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Anthropometric and motor characteristics of Senegalese children with different nutritional histories

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Accepted for publication 23 November 1995

Summary

The effects of Protein Energy Malnutrition (PEM) on the motor performance of 4.5–6.5-year-old Senegalese children were studied. Body dimensions included weight, lengths, circumferences, and four skinfolds. Motor performance tests included a 3-min endurance run, 4 × 10 m shuttle-run, distance throw, standing long jump and grip strength. The sample consisted of 147 children: 52 children who were hospitalized for severe undernutrition (severe UN group) during infancy but who had been nutritionally rehabilitated; 63 children who were never severely malnourished but who were chronically exposed to mild-to-moderate undernutrition up to the time of study (chronic UN group); and 32 well nourished children (well nourished group) from well-off households. After adjusting for sex and age, the well nourished group performed better than the severe UN and chronic UN groups. Principal components analysis resulted in two factors which explained 65% of the variance in anthropometry and motor performance. One was related to body size and the second to body composition. The three nutritional groups differed significantly in principal component scores for the two factors; chronic UN and severe UN children also differed for the second factor. Body composition, especially low fat mass

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appeared to be an important feature for motor performance in chronically undernourished children.

Keywords: Africa, motor performance, anthropometry, protein energy malnutrition

Introduction

Protein Energy Malnutrition (PEM) is the most widespread nutritional problem in developing countries. In Africa, it has been estimated that 33% of children under 5 years of age suffer from chronic PEM (FAO 1992). The outcome of PEM is determined by its severity and duration. Various forms of PEM in a population are most often differentiated by anthropometry. Current malnutrition results in a loss of weight in relation to height or wasting, while chronic malnutrition is reflected in reduced height for age or stunting (Waterlow 1972). These changes lead to modification of body size and composition that may contribute to reduced motor performance observed in undernourished children. In rural Mexico, for example, chronically undernourished schoolchildren had poorer motor performances than well-nourished children; however, most of the differences were reduced after controlling for age, weight and height (Malina & Buschang 1985). Similar results were found in Africa (Ghesquiere & Eeckels 1984; Bénéfice 1993). Poorer motor performances of undernourished children may also be the consequence of slow motor development. Malnourished children have slower motor development compared with non-malnourished children (Malina 1984). In Jamaica chronic undernutrition explained the slower motor development better than the occurrence of an episode of acute PEM (Grantham-McGregor *et al.* 1989). In West Java, Pollitt *et al.* (1994) recently observed that stunting, and not wasting, was a predictor of the date of appearance of independent walking. Note, however, the relationship between early motor development and subsequent motor performance has not been established. Nevertheless, the existence, form and duration of malnutrition should be considered in evaluating the motor performances of children in developing countries.

The objectives of this study are to compare the motor performances and anthropometric dimensions of Senegalese childen with different nutritional histories; and to examine the relationship between motor and anthropometric characteristics in order to assess the role of altered body size, composition and/or proportions as a factor affecting motor performance in undernourished children.

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Methods

Site of the study

The site of study is located in the central western part of Senegal, an area called the 'peanut basin'. Children came from a small town (Thiès) and a rural district (Lambaye). Their parents were Muslim peasants growing peanuts and millet, or small shopkeepers with low incomes. The basic diet consists of rice and fish at midday, and a gruel of sorghum in the evening. Meat is consumed mainly during festivals or special ceremonies. People living around the road or in the town of Thiès have better access to fresh fish, bread, milk and vegetables than do rural people in Lambaye. Wolof is the main ethnic group of the area. Surveys were conducted from February to June 1994.

Sample

The sample included 147 children (mean age 5.6 ± 0.7 years), 79 boys and 68 girls of the same ethnic group, classified into three different nutritional groups:

1 The first group comprised of 63 children, 26 boys and 37 girls, of rural origin. It was drawn from a sample of 105 children whose growth was monitored between 1988 and 1990. Of the 105 children, 86 were located 4 years after the initial study and results for the children under 6.5 years of age were retained for this study. Their health status was checked each week by a nurse. The children received appropriate medical treatment when they were ill or were evacuated to the paediatric department of the capital city hospital. None of the children developed severe malnutrition. However, during the monitoring period, weight-for-height (W/H) was more than two standard deviations (–2 SD) below World Health Organization reference data (WHO 1986) in 6.4% of the measures taken, with maximum incidence occuring between 12 and 24 months of age. Height-for-age (H/age) was more than –2SD in 42% of the children. This group was classified as chronically undernourished (chronic UN).

2 The second group included of 52 children, 27 boys and 25 girls, hospitalized for an episode of severe malnutrition in a Nutritional Rehabilitation Center of the town of Thiès (NRC, Terre des Hommes) between 1988 and 1992. They lived in the poor suburbs of Thiès without access to facilities such as electricity or running water. They were 6- to 24-months of age at the time of hospitalization and suffered from marasmus, non-oedematous, acute malnutrition. On entrance to the NRC, the mean

W/H z-score was −2.4 ± 0.8 SD; 23.5% were < −3 SD while 70% were < −2 SD of the reference data. They stayed at the NRC for 6–8 weeks during which they received medical and nutritional care by qualified physicians and nurses. They left the centre after recovery, when their W/H z-score reached −1SD. All the children living in Thiès at the time of the present study, about 65% of the original sample, were surveyed. They were termed severely undernourished early in life (severe UN).

3 The third group consisted in 32 children, 16 boys and 16 girls, attending a kindergarden in Thiès. Examination of medical records and interview of their parents did not reveal any episode of malnutrition or severe disease during infancy. They belonged to a privileged social class of public employees or small businessmen with access to medical and educational facilities. They were considered well-nourished (well-nourished).

The aim of the study and the nature of the tasks and measurements were explained individually to the parents and also to the political and religious leaders of the Lambaye villages and Thiès suburbs. Written consent was obtained from the parents of the well nourished who were literate. Oral consent was given by the parents of severe UN and chronic UN children because they were illiterate. Children were tested in the presence of a family member, generally the mother. The study was authorized by the national health authorities, but formal approval could not be obtained since no ethical committee existed in Senegal at the time of the study.

All anthropometric and motor characteristics were taken by a single investigator with the help of the same assistants. The tests were conducted outdoors in a shaded area in the morning and at the end of the afternoon.

Anthropometry

Bodyweight (kg) was measured with an electronic medical scale accurate to 100 g. Children were barefoot in underpants. Standing height (cm) was measured to the nearest mm with a portable Harpenden anthropometer. Children stood upright on a platform with the head/eyes in the horizontal plane, the arms along the sides and the feet making an angle of 45°C. Sitting height (cm) was measured with the same anthropometer. Children sat on a table with the back erect. Height of the anterior iliac spine (HASIS, cm) and biacromial diameter (BIAD, cm) were measured with the anthropometer according to the techniques of the International Biological Program (IBP) (Weiner & Lourie 1981). Arm (arm circum, cm), calf (calf circum, cm) and thigh (thigh circum, cm) circumferences were measured on the left side with an non-stretchable fibre glass tape at the sites recomended by the IBP (Weiner & Lourie 1981). Finally, four skinfold thicknesses were measured with a Holtain caliper: triceps (triceps SF, mm), biceps (biceps SF, mm), subscapular (subscap SF, mm) and suprailiac (suprailiac SF, mm), on the left side (Weiner & Lourie 1981). Skinfold thicknesses were measured at least three times until the same value was recorded on two consecutive times.

Motor performances

Motor performances included tests of several capacities: power — standing long jump with a two feet take-off and landing; power and co-ordination — tennis ball throw for distance; static strength — grip strength as measured by squeezing a rubber bulb connected to a manometer (Martin®, Tuttlingen, Germany); speed and agility — a 4 × 10 m shuttle run; and cardiorespiratory endurance — a 3 min run in which distance run was recorded. The first three tests included three trials and the best was retained for analysis. Only one trial was given for the shuttle and endurance runs. Nine children were unable to jump correctly; one child stopped running before the end of the 3-min run; two girls could not produce an acceptable performance in agility even after repeated trials; overall 12 children (eight from Lambaye and four from Thiès) had incomplete data for motor performance.

Reliability

During preparation for the study, 30 children from Lambaye were measured twice at a 1 week interval. These children were different from those of the study but were of the same sex and age. Test-retest correlations were high for weight (0.98), height (0.99), sitting height (0.93), and HASIS (0.97); moderately high for BIAD (0.86), circumferences arm (0.87), thigh (0.84), calf (0.73), and the skinfolds, triceps SF (0.84), suprailiac SF (0.84). Coefficients were lower for biceps SF (0.67) and subscap SF (0.60). Motor performance was also tested twice, 1 day apart for 86 children from the villages of the Lambaye district. Coefficients were moderately high for the endurance run (0.83), throwing (0.74) and jump (0.78), and somewhat lower for the shuttle-run (0.55) and hand grip strength (0.57). Differences between the two pairs of measurements were not significant. These values are comparable to those found in another study on the motor performance of pre-school African children which showed a high coefficient for the throwing task (0.80) and a lower value for an agility task (0.50)

(Toriola *et al.* 1986), and in the range of within day correlations for several strength and motor tasks in chronically undernourished school age Mexican children (Malina & Buschang 1985). The lower reliability of agility and hand grip strength in the present study may be due to uncontrolled factors such as experience in testing and motivation.

Statistical analysis

Age and sex differences were tested by analysis of variance. Differences between nutritional groups were tested after adjusting for sex and age by analysis of covariance; there were no interactions between sex and age. Student *t*-tests were then done for post-hoc comparisons between nutritional groups. In order to reduce the anthropometric data for more specific comparisons among the three nutritional groups, a principal component analysis was done. The 12 subjects with incomplete data were removed for this analysis. Components with eigenvalues greater than 1.0 were retained and scores on each principal component were calculated for each subject in order to evaluate the contribution of anthropometry to motor performances in the three nutritional groups. SPSS software was used for the statistical analysis.

Results

At the time of study, the children were healthy and did not show any overt signs of clinical malnutrition such as muscle wasting. They were divided in two age groups: < 5.5 years (mean 4.9 ± 0.3 years) and > 5.5 years (mean 6.1 ± 0.4 years). Comparisons of the groups by age and sex are given in Table 1. As expected, body dimensions increased with age. Girls had a smaller BIAD and sitting height than boys. Girls were also lighter and shorter, but the differences were not significant. Subcutaneous fat decreased with age and girls had a higher amount than boys (not significant for biceps SF). Motor performances of older children were better than those of younger children, and boys performed better than girls (Table 2).

Anthropometric characteristics of the three nutritional groups were compared after adjusting for sex and age by analysis of covariance (Table 2). In general, well-nourished children had higher anthropometric values, but the differences in specific skinfolds did not reach significance except for suprailiac SF. Severe UN children had a greater arm circum and suprailiac SF than chronic UN children. Well-nourished children performed better than severe UN and chronic

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Table 1 Anthropometric characteristics of Senegalese children

Age group (years)		<5.5		>5.5			
		Boys	Girls	Boys	Girls		
	n	(33)	(36)	(46)	(32)	*F*(sex)	*F*(age)
Weight (kg)		16.2[1]	15.8	17.7	16.9	2.5	10.0
		2.4[2]	2.1	1.9	3.0	NS	0.001[3]
Height (cm)		105.5	103.0	110.6	110.0	2.4	38.1
		6.6	5.9	4.5	6.6	NS	0.000
HASIS (cm)		61.0	59.4	64.4	64.1	1.9	24.0
		4.6	4.4	3.3	4.3	NS	0.000
Sitting height (cm)		57.1	55.7	59.1	58.2	6.3	23.6
		3.1	2.6	2.5	3.1	0.01	0.000
BIAD (cm)		23.3	22.2	24.0	23.4	10.6	14.1
		1.4	1.7	1.3	1.6	0.001	0.000
Arm circumference (cm)		15.8	16.1	15.7	15.5	0.1	2.1
		1.0	1.3	1.1	1.6	NS	NS
Calf circumference (cm)		20.7	20.7	21.0	20.6	0.4	0.1
		2.6	1.6	1.5	2.3	NS	NS
Thigh circumference (cm)		30.9	32.6	31.6	32.0	5.8	0.0
		2.5	2.7	2.2	3.2	0.01	NS
Triceps SF (mm)		7.6	9.1	6.5	7.3	16.5	24.7
		1.3	2.0	1.5	1.3	0.000	0.000
Biceps SF (mm)		4.9	5.5	4.1	4.4	4.6	21.9
		1.4	1.4	0.9	1.1	0.03	0.000
Subscap SF (mm)		4.8	6.3	4.7	5.1	24.2	11.8
		0.7	1.7	0.9	1.0	0.000	0.000
Sup. iliaque SF (mm)		5.1	5.9	4.9	5.0	2.8	3.9
		1.3	2.0	1.8	1.0	NS	0.05

[1] mean; [2] 1 SD; [3] *P*-value; NS, not significant.

UN children except in the endurance run (Table 3). Differences between the two malnourished groups, chronic UN and severe UN, were not significant except in the throwing task, but there was a trend for chronic UN children to have poorer motor performances than severe UN children.

The principal components analysis resulted in two factors (Table 5). The first had high, positive loadings for bodyweight, lengths and breadths, and moderate loadings for the three limb circumferences. It accounted for 41% of the variance and represented a general body size factor. The second component had positive, moderately high loadings for subcutaneous fat and limb circumferences. It accounted for 25% of variance and apparently represented a body composition factor. Motor performances loaded positively and moderately high for the first factor, and negatively for the second (note that the sign for the shuttle run is negative because a lower time is a better performance). Scores for each principal

Table 2 Motor performance of Senegalese children

Age group (years)	<5.5		>5.5			
	Boys	Girls	Boys	Girls		
n	(33)	(36)	(46)	(32)	*F* (sex)	*F* (age)
3-min run run (m)	355.2[1]	327.6	410.2	373.3	10.7	26.2
	55.0[2]	57.3	50.9	73.2	0.001	0.000[3]
		(35)[4]				
Jump (m)	0.67	0.64	0.85	0.73	3.7	13.5
	0.19	0.25	0.18	0.24	0.05	0.000
	(32)	(29)		(31)		
Agility (s)	19.0	22.2	17.5	19.0	10.5	10.5
	3.6	6.5	3.0	3.3	0.000	0.000
		(35)		(31)		
Throw (m)	7.3	5.4	8.7	7.2	27.1	25.1
	2.2	1.7	1.7	2.1	0.000	0.000
Hand grip (kPa)	27.3	22.1	33.3	31.8	5.6	27.6
	7.8	8.0	7.3	10.6	0.02	0.000

[1] mean; [2] 1 SD; [3] *P*-value; [4] numbers when different from the initial sample.

component were calculated for children in the three nutritional groups and then compared by analyis of variance. Mean component scores for the three groups were distinct (Table 6). The mean score for the first principal component (overall body size) was significantly greater for well nourished children, while those for severe UN and chronic UN children did not differ. The mean score for the second principal component (body composition) was significantly lower in chronic UN children, but did not differ between severe UN and well nourished children.

Discussion

Children exposed to severe or chronic undernutrition during infancy and childhood have lower indices of physical growth and motor performance than well-nourished children (Malina 1984). The results confirm the importance of reduced body dimensions in motor performances of undernourished children, and emphasize the long-term negative impact of PEM on growth even years after the initial episode (Alvear *et al.* 1991). Several studies have investigated the long-term effect of undernutrition in infancy, and generally found an association with mental impairment, low academic performances, and reduced motor abilities later during childhood and adolescence (Hoorweg & Stanfield 1976;

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Table 3 Comparison of anthropometric characteristics of Senegalese children with different nutritional histories after adjusting for differences in sex and age by covariance analysis

Nutritional group *n*	Severe UN (52)	Chronic UN (63)	Well-nourished (32)	*F*	Differences
Weight (kg)	16.4[1]	16.2	18.2	9.5	Well-nourished > severe UN & chronic UN
	0.3[2]	0.2	0.3	0.000[3]	
Height (cm)	107.0	105.8	111.8	14.4	Well nourished > severe UN & chronic UN
	0.7	0.6	0.9	0.000	
HASIS (cm)	61.6	61.2	65.8	19.9	Well-nourished > severe UN & chronic UN
	0.5	0.5	0.6	0.000	
Sitting height (cm)	57.6	56.8	59.3	8.9	Well-nourished > severe UN & chronic UN
	0.3	0.3	0.4	0.000	
BIAC (cm)	23.0	22.8	24.5	17.3	Well-nourished > severe UN & chronic UN
	0.2	0.1	0.2	0.000	
Arm circ (cm)	15.9	15.3	16.5	9.6	Well-nourished > severe UN & chronic UN
	0.1	0.1	0.2	0.000	severe UN > chronic UN
Calf circ (cm)	20.7	20.2	22.2	10.9	Well-nourished > severe UN & chronic UN
	0.2	0.2	0.3	0.000	
Thigh circ (cm)	31.7	31.0	33.6	10.7	Well-nourished > severe UN & chronic UN
	0.3	0.3	0.4	0.000	
Triceps SF (mm)	7.9	7.3	7.9	1.9	No difference
	0.2	0.2	0.2	NS	
Biceps SF (mm)	4.9	4.8	4.4	1.8	No difference
	0.1	0.1	0.2	NS	
Subscapul SF (mm)	5.5	4.9	5.1	2.6	No difference
	0.1	0.1	0.3	0.07	
Sup. iliaque SF (mm)	5.5	4.8	5.7	3.9	Well-nourished > chronic UN
	0.1	0.1	0.2	0.05	severe UN > chronic UN

[1] adjusted group mean; [2] standard error; [3] *P*-value; NS, not significant.

Stoch & Smythe 1976; Richardson *et al.* 1978; Galler *et al.* 1983; Galler, Ramsey & Solimano 1984).

It is difficult to compare the results obtained in these Senegalese children with those of children from more developed countries, since environmental and psychological conditions of testing are quite different; moreover, reference data for comparisons are very scarce. Nevertheless, as a group, the Senegalese children had lower performances than the American children of the same age (Morris *et al.* 1982). Their performances were about 65–70% lower for the jump and 72–76% for the throw. However, well nourished children performed as well as the American children; it should be noted that, while as a whole sample the Senegalese children were shorter and lighter than the American children, well nourished children were near the median of the WHO/NCHS reference data

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Table 4 Comparison of motor performances characterisitcs of Senegalese children with different nutritional histories after adjusting for differences in sex and age by covariance analysis

Nutritional group *n*	Severe UN (52)	Chronic UN (63)	Well-nourished (32)	*F*	Differences
3-min run (m)	372.9[1]	370.1	364.7	0.2	No difference
	8.2[2]	7.5	10.3	NS[3]	
	(51)[4]				
Jump (cm)	0.72	0.67	0.88	12.6	Well-nourished > chronic &
	0.03	0.02	0.03	0.000	severe UN
	(45)	(61)			
Throw (m)	7.8	6.5	8.1	10.7	Well-nourished > chronic UN
	0.2	0.2	0.3	0.000	severe > chronic UN
Agility (s)	19.9	20.5	16.2	12.6	Well-nourished > chronic &
	0.6	0.5	0.7	0.000	severe UN
	(51)	(62)			
Hand grip (kPa)	25.2	28.9	34.8	16.7	Well-nourished > chronic &
	1.0	0.9	1.3	0.000	severe UN

[1] Adjusted group mean; [2] standard error; [3] *P*-value; NS, not significant; [4] numbers when different from the initial sample.

Table 5 Principal component analysis of anthropometric and motor performances characteristics of Senegalese children

	Factor 1	Factor 2
Weight	0.85	0.40
Height	0.93	0.01
HASIS	0.89	−0.01
Sitting height	0.82	0.10
BIAD	0.79	0.05
Arm circumference	0.47	0.75
Calf circumference	0.60	0.56
Thigh circumference	0.50	0.76
Triceps SF	−0.32	0.85
Biceps SF	−0.36	0.71
Subscapul SF	−0.23	0.81
Sup. iliaque SF	−0.04	0.78
Age	0.52	−0.35
Endurance run	0.55	−0.39
Jump	0.68	−0.19
Throw	0.61	−0.19
Agility	0.70[1]	−0.09[1]
Hand grip	0.79	−0.11
Eigenvalue	7.38	4.55
% variance explained	41.0	25.3

[1] signs for the agility (shuttle) run were inverted because the lower time is a better performance.

Table 6 Comparison of factors scores between groups of different nutritional histories

Groups	Mean	SE[1]
Component 1 (body size and performance)		
Severe UN (45)	–0.33	0.12
Chronic UN (56)	–0.03	0.14
Well-nourished (32)	0.52	0.15
Component 2 (body composition)		
Severe UN (45)	0.13	0.16
Chronic UN (56)	–0.33	0.11
Well-nourished (32)	0.38	0.15

[1] standard error

$F(2,130) = 7.67$ ($P < 0.000$)

Student-Newman-Keuls: Well-nourished > Severe UN & Chronic UN

$F(2,130) = 6.32$ ($P < 0.002$)

Student-Newman-Keuls: Severe UN > Chronic UN; Well nourished > Chronic UN

(WHO 1983). Although not the specific purpose of the study, these findings suggest that conditions of living and nutritional status are important determinants of motor performances during. Anthropometric differences by age were more pronounced than differences by sex; for motor performances, however, boys had higher results than girls. This is consistent with the literature indicating early sex differences in motor performance(Morris *et al.* 1982; Parizkova *et al.* 1984; Toriola *et al.* 1986).

Well-nourished children performed better than chronic UN and severe UN children except in the 3-min endurance run. Conditions of testing were the same for all three groups, and there was no reason for a systematic bias in the results. In the case of the 3-min endurance run, it is possible that test duration was too short to produce a cardiorespiratory stress sufficient to adequately differentiate children by endurance status. The young child is immature in running economy and takes some time to adapt the length of stride to speed (Rogers *et al.* 1994). This may be a confounding factor.

In general, differences between chronic UN and severe UN children did not reach statistical significance, except for the throw. There was however, a trend severe UN to perform better than chronic UN. It is also possible that some severe UN children, even if they were released in good nutritional condition after revovery, subsequentely suffered from chronic mild-to-moderate malnutrition. Results for these children may have lowered the overall severe UN group means. If true, this would suggest that the impact of PEM on motor performance is less in children having fully recovered from a severe episode than for children chronically exposed to mild-to-moderate PEM.

Principal component analysis confirmed the differences between nutritional groups with several additional insights. The 'body size' factor confirmed the expected relationships between physical growth and motor performance, whereas the second factor pointed to the importance of subcutaneous fat mass. Chronic UN children had the lowest scores for the second component, which suggested that the differences between the two groups of malnourished children were largely differences in body composition: subcutaneous fatness was lower in chronically undernourished children. Body composition may thus be an underlying factor in the differences in motor performance that are not explained by differences in body size. The negative, low loadings in factor 2 suggest a possible negative effect of subcutaneous fat on motor performance. Among well-nourished children in developed countries, skinfold thicknesses have consistently negative correlations with performance on a variety of motor tasks, especially those requiring movement or projection of the entire body (Malina 1975, 1994). However, in malnourished children the effect of fatness may be different. For example, relative fatness has low or no effect on motor performance of mildly to moderately undernourished school age boys, which suggested that fatness in undernourished children may be an indicator of better nutritional status and in turn may have a possible positive influence on motor performance (Malina & Little 1985). This point is interesting since the role of body composition, and fat mass in particular, in malnutrition had seldom been studied. Peripheral muscle and fat masses are potential reserves of protein and energy, respectively. They may be used when nutrient and energy supplies are limited, and thus deserve special consideration in assessing the severity of PEM and its functional consequences.

Reduction of body dimensions can directly affect motor performance because it implies an absolute decrease in the amount of muscle mass available to perform an activity. Such changes play an important role in running and jumping tasks in young children. Ball *et al.* (1992) for example, have shown that total body and leg lengths were better predictors of running and jumping performances of normal children than strength measurements. It should also be noted that a reduction in size and circumferences leads to a modification of the length of muscle levers and moment arms, i.e. the biomechanical aspects of the performance. These changes in turn, may alter the learning proficiency and movement skill of the growing child (Zernike & Schneider 1993). The net result is reduced motor control in undernourished children.

Several other factors could explain the differences in performance between nutritional groups, especially differences in quality of environment and rearing conditions that are related to learning and experience. These factors are important for the development of Senegalese children living in the same area (Benefice & Bâ 1994). However, it is very difficult to distinguish between PEM and accompanying impoverished conditions (Pollitt 1990), and in developing countries, undernutrition is almost always associated with poverty (Santfield 1993). Whatever the mechanism, PEM in childhood has long-term effects on motor performances which are an outward sign of obvious alterations in strenth, power and perceptual-motor development. Motor skills are an important component of the behavioural repertoire of young children, and activities incorporating these skills are often the medium through which children interact with their multiple environments.

Acknowledgement

This study was supported by the 'Conditions d'Amélioration des Situations Nutritionnelles' Research Unit of the Institut Français de Recherche Scientifique pour le Developpement en Cooperation (ORSTOM). The manuscript was prepared while the first author was a visiting scholar with R.M. Malina in the Department of Kinesiology and Health Education of the University of Texas at Austin.

Special thanks are due to Dr Antoinette Bâ and the staff of the Terre des Hommes Nutritional Rehabilitation Center of Thiès, to the teachers of the Catholic kindergarten of Thiès, and to all the children and their parents who accepted to collaborate with this study.

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