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Physical activity and anthropometric and functional characteristics of mildly malnourished Senegalese children

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Summary This study examines the effects of chronic malnutrition on the functional capacities and physical activity patterns of a group of 100 healthy Senegalese children between the ages of 10 and 13 years. Anthropometric measurements, a sub-maximal step test, spirometric tests and testing of four motor skills (foot races, jumping, throwing, gripping) were conducted and their physical activity was monitored by recording of heart rate every minute for 6 hours. The weights of two-thirds of these children fell below −1 SD from the WHO/NCHS* norm for their ages, their test results were inferior to those of Western children, and the level of their physical activity appeared also to be low. When these children are divided on the basis of weight deficits for age into well nourished and malnourished groups, malnourished children register poorer functional performances than well nourished children, but no difference exists with respect to the intensity of physical activity. These results highlight the negative effect of malnutrition on children's physical performance. The consequences are disturbing as the subsistence in the Sahelian Region depends on substantial physical labour.

Introduction

Two factors which determine the level of physical fitness should be considered in the case of protein-energy malnutrition: existing muscle mass which has a direct effect upon motor performance,[1] and the level of physical activity which generates a training effect.[2,3] The visible results of protein-energy malnutrition, if prolonged, are wasting and stunting which can contribute to the reduction of muscle mass.[4] Physical activity, which constitutes an important part of daily energy expenditure, estimated at 31% of total expenditure for boys and 25% for girls,[5] can be decreased to balance energy requirements when intakes are low or insufficient.

The limiting role of muscle mass in determining the working capacity of undernourished children has been well studied,[6–8] but studies on physical activity are more rare. It would seem that the activity of undernourished school-age children differs little from that of well-nourished children[9] as opposed to that which appears to occur in pre-school-age children.[10–13]

In Africa, despite the high prevalence of malnutrition,[14] little work has been undertaken concerning the relationships between children's physical activity and performance.[15,16] In these non-mechanized regions, most agricultural tasks require muscular effort and the proficiency with which these difficult tasks are accomplished is directly related to the physical capacity of the

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individual.[17,18] Children themselves are fully fledged producers, contributing to family subsistence.

This paper has two objectives: (i) to describe both the performance and the physical activity pattern of a group of Senegalese children; and (ii) to demonstrate the importance of nutritional status with respect to physical fitness.

Subjects and methods

The physical environment

The children who were studied come from two regions of Senegal: 41 are from the district of Bambey in the centre of the country and 59 from the district of Podor, located in the extreme north in the bend of the Senegal River. The climate in both regions is Sahelian: rainfall is sparse, registering between 300 and 600 mm throughout the rainy season from July to October, followed by a very hot dry season. The principal crops are groundnuts and millet in the centre and millet, sorghum and irrigated rice in the north. The energy content of the diet is deficient. A survey conducted several years ago in the Bambey district demonstrated that daily *per capita* intake was less than 2200 calories, with two-thirds of the individuals not meeting their minimum requirements.[19] The situation in the north is similarly precarious: *per capita* intake was 2240 calories/day and one-third of the households studied did not meet their energy requirements.[20] The prevalence of malnutrition is high: in the district of Bambey, 34% of children under 5 years of age who participated in a nutritional assistance programme weighed less than 80% of the WHO/NCHS median for their age group.[21] A sample survey in the villages located in the north revealed that 23% of pre-school-age children have weight-for-age values less than -2 SD from the WHO/NCHS mean for their age group and 21% have height-for-age below -2 SD.[22]

The sample

One hundred children between the ages of 9 and 14 years (46 boys, 54 girls) were recruited. Forty-one of these were Wolofs from the central part of the country, who were examined between January and March 1990, and 59 were young Toucouleurs from the north, who were observed during school holidays from June to July 1990. As no significant somatic differences were noted between the two ethnic groups, this factor was not taken into account at this stage of the analysis.

The subjects were chosen after a preliminary demographic census which covered each household in the selected villages. In most cases, no birth certificate existed; thus, age was determined from historical reconstruction using dates of Muslim religious ceremonies and, when possible, by comparison with a child of known age from the same family. Only normal children in apparent good health who had had no recent serious illness or clinical signs of malnutrition or anaemia were included. Parents, administrative officials and traditional village chiefs were clearly informed as to the nature and objectives of the study and a person close to each child was invited to attend the testing which was conducted in public.

Methodology

Each child underwent a clinical and an anthropometric examination, a step-test, spirometric and athletic testing and, finally, heart rate monitoring lasting 6 hours. Monitoring was conducted in the afternoon on those children tested in the morning or on the following morning on those who were tested in the afternoon.

Clothed only in underpants, children were weighed on an electronic scale precise to the nearest 100 g. Their standing height was measured with a Harpenden anthropometer, exact to 1 mm. Arm circumference (AC) was measured mid-way up the left upper arm to the nearest 1 mm with an inextensible ribbon; skinfolds surrounding the biceps and triceps (TSF) were measured at the same level with a Holtain compass accurate to within 0.2 mm. Measurements of subscapular and supra-iliac skinfold were also taken from the left side.

The arm muscle area (AMA) was measured according to the formula proposed by Gurney & Jelliffe[23]:

$$AMA(\text{cm}^2) = (AC - \pi \times TSF)^2 / 4\pi$$

Measurements of the four skinfolds permitted determination of body density, based on Durnin & Ramahan's equation[24], percentage of body fat (%BF) in the organism according to Siri's formula[24] and, finally, lean body mass (LBM) by subtracting body fat from total body mass (Table I).

The children then executed spirometric manoeuvres using a portable spirometer (Micro Medical Ltd, Rochester, England). While standing, they were asked to inhale fully and then to exhale until all air had been expelled. The best of three trial results was retained. Results for both forced vital capacity (FVC) and one second forced expiratory volume (FEVl) are shown in Table II.

The working capacity test consisted of a sub-maximal step test with the following protocol: after resting in a sitting position for 3 minutes, the children climbed up and down first a 17 cm step, then a 23 cm step and finally a 30 cm step, each for 3 minutes, at a rate of 30 steps per minute, controlled by a metronome which beat on the second. Children were cheered on during the course of the test. At the end of the test, there was a rest period lasting 5 minutes. During the entire 17 minutes of testing, heart rates were recorded every 15 seconds with a Sport Tester (Polar Electro KY, Kempele, Finland). This device is made of an emitting electrode attached to the chest by an elastic band and a receiver attached to the wrist which recorded the frequencies. Children practiced the climbing movements for a few minutes early in the morning.

The different heights of the benches allows continuous exercise of increasing difficulty. The total mechanical work performed on climbing may be expressed by:

$$\text{Work (joule)} = \text{body weight} \times \text{height of the step} \times 9.8 \times \text{number of mounts.}$$

The work performed on dismounting the step was estimated as one-third that of climbing.[25] Thus, for the first 17 cm step, the total work performed during 1 minute would be:

$$\text{Work (J)} = \text{body weight} \times ((0.17 + 0.17/3) \times 9.8) \times 30. = \text{body weight} \times 66.6.$$

The equivalence for mechanical power, energy produced per unit of time, is set as: 1 watt = 60 joules per second.[28] Thus, the mechanical power produced will be:

$$\text{Power (watt, W)} = (\text{body weight} \times 66.6)/60. = \text{body weight} \times 1.1 \text{ (approximately } 1\ \text{W.kg}^{-1}).$$

In the same way, we can show that the power produced for the second bench is about 1.5 W.kg^{-1} and 2 W.kg^{-1} for the last.

The work performed and power produced were then calculated for each minute of the 9 minutes exertion test. Finally, we calculated the regression equation between heart rates and power produced and the estimated amount of power that would produce a heart rate of 170 beats per minute (PWC 170) and this was chosen as an individual indicator of aerobic capacity of the child.[25]

Finally, the children performed four physical exercises:

(i) A dynamometer grip test to measure the maximal force developed by the forearms. This consisted of squeezing a rubber bulb connected to a manometer (Martin, Tuttlingen, RFA). The children were given three tries using both hands, and the highest readings are those analysed. The results are expressed in kilopascal (kpa).

(ii) A 33 m race. The children ran barefoot on a sandy track, two-by-two to stimulate one another; they were timed to within 0.01 seconds.

TABLE I. Mean values of anthropometric parameters in school-age Senegalese children. Numbers in parentheses are SD

	Boys				Girls			
	Age (yrs) $n=18$ 10–11.9	Reference	Age (yrs) $n=28$ 12–13.9	Reference	Age (yrs) $n=33$ 10–11.9	Reference	Age (yrs) $n=21$ 12–13.9	Reference
Weight (kg)	26.7 (3.6)	31.4 (a)	29.5 (2.9)	39.8	27.1 (4.7)	32.5	34.7 (5.8)	41.5
Height (cm)	134.5 (6.4)	137.5 (a)	141.5 (6.2)	149.7	134.7 (6.2)	138.3	146.7 (9.3)	151.5
Triceps skinfold (mm)	5.4 (1.2)	6.9 (b)	5.2 (0.8)	7.1	6.6 (2.2)	11.1	7.2 (2.6)	12.9
BMI (kg/m^2)	14.7 (1.2)	16.6 (b)	14.7 (0.7)	17.7	14.8 (1.5)	17.1	16.1 (2.1)	18.7
%BF	12.0 (2.0)	—	11.9 (1.5)	15.9 (c)	18.6 (3.0)	—	19.3 (2.2)	24.0
LBM (kg)	23.5 (3.1)	—	25.9 (2.5)	—	21.9 (3.1)	—	27.9 (4.1)	—
AMA (cm^2)	18.0 (2.9)	25.7 (d)	19.9 (2.7)	30.2	18.7 (2.9)	22.9	22.8 (3.7)	29.0

References: (a) 50th percentile, data from WHO/NCHS.[4] (b) 50th percentile of black children, data from Hanes, I.[26] (c) Adolescents.[24] (d) 50th percentile, data from Hanes, I.[27]

TABLE II. Mean values of spirometric, working capacity and motor performance tests in school-age Senegalese children. Numbers in parentheses are SD

	Boys				Girls			
	Age (yrs) $n=18$ 10–11.9	Reference	Age (yrs) $n=28$ 12–13.9	Reference	Age (yrs) $n=33$ 10–11.9	Reference	Age (yrs) $n=21$ 12–13.9	Reference
FVC (l)	1.6 (0.2)	2.0 (a)	1.8 (0.2)	2.3	1.4 (0.2)	1.8	1.9 (0.4)	2.2
FEV1 (l)	1.4 (0.1)	1.7 (a)	1.5 (0.2)	1.8	1.3 (0.1)	1.7	1.8 (0.2)	2.2
PWC 170 (W)	68.2 (19.7)	79.7 (b)	69.1 (16.0)	83.8	54.3 (13.9)	62.1	76.2 (24.6)	86.6
33 m dash (sec)	6.9 (0.5)	5.9 (c)	6.5 (0.5)	5.6	7.4 (1.0)	6.2	7.1 (1.2)	5.7
Jumping (m)	1.40 (0.20)	1.5 (c)	1.45 (0.18)	1.7	1.28 (0.22)	1.33	1.39 (0.26)	1.57
Throwing (m)	14.8 (4.3)	27.1 (c)	16.4 (3.8)	33.6	11.3 (2.8)	14.1	15.1 (4.5)	17.2
Right hand grip (kPa)	51.5 (20.6)	40–80 (d)	53.9 (13.4)		42.7 (12.5)	40–80	55.0 (18.9)	

References: (a) Tables scientifiques, Ciba Geigy.[28] (b) Healthy black American children.[29] (c) Black children from Philadelphia.[30] (d) Ranges proposed by the maker of the apparatus (Gebrüder Martin, Tuttlingen).

(iii) A long jump—feet together from a standing start. Distances were measured from toemark to heelmark.

(iv) An over-arm throw with a 184 g softball.

For jumping and throwing, the best of three consecutive tries was taken as the result.

At the conclusion of the exercises, the children's pulses were recorded each minute during 6 hours by means of Sport Testers; children were asked not to modify their normal activities. This length of time was chosen because it corresponded to the amount of time children could comfortably tolerate the device, given the high temperatures. The results were expressed in percentage of time at different heart rates: rate <125 beats per minute corresponding to unstressful activity, a rate of between 125 and 140 beats per minute corresponding to moderate activity of approximately 60% of maximum heart rate and finally intense activity, >140 beats per minute, corresponding to 70% of maximum heart rate.

The order in which the tests were carried out was constant: clinical exam, anthropometric test, spirometric test, step test, test of motor skills. All the children were measured by the author.

The analyses of the results were conducted using the BMDP Statistical Software Package. Tests comparing means, analysis of variance and co-variance, and multiple regression were employed.

Results

Although clinically in good health, these children showed weight and height deficits relative to well nourished children of the same age. Figure 1 shows the weight distribution (W/age) and height distribution (H/age) according to age, expressed as a fraction of a SD (*Z*-score) from the WHO/NCHS mean.[4] The sample's curve is situated on the left, corresponding to low values: 50% of those studied have H/age below -1 SD; the weight deficit is even more pronounced, 63% having a W/age less than -1 SD. Moreover, deficits increase with age: 80% of children older than 11 years show a weight deficit of -1 SD compared with 45% of children younger than 11 ($\chi^2 = 18.1$; $p < 0.001$, 1 d.f.).

These observations are confirmed by comparing the children's mean anthropometric values with those of well nourished children from diverse origins (Table I): the somatic deficits are more pronounced in the children over 11 years of age. Values for body fat (TSF) and muscle mass (AMA) are less than the 5th percentile for the TSF and the 10th percentile for the AMA, respectively.

Lung function and motor skills test results (Table II) show that in all cases the performances of Senegalese children are worse than accepted norms for corresponding age and height. It should, however, be noted that the PWC 170 of the boys is higher than those of Ethiopian children of the same age,[15] and that they run faster and jump further than Mexican children.[31]

Recording heart rates over a period of 6 hours indicates in general a very moderate level of physical activity, although it is difficult to establish a basis for comparison (Table III). Variations between individuals are very great. As a rule, younger children are more active than older ones, boys under 11 years of age spend less time on moderate activities (heart rate <125 beats/min) than older girls ($t = 1.99$; $p < 0.05$), and, generally, boys spend more time on intense activities than girls ($t = 1.99$; $p < 0.05$).

An investigation was done to determine the influence of height and weight deficits on the variations in functional performances of these children, taking into account the effects of age and sex on development. The summary of multiple regressions (Table IV) reveals that the part of the variance explained by W/age is in general 5–7% but reaches 26% for the FVC and 34% for the AMA, which would indicate that weight deficit is a significant determinant of functional and muscular status of malnourished children. Height deficits have only a moderate

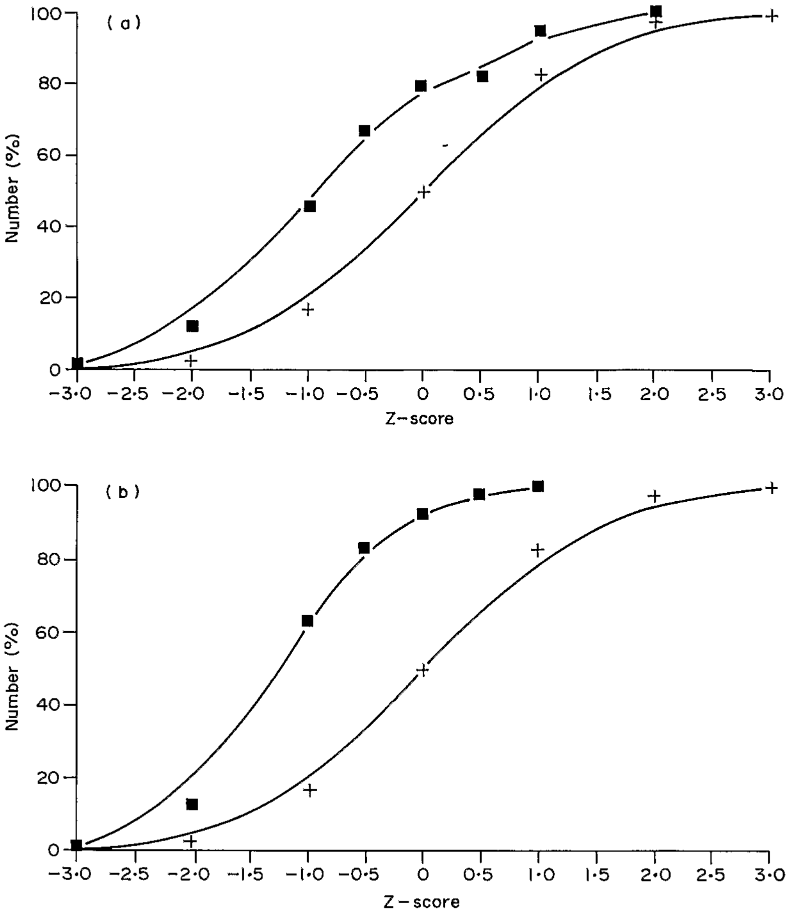

FIG. 1. Cumulative distribution curves of (a) Height/age and (b) Weight/age *Z*-scores (—■— Sénégal; —+—NCHS).

influence on the variance of the AMA and gripping scores. On the other hand, weight- and height-for-age indicators do not have an impact on the variations in intensity of physical activity. In addition, it could not be shown that the level of physical activity influenced the level of performance: no relationship exists when the different categories for heart rates are used as independent variables to explain the children's performances.

Thus, two groups of children were formed, one malnourished with a W/age less than −1 SD for the reference ($n = 65$), the other well nourished (W/age >1 SD; $n = 35$), and the values for somatic and functional parameters and physical activity adjusted for age and sex were compared through an analysis of covariance. The equality of the slopes of the regression lines were tested and no interaction was found, except in the case of the FVC, thus permitting comparisons of adjusted means.[32] In the case of the FVC, separate comparisons were made between the groups of young and older children. The results are shown in Table V. One concludes that for all of the variables tested the well nourished children always have better scores than malnourished children. However, there is no difference between the groups regarding the level of physical activity, as shown by the distribution of heart rates.

Discussion

This study demonstrates that the values of anthropometric and functional parameters of

TABLE III. Mean percentage of time spent at three different heart rates during a 6-hour heart rate recording. Numbers in parentheses are SD

	Boys		Girls	
	Age (yrs) $n=17$ 10–11.9	Age (yrs) $n=28$ 12–13.9	Age (yrs) $n=31$ 10–11.9	Age (yrs) $n=19$ 12–13.9
% HR < 125	86.4 (18.6)	92.3 (9.9)	91.1 (8.9)	94.1 (6.1)
Two-way analysis of variance				
Effect				
Age $F=3.5$ ($p<0.05$)				
Sex $F=1.9$ (ns)				
% 125 < HR < 140	9.4 (15.0)	5.0 (7.2)	5.9 (6.6)	3.9 (4.3)
Two-way analysis of variance				
Effect				
Age $F=3.0$ ($p<0.08$)				
Sex $F=1.7$ (ns)				
% HR > 140	4.1 (4.2)	2.6 (3.0)	2.1 (2.2)	2.1 (2.4)
Two-way analysis of variance				
Effect				
Age $F=1.5$ (ns)				
Sex $F=3.6$ ($p<0.05$)				

ns: Not significant.

a group of Senegalese school children are always inferior to those registered among well-nourished children from the West. The smaller physical stature of these children is a determining factor in the level of their functional capacities; their physical activity appears to be very moderate but there is not a significant relationship between this fact and either nutritional status or the quality of registered performances.

These poor results may be attributed partly to methodological imperfections. The comparisons are based on the age of the subjects, but age is generally not exactly known in Senegal. Nevertheless, in view of the care that has been taken, it is thought that the error is less than 1 year and probably around 6 months. A second factor to be considered is that the onset of growth during puberty appears to occur very late in Senegal, as is often the case among malnourished groups.[33] This would explain the particularly mediocre results of children older than 12 years.

The conditions under which the testing was done were not favourable to the Senegalese children. Cultural and psychological factors should also be mentioned. The attainment of good results requires a high degree of motivation, a sense of competition and a measure of agressiveness which are lacking in these children who come from a traditional environment where these values are not developed.

The methodology used in the sub-maximal step test could also give rise to an underestimation of the results. Testing was conducted on a bench and measuring the load is necessarily less precise than with an ergometric bicycle or a treadmill.

Taking these observations into account, the data from this study conform to other studies which underline the importance of

TABLE IV. Summary of multiple regression analysis between age, sex, W/age and H/age and selected body composition and functional variables

Dependent variable	Step	Entered variables	Multiple R	R^2	Change in R^2	F to enter
%BF	1	Sex	0.83	0.69	0.69	219.1
	2	W/age	0.86	0.74	0.05	20.2
	3	Age	0.88	0.78	0.04	17.9
AMA	1	Age	0.47	0.22	0.22	27.9
	2	W/age	0.75	0.57	0.34	78.8
	3	H/age	0.79	0.63	0.06	16.9
PWC	1	Age	0.44	0.19	0.19	23.2
	2	W/age	0.48	0.24	0.04	5.8
FVC	1	Age	0.55	0.30	0.30	42.9
	2	W/age	0.75	0.57	0.26	58.3
	3	Sex	0.77	0.59	0.02	6.4
33 m dash	1	Sex	0.31	0.09	0.09	10.5
	2	Age	0.38	0.14	0.05	5.7
	3	W/age	0.45	0.20	0.05	6.4
Jumping	1	Age	0.28	0.08	0.08	8.9
Throwing	1	Age	0.41	0.17	0.17	20.6
	2	Sex	0.49	0.23	0.06	8.4
	3	W/age	0.58	0.34	0.10	15.4
Hand grip	1	Age	0.22	0.05	0.05	5.1
	2	W/age	0.34	0.12	0.07	7.9
	3	H/age	0.40	0.16	0.04	4.7
	4	Sex	0.45	0.20	0.04	4.9

body dimensions in determining the physical aptitude of undernourished children. Accordingly, in India, Satyanarayara showed that in a group of adolescents 64% of the PWC variance can be attributed to differences in weight and 10% to differences in the level of physical activity.[6] In Brazil, the performances on an ergocycle of children from poorer neighbourhoods were inferior to those of children attending private schools,[34] and, among adolescents, weight and stature account for 57% of PWC variance.[7] The muscular performances and physical aptitude of undernourished children, when expressed as a function of weight or muscle mass, or adjusted for height, approach or even surpass performances by European children.[15,16,35] These observations only highlight the importance of muscle mass in the accomplishment of physical exercise but do not imply any advantage on the part of undernourished children. Spurr *et al.* showed that during treadmill walking the mechanical efficiency of undernourished children is not greater than those who are wellnourished. This implies that the anomaly is related to the quantity of available muscle mass and not to its quality. For a given task, an undernourished child must work to a higher level of oxygen uptake. It is the absolute value of the functional capacity that must be considered in evaluating the effects of malnutrition and not its relative indicators.[38]

Physical activity, as evaluated through heart rate monitoring, appears to be moderate compared to other studies: monitoring heart rates for 12 hours each day for 3 days

TABLE V. Comparison of selected body composition, functional and physical activity variables between wasted and normal school-age children

Variables	Status	Adjusted mean	Standard error	t-test	p
%BF	Wasted	15.0	0.28	3.5	<0.001
	Normal	16.9	0.39		
AMA (cm²)	Wasted	18.7	0.33	6.0	<0.001
	Normal	21.8	0.47		
PWC 170 (W)	Wasted	60.9	2.8	3.2	<0.001
	Normal	75.1	4.4		
FVC (<132) (l)	Wasted	1.33	0.04	4.5	<0.001
	Normal	1.61	0.04		
FVC (>132) (l)	Wasted	1.73	0.03	4.7	<0.001
	Normal	2.23	0.09		
33 m dash (sec)	Wasted	7.22	0.10	2.9	<0.01
	Normal	6.60	0.15		
Jumping (m)	Wasted	1.34	0.02	1.9	<0.05
	Normal	1.43	0.03		
Throwing (m)	Wasted	13.4	0.4	2.7	<0.01
	Normal	15.7	0.6		
Hand grip (kPa)	Wasted	47.5	2.0	1.9	<0.05
	Normal	54.6	2.9		
HR (%) >125	Wasted	8.85	1.45	0.37	ns*
	Normal	7.85	2.06		

*Significant interaction with age: age <132 months: wasted $n=22$; normal $n=27$. Age >132 months: wasted $n=42$; normal $n=7$. ns: Not significant.

revealed that English boys and girls passed 6.2 and 4.3% of their time, respectively, at rates greater than 140, which was considered insufficient by the authors of the study.[38] These values, however, are superior to this study's observations of 4 and 2%. Another study on children between the ages of 6 and 7 years showed that they spent 75% of their time at cardiac rates less than 120 beats per minute,[39] whereas young Senegalese children passed between 85 and 90% of their time at rates less than 125 beats per minute, although they were able to move about freely and were not constrained by scholastic obligations.

The evaluation of physical activity by heart rate monitoring has been criticized. Numerous factors other than effort, such as fever, emotion or anaemia, can increase the pulse. In addition, when the load of a task is low, cardiac variations can arise independently of variations in the consumption of oxygen. However, in field test conditions and for population studies, the use of heart rates remains an acceptable method.[40]

Our study could not demonstrate clearly the influence of nutritional status on the level of physical activity, nor a relationship between physical activity and the physical aptitude of the children, although one could have anticipated a lower level of activity among malnourished children in view of their poor performances. Several explanations are possible: the study sample was, from a physical standpoint, very homogeneous, and the intense physical activities of children are generally brief, lasting less than 1 minute,[30] thus poorly apprehended here. Nevertheless, in the same manner, studies conducted in Columbia using the heart rate accumulation method did not show a difference in activity-related expenditures between the undernourished and wellnourished.[41,42] The explanation offered by the authors was that undernourished children who play with normal children are under intense peer pressure, the energy adjustment being made in a reduction of growth rather than a decrease in activity. This explanation appears pertinent to our study also.

This study is one of the first on the physical condition of children from the Sahel. It reaches most of the same conclusions of similar studies conducted elsewhere. It underlines the determinant role of malnutrition and stunting in the poor muscular performances of these children. The low level of activity which was observed can also be reasonably attributed to malnutrition, which clearly highlights the problems of subsistence and development of these communities.

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