Fatness and muscularity as risk indicators of child mortality in rural Congo

Jan Van den Broeck,[a] Roger Eeckels[b] and Anita Hokken-Koelega[a]

Objectives To examine the relationship of anthropometrical indicators of fatness and muscularity with mortality in children in a rural African community.

Background A prospective cohort study was carried out in the rural health zone of Bwamanda, Northern Congo using a random cluster sample of 5167 children, aged 0–5 years.

Main outcome measures Short- and long-term mortality rates, being deaths within 3 months and deaths in 3-month periods observed 3–30 months after enrolment. Rates of all cause mortality and of mortality from kwashiorkor or marasmus, by level of baseline fatness and muscularity. Indicators of fatness and muscularity were obtained by correcting anthropometric arm fat and arm muscle areas for age, sex, weight and height.

Results The relationship of both the fatness and muscularity scores with short-term mortality was marked by a clear threshold (–0.5 SDS) below which there was a significant rise in mortality from all causes as well as from kwashiorkor and marasmus. These excess mortalities were also found in normal weight children. Fatness and muscularity scores remained significant determining factors of short-term mortality in a multiple logistic regression analysis with sex, age, season and weight-for-age. A ROC curve analysis showed that fat and muscularity scores had better predictive abilities than weight-for-age. Low fat status had a bad prognosis on the long-term in underweight children.

Conclusions Measures of current nutritional status should not be based on weight indices alone. Objective and/or clinical evaluation of fat and muscle status (also in normal weight children) should be added in order to detect a higher proportion of malnourished children and to more accurately evaluate mortality risk.

Keywords Body composition, child mortality, Congo

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In less developed, as well as in more industrialized countries, it has been shown that anthropometry is able to define groups of children at increased risk of death.[1–3] Excess mortality has been demonstrated in children who are underweight, wasted, or have a low arm circumference. However, most children who die, do not belong to one of these categories. In fact, weight-for-age and weight-for-height are both poor predictors of mortality.[4–6] This is partly because underweight or wasted children constitute only a fraction of all malnourished children.[6,7] Various forms and degrees of malnutrition occur in children who are (still) within normal international references for weight and/or height. It is therefore important to investigate whether there are other anthropometrical measures that can identify children at increased risk of death independently of the traditional measures of weight, height or arm circumference. In this study we examined the influence of anthropometric fat and muscle status on mortality.

Anthropometric methods to estimate body fat include assessment of skinfold thickness such as triceps skinfold thickness (TST) and the fat area of an imaginary cross-section of the upper arm (arm fat area or AFA).[8,9] Body muscle mass can be estimated anthropometrically by, for example, the muscle area on an imaginary cross-section of the upper arm (arm muscle area or AMA).[10,11] Both AFA and AMA are secondary variates that can easily be derived from mid-upper arm circumference and triceps skinfold thickness. However, recent studies of total body electric conductivity (TOBEC) have shown that the correlation between skinfold thickness and total body fat, and between AMA and total body muscle are far from perfect.[12] Although for individual assessment of body composition, anthropometry is being replaced by more accurate but also more complicated methods, it remains a valid tool for epidemiological studies of the body composition in large groups.[12]

[a] Dutch Growth Foundation, Sophia kinderziekenhuis, PO Box 2060, 3000 CB Rotterdam, The Netherlands.

[b] Department of Paediatrics, University of Leuven, Belgium.

Subjects and Methods

Study area

The Bwamanda project is a cohort study of health, nutrition and mortality among Bantu children aged 0–5 years.[2] Bwamanda is a traditional rural tropical area in North-Western Congo. People live in huts with mud walls and thatched roofs. There is a rainy season from June to November and a dry season from December to May. Food is scarce in the dry season and in the rainy season there is an increased infectious burden.[13] The society is characterized by an almost complete absence of socio-economic stratification, literacy and birth control. Women bear the major responsibility for survival. They have to cope with a lot of conflicts of interest, in particular allocation of time spent on child bearing and caring, subsistence farming of maize and cassava, fetching water and wood, looking after their husbands' needs and preparing meals.

The commonest causes of death among children in Bwamanda[2] are malaria (26%) and anaemia (24%), which is often malaria-related, and not diarrhoea, unlike in many other tropical areas. Marasmus or kwashiorkor also are important causes of death (17%). In Bwamanda, mortality risk remains almost unchanged over a wide range of weight-for-age (WFA) and weight-for-height (WFH) standard deviation scores (SDS), but rises steeply at extremely low scores (WFA<−3 SDS, WFH<−1.5 SDS).[2] We have also shown that children with normal WFA (SDS>−2) or WFH (SDS>−1.5) do have an increased mortality risk if they have clinical signs of muscle wasting.[7] This combination of normal WFA or WFH with signs of muscle wasting was shown to affect 17.6% of children and was termed clinical-anthropometrical mismatch. This suggested that it may be important to assess muscularity in normal weight children in order to better predict risk of death.

Sampling and surveys

We anticipated that for a reasonably detailed study of risk factors of mortality, the deaths of 300 children should be analysed. The required sample size was therefore calculated, taking into account that in the study region birth rate is 31 o/oo, infant mortality 98 o/oo and child mortality 38 o/oo.[14] A cohort of 4000 children should then be followed over 3 years. The mean number of inhabitants per village was estimated at 1500 and the proportion of pre-school children at 15–20%. Hence, a sample of 16 villages was taken from the total of 52 villages. All the huts were visited by a team of 15 interviewers and 4238 children were declared. All were enrolled. Six trimestrial surveys of this cohort were done at the children's homes or at under-5 clinics; the first in October to December 1989. At each survey, new births, immigrants and previously undetected children were added to the cohort. The latter's size eventually reached a maximum of 5167. In April 1992, 30 months after start, an extra seventh mortality survey was done. Mortality interviews at each round and hospital and funeral registers revealed 246 deaths. Relatives were asked for date and cause of death and whether the deceased child had had marasmus or kwashiorkor, two conditions well known to the local population. At each survey, measurements of weight, length-height, MUAC and TST were done by two anthropometrists helping and supervising one another. Coverage, from the first to the sixth survey, was 88%, 87%, 88%, 86%, 89% and 81%.

Assessment of fatness and muscularity

The AFA and AMA were derived from MUAC and TST with the formulas[8,10]:

$$AFA = MUAC^2/4*\pi - AMA$$

$$AMA = (MUAC - TST*\pi)^2/4*\pi$$

To make AFA and AMA comparable between sexes and ages, standardization was necessary. Furthermore, for a same sex and age, one AFA or AMA may represent totally different degrees of fatness and muscularity as a function of total body mass. Therefore an additional adjustment for weight and height was necessary. It should be noted that by adjusting for body weight we did not want to obtain an estimate of absolute fat mass or muscle mass, but indicators of body fat percentage and body muscle percentage. The corrected values were the studentized residuals of a multiple linear regression[15] of AFA or AMA on sex, age, weight and height. Regressions were done separately for age categories of one month up to 12 months of age and for categories of 3 months, thereafter. The obtained residuals are further referred to as corrected internal standard deviation scores (SDS_c). For each child AFA-SDS_c and AMA-SDS_c were computed. Checking the Root Mean Square Errors of the regressions of AFA and AMA on the correcting variables revealed that in boys, one SDSc unit at age one year represents 89 mm^2 of AFA and 118 mm^2 of AMA. At age 5 years it represents 119 mm^2 of AFA and 191 mm^2 of AMA.

Influence of fatness and muscularity on child mortality

For this analysis, the method of child periods at risk was used.[2] Death rates are expressed as number of deaths per number of child trimesters. Short-term mortality was analysed separately from long-term mortality because the former comprises mainly case fatalities from acute illnesses and is therefore expected to have another risk factor profile. In addition, short-term mortality is expected to be more strongly related to anthropometry than long-term mortality because of the instability of anthropometric characteristics in tropical circumstances. Short-term mortality was defined as deaths occurring within 3 months after examination and long-term mortality as deaths between 3 and 30 months after it. Child periods were observed from the first survey on, except for new-borns and immigrants, for whom observation started at the survey of first assessment. Separate analyses were done for all-cause mortality and mortality attributed to severe malnutrition i.e. marasmus or kwashiorkor. We examined whether there was any AFA-SDS_c or AMA-SDS_c cutoff below which there was an excess mortality. On the basis of these *a posteriori* cutoffs, children were categorized as 'lower' or 'higher' AMA or AFA. Relative risks (RR) with 95% confidence intervals (CI) were used to compare death rates between both categories.[16] We were especially interested in the question whether fat or muscle scores would also be related to mortality in normal weight children. For this analysis normal weight was defined as a WFA-SDS >−2, underweight as WFA-SDS ≤−2. A previous analysis[6] has shown that the WFA-SDS cut-off of −2 SDS is the optimal cutoff with respect to mortality prediction. A multiple logistic regression was done to check whether the relationship between fatness/muscularity and short-term mortality persisted if they were examined together with the other mortality determining variables sex, age, season and WFA. Interaction terms between any of these variables were added to the model. Finally, an ROC curve analysis[6] was performed to compare the predictive abilities of weight, muscle and fat indices and of a prognostic index derived from combining the variables that were significant in the multiple logistic regression. This combination was done by weighting these variables proportionally to their parameter estimates.[6] All analyses were done with the SAS statistical package.[17]

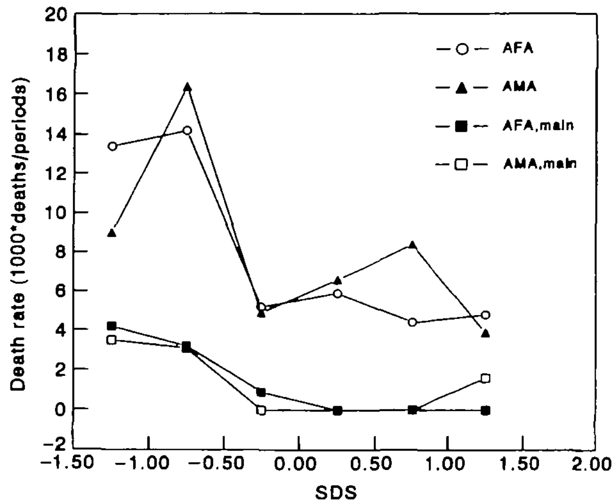

Figure 1 Three months mortality from all causes and from marasmus/kwashiorkor in function of baseline arm fat area (AFA) or arm muscle area (AMA): AFA and AMA are corrected for weight, height, age and sex

Results

Of the 246 children who died during follow-up, AFA, AMA, age, weight and height were all available for 211 (86%) at study entry, which is identical to the global coverage rate in all patients (86%).

The relationships between short-term mortality and indicators of fatness or muscularity were characterized by a clear threshold phenomenon (Figure 1). Below SDS_c –0.5, there was a sharp rise in mortality from all causes as well as from kwashiorkor or marasmus. Death rates associated with fatness and muscularity were almost the same at every SDS_c level. This was not due to a high correlation between AFA-SDS_c and AMA-SDS_c ($r = -0.01$; $P = 0.51$).

Table 1 shows the observed death rates and relative risks of death associated with lower ($SDS_c \leq -0.5$) versus higher ($SDS_c > -0.5$) AFA and AMA. It appears that both fat and muscle status are determinants of short-term survival. This was most obvious in children with normal weight. The presence of a lower muscle status did not have demonstrable adverse consequences in the long-term. In contrast, with a lower fat status, there was an increased long-term mortality from all causes in underweight children. Only seven children died from severe malnutrition, marasmus or kwashiorkor, within 3 months of first assessment (not in Table). Yet, the event occurred more frequently in those with lower muscle status (4/1576 versus 3/3661; RR = 3.10, 95% CI : 0.69–13.82) and even significantly so in the rainy season (4/1220 versus 1/2925; RR = 9.59, 95% CI : 1.07–85.72). A lower fat status was associated with a considerably increased short- (6/1669 versus 1/3569; RR = 12.83, 95% CI : 1.55–106.49) and also long-term (15/13 602 versus 15/29 017; RR = 2.13, 95% CI : 1.04–4.36) risk of death from marasmus or kwashiorkor.

Table 1 Short- and long-term mortality from all causes in function of arm fat and arm muscle score

	Short-term mortality[b]		Long-term mortality[c]	
Fat or muscle score[a]	Deaths/periods	RR (95%CI)	Deaths/child trimesters at risk	RR (95%CI)
All children				
Fat score lower	24/1729	2.7 (1.5–4.9)	57/13 732	1.1 (0.8–1.51)
higher	19/3683	*	111/29 289	NS
Muscle score lower	21/1628	2.2 (1.2–4.0)	46/12 897	0.9 (0.6–1.3)
higher	22/3784	*	122/30 124	NS
Normal weight children (WFA-SDS >–2)				
Fat score lower	21/1231	3.0 (1.6–5.8)	31/9611	0.8 (0.5–1.2)
higher	15/2644	*	82/20 638	NS
Muscle score lower	18/1161	2.3 (1.6–5.8)	30/9030	0.9 (0.6–1.3)
higher	18/2689	*	81/20 939	NS
Underweight children (WFA-SDS ≤–2)				
Fat score lower	3/498	1.6 (0.4–7.0)	26/4121	1.9 (1.1–3.2)
higher	4/1039	NS	29/8651	*
Muscle score lower	3/467	1.8 (0.4–7.8)	16/3867	0.9 (0.5–1.6)
higher	4/1095	NS	41/9104	NS

[a] Lower AFA = AFA-$SDS_c \leq -0.5$; higher AFA = AFA-$SDS_c > -0.5$, lower AMA = AMA-$SDS_c \leq -0.5$; higher AMA = AMA-$SDS_c > -0.5$.

[b] Deaths within 3 months after study entry.

[c] Deaths in 3 months periods from 3–30 months after study entry.

* $P < 0.05$.

NS not significant.

Table 2 summarizes the results of the multiple logistic regression analysis of determinants of short-term mortality. The WFA-SDS was not a significant factor but showed some significance in interaction with age. Fatness and muscularity were significant factors. Poor fat score had a poor prognosis as such and more so in the dry season. Poor muscle score had a poor prognosis in the rainy season. Rainy season and age were related positively and negatively to mortality, respectively. Apart from the ones mentioned, no other interactions were significant.

The ROC curve analysis (Figure 2) confirms that WFA-SDS has poor predictive power for short-term mortality since it had the lowest sensitivity for any specificity. The AFA-SDS_c and AMA-SDS_c perform much better but the best predictive abilities are obtained with the prognostic index we derived from the multiple logistic regression equation.

Table 2 Multiple logistic regression of 3-month mortality on age, season, weight-for-age-SDS, fat score and muscularity score[a]

Risk factor	Significant yes/no	*P*-value	Sign of parameter estimate
Sex	No	>0.05	
Age	Yes	0.0001	negative
Season (0 = dry 1 = rainy)	Yes	0.046	positive
Weight-for-age-SDS[b]	No	>0.05	
Fat score	Yes	0.0134	negative
Muscle score	No	>0.05	
Muscle score × season	Yes	0.007	negative
Fat score × season	Yes	0.027	positive
Age × Weight-for-age-SDS	Yes	0.0361	negative
Other interactions	No	>0.05	

[a] Fat and muscularity scores arm fat area and arm muscle areas corrected for age, season, weight and height.

[b] Standard Deviation Scores calculated using the US NCHS references.

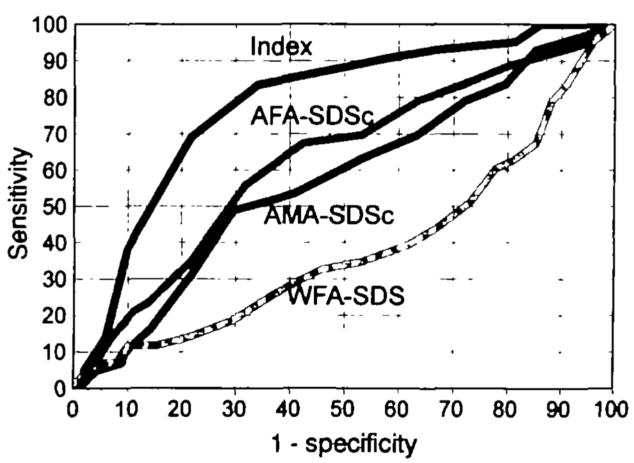

Figure 2 ROC curve analysis of 3-months mortality from all causes as predicted by Weight-for-age Standard Deviation Score (WFA-SDS), standardized corrected arm fat area (AFA-SDSc), standardized corrected arm muscle area (AMA-SDSc) and by a prognostic index combining the preceding with age and season

Discussion

This epidemiological study uses an anthropometric method to assess fatness and muscularity and to study their significance for mortality prediction in large groups of children. It consists of standardizing anthropometric indicators of fat and muscle, correcting for age, sex, weight and height. It is interesting to note that this method is a research tool and not as such useful for clinical use.

Variability in body composition means that the same body mass (weight) can be composed of different proportions of, principally, bone mass, muscle mass, fat mass and extracellular water.[18] The study of the muscle and fat components is of primary interest as they are frequently severely affected by nutritional disorders.[19,20] Such study implies that one should control for bone mass and extracellular water. The usual solution is to assume that variability in extracellular water is small and to study body composition in children with approximately the same length or height,[9] hereby controlling for bone mass to a certain extent. Most studies of obesity make the additional assumption that body weight, above some reference for height (weight-for-height) or for height squared (body mass index or Quetelet index) is a good measure of relative body fatness, disregarding variability in muscle mass. This last assumption may be valid for obesity but it is certainly not for non-obese or malnourished subjects, where the muscle and fat components must be measured more specifically. Therefore, it seems more rational to relate indicators of muscle or fat mass to weight and height simultaneously, which we did in our study.

The results of this study show that low fatness and muscularity scores are associated with excess 3-month mortality, even in normal weight children. Fatness and muscularity scores remained significant determining factors of short-term mortality in a multiple logistic regression analysis with sex, age, season and weight-for-age. The ROC curve analysis showed that fat and muscularity scores had better predictive abilities than weight-for-age. These results suggest that measures of current nutritional status should not be based on weight-for-age alone. Additional assessment of fat and muscle status, also in normal weight children, is useful in order to detect a higher proportion of malnourished children and to more accurately evaluate mortality risk. The question is how should assessment of body composition be done under field circumstances where modern methods of measuring body composition are as yet unavailable? Obviously, the method presented in this study is a research tool, impossible to use for clinical purposes. We propose a few imperfect but practical solutions for field use. First, MUAC, which can be considered as a kind of summary measure of fat and muscle status, is simple to measure and to compare with existing references.[21] The superior prognostic abilities of MUAC have sufficiently been demonstrated.[6,20] Secondly, we have previously developed a non-anthropometrical approach to assess fatness and muscularity by inspection and palpation.[7]

The underlying biological explanation for the mortality-determining role of fat and muscle is most obviously the fact that these tissues constitute energy reserves for supporting vital functions during starvation and infections. In Bwamanda, weaning foods are known to be of low energy content and this makes energy reserves more critical during stress periods. Nutritional supplementation may be important for the survival of underweight as well as of normal weight children. In Bwamanda, efforts should be made to increase the energy content of weaning foods of all children. We believe that this should be done in the first place by adding (palm) oil to the low-energy starchy gruel that are usually given. In rural tropical environments, the cause of low fat/muscle status involves usually both food and disease as well as more distal factors that can be summarized as 'poverty'. Knowing that a child is at risk must lead to better feeding practices and disease prevention for that child. Detection of low fat/muscle in a population must raise the awareness of the community, stimulate community action and possibly external help to improve feeding practices, primary health care and to combate poverty.

We found some long-term adverse effects of poor fatness, not of poor muscularity. It should be emphasized that anthropometric risk factors are unstable in the long term, especially in poor tropical environments. Therefore, one expects less long-term effects than short-term effects.

In conclusion, we have shown that low anthropometric indices of relative body fatness and muscularity are associated with excess mortality, also in normal weight children. Assessment of fat and muscle status is useful for evaluating undernutrition and the mortality risk associated with it.

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