Screening for marasmus: a discriminant analysis as a guide to choose the anthropometric variables[1-4]

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ABSTRACT In a cross-sectional study, children 0–6 yr of age from eight different population groups in Africa and Asia were examined. Clinical assessment defined 8750 children as being well nourished and 194 as having marasmus. Height, weight, arm circumference (AC), and triceps skinfold thickness were measured; the latter two measurements and the clinical assessment were done by the same observer. Based on data from normal children, local growth curves were computed for each group. Each child's growth was expressed in standard deviation scores (SDS) of his own group. On the basis of the results of a discriminant analysis, all variables were ranked by their decreasing power to discriminate between normal and marasmic children. For 83% of the children one measurement (AC/age) is sufficient to classify them definitely; for the others, several variables are needed. This strategy yields an overall sensitivity of 80%, a specificity of 97%, and a positive predictive value of 38%. *Am J Clin Nutr* 1987;45:488–93.

KEY WORDS Growth standards, local references, nutritional screening, growth-analysis, anthropometry, arm circumference, triceps skinfold

Introduction

The definition of a malnourished child is commonly based on anthropometric measurements, often in comparison with Western or NCHS references (1–3). In order to define an optimal selection procedure, this study uses a discriminant analysis to choose the most appropriate anthropometric variables for distinguishing clinically defined marasmic children from clinically normal children. This selection procedure would be a better alternative for routine practice in health clinics than the commonly used procedures of weight for age or weight for height.

Methods

Between 1974 and 1981, 9011 children aged 0–6 yr were examined clinically and measured for height, weight, arm circumference, and triceps skinfold thickness. The children belonged to eight different geographical areas of Africa and Asia and had important differences in genetic background, in ecology (eg, climate, rainfall, altitude), in feeding pattern and available food, and in socio-cultural factors.

The clinical assessment and the measurements were taken during sessions at mother and child clinics, which were attended by > 90% of the children living in each village. Children with an acute illness (eg, acute diarrhea, pneumonia, etc) were treated. They, as well as those presenting a chronic physical handicap (eg, polio), were not entered in the study (estimated at 1–2%).

The number of normal and malnourished children in the different ethnic groups are shown in **Table 1.** Children were considered as marasmic when presenting at least one of the following signs: severe muscle wasting, loose folds of skin over the glutei, *old man* face (lacking buccal pad of fat) and as kwashiorkor when presenting with edema (localized or generalized or *moon* faces). The clinical picture of the children was assessed by the same observer. Kwashiorkor children are easy to detect clinically and were excluded from this analysis.

All the children, clothed with very light pants, were weighed to the nearest 100 g with a springscale or a beam scale. All scales were regularly calibrated with standard weights. For children up to 2 yr, length was measured to the nearest millimeter on a measuring board with a fixed headpiece and a movable footpiece in the recumbent position. For children older than 2 yr, height was measured with a microtoise® (Stanley Ltd), reading to the nearest

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TABLE 1
The number of children in the different ethnic groups by clinical classification and sex

Ethnic group	Normal		Malnourished: Kwashiorkor		Malnourished: Marasmus		Total
	Boys	Girls	Boys	Girls	Boys	Girls	
Africa (Zaire)							
Ngbaka	370	333	1	0	13	10	727
Wazimba	1101	1075	6	12	14	21	2229
Warega	1127	1190	16	17	16	22	2388
Bantandu	471	447	0	4	15	22	959
Asia							
Oraons	681	645	3	2	19	15	1365
Thai	189	190	0	0	3	5	387
Bengali	146	126	1	4	7	3	287
Warli & Kokona	348	311	0	1	5	4	669
Total	4433	4317	27	40	92	102	9011
	8750		67		194		

millimeter. Height and weight were taken by well-trained local personnel. Mid-arm circumference (AC) was assessed with a flexible steel tape measure 6 mm wide, reading to the nearest millimeter: the left upper midarm was held to the horizontal by the examiner and the tape measure was left dangling resulting in a constant traction of ~70 g (4). This method was used in order to diminish the variability caused by an eventually variable traction as described by Jelliffe (5). The triceps skinfold thickness (TS) was measured with a Harpenden skinfold caliper as recommended by Edwards (6). The last two measurements, AC and TS, as well as the clinical classification were all taken by the same examiner. Arm muscle area and arm fat area were computed as described by Frisancho (7).

Age was rounded to the nearest month. The birthdate was either known or was confirmed by a careful interview of the mother by a local nurse well-known to the population. For the analysis of the data, different age classes were defined taking into account the rate of changes in the variables as well as the necessity of obtaining a sufficient number of children in each age class. Only the children without clinical features of malnutrition, ie normal children, were used to draw local growth curves.

The gaussian distribution of all the variables used was ascertained by the Kolmogorov-Smirnoff goodness to fit ($p > 0.05$). A decimal logarithmic transformation (8) was necessary to normalize triceps skinfold for age and muscle area for age. All measurements of both normal and marasmic children were transformed to their standard deviation scores (SDS) based on the growth curves of their own ethnic group. The mean and standard deviation (SD) of the arm circumference and of the SDS of the arm circumference by age class of the marasmic children are given in **Table 2**. A discriminant analysis was used to find an appropriate procedure to select the marasmic children from the normal ones. All statistical computations were performed using the Statistical Analysis System (SAS Institute Inc, Cary, NC).

Results

The different variables used in the successive steps of the analysis are summarized in **Table 3**. Because each anthropometric measurement demands resources, in a first step only the measured variables (height/age, weight/age, arm circumference/age, log skinfold/age) were used. The first run in the discriminant analysis gave the same result consistently for all groups (**Table 4**) as is obvious from the comparisons of the coefficients of determination in the different groups (R^2), which is the proportion of variance in the group explained by that variable.

TABLE 2
The mean and SD of the arm circumference and of the SDS of arm circumference by age class for the marasmic children

Age class	Number of children	Arm circumference mean	Arm circumference SD	SDS of arm circumference mean	SDS of arm circumference SD
mo		*cm*			
0–	1	6.9	—	−2.91	—
1–2	4	8.7	0.6	−2.33	0.80
3–5	8	9.0	1.0	−3.65	1.75
6–8	21	9.6	0.9	−2.11	0.86
9–11	23	9.9	0.7	−2.40	0.78
12–14	21	10.4	0.8	−1.89	1.06
15–17	31	10.2	0.9	−2.36	0.89
18–20	13	10.3	0.7	−2.62	0.66
21–23	19	10.3	0.7	−2.61	0.79
24–26	17	11.1	0.9	−1.89	1.00
27–29	6	10.5	0.4	−3.22	0.53
30–35	9	11.1	0.8	−2.26	1.16
36–41	10	11.3	1.2	−2.22	1.53
42–47	5	10.8	0.4	−2.72	0.81
48–53	5	11.6	0.5	−2.94	1.34
54–60	3	11.1	0.7	−2.55	0.86
60–72	2	12.7	2.4	−1.21	2.03

TABLE 3
Rank of the different variables used in the successive steps of the analysis

Variables	Rank of the variables* Step 1	Step 2	Step 3
Measured variables			
Height for age (H/A)	3†	NS	5†
Weight for age (W/A)	NS	2†	NS
Arm circumference for age (AC/A)	1†	(−)	(−)
Log skinfold for age (TS/A)	2†	3†	1†
Derived variables			
Muscle circumference for age (MC/A)	(−)	NS	2†
Log arm muscle area for age (MA/A)	(−)	4‡	NS
Arm fat area for age (FA/A)	(−)	5†	3§
Arm circumference for height (AC/H)	(−)	1†	(−)
Weight for height (W/H)	(−)	NS	4§
Muscle circumference for height (MC/H)	(−)	NS	NS

* All variables in SDS scores. NS: not significant ($p > 0.05$). (−): not included.
† $p < 0.0001$.
‡ $0.01 < p < 0.0001$.
§ $0.05 < p < 0.01$.

Arm circumference for age best discriminated the normal from the marasmic children. This effect was not due to the results of only a few groups: arm circumference for age was the most discriminating variable in 9 of the 16 groups and in the remaining 7 it was the second most discriminating (Table 4). The number of the normal and the marasmic children based on SDS of arm circumference for age is shown in **Table 5.** The children < -3 SDS were considered as marasmic, those > -1 SDS as normal. These cutoff points allowed for the definite classification of 83.0% of the children with only one measurement (**Table 6**). For the remaining 17% a second step was needed. The discriminant analysis was carried out using all the variables excluding AC/A (Table 3).

The results of the second step are shown in **Table 7.** At this step arm circumference for height had the greatest discriminating power. The classification of the normal and the marasmic children in groups based on SDS of arm circumference for height is shown in Table 5. The children < -2 SDS were considered as marasmic, those > -1 SDS as normal. At this level a decision could be made for an additional 6% of the children so that almost

TABLE 4
The first step: number of normal and marasmic children by ethnic groups and sex and the two variables with their R^2

Ethnic group	Sex	Number: Normal	Marasm	Variables with highest R^2*: First variable	R^2	Second variable	R^2
All groups		8750	194	AC/A	0.110	TS/A	0.090
Ngbaka	M	370	13	AC/A	0.234	W/A	0.091
	F	333	10	AC/A	0.165	W/A	0.105
Wazimba	M	1101	14	TS/A	0.062	AC/A	0.058
	F	1075	21	AC/A	0.084	TS/A	0.073
Warega	M	1127	16	AC/A	0.069	TS/A	0.064
	F	1090	22	AC/A	0.090	TS/A	0.053
Oraons	M	681	19	TS/A	0.171	AC/A	0.144
	F	645	15	TS/A	0.058	AC/A	0.054
Bantandu	M	471	15	AC/A	0.161	TS/A	0.133
	F	447	22	AC/A	0.230	TS/A	0.162
Thai	M	189	3	W/A	0.088	AC/A	0.074
	F	190	5	W/A	0.154	AC/A	0.108
Bengali	M	146	7	TS/A	0.337	AC/A	0.280
	F	126	3	AC/A	0.095†	TS/A	0.049†
Warli & Kokona	M	348	5	TS/A	0.103	AC/A	0.064
	F	311	4	AC/A	0.079	W/A	0.077

* If not mentioned, the R^2 are significant at a p-value < 0.0001.
† $0.0001 < p < 0.05$.

TABLE 5
The number of normal and marasmic children with different cutpoints following the different steps in the analysis

		First step*							Second step†						Third step‡				
Normal	B§	14	71	625	1584	2170	4464	B	60	459	169	8	696	B	47	171	170	71	459
	G	9	69	608	1484	2080	4250	G	57	413	203	4	677	G	41	160	164	48	413
	T	23	140	1233	3068	4250	8714	T	117	872	372	12	1373	T	88	331	334	119	872
		(0.3)‖	(1.6)	(14.2)	(35.2)	(48.8)	(100)		(8.5)	(63.5)	(27.1)	(0.01)	(100)		(10.1)	(38.0)	(38.3)	(13.6)	(100)
		−3	−2	−1	0		AC/A		−2	−1	0		AC/H		−2	−1	0		TS/A
							8908¶						1507						921
Marasm	B	23	44	19	4	1	91	B	40	21	2	0	63	B	9	8	3	1	21
	G	22	43	28	7	3	103	G	39	28	4	0	71	G	12	13	3	0	28
	T	45	87	47	11	4	194	T	79	49	6	0	134	T	21	21	6	1	49
		(23.2)	(44.8)	(24.2)	(5.7)	(2.1)	(100)		(58.9)	(36.6)	(4.4)	(0)	(100)		(42.9)	(42.9)	(12.2)	(2.0)	(100)

* Arm circumference for age (−3, −2, −1, 0 SDS).
† Arm circumference for height (−2, −1, 0 SDS).
‡ Log triceps skinfold for age (−2, −1, 0 SDS).
§ B: boys; G: girls; T: total.
‖ The figures between brackets are row percentages.
¶ 36 observations with missing values for age or arm circumference.

90% were classified after the first two steps (Table 6).

The third step of the analysis was performed on the remaining (10% of the total). Because of the small number of marasmic children, the analysis was only done considering all ethnic groups together. All variables were used except AC/A and AC/H (Table 3). The results of the third step are shown in Table 7. Log skinfold thickness for age had the greatest discriminating power on the third step. The classification of the normal and the marasmic children in groups based on SDS scores of log skinfold for age is shown in Table 5. The children < −2 SDS were considered as marasmic, those > −1 SDS as normal. On the remainder (nearly 4%, Table 6) a fourth step was executed and MC/A came out as the most discriminating variable. The MC/A can be derived from the previously used variables: AC/A (first step) and TS/A (third step). AC/A was substituted for MC/A to avoid additional calculations for the field assessment. Only one cutoff point was necessary to classify all the remaining children: the children with AC/A < −2 SDS (ie poor muscle) were classified as marasmic, those > −2 SDS for AG/A as normal.

The overall results of the selection procedure are given in **Table 8.** At a prevalence of marasmus of 2.17%, the proposed selection procedure had an overall sensitivity of 79.6%, a specificity of 97% (9), and a positive predictive value (PPV) of 37.8% (10).

Discussion

Developing countries, were scarcity of resources is a daily reality, need uniformly efficient selection procedures in order to tackle their very common problem: marasmus. Using the clinical definition of marasmus as a substitute for morbidity and mortality, the proposed selection procedure is able to select children at risk with high sensitivity and a very low number of false positives.

The procedure developed has a positive predictive value (PPV) of 37.8% (Table 8). Weight for age (2) applied to the same data and based on NCHS references has a PPV of 6.6% with a sensitivity of 86.8%. Weight for height (1) applied similarly has a PPV of 6.2% with a comparable sensitivity of 87% (Table 8).

TABLE 6
Percentages and cumulative percentages of the children classified after each step

	Normal (8714)	Marasmic (194)	Total (8908)	Variable used
First step	84.2%	30.9%	83.0%	AC/A
Second step	5.8%	43.8%	6.6%	AC/H
	90.0%	74.7%	89.6%	
Third step	6.1%	14.4%	6.4%	TS/A
	96.1%	89.1%	96.0%	
Fourth step	3.9%	10.9%	4.0%	AC/A
	100.0%	100.0%	100.0%	

Assuming that the children not entered in the study (1–2% see Methods) include a high proportion of clinically marasmic children, the prevalence of marasmic children would increase if these children were entered. Therefore, using the same selection procedure for the total population would increase the PPV and affect the results in a positive way.

The problem in selection procedures based on NCHS references and weight for age or weight for height are the large number of false positives. With these selection procedures 25–40% of the children are considered to be malnourished.

First, no country has sufficient resources to implement nutritional programs for 30% of its total child population.

Secondly, a majority of these malnourished children have no clinical signs of malnutrition, and we could hypothesize that a large percent of these children are not at a higher risk for morbidity and mortality. They only have a different growth pattern adapted to the local ecology. In fact they do not even need specific nutritional interventions. There is no evidence to suppose that a screening procedure very inefficiently selecting the clinically malnourished children (eg, weight for age and weight for height based on NCHS), would be better than the present screening procedure, which is more specific. This selection procedure should relate to morbidity and mortality in a prospective study.

Thirdly, the developed procedure is very inexpensive. In 80% of the children only one measurement (AC) has to be taken. Because of the enormous reduction of the number of false positives, the implementation of a nutritional program becomes realistic, reasonable, and feasible.

Finally, another advantage is that when age is unknown, one can skip the first step and still classify 90% of the children: however, one then has to measure two variables (arm circumference and height) on all of the children instead of one variable. This is similar to the Quac-stick procedure (11): the number of

TABLE 7
The 2nd and 3rd steps: the number of normal and marasmic children and the selected variables with their R^2

Ethnic group	Number		Variables with highest R^{2*}			
	Normal	Marasm	First variable	R^2	Second variable	R^2
Second step						
All groups	1373	134	AC/H	0.194	TS/A	0.131
Ngbaka	109	12	AC/H	0.171	TS/A	0.132
Wazimba	352	24	AC/H	0.110	FA/A	0.092
Warega	361	30	AC/H	0.164	FA/A	0.087
Oraons	194	24	AC/H	0.277	FA/A	0.204
Bantandu	139	27	AC/H	0.294	W/H	0.204
Thai	80	4	W/H	0.115*	W/A	0.115†
Bengali	42	5	AC/H	0.483	TS/A	0.329
Warli & Kokona	96	8	FA/A	0.169	TS/A	0.146
Third step						
All groups						
Boys	459	21	TS/A	0.055	FA/A	0.049
Girls	413	28	FA/A	0.067	TS/A	0.063
All groups						
Total	872	49	TS/A	0.058	FA/A	0.057

* If not mentioned, the R^2 correspond with a p-value < 0.0001.
† $0.0001 < p < 0.01$.

TABLE 8
Sensitivity, specificity, and PPV: a comparison between different screening procedures

	W/age*		W/height†		AC‡	AC/age§	Four step‖
	60%	75%	85%	90%	<12.5 cm	−2 SDS	procedure
Sensitivity	41.6	86.8	73	87	97.5	68.0	79.6
Specificity	97.8	71.1	85	69	62.0	98.1	97.0
PPV¶	27.5	6.6	10.5	6.2	5.6	44.7	37.8

* Weight for age, % of the median with NCHS as reference.
† Weight for height, % of the median with NCHS as reference.
‡ Arm circumference < 12.5 cm.
§ Arm circumference for age, first step alone (cutpoint at −2 SDS).
‖ Four step procedure.
¶ At a prevalence of 2.2%.

correctly classified marasmic children remains identical, but there are a few more false positives. Thus 90% of the cases can be classified without knowing their ages. To classify the remaining 10% the ages must be known.

The use of arm circumference < 12.5 cm (12) as a screening method has the advantage of being very simple and can be implemented at very low costs (personnel, training, etc). Applied to the same data this method yields a PPV (5.6%) similar to that from common selection procedures (Table 8) although with a very high sensitivity (97.5%).

It is notable that using only the first step of the selection procedure (AC/age) with −2 SDS as a single cutoff point the PPV is similar (44.7%) although the sensitivity drops to 68% (Table 8). In emergency situations or when there is a lack of trained personnel, this method seems to be very attractive because of its simplicity, but it is not sensitive enough to be acceptable in daily practice. This stepwise selection procedure can give the health worker an efficient instrument for operating a nutritional rehabilitation program.

Two important points are considered here. First, the problem of the local standard can be solved by using a local survey. This reference has to be updated regularly in order to follow the secular changes (13). Secondly, the personnel executing the measurements have to be trained adequately. If it appears that skinfold measurement can not be delegated to the first line personnel, it is still possible to refer these cases (only 10% of the child population) to a more skilled level.

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