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Body size, body composition and motor performances of mild-to-moderately undernourished Senegalese children

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Summary. Relationships between anthropometric dimensions (stature, weight, arm and calf circumferences, and four subcutaneous skinfolds), and motor performances (dash, standing long jump, throw for distance and grip strength) were considered in 348 mild-to-moderately undernourished Senegalese children 5–13 years of age (168 boys and 180 girls). Weights and statures are, on average, below the National Center for Health Statistics (NCHS) reference medians at each age, and deviations are more pronounced in children >8 years of age and in boys more than girls. Boys, on average, perform better than girls on all tasks. Stature and weight explain about 30–50% of the variance in the performances of children <10 years of age, while weight explains about 10–25% in children >10 years of age. Indicators of body composition (estimated arm muscle and subcutaneous fat) have only a limited contribution to the remaining variance in motor performances. Fatness negatively affects the performances of girls >10 years, but has no effect on performances of boys.

1. Introduction

There are close relationships among body size, body composition and motor performance in growing children (Malina 1975, 1994). These relationships are likely to be altered in protein–energy malnutrition (PEM). Epidemiological and clinical definitions of PEM are ordinarily based on deviations from normal height-for-age or expected weight-for-height (Waterlow 1972). Reduction in body size and wasting of muscle mass are the main contributors to low motor performance and low physical fitness in undernourished children (Malina and Buschang 1985, Spurr, Reina, Dahners and Barac-Nieto 1983). There is apparently some parallel decline in motor performance and body dimensions in undernourished children; as a consequence, when motor performances are expressed per unit of stature or body weight, differences between undernourished and normal children are significantly reduced or disappear (Malina, Little, Shoup and Buschang 1987). This does not mean that undernourished children are physiologically adapted to their condition; rather it emphasizes the role of reduced body size in the performance of the children (Spurr, Barac-Nieto, Reina and Ramirez 1984, Malina 1994).

It has been suggested that PEM leads to an absolute decrease in muscle mass, but does not affect the quality of the muscle function (Satyananayana, Nadamuni Naidu and Narasinga Rao 1979, Spurr 1988). Fat mass has a negative influence on motor performances of normal and slightly undernourished children (Malina 1994). However, in chronically mild-to-moderately undernourished boys in southern Mexico, relative fatness was positively related to grip strength and had no relationship with running and jumping performances (Malina and Little 1985). This suggests that in undernourished children there may be a threshold below which fatness no longer exerts a negative influence on motor performance as it does in well-nourished children.

This paper examines the relationship between anthropometric characteristics and motor performances in a sample of 348 Senegalese children of both sexes, 5–13 years of age. It specifically examines the relative influence of body dimensions and estimated body composition on variability in motor performance.

2. Methods

2.1. *Sampling*

A sample of 287 children was drawn from surveys done between 1988 and 1992 in an area of Central Western Senegal known as the 'peanut basin', in the district of Lambaye (14·45° north latitude and 17·30° west longitude). In addition, 59 children came from the district of Podor in the extreme north in the bend of the Senegal river. There were no significant differences in anthropometry or motor performance between children from Lambaye and Podor. They were thus combined into a single group. All children lived in a rural environment and were from poor farm families.

Climate in the area is hot and dry with a short rainy season from June to November. Conditions of living, nutritional status and food consumption of these communities has been described (Benefice and Simondon 1993, Chevassus-Agnès and Ndiaye 1981). Briefly, the average per-capita energy intake was on a par with the FAO/WHO/UNU (1985) recommendation and high for protein; however, one-third of the households surveyed did not meet their energy and protein requirements. Estimated intakes of several nutrients: vitamin A, riboflavin, zinc, calcium, folates and heminic iron were below the recommendations. According to national statistics, prevalence of stunting and wasting in this area is the highest in Senegal.

The children were recruited after a preliminary home-by-home census in the villages. When a birth certificate did not exist (this was the case in almost 50% of the individuals), age was determined from a local calendar based on Muslim ceremonies and events, and by comparison with a child of known age living in the same compound. It was estimated that the accuracy of this age determination was 3 months until 8 years of age and 4–6 months thereafter. Only children free from clinically detectable disease or congenital abnormalities were selected. The sample included 168 boys and 180 girls, 5–13 years of age. Less than 90 children attended elementary school on a regular basis; however, most of them received a Muslim religious education.

The aim and methods of the survey were explained to the parents, administrative officials, village leaders and religious authorities. Oral consent was given by the parents who, as a rule, were illiterate. The study was authorized by national health authorities of Senegal. Examinations were conducted outdoors in public, and mothers or other persons close to the child were invited to attend the testing.

2.2. *Anthropometry*

Body weight (kg) was measured with an electronic scale accurate to 100 g. Children were barefoot and in underclothes. Stature (cm) was measured with a Harpenden anthropometer with children standing upright on a platform with the eyes in a horizontal (Frankfort) plane. Calf (CC, cm) and mid-arm circumferences (AC, cm) were measured on the left side with a fibreglass tape. On the same plane of AC, the triceps (TSF, mm) and biceps (BSF) skinfolds were measured with a Holtain caliper. The subscapular (SSF) and suprailiac (SIF) skinfolds were also measured on the left side according to the techniques recommended by Weiner and Lourie (1981). Skinfold thicknesses were measured at least three times until the same value was recorded two consecutive times.

Estimated mid-upper arm muscle circumference (MUAC) was calculated as: MUAC=AC$-\pi\times$TSF (Gurney and Jelliffe 1973).

2.3. *Motor performance*

Measures of performance included: (a) 20 m dash in children <6 years of age and 33 m dash >6 years of age (expressed as speed: m/s); (b) tennis ball throw for distance for children <6 years of age and of a softball throw >6 years of age; (c) standing long jump; (d) hand grip strength by squeezing a rubber bulb connected to a manometer (Martin®, Tuttlingen, Germany). Children performed three trials for the jump, throw and hand grip test; the best value was retained for analysis. Because there were slight differences between the right and left hands in the grip test, results were expressed as the sum of right and left grip strength. All anthropometric dimensions and motor performance tests were done by the same observer (the first author) with the help of the same field assistants.

2.4. *Reliability*

Among children 5·5–6 years of age, 88 (56%) were measured twice at a 1-day interval. Test–retest correlations were high for stature (0·98) and weight (0·95), and moderately high for AC (0·85), CC (0·86) and the sum of four skinfolds (0·76). They were moderate in the 20 m dash (0·76), jump (0·69), throw (0·67), and hand grip strength (0·83). Correlation coefficients for motor performance were slightly higher in boys than in girls. Forty children between 9 and 11 years of age (21%) were also tested twice at a 1-week interval. Test–retest coefficients were high for weight (0·98) and stature (0·99), and lower for AC (0·87), CC (0·73) and the sum of four skinfolds (0·88). Coefficients were moderate to low for the 33 m dash (0·67), jump (0·73) and hand grip strength (0·71), but were high for the throw (0·93). There was no noticeable difference between girls and boys. These coefficients are similar to those reported under rural field conditions in southern Mexico (Malina and Buschang 1985) and in urban São Paulo, Brazil (Rocha-Ferreira 1987).

2.5. *Statistical analysis*

Analyses were done using the BMDP statistical software (Dixon 1985). Pearson correlations and partial correlations, analysis of variance and multiple regression procedures were employed.

3. Results

Means and standard deviations for anthropometric dimensions of boys and girls classified by age are given in table 1. Values increase significantly with age. Except for stature, girls have higher values than boys. Between 8 and 12 years of age, boys do not show a marked difference in weight and stature (figure 1a); as a result the 12-year-old boys are below the 5th percentile of National Center for Health Statistics (NCHS) reference data (WHO 1983). This trend is less pronounced in girls, in whom each age group is above the 5th percentile (figure 1b). The same trend is evident in AC in boys, whereas at all ages girls are on the 5th percentile of National Health and Nutritional Examination Survey I (NHANES I) reference data (Frisancho 1981) (figure 2a and 2b). The triceps skinfold approximates the 5th percentile in both sexes. The stunting in growth is more pronounced in boys than in girls, and may be attributed to prolonged nutritional stress. In contrast to the results for anthropometry,

Table 1. Anthropometric measurements (means and SD) of Senegalese children.

Age (years)	n	Stature (cm)	Weight (kg)	AC (cm)	CC (cm)	TSF (cm)	Sum of four skinfolds
Boys							
5±	15	105·0 (3·6)	16·4 (2·4)	14·7 (1·0)	20·4 (1·5)	6·7 (1·0)	22·0 (3·4)
6±	24	113·9 (4·7)	18·8 (1·8)	15·1 (0·9)	20·9 (1·0)	5·8 (1·4)	18·7 (3·7)
7±	24	118·0 (3·8)	19·9 (2·0)	15·6 (1·0)	21·6 (1·0)	5·4 (1·0)	19·0 (3·0)
8±	18	127·4 (8·2)	23·6 (3·3)	16·3 (1·3)	22·9 (1·7)	5·8 (1·3)	19·1 (2·8)
9±	7	129·9 (7·6)	25·2 (5·2)	16·5 (1·5)	24·1 (1·9)	5·2 (1·2)	17·3 (2·9)
10±	23	134·7 (5·7)	26·8 (3·2)	16·9 (1·1)	24·2 (1·7)	5·4 (1·1)	18·6 (3·0)
11±	27	136·3 (6·1)	27·5 (3·0)	16·7 (0·7)	24·0 (1·3)	4·9 (0·6)	17·4 (1·7)
12±	15	138·0 (4·9)	27·8 (2·0)	17·0 (0·9)	24·3 (1·3)	5·3 (0·8)	18·9 (2·8)
13±	15	146·2 (4·8)	32·2 (3·3)	18·3 (1·6)	25·7 (1·4)	5·7 (2·1)	19·9 (6·0)
Girls							
5±	23	106·1 (4·6)	16·0 (1·6)	14·7 (0·8)	19·8 (1·6)	6·9 (1·2)	22·6 (3·4)
6±	25	112·8 (5·3)	18·4 (1·9)	15·5 (1·0)	21·2 (1·2)	6·8 (1·6)	22·5 (4·5)
7±	18	117·7 (7·2)	19·5 (2·5)	15·5 (1·0)	21·6 (1·3)	6·7 (1·3)	21·4 (2·8)
8±	13	127·7 (8·5)	22·9 (5·2)	16·3 (1·3)	22·8 (2·9)	5·7 (1·2)	19·9 (3·7)
9±	25	129·7 (7·2)	25·3 (4·0)	17·0 (1·4)	24·0 (2·0)	6·8 (2·1)	22·1 (6·7)
10±	18	133·0 (5·4)	26·7 (5·2)	17·4 (1·7)	24·2 (2·2)	6·7 (2·1)	23·0 (7·1)
11±	30	139·4 (6·9)	28·9 (4·2)	17·8 (1·4)	24·8 (1·7)	6·3 (1·4)	21·3 (3·9)
12±	22	143·2 (8·2)	32·9 (5·9)	18·9 (1·5)	26·2 (2·1)	7·2 (2·7)	23·6 (5·6)
13±	6	153·0 (7·9)	36·6 (4·4)	19·4 (1·1)	27·0 (1·6)	7·0 (1·2)	24·4 (3·2)
Two-way analysis of variance							
F age		174·2	90·6	37·3	51·4	2·2	2·5
p		***	***	***	***	ns	ns
F sex		3·0	5·9	18·2	3·8	36·8	52·3
p		ns	**	***	*	***	***

boys perform significantly better in all motor tasks, while comparisons of boys and girls in grip strength are variable (table 2).

Table 3 reports sex-specific correlations between age, stature and weight and each motor task. All correlations are statistically significant and are slightly higher between stature and motor performance in boys than in girls. In boys correlations between age, body dimensions and speed and the jump are higher than for the throw and grip strength. Since motor performances are related to age, weight and stature during growth, partial correlations were also calculated (table 4). After controlling for age, weight and stature, correlations with each motor performance task are reduced, and most are not significant. In both sexes, relationships between motor performance and body dimensions are separated into two categories: grip strength and throw >6 years are related to weight adjusted for stature and age; and speed, the jump and throw <6 years are related to stature adjusted for weight and age.

The children were then classified into three age groups: <6 years (ages where motor patterns are generally being established); 6–10 years (pre-adolescence); >10 years (beginning of the adolescence spurt). Table 5 shows the results of a stepwise regression of weight, stature and age on each motor task. Variables allowed to enter in the equation are represented by their order of entry. In general, stature and age explain most of the variance in performance in children <10 years, except for hand grip in children 6–10 years, and speed in boys. In contrast, weight is the best predictor in children >10 years. Standardized regression coefficients for stature are always positive, while coefficients for weight are negative for speed in girls 6–10 years, but positive with motor performance and grip strength in children >10 years of age.

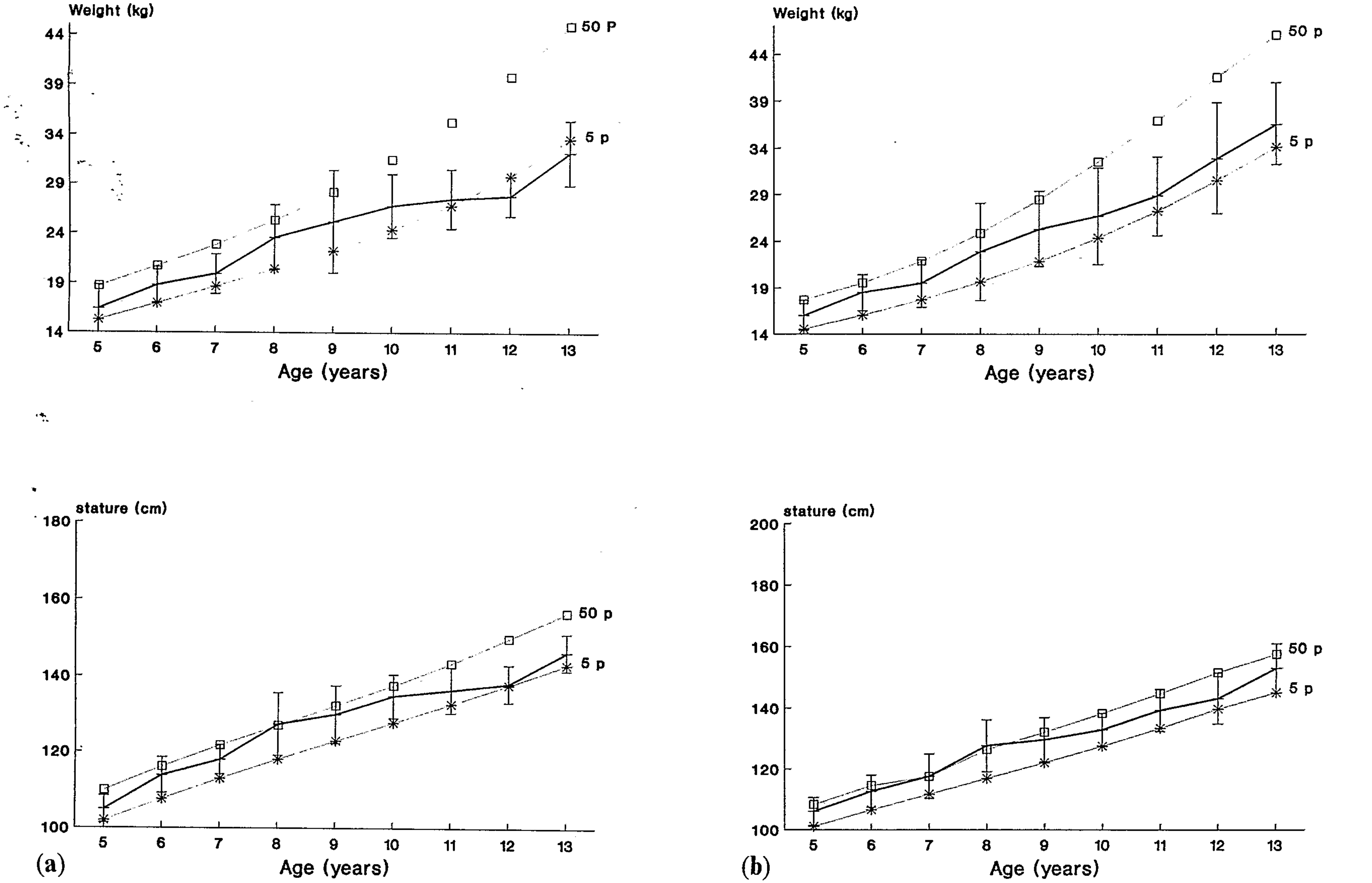

Figure 1. (a) Weight and stature of boys (mean, SD) relative to the 5th and 50th percentiles of US reference data. (b) Weight and stature of girls (mean, SD) relative to the 5th and 50th percentiles of US reference data.

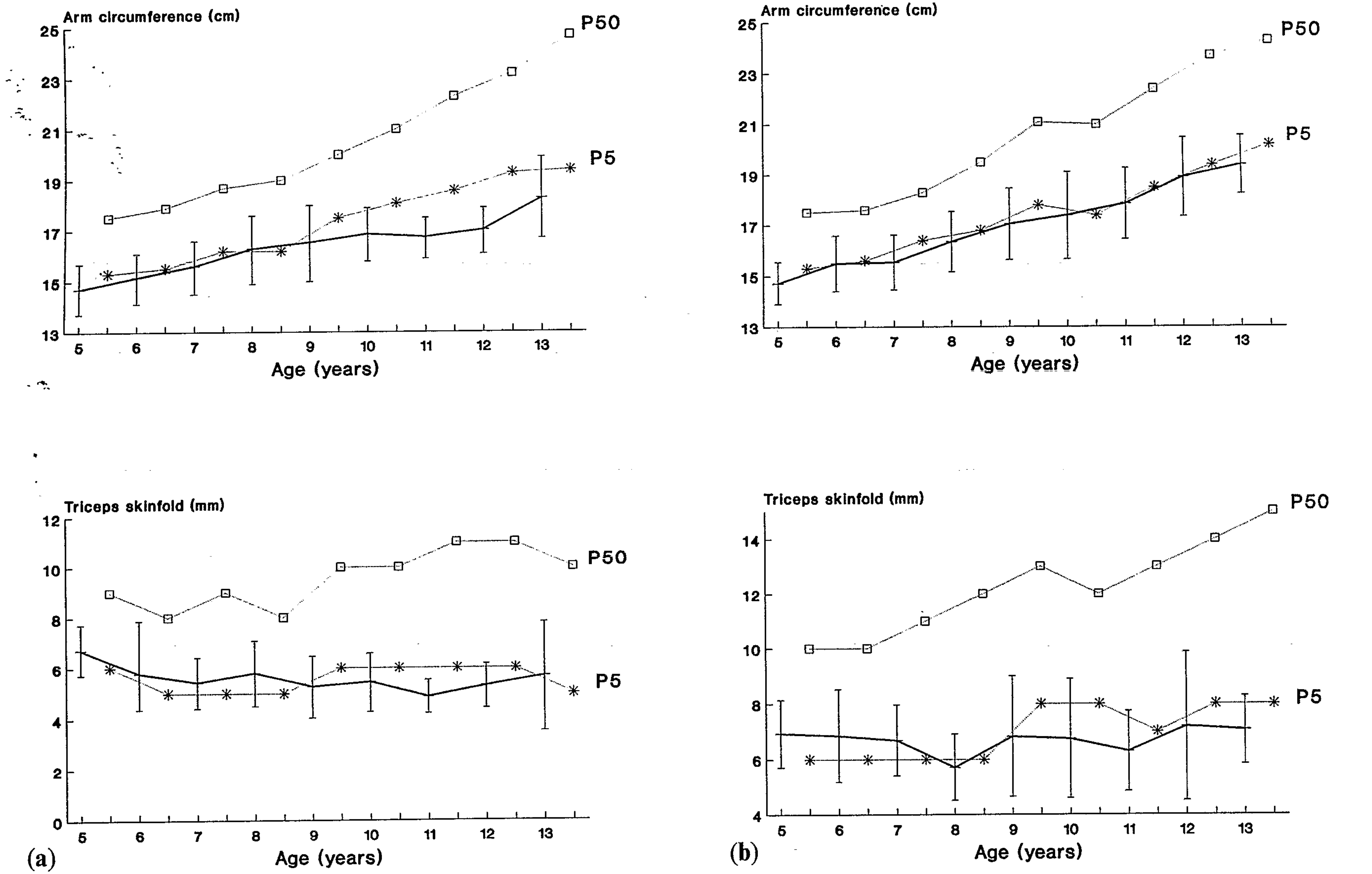

Figure 2. (a) Arm circumference and skinfold thicknesses of boys (mean, SD) relative to the 5th and 50th percentiles of US reference data. (b) Arm circumference and skinfold thicknesses of girls (mean, SD) relative to the 5th and 50th percentiles of US reference data.

Table 2. Motor performance (means and SD) of Senegalese children.

Age (years)	n	Speed (m/s)	Jump (m)	Throw (m)	Grip strength (kPa)
Boys					
5±	15	3·2 (0·4)	0·74 (0·19)	4·6 (1·0)	48·6 (12·7)
6±	24	3·6 (0·4)	0·94 (0·20)	7·9 (2·0)	64·6 (16·6)
7±	24	3·8 (0·5)	1·03 (0·20)	8·4 (2·0)	78·3 (19·6)
8±	18	3·9 (0·4)	1·25 (0·21)	12·4 (3·2)	88·9 (22·1)
9±	7	4·2 (0·3)	1·33 (0·19)	14·2 (3·6)	98·1 (26·4)
10±	23	4·3 (0·3)	1·37 (0·20)	15·5 (4·0)	108·1 (34·0)
11±	27	4·4 (0·3)	1·41 (0·19)	15·3 (2·5)	115·3 (22·7)
12±	15	4·5 (0·4)	1·42 (0·16)	17·2 (3·9)	106·9 (28·0)
13±	15	4·5 (0·4)	1·52 (0·18)	17·7 (3·4)	107·6 (27·0)
Girls					
5±	23	3·3 (0·4)	0·75 (0·22)	4·2 (1·5)	49·7 (10·2)
6±	25	3·3 (0·5)	0·88 (0·20)	5·9 (2·1)	66·1 (13·5)
7±	18	3·3 (0·5)	0·97 (0·22)	7·0 (2·2)	81·4 (18·4)
8±	13	3·5 (0·4)	1·09 (0·18)	8·3 (3·2)	75·6 (21·1)
9±	25	3·9 (0·4)	1·19 (0·16)	10·8 (2·6)	90·4 (16·8)
10±	18	3·9 (0·5)	1·33 (0·23)	11·1 (2·6)	96·6 (29·3)
11±	30	4·0 (0·5)	1·36 (0·21)	12·5 (2·6)	108·4 (27·2)
12±	22	4·5 (0·5)	1·43 (0·17)	14·7 (4·1)	117·7 (32·0)
13±	6	4·4 (0·9)	1·37 (0·24)	14·7 (3·8)	112·6 (23·6)
Two-way analysis of variance					
F age		31·2	58·1	76·8	27·4
p		***	***	***	***
F sex		26·9	8·8	64·4	29·4
p		***	**	***	***

Table 3. Correlations between age, stature and weight and motor performances and strength in Senegalese children.

	Boys (n = 168)			Girls (n = 180)		
	Weight	Age	Stature	Weight	Age	Stature
Speed	0·72	0·76	0·75	0·58	0·64	0·60
Jump	0·75	0·80	0·79	0·75	0·77	0·73
Throw						
age <6	0·61	0·69	0·61	0·66	0·82	0·80
age >6	0·33	0·47	0·52	0·52	0·59	0·59
Grip strength	0·61	0·68	0·70	0·69	0·69	0·70

All coefficients are significant at $p < 0{\cdot}01$.

Overall, the amount of variance in motor performance explained by age, stature and weight is relative modest (table 5).

Another stepwise regression was performed to evaluate the influence of other anthropometric dimensions related to body composition on the variance in motor performance. Estimated mid-upper arm muscle circumference (MUAC) and CC were used as proxies for limb muscle mass. After log transformation, extremity (TSF plus BSF) and trunk (SSF plus SIF) skinfolds were used as proxies for fat mass. Residuals of the indicators of body composition and of motor performance instead of actual values were used, to remove the effects of age, weight and stature. Results are shown in table 6. After the effects of age, stature and weight are removed, estimated muscle

Table 4. Partial correlations between age, weight, stature and motor performance.

	Age	Stature	Weight
Controlling for:	Weight and stature	Age and weight	Stature and weight
Boys ($n = 168$)			
Speed	0·12	0·13	0·14
Jump	0·10	0·18*	0·15
Throw			
age <6	0·00	0·20*	0·13
age >6	0·17*	0·01	0·25*
Grip strength	0·09	0·04	0·25*
Girls ($n = 180$)			
Speed	0·03	0·19*	0·03
Jump	0·22**	0·16*	0·06
Throw			
age <6	0·00	0·26**	0·27**
age >6	0·19*	0·10	0·19*
Grip strength	0·25**	−0·08	0·28*

* $p < 0{\cdot}05$, ** $p < 0{\cdot}01$.

and subcutaneous fat have only a limited effect on the remaining variance of motor performance. They do not predict performances of younger and older boys, but they do contribute to the performances of boys 6–10 years. On the other hand, estimate of muscle and fat mass contribute to the variance in the performances of girls in the three age groups. Regression coefficients for indicators of muscularity are positive, while those for indicators of fat mass are negative.

Comparison of the performances of children >10 years in the upper and lower quartile of the sum of four skinfolds indicates that fatter boys tend to perform better than thinner boys. The difference is statistically significant for the standing long jump (1·33 SD 0·17 m for thin boys versus 1·51 SD 0·19 m for fat boys; $t = 2{\cdot}69$, $p < 0{\cdot}01$) (Figure 3a). The differences are not statistically significant for girls (figure 3b). Similarly, comparison of upper and lower quartiles of MUAC shows that more muscular girls have better performance than the less muscular girls; in contrast there are no differences between boys grouped on the basis of MUAC.

4. Discussion

The reduced, perhaps stunted, anthropometric dimensions of Senegalese children compared with reference values are consistent with other data for Africa and are related to the generally unfavourable environmental conditions, particularly nutritional (de Onis, Monteiro, Akre and Glugston 1993). It appears that the stunted growth is more severe in boys than in girls. There are only a limited number of longitudinal studies describing the growth of African children and youth. Data from the Gambia suggest a delay in age at take-off and at peak height velocity compared with British reference data in boys and girls; the interval between age at take-off and age at peak height velocity is also longer in Gambian than in British adolescents. Interestingly, the total adolescent height gain for Gambian and British youth is the same (Billewicz and McGregor 1982). In South Africa, similar deviations of stature and weight relative to American reference data before the start of adolescence are evident and the adolescent growth spurt is extended (Cameron and Kgamphe 1993). This prolonged pattern of growth is termed 'compensatory growth' by Cameron, Gordon-Larson and Wrchota (1994). For example, height-for-age z-scores decreased

Table 5. Stepwise regression of motor performances and strength on stature, weight and age in 3 age-groups of Senegalese children.

(*a*) *Age* <6 *years*

	Boys ($n = 51$)				Girls ($n = 58$)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r
Speed	Stature	0·30	21·3[b]***	0·16	Stature	0·28	21·9***	0·90
					Age	0·08	7·4**	−0·38
Jump	Stature	0·29	20·0***	−0·07	Stature	0·39	36·0***	0·26
	Weight	0·04	3·8*	0·39				
Throw	Stature	0·51	52·0***	0·42	Stature	0·43	42·3***	0·26
	Age	0·04	4·8*	0·32				
Grip	Stature	0·41	35·2***	0·39	Age	0·48	53·5***	0·43
					Weight	0·11	15·3***	0·26

(*b*) >6 *years to* <10 *years*

	Boys ($n = 60$)				Girls ($n = 64$)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r[a]
Speed	Weight	0·42	43·4***	0·42	Stature	0·25	20·8***	0·94
	Age	0·03	3·4*	0·19	Weight	0·05	5·0*	−0·52
Jump	Stature	0·36	33·5	0·35	Stature	0·21	16***	0·36
					Age	0·04	3·6*	0·24
Throw	Stature	0·47	53·4***	0·23	Stature	0·43	48·1***	0·74
Grip	Weight	0·31	26·6***	0·68	Weight	0·25	20·8***	0·61

(*c*) *Age* >10 *years*

	Boys ($n = 57$)				Girls ($n = 58$)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r[a]
Speed	Weight	0·13	8·3**	0·26	Weight	0·11	7·3**	0·33
Jump	Weight	0·26	19·1***	0·58	Weight	0·12	7·8**	0·33
Throw	Weight	0·19	13·3***	0·54	Weight	0·26	20·4***	0·51
Grip	Weight	0·07	4·6*	0·72	Weight	0·08	5·4*	0·71
	Age	0·19	13·9**	−0·45	Stature	0·09	6·4**	−0·51

[a] Standardized regression coefficient.
[b] $p < 0·05$; $^{**}p < 0·01$; $^{***}p < 0·001$.

from 8 to 15·5 years in boys and 8 to 13·5 years in girls, followed by an increase during mid- and late-adolescence. It is thus tempting to attribute the increased deviation from NCHS reference data in height- and weight-for-age in Senegalese children to a similar delay in age in take-off. However, the cross-sectional data do not permit a definitive statement.

One obvious reason for growth stunting is the restriction of food. The area under study is considered as at-risk of food deficiency by the Senegal authorities. The daily ration is less than 2200 kcal per capita and two-thirds of the population do not meet their nutritional needs. Further, consumption of products of animal origin is very low (Chevassus-Agnès and Ndiaye 1981). Limitation in total caloric and animal protein intakes could lead to serious growth stunting and delay in pubertal maturation (Pugliese, Lifschitz, Grad, Fort and Marks-Katz 1983). Conversely, it is interesting to note that when a diet is limited in total energy but rich in animal

Table 6. Stepwise regression of residuals of motor performances and strength on residuals of muscle and fat mass indicators in Senegalese children.

(*a*) *Age <6 years*

	Boys (n = 51)				Girls (n = 58)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r
Speed		No steps			Trunk	0·07	4·2*	−0·45
Jump		No steps				No steps		
Throw		No steps			Extremities	0·10	6·0**	−0·18
					MUAC	0·06	3·9*	0·34
Grip		No steps			MUAC	0·09	5·9**	0·26

(*b*) *>6 years to <10 years*

	Boys (n = 60)				Girls (n = 64)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r[a]
Speed	Trunk	0·09	5·7**	−0·35	Trunk	0·07	4·8*	−0·29
Jump	MUAC	0·06	3·8*	0·24	Extremities	0·11	8·1**	−0·24
Throw	Extremities	0·07	4·5*	−0·16	Trunk	0·22	27·4**	−0·49
Grip	Trunk	0·10	6·7**	−0·43	Trunk	0·15	11·4***	−0·40

(*c*) *Age >10 years*

	Boys (n = 57)				Girls (n = 58)			
	Variable	R^2	F	r[a]	Variable	R^2	F	r[a]
Speed		No steps				No steps		
Jump		No steps			Extremities	0·14	9·3***	−0·24
					CC	0·05	3·5*	0·05
Throw		No steps				No steps		
Grip		No steps			MUAC	0·07	4·1*	0·32
					Trunk	0·06	3·8*	−0·25

[a] Standardized regression coefficient.
[b] *$p < 0·95$; **$p < 0·01$; ***$p < 0·001$.

protein, as in the Turkana pastoralists from North Kenya who receive more than 60% of their food intake from milk, children achieve normal linear growth while weighing less and having less adiposity than American children (Little and Johnson 1987). It should be stressed that milk from goats or zebu in Africa is rich not only in animal protein but also in fat. Quality of the diet thus is an important factor in the development of stunting (Waterlow 1994).

Differences between the sexes in anthropometric characteristics are evident. They tend to indicate more favourable growth status for girls compared to boys in the prepubertal years. Earlier studies from Japan showed evidence of greater achievement of growth potential by girls than boys under adverse conditions. In addition, boys took a longer period to recover from unfavourable conditions (Greulich 1957). Males, in general, seem to be more sensitive to environmental stresses than females (Stinson 1985). This suggests a lesser buffer effect against the environment in boys than in girls, which apparently begins prenatally in terms of foetal growth and mortality *in utero*, and continues during childhood. Earlier animal studies demonstrated that the effect of undernutrition is more detrimental in males than in females,

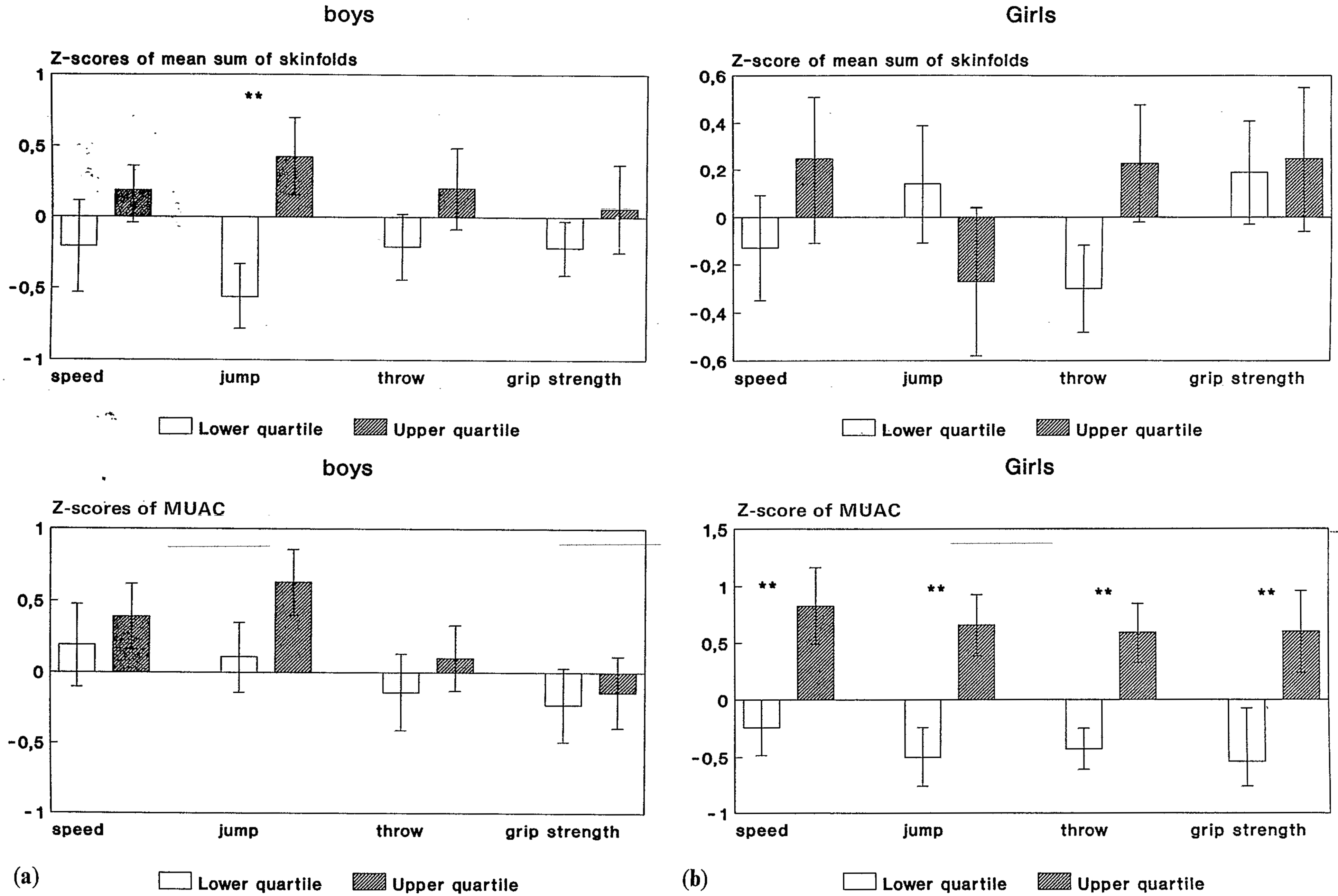

Figure 3. (a) Comparison of motor performance of boys >10 years of age in the lower and upper quartiles of subcutaneous fat and of MUAC (mean, standard error of the mean). (b) Comparison of motor performance of girls >10 years of age in the lower and upper quartiles of subcutaneous fat and of MUAC (mean, standard error of the mean).

and that males never recover their full genetic dimensions after rehabilitation (McCance 1966). Interestingly, a higher morbidity for boys was also noticed in cases of overnutrition (Must, Jacques, Dallal, Bajema and Dietz 1992). It is also possible that the girls have better access to food than boys, but this advantage may be challenged by the higher daily energy expenditure of girls due to participation in domestic tasks in Senegal (Benefice 1993). In addition, the differences between girls and boys are probably related to sex differences in the timing of adolescence growth spurt.

It has earlier been reported that in all age groups, and in both sexes, Senegalese children score lower in motor performance than children from developed countries, though the differences tend to disappear when values are expressed per unit of weight or stature (Benefice 1992, 1993). In the present study the correlations between weight and stature and motor performance are only moderate, as also observed in other studies (Malina 1975, 1994). The results are also consistent with observations on mild-to-moderately undernourished children of the same range in southern Mexico (Malina and Buschang 1985). Partial correlations are lower, but consistent with those reported for Mexican children. However, the running task is negatively correlated with body weight in Mexican children, while there is no significant correlation, or a positive correlation, in Senegalese children. It was shown from comparison of two contrasted cultures that relationships between body dimensions and motor performance change according to the task studied, and also between populations. Factor such as habitual physical activity, type of activities, motivation, and cultural factors need to be considered (Malina *et al.* 1987).

It is not surprising to find a positive relationship between the throw (in children >6 years) and grip strength and weight, after controlling for age and stature, since both tasks depend largely on muscular strength and power, which are related to total body mass (by inference, muscle mass) apparently more than by stature. In contrast, jumping and running performance are more influenced by stature, i.e. absolute length of especially the lower extremities, in addition to muscular power. An additional concern is neuromuscular maturation and motivation, which influence all motor performances. Unfortunately, measures of neuromuscular maturation or motor control are not available for the Senegalese children.

Stepwise regression analyses add further information. They indicate a difference in the effect of stature and weight on motor performance according to age. In children <6 years, stature is the main predictor, and enters the equation first; after 6 years, weight has a noticeable effect in speed and hand grip strength, whereas in the children >10 years (and perhaps just before the onset of puberty), weight is the main regressor. It is possible that, in younger children, past and chronic undernutrition, represented by reduced stature, has a stronger influence in motor performance than in older children, in whom the interaction of chronic undernutrition and delayed pubertal maturation underlie changes in weight. However, the proportion of variance in motor performance explained by weight alone remains modest, as are the additional effects of subcutaneous fat and muscle mass.

Estimated arm muscle circumference and/or calf circumference are positively related to motor performance while subcutaneous fat is negatively related. This is reasonable, since fat mass represents to some extent dead weight which must be carried when the body is projected as in the run or jump. In a normally nourished population the majority of fat is subcutaneous, and skinfold thicknesses are good estimators of body fat (Norgan 1991). However, the relationship may be somewhat different in undernourished people, for example simply because skin thickness is less in protein–energy malnutrition. Despite these limitations, subcutaneous fat is still held to be a good indicator of population at risk of nutritional deficiencies (Garn 1991).

In children <6 years or >10 years there is no effect of subcutaneous fat mass. The group of older boys is composed of very thin boys with a mean triceps skinfold of 5·2 SD 1·2 mm; they are also lighter and shorter than girls of the same age. It seems that, in extremely lean children, there is a close relationship between fatness and performance; that may be a threshold below which fat mass no longer exerts a negative influence on motor performance, and in fact is positively related to performance. This may be inferred from the comparison of performance of boys >10 years in the upper and lower quartiles of subcutanteous fat (figure 3a). Boys >10 years of age on the upper quartile of subcutaneous fat perform better than boys in the lower quartile (although the difference is significant only for the jump). In another situation, estimated relative fatness of Mexican boys from Oaxaca was positively correlated with static strength, and may be considered an indicator of larger body size and better nutritional status (Malina and Buschang 1985). This also raises the possibility of qualitative changes in muscle composition in undernourished children. Hence, mean fat-free mass per unit of stature of the boys from southern Mexico was less than those of Mexican American or French Canadian boys, suggesting a reduction of total body cell mass. The Mexican boys also had less grip strength per unit of estimated fat-free mass than Mexican American boys (Malina, Little and Buschang 1991).

In contrast, girls >10 years of age in the upper quartile of MUAC perform significantly better in the four motor tasks than girls in the lower quartile (figure 3b) and do not differ according to subcutaneous fat. In well-nourished healthy European girls it was found that girls with more subcutaneous fat performed poorly in various motor fitness task than the leanest girls (Malina, Beunen, Claessens, Lefevre, Vanden Eynde, Renson, Vanreusel and Simons 1995). In mild-to-moderately undernourished girls this sort of association is not warranted.

It is not clear if the low motor performance of children reared under marginal conditions is the long term consequence of stunting associated with episodes of malnutrition early in life, or the consequence of a chronic undernutrition during childhood. It is also not known if catch-up occurs during puberty, when marked changes in strength and motor performance ordinarily occur in boys more so than in girls (Malina and Bouchard 1991). This issue is of importance because stunting and associated reduced strength and power prevail precisely in those societies in which physical work is a key factor for subsistence.

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Zusammenfassung. An 348 5–13 jährigen senegalesischen Kindern (168 Jungen und 180 Mädchen) mit leichter bis moderater Unterernährung wurde die Beziehung zwischen anthropometrischen Dimensionen (Körperhöhe, Gewicht, Arm- und Wadenumfang sowie vier Hautfaltendicken) und motorischen Leistungen (Kurzstreckenlauf, Weitsprung aus dem Stand, Werfen und Greifkraft) untersucht. Die Körperhöhen und Gewichte lagen im Durchschnitt für alle Altersklassen unterhalb des Medians der Referenzwerte vom National Center for Health Statistics (NCHS). Die Abweichungen waren für Kinder im Alter über 8 Jahren ausgeprägter als für jüngere und bei Jungen deutlicher als bei Mädchen. Die Jungen zeigten im Durchschnitt in allen Disziplinen bessere Leistungen als Mädchen. Körperhöhe und Gewicht erklären ca. 30% bis 50% der Varianz der sportlichen Leistung bei Kindern im Alter unter 10 Jahren, während das Gewicht bei Kindern im Alter unter 10 Jahren, während das Gewicht bei Kindern im Alter über 10 Jahren ca. 10% bis 25% der Varianz erklärt. Indikatoren der Körperzusammensetzung (geschätzte Muskel- und Fettanteile am Arm) tragen nur begrenzt zur Erklärung der Restvarianz der motorischen Leistungen bei. Der Fettanteil beeinflußt die Leistungen der über 10 jährigen Mädchen negative, hat jedoch keinen Effekt auf die Leistung bei Jungen.

Résumé. Les relations entre dimensions anthropométriques (stature, poids, circonférences de bras et du mollet ainsi que quatre plis cutanés) et les performances motrices (course rapide, saut en longeur sans élan, lancer et force dynamométrique) ont été considérées chez 348 enfants sénégalais de 5 à 13 ans (168 garçons et 180 filles) légèrement ou modérément sous-nutris. Les poids et les statures sont en moyenne inférieurs aux valeurs médianes de référence du National Center for Health Statistics (NCHS) à chaque âge, les écarts sont plus prononcés chez les enfants de plus de huit ans et chez les garçons plus que chez les filles. Les garçons obtiennent en moyenne de meilleurs résultats que les filles pour toutes les activités. La stature et le poids expliquent de 30% à 50% de la variance dans les performances des enfants de moins de dix ans, tandis que le poids en explique de 10% à 25% chez les enfants de plus de dix ans. Les indicateurs de composition corporelle (estimation des parts de muscle et de graisse sous-cutanée du bras) ne contribuent que modérément à la variance restante des performances motrices. L'adiposité affecte négativement les performances des filles du plus de dix ans mais n'influe pas sur celles des garçons.

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