# Evaluation of Arm Circumference as a Public Health Index of Protein Energy Malnutrition in Early Childhood

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Arm circumference (AC) is an easy and inexpensive way to detect pre-school malnutrition and is, therefore, being used increasingly in lesser-developed nations for rapid and extensive nutrition surveillance and screening programs, as well as for monitoring nutrition rehabilitation (1–7).

It is the purpose of this paper to evaluate the AC measurement as a public health index of protein-energy malnutrition (PEM) as compared with more commonly used anthropometric measures like weight for height and weight for age. The literature is reviewed concerning these relationships, and in the second part of the paper, AC will be compared with weight for height and weight for age by using measurements made on 144 pre-school Guatamalan children.

The AC measure can detect a depletion in muscle tissue (8) and calorie stores, in the form of subcutaneous fat (9,10), and progress in growth (11,12). The AC of pre-school children, excluding infants, has been shown to increase very little with age (11,13) and to vary little between ethnic groups (10). Based on a large sample of healthy Polish children (14), Wolanski demonstrated that the AC of children aged 0 to 12 months increased rapidly, whereas it varied little between 12 and 60 months as well as between the sexes, and that from the second to fifth year fat tissue is replaced by muscle so that overall AC increases only 1.5 cm. Therefore, an age constant measurement of 16.5 cm has been recommended as a standard for use during this 4-year period when age is not known (15). Percentages of this standard have been applied to determine degrees of malnutrition and are as follows (5):

| *Nutritional Status* | *Percent of Standard* | *Arm Circumference* |
|---|---|---|
| Severe malnutrition | Less than 75% | Less than 12.5 cm |
| Moderate malnutrition | Between 75% and 85% | 12.5–13.5 cm |
| Normal | Over 85% | Over 13.5 cm |

Since most cases of malnutrition occur within this 4-year age span, AC seems to be a promising public health index for screening malnutrition.

### Review of the Literature

The literature was reviewed concerning the relationship between AC and the more conventional anthropometric indices of malnutrition, e.g., weight for height and weight for age. Table 1 gives correlation coefficients in ascending order for various studies in which AC was compared to weight for height, weight for age, and weight alone. Since the author's data concern only AC versus weight for height and weight for age, these two variables will be emphasized in the discussion.

Most of the correlation coefficients between AC and weight for height are similar. All but four of the correlation coefficients between AC and weight for height lie in the 0.66 to 0.79 range. Even though the coefficient is low for the Colombian sample, Acciarri *et al.* (17) stated that AC was highly associated with acute malnutrition, as manifested by weight for height, and considered the relationship between weight for height and AC to be good. They also believe the relationship between AC and weight for age to be good. Likewise both coefficients are low in the Guatemalan study (17). The 0.55 coefficient for

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weight for height and AC derived by Rutihauser (19) for the 37 to 48-month old Nilotic population of Uganda also falls out of the range, although these coefficients are higher for the younger age groups of this same population. The opposite applies to the Indian population of Hyderabad studied by Visweswera and Singh (20). These investigators recorded a stronger relationship between the AC and weight for height of older children than for the 1 to 2-year age group.

The correlation coefficients for AC and weight for age are similar to those for AC and weight for height and fall in the 0.59 to 0.78 range. The low correlation for the Egyptian children at first led El Lozy (23) to place little trust in AC. However, subsequent studies (32) convinced him of its validity. The data collected by Jelliffe and Jelliffe (24) during a nutritional study, where 19 per cent of all households in Barbados were sampled, also revealed a low correlation with weight for age (0.62). The investigators believed this was due to the marked layer of subcutaneous fat exhibited by a substantial number of children. Of children 12 to 59 months old, 47.3 per cent had triceps measurements 80 per cent of the standard, while 18.6 per cent had fatfolds of 100 per cent or more of standard.

The largest range of correlation coefficients reported (0.52 to 0.95) is for AC and weight alone (Table 1). The study done in the United States (31) is the highest of the coefficients, most likely because of the choice of study subjects. Weight alone is less acceptable as a measure of malnutrition in children and was not used in the present study.

Some concern has been expressed over the sensitivity of AC, or its ability to detect malnourished children with respect to weight for height and weight for age. Shakir (15) found that one of the major limitations to using AC was that it was not a very sensitive indicator of moderate or mild malnutrition as determined by weight for age. Based on data collected from 800 Colombian pre-school children, Acciarri *et al.* (33) observed AC to be more sensitive in detecting cases of acute, rather than chronic, malnutrition and in cases of severe, rather than mild, malnutrition. In their national probability samples

TABLE 1
*Studies correlating arm circumference of individuals (Loewenstein and Phillips,[16] updated by authors)*

| Country and (Investigators) | Location or Ethnic Group | No. | Age | Measurements | Correlation Coefficients |
|---|---|---|---|---|---|
| Colombia (Acciarri *et al.*)[17] | Cali | 800 | 0 3 yrs | AC vs wt/ht | 0.47 |
| Guatemala (INCAP, unpublished)[18] | Patulul | 2,792 | 1 5 yrs | AC vs wt/ht | 0.53 |
| Uganda (Rutihauser)[19] | Nilotic | 23 | 37 48 mths | AC vs wt/ht | 0.55 |
| India (Visweswara and Singh)[20] | Hyderabad | Total 2,292 | 1 2 yrs | AC vs wt/ht | 0.58 |
| | | | 2 3 yrs | AC vs wt/ht | 0.60 |
| | | | 3 4 yrs | AC vs wt/ht | 0.67 |
| Nepal (Nichaman *et al.*)[21] | National probability sample | | 0 5 yrs | AC vs wt/ht % of median | 0.67 |
| Uganda (Rutihauser)[19] | Bantu | 19 | 25 36 mths | AC vs wt/ht | 0.67 |
| | Nilohamatic | 34 | 37 48 mths | AC vs wt/ht | 0.70 |
| | Nilotic | 29 | 13 24 mths | AC vs wt/ht | 0.71 |
| Sri Lanka Nichaman *et al.*)[21] | National propability sample | | 0 5 yrs | AC vs wt/ht % of median | 0.72 |
| Uganda (Rutihauser)[19] | Nilohamatic | 72 | 25 36 mths | AC vs wt/ht | 0.73 |
| | Bantu | 36 | 13 24 mths | AC vs wt/ht | 0.75 |
| | Nilohamatic | 85 | 13 24 mths | AC vs wt/ht | 0.76 |

TABLE 1 (*continued*)

| Country and (Investigators) | Location or Ethnic Group | No. | Age | Measurements | Correlation Coefficients |
|---|---|---|---|---|---|
| Togo (Nichaman *et al.*)[21] | National probability sample | | 0-5 yrs | AC vs wt/ht | 0.76 |
| Uganda (Rutihauser)[19] | Nilotic | 25 | 25-36 mths | AC vs wt/ht | 0.77 |
| Uganda (Rabinow and Jelliffe)[22] | Busoga | 156 | 2-33 mths | AC vs wt/ht | 0.79 |
| Guatemala (INCAP, unpublished)[18] | Patulul | 2,972 | 1-5 yrs | AC vs wt/age | 0.59 |
| Egypt (El Lozy)[23] | | | | AC vs wt as % normal | 0.59 |
| Colombia (Acciarri *et al.*)[17] | Cali | 800 | 0-6 yrs | AC vs wt/age | 0.62 |
| Barbados (Jelliffe and Jelliffe)[24] | 1% Household survey | | 12-59 mths | AC vs wt/age | 0.62 |
| Uganda (Cool)[25] | Ankole | 70 | 36-47 mths | AC vs wt/age | 0.68 |
| | | 59 | 28-59 mths | AC vs wt/age | 0.70 |
| | | 77 | 12-23 mths | AC vs wt/age | 0.73 |
| | | 76 | 24-35 mths | AC vs wt/age | 0.78 |
| Tanzania (Kondakis)[26] | Kilimanjaro Region | 211 | 1-48 mths | AC vs wt | 0.52 |
| Malaysia (McKay)[27] | Alu trangrance | 26 | 4.0 yrs | AC vs wt | 0.60 |
| India (Visweswera and Singh)[20] | Hyderabad | Total 2,292 | 1-2 yrs | AC vs wt | 0.61 |
| | | | 2-3 yrs | AC vs wt | 0.65 |
| | | | 3-4 yrs | AC vs wt | 0.65 |
| Iran (Froozani)[28] | Esfahan | 40 | 13-24 mths | AC vs wt | 0.68 |
| Zambia (Blankhart)[29] | African | 975 | 6-36 mths | AC vs wt | 0.75 |
| Sierra Leone (Blankhart)[29] | African | 1,351 | 6-36 mths | AC vs wt | 0.75 |
| Malaysia (McKay)[27] | Alu Trangance | 54 | 3.0 yrs | AC vs wt | 0.78 |
| | | 41 | 2.0 yrs | AC vs wt | 0.79 |
| Lebanon (Kanawati *et al.*)[30] | Arab | 1,049 | 3-48 mths | AC vs wt | 0.79 |
| Uganda (Robinow and Jelliffe)[22] | Busoga | 156 | 35-36 mths | AC vs wt | 0.79 |
| Tanzania (Kondakis)[26] | Dodoma | 359 | 1-48 mths | AC vs wt | 0.82 |
| United States (Chovivathanavanich and Kanthavichitra)[31] | Negro and Puerto Rican | 316 | 1-72 mths | AC vs wt | 0.95 |

for Sri Lanka, Nepal, and Togo covering 18,751 pre-school children, Nichaman *et al.* (21) found the specificity of AC (ability to detect those who do not have malnutrition) to be high, but the sensitivity (ability to detect those who do have the disease) to be low and to vary with each age group. In this study the median weight for height for each population was used as the criterion for comparison.

Zeitlin (34) described the degree of sensitivity of AC versus weight for age by diagrammatically demonstrating that Filipino cases of malnutrition by weight for age and AC did not completely overlap. She discovered, however, that those children shown to be malnourished by weight for age and not by AC were above the critical 16–24 months age period, that their weight for age did not exceed the Harvard third percentile for weight for age, and that weight for age did not differ for the non-overlapping pairs. Thus, her results indicated that 'younger children are selected by AC at an earlier, more easily reversible stage of malnutrition, when weight has fallen off, but length is more normal' (34, p. 303).

Margo (35) is more directly critical of the measurement. He maintains that, if AC is indeed a valid measurement, the difference between cases detected by the AC or weight for age measurement should be more or less constant for all studies. When reviewing the literature, he found this not to be the case (Table 2). Shakir and Morley (5) identified only 3 per cent of their study population as normally AC and below 80 per cent of the Harvard standard (false negative), and 20 per cent as below 85 per cent of the standard for AC and normal for weight (false positive). Cook (25) and Margo (35), on the other hand, encountered much higher false negative rates (13.5 per cent and 70.2 per cent, respectively) in their African pre-school study populations. The discrepancies between results obtained from various studies are summarized in Table 2, and illustrate Margo's skepticism toward the reliability of AC as a surveillance tool. The false negative and positive rates for AC versus weight for age based on data collected from 3,801 pre-school Ladino children of migrant workers in Patulul, Guatemala, were 48.9 per cent and 24.3 per cent, respectively (18). These rates were 6.7 per cent and 71.2 per cent when weight for height was used as a criterion.

Unfortunately, studies such as these are limited, and their varied results have led to the confusion and skepticism of many nutrition-related workers who might have been able to profit from the use of the AC measurement in field surveillance programs. It is hoped that the increasing amount of work done in this area, using standard techniques, will illuminate the trade-offs of this economically efficient tool for malnutrition detection.

## Materials and Methods

In an effort to develop methodology for rural health systems, the Division of Human Development of the Institute for Nutrition for Central America and Panama (INCAP) has undertaken a project in four Indian villages on the shores of Lake Atitlan in the Department of Solola, Guatemala. Since the project employs minimally trained health promoters to work in the community, AC was proposed by the investigator as a simple and inexpensive tool with which to perform continual screening for malnutrition in pre-school children. In order to support this choice in this setting, the investigator collected and analyzed relevant data from one village, San Pablo La Laguna. Height, weight, and AC measurements were taken by

TABLE 2
*Studies using arm circumference compared to weight for age*[35]

| Country and (Investigators) | Ethnic Group | Number | Age Months | False Positive | False Negative |
|---|---|---|---|---|---|
| Bagdad, Iraq (Morley and Shakir)[5] | Arab | 777 | 13–72 | 20 | 3 |
| Uganda (Cook)[25] | Ankole | 282 | 12–60 | 21 | 13.5 |
| South Africa (Margo)[35] | Non-white | 621 | 13–60 | 1.3 | 70.2 |
| Sierra Leone (Blankhart)[29] | African | 544 | 7–36 | 16[a] 24[b] | 5[a] |
| Guatemala (INCAP)[18] | Guatemalan | 2,801 | 12–60 | 24.3[c] | 48.9[d] |

[a]Figures obtained using 12.0 cm cut-off point for malnutrition.
[b]Figures obtained using 12.5 cm cut-off point for malnutrition.
[c]Unpublished data added to table by authors.
[d]Figures obtained using 13.5 cm cut-off point for malnutrition.

the investigator for 144 children, aged 0 through 5 years, who attended the health post voluntarily. Age data were solicited from the mother by the health promoters in Indian dialect and the investigator recorded the data. The children included in the study were believed to be chronically malnourished, as exemplified by their low weight for age (75 per cent of the Harvard standard) and normal weight for height (98 per cent of the standard) (17,36). Although no cross-sectional data exist on the nutritional status of the pre-school population of San Pablo, it is the investigator's opinion, based on the health personnel's experience in the community, that the attenders were somewhat healthier than those who did not attend.

Weight for age and weight for height were chosen as the criteria with which to compare AC, since these are the most commonly used field measures of malnutrition. For the analysis, the Wolanski standards were used for AC, and the Harvard standards were selected because they are the most universally applied and, therefore, lend themselves to international comparison.

The cut-off point for malnutrition used for AC was 13.5 cm. Children were categorized as malnourished if their weight for height and weight for age were 90 per cent and 80 per cent or less, respectively, of the Harvard standards. These cut-off points are commonly used in field surveys (17,19,37) and are recommended by Jelliffe (14). Because it is generally believed that environmental rather than genetic factors influence the size of a young child (38), the Harvard and Wolanski standards may and have been applied to ethnically different populations.

[illegible] manufactured child-meter for height, and a strong plastic measuring tape for AC. All shoes, hair ornaments, and extraneous objects were removed before weighing and measuring. Since it was culturally unacceptable to remove clothes, an estimation of the weight of clothes was used to correct the body weight. The AC measurement was taken at the midpoint of the upper arm between the acromion and olecranon. This point was visually located, a method which has been shown to be quicker and as reliable as locating the midpoint by measurement (24,30,39). All measuring equipment was calibrated daily.

## Results

### *Correlation Analysis*

In order to study the relationships between the various measures, correlation analyses were performed for weight for age, weight for height, AC, and AC for age measurements. Age was correlated with all those measures. The results are presented in Table 3 and show that AC was the most highly correlated with weight for height (0.7911). The correlation of AC with weight for age was somewhat lower (0.7127). There is a very strong correlation between AC and AC for age (0.9683) and the relationships of each of these variables to weight for age and weight for height are similar (0.7127 and 0.7911, 0.7573 and 0.7416, respectively). Age was shown to have some relationship with both AC (0.5132) and weight for height (0.3234). Although these coefficients are low, they are significant.

### *Sensitivity and Specificity Analysis*

In order to determine how well AC was able to identify groups of malnourished children as defined by a single cut-off point, cross tabulations were made between cases detected by AC and those categorized by weight for height and weight for age as presented in Tables 4 and 5, respectively. Only children 12 through 60 months (n = 109) were used for this analysis, since AC cut-off points based on the con[illegible] this age group (5,15).

### *Weight for Height*

When compared with weight for height, AC had a specificity of 65 per cent and a sensitivity of 90 per cent, with false positive and negative rates of 35 per cent and 10 per cent, respectively (Table 4). The false negative group (those categorized as malnourished by weight for height but not by AC) was made up of only

TABLE 3
*Correlations of anthropometric measures taken in health post children 12 to 60 months (N = 144)*

| | Weight/Age | Weight/Height | AC | AC/Age | Age |
|---|---|---|---|---|---|
| Weight/Age | 1.0 | | | | |
| Weight/Height | 0.6953 | 1.0 | | | |
| AC | 0.7127 | 0.7911 | 1.0 | | |
| AC/Age | 0.7573 | 0.7416 | 0.9683 | 1.0 | |
| Age | 0.11788* | 0.3234 | 0.5132 | 0.3006 | 1.0 |

* Not significant ($p > 0.05$); all other numbers significant ($p < 0.001$).
AC = Arm Circumference.

TABLE 4

*False negative, false positive, sensitivity and specificity rates for AC compared to weight for height for 109 children 12 to 60 months measured in the health post*

| | Weight for Height | | |
|---|---|---|---|
| AC | Normal >90% Harvard Standard | Malnourished ≦90% Harvard Standard | Total |
| Normal >13.5 cm | True negatives = 58<br>Specificity = 65% | False negatives = 2<br>10% | 60 |
| Malnourished ≦13.5 cm | False positives = 31<br>35% | True positives = 18<br>Sensitivity = 90% | 49 |
| Total | 89 | 20 | 109 |

AC = Arm Circumference.

TABLE 5

*False negative, false positive, sensitivity and specificity rates for AC compared to weight for age for 109 children 12 to 60 months measured in the health post*

| | Weight for Height | | |
|---|---|---|---|
| AC | Normal >80% Harvard Standard | Malnourished ≦80% Harvard Standard | Total |
| Normal >13.5 cm | True negatives = 29<br>Specificity = 91% | False negatives = 31<br>40% | 60 |
| Malnourished ≦13.5 cm | False positives = 3<br>9% | True positives = 46<br>Sensitivity = 60% | 49 |
| Total | 32 | 77 | 109 |

AC = Arm Circumference.

two cases, one of which was borderline for weight for height (89 per cent of standard), and thus, not severely malnourished.

The percentage of false positive cases (those identified as malnourished by AC and not by weight for height) was high (35 per cent). Fifty-two per cent of these children had ages in the critical 6-24 month age period,* and a total of 73 per cent were under three years old. All children categorized as false positive were malnourished by weight for age. All but two cases were shown to be moderately malnourished by AC.**

The predictive value of a normal AC was 97 per cent, which means that of all those cases declared normal by AC, 97 per cent really are normal when weight for height was used as a criterion. The predictive value of a deficient AC, however, was considerably lower (37 per cent).

*Weight for Age*

As seen in Table 5 the sensitivity and specificity rates of AC, when weight for age is the criterion, are 60 per cent and 97 per cent, and the false negative and positive rates are 40 per cent and 9 per cent, respectively.

* Children younger than two years are especially vulnerable to malnutrition in developing countries where food intake is low and sanitation below optimum. During the first two critical years a child utilizes one-third of his food for growth as opposed to 1 per cent for older children (40), he is more susceptible to disease and is not yet eating an adult diet. For these reasons most serious cases of malnutrition occur during this age.

** The two cases were a set of twins who showed classic symptoms of marasmus and were very underweight for their 14-month age (44 per cent and 49 per cent, respectively). Their AC was also very low (10.1 cm) although they had normal weight for heights (93 per cent), which was due to the excessive degree of stunting which had already affected them. The only child in the measured population whom the investigator classified as having symptoms of kwashiorkor also had a normal weight for height (93 per cent). This child's AC, on the other hand, was 12.9 cm and her weight for age only 69 per cent of the standard.

The false negative percentage is very high and cause for concern, since these children would not be detected by AC and hence not referred to the health post for confirmation. Therefore, these cases were reviewed to gain insight into their characteristics. The mean age of these children was 44 months; only four (13 per cent) were younger than 30 months. In other words, most of them were past the critical age period. Moreover, of the four under 30 months, all but one had a weight for age adequacy between 75 per cent and 80 per cent of the standard (degree 1, Gomez). The one exception was a child of 28 months. All of the 43 false negative children had a normal weight for height percentage (above 90 per cent) with a mean of 103 per cent. This group was generally very stunted with a mean height of 82 per cent of the standard, which caused them to be categorized as malnourished by weight for age and normal by weight for height and AC.

With respect to weight for height, the predictive value of a normal AC was only 48 per cent, whereas that of a deficient AC was 94 per cent. This trend is the opposite of that shown by AC when it was compared to weight for height.

*AC vs. Weight for Height vs. Weight for Age*

The ability of each of these measures to identify cases of malnutrition with respect to one another is illustrated in the Venn diagram (Figure 1). Of all the 109 cases measured, none was categorized as being malnourished by weight for height alone. Only 3 (2.8 per cent) were so categorized by AC, as compared to 29 (26.6 per cent) for weight for age. All cases identified as being malnourished by weight for height (20 = 18 per cent) were malnourished by weight for age and 18 (90 per cent) of those had a low AC. Of the 77 categorized as malnourished by weight for age, less than one-fifth (16 per cent) had weight for height measures below 90 per cent of the standard, whereas 60 per cent (46) had an AC measure of 13.5 cm or below. Most of the 49 cases with low AC had a low weight for age (94 per cent), whereas for weight for height this was true for only 37 per cent (18) of the cases. Weight for age classified 71 per cent of the children as malnourished, which is 37 per cent more than AC (45 per cent) and 75 per cent more than weight for height (18 per cent).

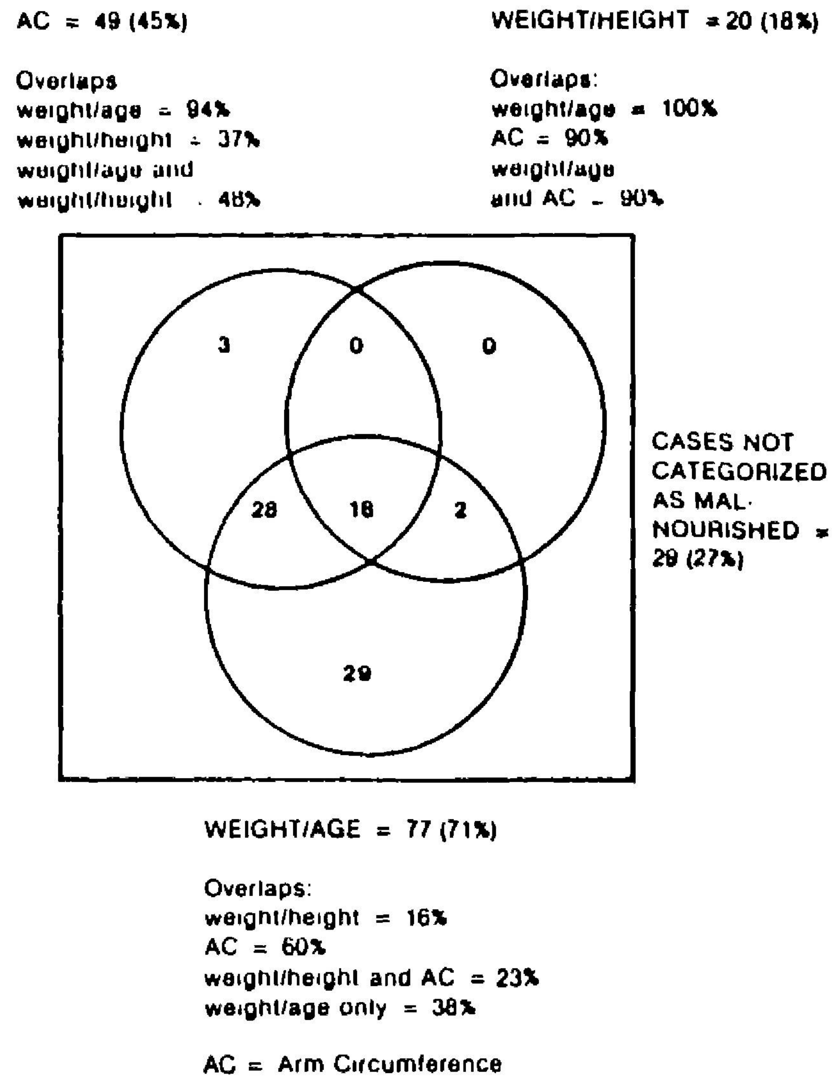


FIG. 1. Venn diagram illustrating relationship of ability of arm circumference, weight/height, and weight/age to detect cases of malnutrition (n = 109). Children 12 to 60 months measured in health post.

## Discussion

The analysis demonstrated that there was a strong correlation between AC and weight for height, as well as weight for age. The coefficient between AC and weight for height (0.79) was higher than any encountered in the literature reviewed, although most of the correlation coefficients derived by Rutihauser (19) for her Ugandan population and all of those described by Nichaman *et al.* (21) lie within the 0.67 to 0.76 range. It is interesting, however, that the correlation between the measures taken for Latin American populations is consistently lower (17,25) compared to all studies reviewed. Unfortunately, more publications on Latin American populations were not available for review, so that no conclusions can be made concerning correlations within these populations. It is, however, very unlikely that they are so ethnically different from those populations reviewed that the relationships between their anthropometric measurement could vary to such a degree (38). This discrepancy is also found when AC was correlated with weight for age. The 0.71 correlation derived for the Guatemalan study population of San Pablo, however, is within the range of those found by Cook (25) for a pre-school Ugandan population. The San Pablo coefficient also agrees with those listed for AC versus weight in all but one (26) of the studies reviewed.

The high correlation coefficient for AC and AC for age and similar correlations with weight for age and weight for height indicate that either measure may be used in the detection of malnutrition among young children. The 0.5132 correlation coefficient for AC and age demonstrates, however, that there is a relationship between these two variables and that AC, therefore, is not entirely age independent for the San Pablo population. Martorell *et al.* (41) also discovered a relationship between age and AC for 1,240 Ladino Guatemalan pre-school children. Whereas these children showed an increase of 38 per cent in the AC during the first 12 months of life, which is in keeping with the 31 per cent increase found in the standard population of Wolanski, the increase for the next 48 months was nearly twice as high for the Guatemalan population (15 per cent) as that encountered for the Polish children of the standard (8 per cent).* It must be kept in mind, however, that both Guatemalan populations have been subjected to some degree of malnutrition which may in itself vary with age (35,40). Various studies (42–44) concerning the AC of healthy standard populations have shown results similar to those of Wolanski. If, however, AC were dependent on age, the measure would detect more younger children, which is to their advantage, for they are at a higher risk of malnutrition (4,30).

AC was also shown to identify 90 per cent of the cases categorized as malnourished by weight for height. The measure did not perform as well when weight for age was used as the criterion for malnutrition. The Venn diagram, however, demonstrates that weight for height and weight for age do not measure the same thing, the former being an indicator of acute malnutrition and the latter of cumulative episodes of malnutrition (33,45). While all children with low weight for height were also shown to be malnourished by weight for age, the reverse did not apply. This is not surprising considering that the study population was chronically malnourished as demonstrated by their low mean weight for age (75 per cent) and height for age (85 per cent) and normal weight for height (98 per cent). In fact, 71 per cent of all the children had weights below 85 per cent of the standard for their ages, and of all the children classified as malnourished by any of the three measures, over one-third had only weight for age deficiencies, as compared to zero for weight for height, and 3 per cent for AC. Only one-fifth of the total population had low weights compared to their standard heights. Even though only 37 per cent of the children with low AC had a low weight for height, 94 per cent of them had a low weight for age. Thus, whereas AC with respect to weight for height has a high false positive rate (35 per cent) and low false negative rate (10 per cent), these values are reversed (9 per cent and 40 per cent, respectively) when weight for age is the criterion.

* Martorell *et al.* (41) also found AC to be sex dependent. However, the difference between the AC measurement for the Wolanski males and females (0.51 cm for 0–11 months, 0.31 cm for 12–60 months) is consistently larger than those between the Guatemalan sexes (0.125 and 0.23 cm, respectively).

The cross-tabulation analysis points out, however, that these children identified as being malnourished by AC, but not by weight for height (false positives), may have been at risk of malnutrition. They were mostly younger and had low weights for age. In a sytem where AC is used to screen and refer cases to a health post for confirmation by weight for height, the false positives would have been attended. Given the critical age of these children, attendance is preferred, especially since the assessment by weight for age classified the 31 false positives as malnourished. Shakir (5) agrees that this 'misclassification is in favor of the child, and could be useful in crisis situations, for children in this critical age interval' (p. 665).

The false negatives, on the other hand, would have been lost to any kind of follow up. AC would have failed to screen 40 per cent of the children for confirmation by weight for age. Even though the number is large, these children were probably not at a high risk of being severely malnourished, for most of them were beyond the critical age range and all of them had normal weight for heights. The generally stunted nature of this group was most likely responsible for this misclassification.

Similar results concerning classification of children according to AC with respect to weight for height and weight for age were found in the Patulul population of Guatemala (18). The resulting false negative rates (6.7 per cent and 48.9 per cent, respectively) corresponded closely to those counted in San Pablo. Both false positive rates (71.2 per cent and 4.3 per cent), however, were substantially higher. As in the San Pablo study, the Patulul data showed a low false negative rate and high false positive rate when AC was compared to weight for height, while the reverse was true when weight for age was used as the criterion. With the exception of his own investigation of 621 non-white African children, all other studies Margo (35) reviewed (Table 5) had much higher sensitivities (85 per cent to 97 per cent) for AC with respect to weight for age than were encountered in either Guatemalan population.

The San Pablo data suggest that AC may have been a more sensitive indicator of malnutrition among younger age groups when compared to either weight for height or weight for age. Zeitlin's (34) findings for Filipino cases of malnutrition support this view. She found that AC and thigh circumference selected younger children who had experienced weight loss, but who were not yet affected by nutritional stunting. Cook (30) also found the correlation between weight for age and AC for age to be higher for children less than 36 months old, although the highest coefficient was found with the 24 to 36-month age group.

## Conclusion

These findings have definite implications for nutritional screening and prevention programs. Even though it would be ideal to identify and intervene in all cases of malnutrition, in poor areas with high rates of malnutrition resources simply would not allow it. When compared to weight for age, AC selected a younger and more severely malnourished group of cases that was smaller in number and hence more feasible to treat. AC successfully detected children with acute malnutrition as defined by weight for height, who are the children with the greatest risk of deteriorating nutritional status and even death (46). Moreover, AC also performed well in identifying severely malnourished children whose stunted condition made their weight appear normal for their height.

The results of the study presented herein suggest that in areas where malnutrition affects young children and where nutritional stunting is common, AC is a useful indicator of malnutrition. AC has been shown to be a good surrogate for the more commonly used weight for height and weight for age. Therefore, it is recommended that AC be adopted by nutrition screening and surveillance programs in poor areas of the developing world where severe malnutrition is prevalent and resources limited.

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