. Sensitivity and specificity of the indices in identifying children who died in the 6 mo after anthropometry.

Table 4 shows the results of logistic regression analyses when the risk of death is estimated separately from each anthropometric index. Each index was significantly related to the risk of death and the models fit the data well. The concentration of the actual deaths in the top decile of risk was determined to check the models' ability to identify the children at highest risk. The proportion of children who died and who were in the top decile of the risk distribution were higher for AC and ACA than for WA but WA was better than the other indices examined.

Table 5 presents regression coefficients and the log likelihood statistics of different logistic models for different combinations of the anthropometric indices. The predictive ability of the model with AC alone was the same as the model with AC and one of the other indices: WA, WH, or ACH. However, the predictive power improved significantly after addition of HA to the model with AC. Results remained the same when height unadjusted for age was used. Augmenting of the model with WA by age improved the mortality predicting power over the model with WA alone whereas augmenting of the model with WA by HA showed no improvement.

Discussion

The mortality discriminating power of anthropometric indices and of their combinations was assessed by their sensitivity and specificity, and tested by multiple logistic regression models. Results showed the highest sensitivity for AC and ACA. The mortality predicting power was improved for adding HA to the logistic model

TABLE 4
Univariate logistic models of anthropometric indices to predict death*

Indices	Intercept	Coefficient	Odds ratio	Odds ratio (95% CI)	−2 Log likelihood ratio	Number of deaths in top risk decile	Percent of deaths in top risk decile
Arm circumference (mm)	4.632†	−0.073‡	0.93	0.91–0.94	672.9	24	40
Arm circumference for age (%)	4.906†	−0.124‡	0.88	0.86–0.91	674.6	24	40
Arm circumference-for-height (%)	4.976†	−0.116‡	0.89	0.86–0.92	692.3	20	33
Weight-for-age (%)	1.192	−0.090‡	0.91	0.89–0.94	687.0	21	35
Height-for-age (%)	8.208†	−0.153‡	0.86	0.82–0.90	699.1	17	28
Weight-for-height (%)	0.094	−0.059‡	0.94	0.91–0.97	720.0	14	23

* Goodness of fit statistic C* (8 df) has $p > 0.3$ in all models.
† $p < 0.001$.
‡ $p < 0.01$.

with AC alone. The effects of AC and HA on mortality were independent, ie, increase of mortality risk with decrease of one variable did not depend on the level of the other variable. However, the improvement in predicting mortality risk may be of little practical importance because the proportion of children who died in the top risk decile increased only by one percentage point. Briend et al (10) found no improvement of such inclusion in determining deaths of patients aged < 5 y with diarrhea admitted to the ICDDR,B Dhaka hospital. Our results also showed no improvement in predictive ability for adding any weight-based index to the model with AC, on the other hand, addition of AC to the models with weight- and/or height-based indices led to a significant increase in predictive ability. Although it is doubtful whether or not AC can be used for monitoring a child's growth (14), AC could nevertheless be used instead of WA to predict death.

WA is commonly used to predict mortality risks of malnutrition. Our study's results show that for given values of nutritional status measured by WA, the mortality risk significantly decreased with the child's age. Our results also show that age-dependent indices such as ACA, WA, and HA do not emerge better as screening measures for mortality than an age-independent index such as AC. This is because AC selects proportionately more younger children at an earlier stage of malnutrition compared with WA (15).

TABLE 5
Logistic models for combinations of anthropometric indices to predict death

Indices	Coefficient	−2 Log likelihood ratio	Deviance from univariate model with (a)*	Number of deaths in top risk decile	Percent of deaths in top risk decile
1 (a) AC† (mm)	−0.060‡	671.8	1.1	25	42
(b) Weight-for-age (%)	−0.021				
2 (a) AC (mm)	−0.059‡	668.0	4.9	26	43
(b) Height-for-age (%)	−0.066‡				
3 (a) AC (mm)	−0.074‡	671.6	1.3	25	42
(b) Weight-for-height (%)	0.001				
4 (a) AC (mm)	−0.094‡	671.2	1.7	25	42
(b) AC-for-height (%)	0.045				
5 (a) AC (mm)	−0.074‡	672.9	0.0	24	40
(b) Age (mo)	0.003				
6 (a) Weight-for-age (%)	−0.085§	682.5	4.5	23	38
(b) Age (mo)	−0.021†				
7 (a) Weight-for-age (%)	−0.008§	685.4	1.6	22	37
(b) Height-for-age (%)	−0.004				
8 (a) AC (mm)	−0.065§	667.3	5.6	26	43
(b) Height-for-age (%)	−0.008‡				
(c) Weight-for-age (%)	0.002				

* Deviance from univariate model by using only measurement (a) above.
† AC, arm circumference.
‡ $p < 0.05$.
§ $p < 0.01$.

The higher mortality discriminating power of AC over other anthropometric indices found in the present study and in other studies (8, 9, 16) has important functional implications in the screening of malnutrition. First, screening by AC may enhance the effectiveness of the child survival program by enabling it to focus on those children at greatest risk. Second, AC is more practical for use in areas where age is not available or reliable because an estimate of malnutrition by age-dependent indices is affected by error in age and measurement (17). Third, measurement of AC involves simple inexpensive equipment, is faster and easier, and minimally trained persons make fewer errors in measuring AC than measuring weight and height in door-to-door screening (18).

Chen et al's study (4) found no change in mortality risk over a 2-y period in 2-y-old children in Bangladesh. By contrast, our study's results show declining mortality risks of the severely malnourished children with length of follow-up period. These findings are in accordance with those of other studies done in Bangladesh (2, 19) and in India (3). Declining mortality risk with increase of follow-up period suggests that field anthropometry can be more effectively used in identification of shorter period mortality and be accorded with rapid intervention to avert deaths.

The association between nutritional status and mortality observed in this study population in a remote area of Bangladesh may not apply to other regions with different patterns of morbidity and availability of medical services. However, the direct relationship between malnutrition and mortality for all indices confirms the findings of earlier studies (2–4, 19).

AC is an easy and inexpensive measuring technique and its high ability to predict mortality makes it attractive for screening children to identify those at high risk of death.

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