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Physical Activity, Cardiorespiratory Fitness, Motor Performance, and Growth of Senegalese Pre-Adolescents

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ABSTRACT Profiles of usual physical activity, cardiorespiratory fitness, motor performance, and growth were measured regularly for 2 years in 40 rural Senegalese (Wolof) children—20 boys and 20 girls—who were 10 or 11 years of age and clinically healthy at the beginning of the study. Compared to National Center for Health Statistics (NCHS) reference data, the children showed lower weight-for-age and height-for-age throughout the period of observation; the increments of height from year to year were not remarkable and growth spurts were not observed during the study period. The motor performance (running, jumping, throwing) and spirometer test results were inferior to age-matched American children. When adjusted for actual weight and height, jumping and throwing results were similar to those of American children, but running results remained inferior. Cardiorespiratory function appeared inferior to American children of the same age, although speed of recovery after exertion demonstrated good cardiorespiratory efficiency. Physical activity, directly observed over 2-day periods on 4 occasions, corresponded to an average energy expenditure of 1.66 Mets (multiples of basal metabolic rate) (boys) and 1.76 Mets (girls), which are close to the FAO/WHO/UNU values for age. The higher energy expenditure of girls could be explained by their participation in domestic tasks. Both boys and girls spent an average of 42 minutes/day on activities equivalent to energy consumption rates equal or greater than 4.8 Mets. Significant correlations existed between the activity index and cardiorespiratory fitness in boys, and between the activity index and motor performances in girls. Physical aptitudes of sampled children appear compatible with the demands of their social and agricultural tasks. However, it appears that persistent malnutrition may have stunted their growth and motor performances.

Physical activity and the development of physical fitness in children determine, to a large extent, the level of physical fitness in adults and, in general, reflect the health of the population (Kannel et al., 1985). In developed countries, especially in North America, where underactivity has become a heavy burden on the health of the population (Baranowski et al., 1992), these relationships have a real significance. Even though the relationship between physical activity and cardiorespiratory fitness in normal children is not strong (Taylor and Baranowski, 1991), the physical activity and acquired ability during childhood are good predictors for adults (Kuth and Cooper, 1992). The fact that increased physical activity contributes to reduced mortality in adulthood (Arraiz et al., 1992) justifies early intervention measures from childhood.

Although priority physical health concerns are different in developing countries, the maintenance of physical integrity, nonetheless, largely depends on the balance between food intake and energy expenditure, with physical activities and physical fitness

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playing an essential role. It is believed that populations who are active and have good physical fitness can more easily face constraints and physical stress imposed by their subsistence environments (Parizkova, 1991). In developing countries as in developed countries, the development of physical fitness and performance in children may frame future aptitudes in adults, and may be a marker of the health and vitality of the community as a whole. The economies of the developing countries of West Africa rely upon subsistence agriculture, which requires high levels of manual work due to limited mechanization. One can expect that energy expenditure on physical activity in pre-industrialized countries is much higher than in industrialized countries (Ferro-Luzzi, 1985), even though the nature and the intensity of physical activity in Africa has not been studied in detail. The daily energy expenditure of African farmers generally appears to be high (Henderickx et al., 1990). However, factors such as occupation (agriculture vs. pastoral activities) (Benefice et al., 1984), season (Bleiberg et al., 1980; Brun et al., 1981), the technique or skill needed to accomplish the task (Maloiy et al., 1986), and geographical location (e.g., work in mountainous regions) (Panter-Brick, 1992), will influence energy expenditure. One can expect to observe high levels of physical fitness in active populations. However, inadequate nutritional status can negatively affect physical fitness. Poorly developed regions generally have a high prevalence of undernutrition. About 20 million children in the world are malnourished, with more than 80% of these in developing countries. Even though there seems to be a global improvement in nutritional levels, the situation has deteriorated in sub-Saharan Africa (ACC/SCN, 1992).

The reduction in body dimension and body mass as a result of malnutrition should be taken into consideration in all studies dealing with physical fitness in the children of developing countries (Spurr, 1988). In Senegal, current nutrition levels appear better than most African countries. In a study carried out on 14,257 children under five years of age in the Niakhar district (close to the location of the present study), the prevalence of slight malnutrition was 41.5% moderate malnutrition was 14.2%, and severe malnutrition was 1.3%, using a weight-for-age classification (Garenne et al., 1987). Chronic malnutrition results in reduced height. Regarding height for age, 17.6% of the children showed heights less than 2 standard deviations from the median value, and less than 25% of the children had attained the height of the reference population (World Health Organization, 1983).

Physical fitness of a population is determined by physical activity and nutritional status, and will vary according to location and environment. This present study was carried out to better understand the physical functional capacity of the peasant population in West-Sahelian Africa. This is a study of the growth, cardiorespiratory fitness, motor performance, and physical activity of healthy Senegalese children aged between 10 and 13 years.

METHODS

This study was carried out in Ndondol village in the Senegalese District of Lambaye (14.45° north latitude and 17.30° west longitude) within the zone known as the "Peanut Basin." The village, with a total population is 1,015, has a Sahelian climate, with one rainy season from July to October when peanuts and millets are cultivated. The inhabitants are Muslim *Wolof* farmers.

The study was carried out between October 1990 and December 1992. During that period, a group of 20 boys and 20 girls aged between 10 and 11 years were examined at regular intervals. No children were in formal education, but most of them received irregular religious instruction and basic subjects in Arabic. The children chosen for the study were clinically healthy (no orthopedic and neurological abnormalities, normal cardiopulmonary sounds, normal color of conjunctiva, and no recent hospital admissions). The parents were informed of the study and their agreement was given in the present of the village chief. Only children whose age was known with the precision of 3 months, whose birth was either registered or whose birthday could be traced with a Muslim calendar, were chosen. The children had to be available at all phases of the study. When the children were absent or ill during the week of a study phase, they were revisited in the following week. Three girls who were absent in the third visit continued to serve as subjects.

Anthropometry, spirometry, and measurements of motor functions, cardiorespiratory fitness and physical activities, were undertaken over a period of 2 years; measurements of weight, height, arm circumference and the triceps skinfold were made every 6 months (5 times in total), whereas more complete anthropometric examinations, motor function tests, and stress tests were administered once a year (3 times in total), and physical activity was measured 3 times in the first year and once at the end of the second year.

Weight was measured by using an electronic Katron® scale (Pesa Waagen, Switzerland) with a maximal capacity of 60 kg and a precision of 3 g. The subjects were weighed wearing only underwear. Height was measured with a portable Harpenden® anthropometer with a precision of 1 mm. Sitting height was measured with the same anthropometer, with subjects sitting on a flat table. Height of the anterior superior iliac spine (HASIS) and biacromial diameter (BIAD) were measured in the standing position with the anthropometer. Arm circumference (AC) was measured with a non-stretchable glass fiber tape on the left arm, and 4 subcutaneous fat folds (triceps, biceps, subscapular,and suprailiac) were measured with Holtain® skinfold calipers, following the methods recommended by the International Biological Program (Weiner and Lourie, 1981). Arm muscle circumference (AMC) was estimated after Gurney and Jelliffe (1973):

$$\text{AMC (cm)} = \text{AC (cm)} - (\pi \times \text{Triceps skinfold [cm]}).$$

Spirometric testing was done with a portable spirometer (Micro-medical Ltd, Manchester). In the standing position with blocked noses, the children were encouraged to exhale very hard by the mouth for as long as possible. This measured the forced vital capacity (FVC) and one-second forced expiratory volume (FEV1). The best of 3 consecutive trials was used for each subject.

During the third visit hemoglobin and hematocrit were measured by the cyanmethaemoglobin method with a portable spectrophotometer, Datex®, and by centrifugation with a Compur® micro-centrifuge, respectively.

The stress test consisted of a step test with 3 two-step ladders of different heights: the rungs of the first, second, and third ladders were 17, 23, and 30 cm high, respectively. This permitted a gradual increase in levels of effort. The protocol was as follows: the children rested in a sitting position for 3 minutes, then started going up and down the ladders with a rhythm of 30 steps per minute, lasting 3 minutes for each ladder and giving 9 minutes of exercise in total. The children then rested for 5 minutes. Throughout the whole period of the 17-minute test, the heart rate (HR) was recorded every 5 seconds by using a Sport Tester® frequencemeter (Polar Electro Oy, Finland). The rhythm was marked by a metronome which beat every second; the assistant, who steadied the child slightly by holding but not pulling his hand, gently tapped the child's hand to convey the rhythm.

The motor tests consisted of 3 trials of each of the following tasks:

1. Thirty-three meter dash: running alone in bare feet on levelled and cleaned sand.
2. Throwing of a 184 g soft ball using a clockwise movement.
3. Standing long jump with the feet together, measured from the toes on the starting line to the heel of the foot at the point of landing.

Physical activity was measured by direct observation. Specially trained investigators noted the children's activities every minute for 2 periods of 6 hours each day (07.00 hours to 13.00 hours and 14.00 hours to 20.00 hours), totalling 12 hours per observation day. The interval from 13.00 hours to 14.00 hours consisted of a mid-day break for lunch. The investigators watched the children at a distance so as not to interfere with their usual activities. The observations were carried out for 2 consecutive days by the same investigator. Children were randomly assigned to an investigator. They were not observed by the same investigator throughout the different visits. Four investigators assisted by the same supervisor participated at all surveys. Due to some problems, the duration of the observation in the second visit was reduced from 2 days to 1.5 days; thus, the total period of observation was [600 instead of 640 periods of 6 hours.] The investigators had to report the dominant activity of the minute on the activity sheet using a simple code (Table 1); following Bouchard et al. (1983), 9 activity categories graded to increasing energy expenditure were expressed in multiples of BMR (Mets), with the gradation ranging from resting to

TABLE 1. Categories of physical activities and their energy costs

Score	Multiples of BMR[1]	Example of activities
1	1.0	Sleeping, lying in the bed
2	1.5	Light activity while sitting: eating, plaiting hair
3	2.3	Light activity while standing: washing, preparing food, cooking
4	2.8	Walking, light activity in movement: dressing, cutting straw, weaving, washing plates, care of children
5	3.3	Light manual work: cleaning, sweeping, gathering wood, washing clothes, winnowing, sowing, carrying light load
6	4.8	Manual work and sport at a moderate pace: fetching water, cutting wood, loading a cart, stirring a big pot of millet porridge, harvesting sorghum
7	5.6	Manual work at a sustained pace: grinding grain, pounding, hoeing, carrying heavy loads, harvesting peanuts, football
8	6.0	Physical activity of high intensity: digging earth, uprooting manioc, land clearing, walking steeply, dancing
9	7.0	Physical activity of very high intensity: wrestling, very fast dancing, running, jogging

[1]Compiled from published values by: Brun et al, 1983; Bleiberg et al., 1980; Torún et al., 1983; FAO/WHO/UNU, 1985.

maximum effort. The values of energy expenditure were compiled from different measurements (Brun et al., 1981; Bleiberg et al., 1980; Torún et al., 1983; FAO/WHO/UNU, 1985). When a new activity was encountered, the investigator consulted the supervisor, who then determined the category of the specific task depending on the position of the body, movement and speed. At the end of 15 minutes, the investigator recorded the place where the activity took place and the dominant activity. During training, investigators showed 85 to 95% agreement in observing the same child.

The tests were carried out in the open air in the morning or late afternoon, to avoid the hot period of the day. The order of the tests was as follows: anthropometry, spirometry, stress test, and motor function tests. The preliminary training for the step test was done in the beginning of the day or the day before. At least 1 hour was allowed between the stress test and other tests, so that the children could recover between tests. Anthropometry was done solely by the author.

Statistical analysis was done using the logical statistics BMDP (Dixon, 1985). Due to repeated measurements on the same subjects, analyses of variance for repeated measures were done using programme 2V. Since the program was only possible with completed blocks, the missing data (due to the absence of 3 girls in one visit) were calculated using the AM program after verifying that those 3 subjects were no different from the others. In fact, the results analysed with 37 subjects were only very slightly different from the ones with 40 subjects. To draw the general profile of recorded activities, the Mann-Whitney non-parametric test was used.

RESULTS

The children showed a satisfactory state of health at the time of the examinations. Table 2 presents the results of anthropometry at different ages and by sex; there was no interaction between different visits and sex. The only differences between the sexes were for arm circumference, the triceps skinfold (TSF), and the sum of 4 skinfolds, in which girls had higher values than boys. Body size and body mass, which increased significantly at different visits, were identical between the sexes. On the other hand, triceps values were stable throughout the period of study for each sex.

The mean weight-for-age (WAZ) and height-for-age (HAZ) z-scores in this study and another recent survey of 998 schoolchildren in the urban area of Dakar (Bâ, 1991) are presented in Figure 1a,b. For both studies the values were significantly lower than the NCHS reference (WHO, 1983). Differences by sex within studies were not significant. Mean WAZ and HAZ z-scores of the present study were below those of the urban study (WAZ: $F\ [1,10] = 10.30$, $P < 0.009$. HAZ: $F\ [1,10] = 11.96$, $P < 0.006$).

The mean height-for-age of the children was −1.3 z-score during the first visit, −1.4 z-score at the end of the first year, and −1.5 z-score at the end of the second year; this decrease was statistically significant during the course of the study ($F\ [2,76] = 10.02$,

TABLE 2. Means and standard deviations (in parentheses) for anthropometric dimensions of Senegalese children by age and sex[1]

Age (years)	Weight (kg)	Height (cm)	SH (cm)	HASIS (cm)	BIAD (cm)	AC (cm)	TSF (mm)	SSF (mm)	AMC (cm)
Boys (n = 20)									
11	28.4	137.6	69.0	83.9	29.0	17.0	5.3	18.4	15.3
	(4.3)	(7.0)	(3.3)	(5.0)	(2.1)	(1.6)	(1.8)	(5.5)	(1.2)
11.5	29.5	139.5	—	—	—	17.4	5.6	—	15.6
	(4.4)	(7.0)				(1.4)	(2.0)		(0.9)
12	30.8	141.6	71.0	86.2	29.0	17.5	5.4	19.4	15.8
	(4.5)	(6.7)	(3.9)	(6.9)	(2.2)	(1.8)	(2.1)	(7.6)	(1.3)
12.5	32.3	144.2	—	—	—	18.3	5.9	—	16.4
	(5.3)	(7.2)				(1.9)	(2.7)		(1.2)
13	33.4	145.9	72.4	90.6	31.0	18.1	5.4	20.5	16.4
	(5.7)	(6.7)	(3.5)	(5.5)	(1.9)	(1.9)	(2.1)	(10.4)	(1.5)
Girls (n = 20)									
11	28.2	135.9	69.3	82.7	28.9	18.0	6.8	22.3	15.8
	(4.7)	(7.8)	(3.3)	(5.9)	(2.3)	(1.6)	(1.6)	(4.4)	(1.5)
11.5	29.6	138.6	—	—	—	18.2	7.0	—	6.06
	(5.0)	(8.2)				(1.5)	(1.9)		(1.4)
12	31.2	141.0	71.7	85.9	30.4	18.6	7.1	22.8	16.3
	(5.0)	(8.3)	(3.7)	(7.9)	(2.7)	(1.7)	(1.6)	(3.7)	(1.6)
12.5	33.8	144.4	—	—	—	19.3	7.2	—	17.0
	(6.0)	(8.5				(1.5)	(1.7)		(1.4)
13	34.4	145.9	73.4	90.3	31.4	19.3	6.9	23.2	17.1
	(6.3)	(8.5)	(4.0)	(6.1)	(2.2)	(1.7)	(1.8)	(4.3)	(1.7)
Analysis of variance for repeated measures									
Difference between sex (F 1,38)									
	0.1[2]	0.06[2]	0.5[2]	0.08[2]	0.1[2]	4.0*	6.4**	3.8*	1.8[2]
Difference between examinations (F 4,152 and F 2,76)									
	175.2***	528.4***	150.6***	142.3***	38.7***	31.4***	1.8[2]	5.8*	28.6***

[1]SH = sitting height; HASIS = height of antero-superior iliac spine; BIAD = bi-acromial diameter; AC = arm circumference; TSF = triceps skinfold; SSF = sum of 4 skinfolds (biceps, triceps, subscapular, suprailiac); AMC = arm muscle circumference.
[2]Not significant.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

$P < 0.001$). There were no differences between the sexes. The weight of the children also deteriorated from −1.5 z-score in the beginning of the study to −1.7 z-score at the end of the study ($F [2,76] = 13.59$, $P < 0.001$), with no difference between the sexes.

Contrary to the mean values for weight- and height-for-age, the increments in weight and height between visits varied between the sexes (Fig. 2). The increments were more marked in girls than in boys at the third and fourth visits for weight, and between the first and second visits, and the third and fourth visits for height. The increases in weight and height were greatest between the third and fourth visits (representing the period between 12 and 12.5 years) for both sexes.

The mean value for hemoglobin was 11.9 g/100 ml (±1.0) and the haematocrit was 36.5% (±3.0). There were no sex differences, 24 children of 40 (60%) had a hemoglobin value below 12 g/100 ml, which is the lower limit of the normal concentration for this age group (WHO, 1968). The mean corpuscular hemoglobin of 30.7% denoted an hypochromic type of anemia.

The values of spirometry and motor performances are presented in Table 3. The values improved regularly from one year to the other. There was no significant difference in spirometric test results between girls and boys, while the boys were significantly better than girls in the 33 m-dash and ball throwing.

Figure 3a,b,c compares the motor performances of the Senegalese children with those of African American children for Philadelphia (Malina and Roche, 1983). According to age (Fig. 3a,b,c, left side) African American children performed significantly better. Since Senegalese children are small and light compared to age-matched American children, comparisons were also made after adjusting for the weight (Fig. 3a,b,c,

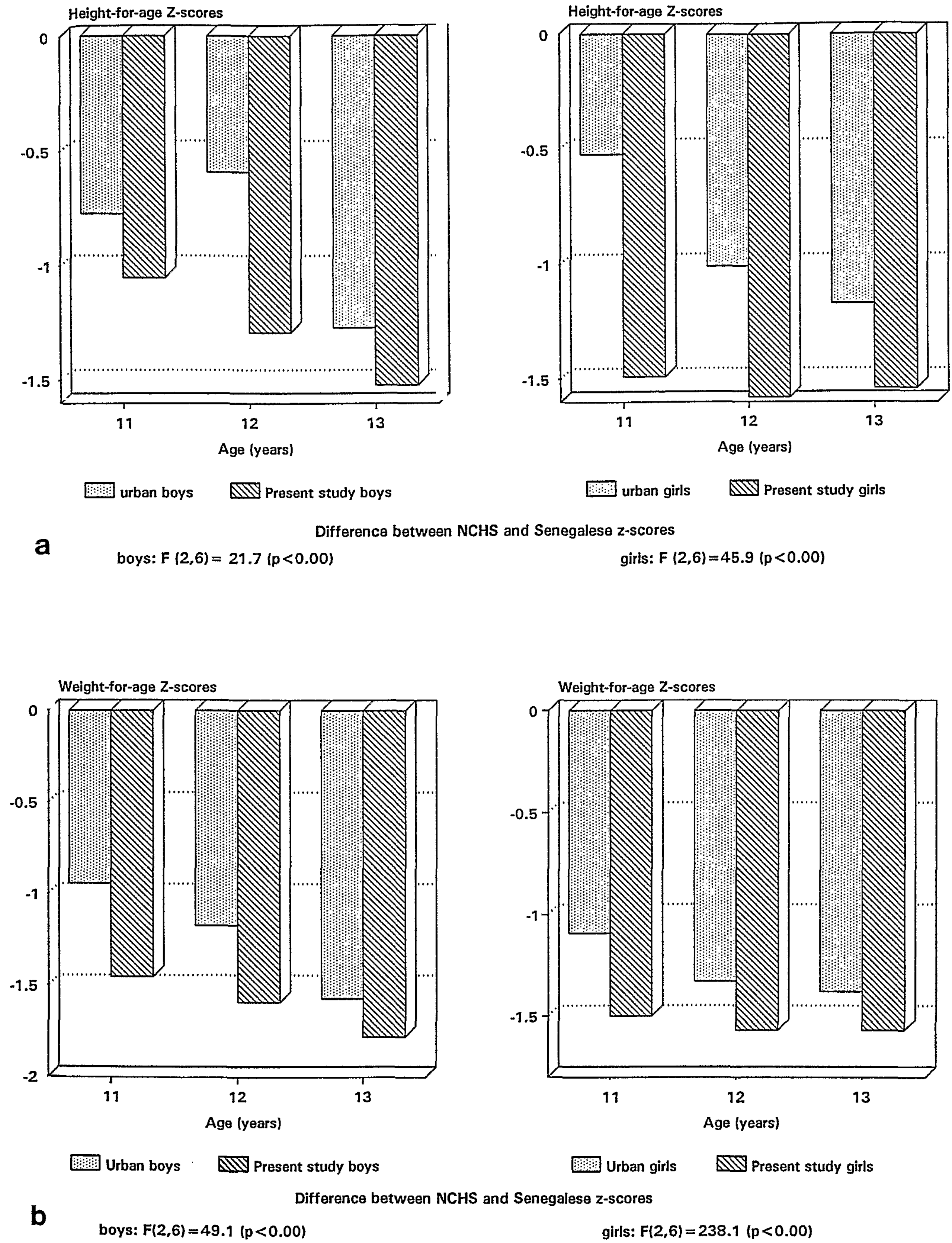

Fig. 1. (a) Height-for-age z-scores; and (b) weight-for-age z-scores of Senegalese children.

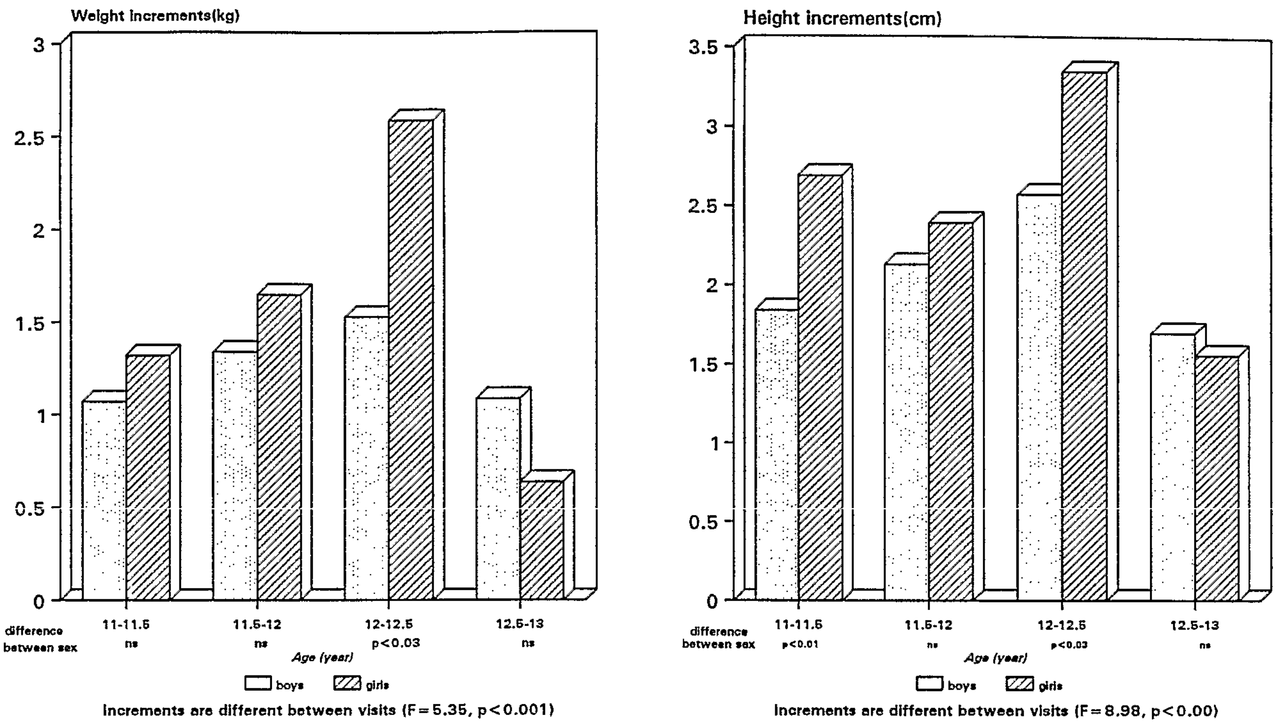

Fig. 2. Weight and height increments between visits.

TABLE 3. Means and standard deviations (in parentheses) for spirometry and motor performance of Senegalese children by age and sex[1]

Age (year)	FEV1 (l)	FVC (l)	33 m dash (sec)	Jumping (m)	Throwing (m)
Boys (n = 20)					
11	1.54	1.67	6.75	1.46	17.02
	(0.24)	(0.29)	(0.45)	(0.16)	(2.89)
12	1.62	1.76	6.71	1.58	18.02
	(0.28)	(0.32)	(0.54)	(0.17)	(2.50)
13	1.75	1.94	6.33	1.61	19.03
	(0.29)	(0.34)	(0.36)	(0.13)	(2.63)
Girls (n = 20)					
11	1.45	1.58	7.43	1.37	12.22
	(0.23)	(0.25)	(0.65)	(0.19)	(3.00)
12	1.57	1.67	7.38	1.51	12.96
	(0.30)	(0.35)	(0.62)	(0.19)	(2.12)
13	1.66	1.79	7.11	1.52	13.82
	(0.29)	(0.28)	(0.34)	(0.16)	(2.32)
Analysis of variance for repeated measured					
Difference between sex (F 1,38)	0.8[2]	1.5[2]	32.9*	3.0[2]	45.8*
Difference between examinations (F 2,76)	21.6*	19.52*	10.1*	22.1*	17.7*

[1]FEV1 = 1-second forced expiratory volume; FVC = forced vital capacity.
[2]Not significant.
*$P < 0.001$.

right side). In this case, Senegalese children were still significantly slower at running, but superior at the long jump compared to African American children, and there were no longer any differences in throwing. The same findings could be established after adjusting performances for the height.

Figure 4 shows the cardiac response to exercise at the time of the first visit. The heartbeat at rest, at 3 stages of exercise, and

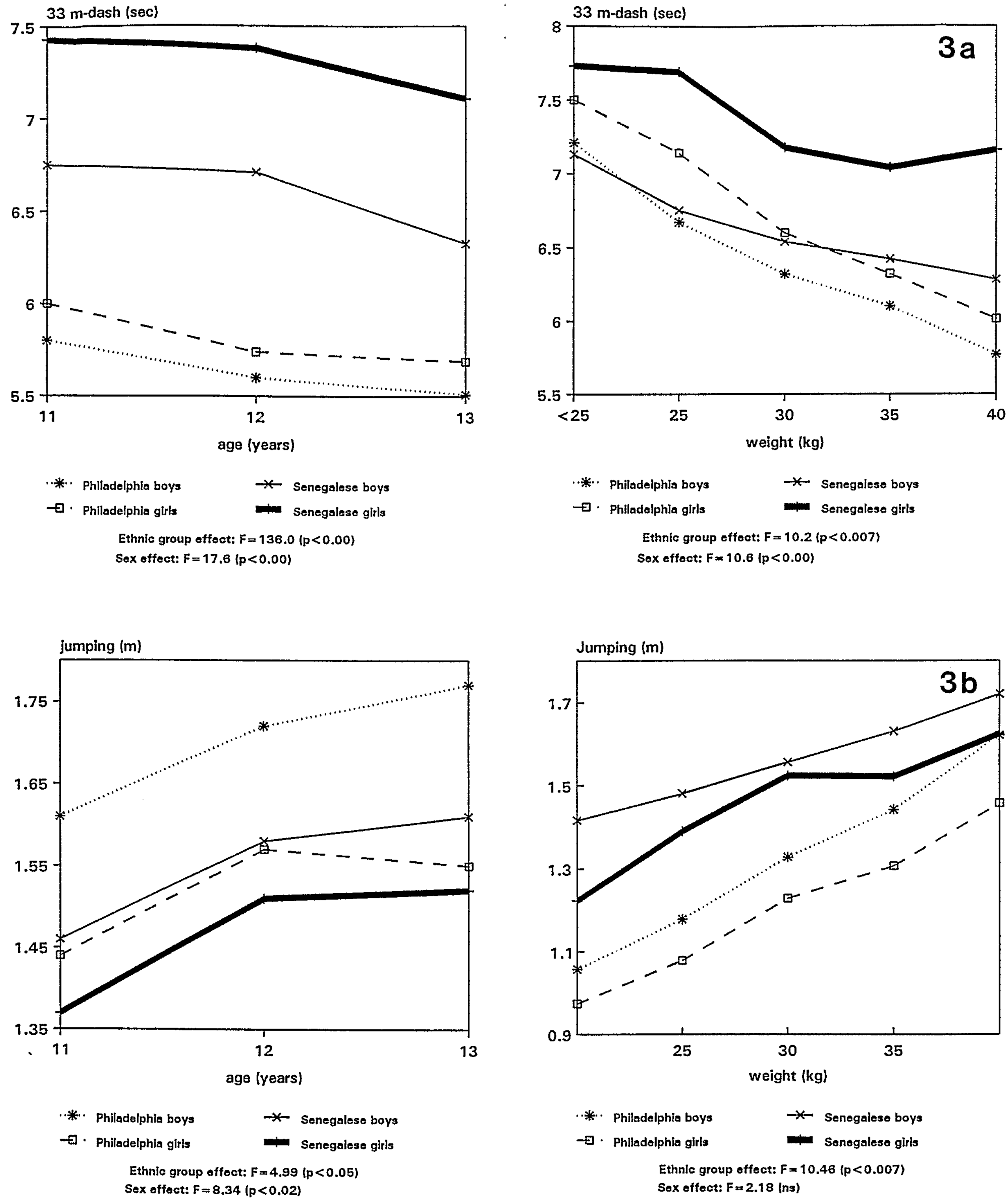

Fig. 3. See legend on following page.

at recuperation for boys was consistently lower than that of the girls. The 5 stages of the stress test were as follows: 3 minutes rest, step 1 of working on the 17 cm ladder, step 2 of working on the 23 cm ladder, step 3 of working on the 30 cm ladder, and finally recovery.

The changes in values of heart rate during exercise and recovery are presented in Table 4. Recovery 1 is the difference in rate of

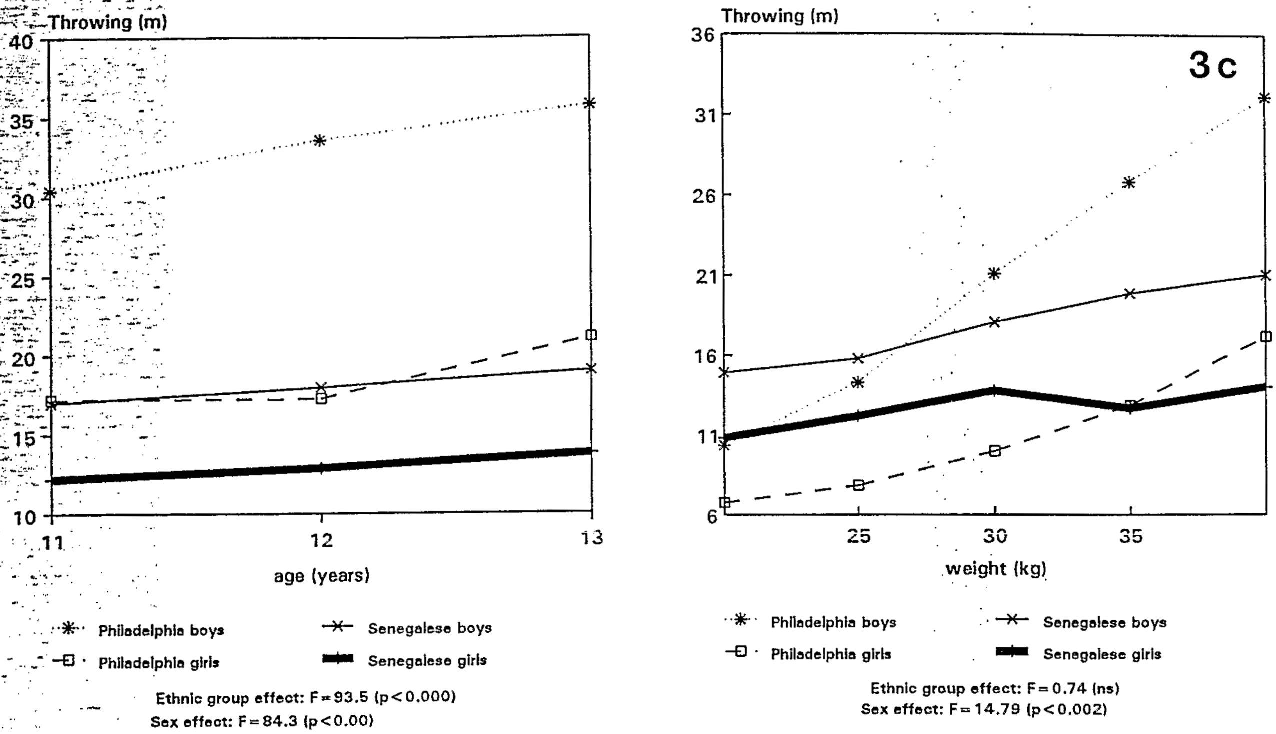

Fig. 3. Comparison of motor performance of Senegalese children with North American children, relative to age and weight. a: Running performance; b: jumping performance; c: throwing performance.

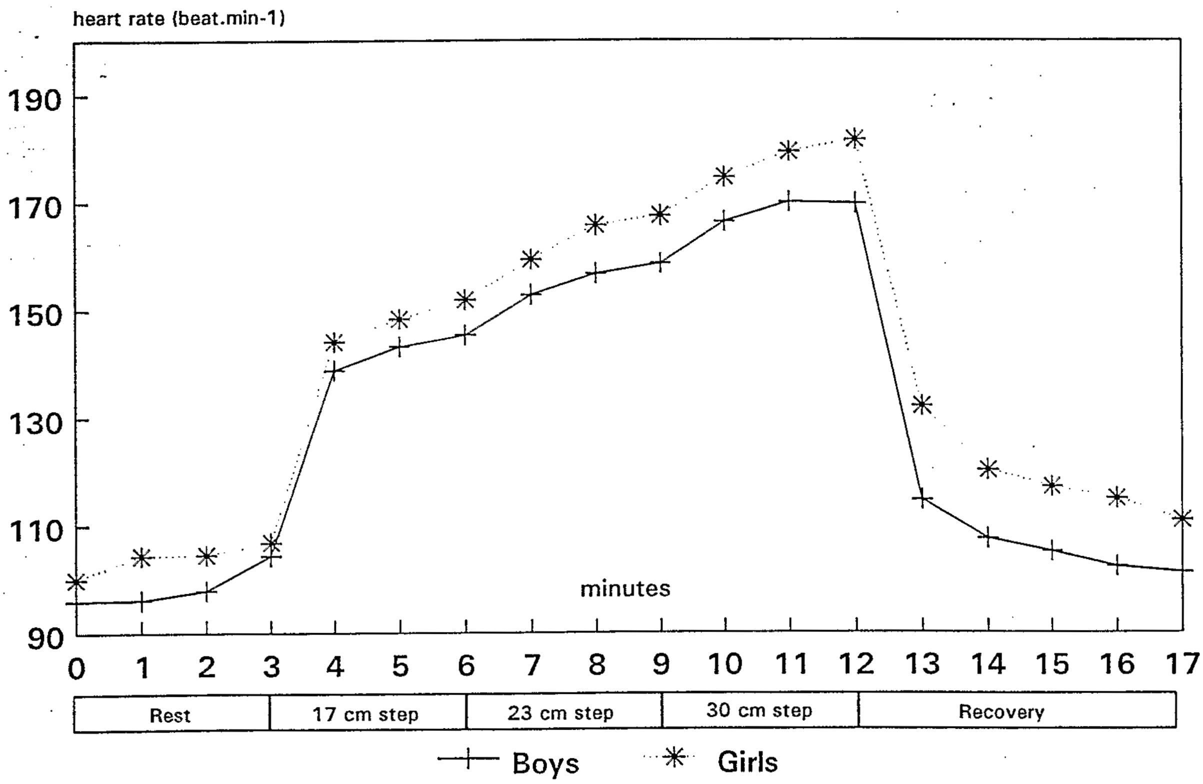

Fig. 4. Cardiac response to exercise in Senegalese children.

heartbeat between the last minute of exercise and the first minute of recuperation and recovery 2 is the difference in the heart rate between the mean of the last 4 minutes of recovery and the mean heart rate during rest. The average heart rate was much lower

TABLE 4. Means and standard deviations (in parentheses) for heart rate at rest, during exercise, and during recovery in Senegalese children by age and sex[1]

Age (year)	Rest	Step test 17 cm	23 cm	30 cm	Recov1	Recov2
Boys (n = 20)						
11	99.5	142.5	156.0	168.7	55.1	4.4
	(10.5)	(11.7)	(10.7)	(9.1)	(13.8)	(7.1)
12	94.1	132.5	148.1	164.9	60.4	1.3
	(10.8)	(11.5)	(12.9)	(12.0)	(14.0)	(10.7)
13	100.1	143.7	158.3	173.5	56.1	5.5
	(13.0)	(11.3)	(12.6)	(13.3)	(11.1)	(6.3)
Girls (n = 20)						
11	105.2	148.1	164.2	178.5	49.5	10.5
	(16.3)	(12.3)	(13.8)	(13.7)	(10.7)	(9.9)
12	103.7	139.9	155.3	170.9	50.8	4.2
	(10.4)	(9.8)	(11.0)	(11.4)	(13.8)	(8.2)
13	100.8	144.9	159.4	173.6	55.6	6.9
	(11.9)	(12.6)	(13.7)	(14.2)	(12.8)	(6.8)
Analysis of variance for repeated measures						
Difference between sex (F 1, 38)						
	5.5*	5.0*	5.7**	5.5**	5.0*	5.2*
Difference between examinations (F 2, 76)						
	0.8[2]	7.4***	5.2***	2.8[2]	0.9[2]	3.4*

[1]Recov1 = heart rate (last minute of exercise) − heart rate (first minute of recovery); recov2 = mean heart rate (4 last minutes of recovery) − mean heart rate at rest.
[2]Not significant.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

in boys than in girls during exercise, as well as in 2 recuperation periods. There was a great reduction of heart rate in the first minute of rest after exercise, but a slight reduction occurred in the following 4 minutes of recuperation compared to the first minute of recuperation. The average heart rates on the 17 cm and 23 cm ladders and during recuperation were lower in the second visit compared to the first visit. This point will be discussed later.

No differences were observed in the motor performances and results of the step-test between anaemic (Hb < 12g/100 ml) and nonanemic children. There were no correlations between physical fitness and hematologic variables.

The total activity expressed in multiples of BMR (Mets) varied according to the time of day and sex, but there was no clear trend between different visits. The energy expenditure in the morning was higher than in the afternoon among girls (2.37 ± 0.28 Mets vs. 2.20 ± 0.23 Mets, t = 5.2, $P < 0.0001$), but there was no difference among boys. Compared to the boys, girls expended more total energy per day (2.28 ± 0.21 Mets vs. 2.1 ± 0.19 Mets, t = 5.7, $P < 0.00$). The major difference between the sexes was due to domestic tasks for girls who spent 30 minutes a day pounding millet and peanuts (estimated to use 5.6 Mets/min).

Table 5 presents the percentage of time spent in 9 categories of activity observed throughout the study. Figure 5 presents the time spent on 4 categories of activity, including pounding as an independent category: rest (1–1.5 Mets), light activity (2.3–3.3 Mets), pounding (5.6 Mets), and moderate to heavy activities (4.8–7.0 Mets). Girls spent less time on activities equal to or more than 4.8 Mets, except for the pounding activity. Also, time of day made a difference; girls spent more time pounding in the morning than in the afternoon (18.2 vs. 12.4 minutes, $P < 0.04$, Mann-Whitney test). Girls rested and performed more light activities in the afternoon. On the contrary, boys were more engaged in those activities requiring 4.8 Mets in the afternoon rather than in the morning (21.2 vs. 17.9 minutes, $P < 0.03$, Mann-Whitney test). It should be emphasized that most of the children had religious and Arabic classes during the morning. The children participated in the agricultural activities of the family. In this region, heavy

TABLE 5. Percentage of time spent daily in different categories of physical activity on Senegalese children[1]

Activity score	Multiples of BMR	Boys	Girls	*P* value of Mann-Whitney test
1	1.0	9.5 (0–53.8)	6.8 (0–48.8)	0.000
2	1.5	41.9 (4.7–91.9)	34.0 (6.1–72.7)	0.000
3	2.3	22.6 (1.6–66.9)	28.3 (5.8–71.9)	0.000
4	2.8	16.8 (1.3–68.6)	17.3 (2.2–45.0)	0.04
5	3.3	2.8 (0.0–32.2)	7.1 (0.0–63.8)	0.000
6	4.8	4.7 (0.0–34.7)	1.6 (0.0–26.9)	0.000
7	5.6	0.3 (0.0–17.5)	4.2 (0.0–33.3)	0.000
8	6.0	0.4 (0.0–11.6)	0.1 (0.0–3.0)	0.000
9	7.0	0.3 (0.0–4.1)	0.07 (0.0–2.5)	0.000

[1]Total observations: n = 600 periods of 6 hours. Numbers in parentheses indicate maximum-minimum percentage of time.

agricultural activity is seasonal and the work load depends on the men in charge and facilities such as animal traction (labor, transport). The activities in which the children participated were light, such as weaving fences, watching fields and animals, and field cleaning and burning.

Physical activities were expressed by 2 different indices: the total energy expenditure (sum of energy in the different activities in each 6-hour observation period) and the time spent in activities requiring more or equal to 4.8 Mets per minute (+4.8 Mets). Table 6 shows the correlation between the 2 variables and anthropometric parameters, motor performance, and physical fitness. In boys, there was a negative correlation between activity +4.8 Mets and heart rate in step testing, but no correlation between +4.8 Mets and the level of motor performances. Total energy expenditure was not related to anthropometric or motor parameters in boys. In girls, +4.8 Mets and total energy expenditure were negatively correlated with running performance, and were positively correlated with long jumping and recovery rates. The total energy expenditure was positively correlated with weight and arm muscle circumference in girls.

DISCUSSION

The children in the present study showed a stunted growth in weight and height compared to NCHS reference data. The children also differed from the NCHS reference in estimated body composition; the triceps skinfold was about one-half of the reference value, and arm circumference (AC) and estimated arm muscle circumference (AMC) were 15 to 20% lower than age-matched American children (Frisancho, 1981). The increments of weight and height were less than those observed in the Fels longitudinal study (Baumgartner et al., 1986), falling between the 10th and 25th percentiles for weight and between the 5th to 10th percentiles for height in boys, and between the 25th to 50th percentiles for both weight and height in girls. During the study period, the children did not show a growth spurt in height, even though the gain in height was rapid between 12 and 12.5 years compared to other ages. Although sexual development has not been systematically assessed, a general model of growth in African children with a late onset of puberty coupled with a prolonged growth period has been reported (Cameron, 1991). The delay or staggering of pubertal growth would explain the absence of sexual dimorphism in the anthropometric dimensions (with the exception of those concerned with fatness). However, serious differences may exist according to the environment, types or levels of activity, or ethnic origin of the subjects. It seems that slow growth is less pronounced in urban environments. In urban areas of the Transkei, growth spurts were observed at about 11 years in girls and 12 years in boys, with an associated peak growth in height from 7.5 cm to 7.9 cm per year (Shamssain, 1991). This represents a superior growth rate compared to the subjects in the present study. Similarly, in Botswana, children in rural environments were lighter than those in urban areas (Corlett and Woollard, 1988). In Senegal, differences in growth patterns were found between the children of the present study and schoolchildren in Dakar who are from the same ethnic origin, *Wolof.* The Senegalese children as a group show slow growth compared to NCHS reference data; however, the children in the present study showed especially slow growth. Urban children live in a more favorable environment, with greater access to health services and education.

The stunting of growth observed in the present study was accompanied by parallel

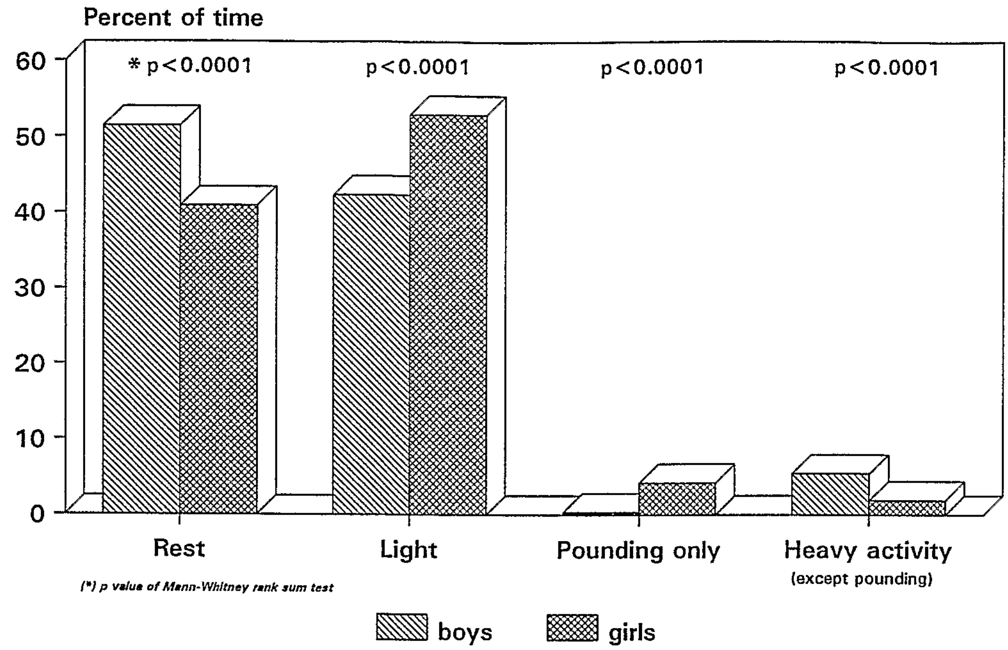

Fig. 5. Percent of time spent in 4 groups of activities by Senegalese children.

TABLE 6. Correlations between indices of physical activity and daily energy expenditure with indicators of anthropometry and physical fitness[1]

	Boys		Girls	
Variables	+4.8 Mets	TEE	+4.8 Mets	TEE
Weight	−0.19	−0.02	0.15	0.26**
Height	−0.17	0.09	0.13	0.22
AMC	−0.10	0.06	0.17	0.23*
33 m dash	−0.01	−0.16	−0.39**	−0.35**
Jumping	−0.04	0.18	0.30**	0.23*
Throwing	−0.12	0.03	−0.00	0.13
Step test 1	−0.25*	−0.00	−0.03	−0.03
Step test 2	−0.33**	−0.13	0.03	−0.04
Step test 3	−0.28**	−0.16	0.15	0.08
Recov1	0.02	0.02	0.30**	0.45**
Recov2	−0.24*	−0.05	0.17	0.16

[1]+4.8 Mets = activity over 4.8 Mets; TEE = total energy expenditure during a 6 hour period; Recov1 = heart rate (last minute of exercise) − heart rate (first minute of recovery); Recov2 = mean heart rate (4 last minutes of recovery) − mean heart rate at rest.
$*P < 0.05$.
$**P < 0.01$.

stunting of motor and functional capacities. In absolute values, the motor performances observed in this study were inferior to those of African American children from Philadelphia of the same age (Malina and Roche, 1983). The difference was most marked in the boys' throwing exercises, where subjects achieved only 53 to 56% (65 to 70% for girls) of the levels of the American counterparts. Running (80 to 87% of the American level) as well as long jumping (91 to 98%) performances were relatively better. However, when the results were expressed on the basis of equal weight, the Senegalese children achieved better performance in the long jump, and there was no longer a difference in throwing. There was, however, no improvement in running results. It appears that the children in the present study who do not participate in any physical education events, do not have the technique to start the race efficiently compared to American counterparts. In the same manner, Ghesquière and Eeckels (1984) found that school children in Kinshasa from unfavorable backgrounds had deficits in weight and height, and had less success in diverse motor performances compared to European children or African children from favorable environments. However, after adjusting for weight, the children from unfavorable backgrounds achieved the same or even better performances as their counterparts from more favorable environments. Similar findings are reported in children from the Ituri forest in Zaire (Ghesquière et al., 1989).

The functional retardation in absolute values exists in other domains such as vital capacity. While American children had a forced vital capacity of 2.41 in boys and 2.21 in girls, the observed values in the present study did not reach even 70% of the reference values (Malina and Roche, 1983).

Contrary to the results of anthropometry, the motor tests and step test provide evidence of sexual dimorphism which favors boys. The heart rates of the boys were much lower than the girls and their recovery was faster; since there was no difference in weight between the sexes, this involves a better cardiac efficiency in boys. Also, the greater speed of recovery after the test, especially in boys, shows good efficiency of cardiorespiratory function. This observation conforms the results of other studies concerning preadolescents (Freedson et al., 1981). A calculation of mechanical work performed from the weight of the child, the height of the ladder and the rhythm of going up and down could be done (Bar-Or, 1987). In this condition, the power delivered at a frequency of 170 beats/min varied between 55–61 W (boys) and 47–60 W (girls). These are much lower values than the 79–87 W observed in healthy African American children (Strong et al., 1978).

The lower exercise and recovery heart rates during the second visit are difficult to explain since children were tested at the same time of the year, by the same examiners, and with the same protocol. However, it perhaps shows a deterioration in aerobic performance of the last visit compared with the two previous visits. Normally during growth, there is a steady improvement in aerobic power which would be represented here by a lowering of HR during exercise and recovery. This was observed between the first and second visits but not afterward. Interestingly, such a deterioration in working capacity should be brought near the already reported deterioration in weight- and height-for-age indices. Other nutritional deficiencies may also be contributory. In Gambia, Powers et al. (1985) reported that subclinical deficiencies were common during the rainy season along with a deterioration in an exercise test performed on a treadmill. This deterioration could be prevented by an administration of hydrosoluble vitamins, vitamin C and riboflavin, and iron. The low mean values of hemoglobin and hematocrit, which are apparently due to iron deficiency, must be taken into account in the low aerobic performance of the Senegalese children as it is known that anemia has a negative impact on working capacity (Viteri and Torún, 1974).

Physical activity can be described in terms of intensity, duration, and the nature of the task, and in terms of behavior (Saris, 1986). The method used in this study takes into account the physiological aspect of activity by expressing the results in units of basal metabolism. This method conforms to the FAO/WHO/UNU (1985) recommendations and gives a concrete expression of results.

The present method enabled the evaluation of energy expenditure in children for 12 hours a day which resulted in mean values of 2.10 Mets for boys and 2.28 Mets for girls. The hours for sleeping are assumed to average 8 hours, and an additional 4 hours in the evening were mainly spent on light activities (1.4–1.6 Mets); thus, the 24 hour energy expenditure was considered to be 1.66 ± 0.09 Mets in boys and 1.76 ± 0.1 Mets in girls ($P < 0.001$). These values are slightly lower for boys and higher for girls compared to FAO/WHO/UNU (1985) values (1.73 Mets for boys and 1.63 Mets for girls). Sex differences in daily energy expenditure are likely due to the participation of girls in domestic chores. The heavier tasks are performed in the morning and this can explain the differences noted in activity levels between the morning and afternoon in girls.

The children spent an average of 42.3 ± 26.4 minutes during the 12 hours of daily observation (5.8% of the time) in moderate to heavy activities. If the girls were not to undertake domestic tasks, then they would spend only 13 minutes in moderate to heavy activities. In another study of physical activities of 10- to 12-year-old children in the north of Senegal, using the continuous study of heart rate, the children spent 6–15% of their time on activities resulting in heart rates higher than 125 beats/minute and 2–5% on activities generating rates beyond 140 beats/minute (Bénéfice, 1992). In yet another Senegalese study, the children spent 2.4–2.8% of their time on activities resulting in heart rates more than 140 beat/minute, while participating for the same time period in agricultural activities (Diaham et al., 1992).

Using the formula suggested by the FAO/WHO/UNU (1985) joint committee for the calculation of BMR, total energy expenditure in boys and girls was 1,978 ± 197.1 Kcal/day with no difference between the sexes. These results are similar to the value by Spurr et al., 1986 for malnourished Colombian children of the same age; by using a heart rate monitoring method, children's energy expenditure was estimated at 1,918 Kcal/day. It may be noticed that the Colombian children were shorter but had a slightly higher weight than the present subjects. When 10% is added to give a safety margin to cover the children's needs, 2,180 Kcal/day becomes the recommended energy intake. This value is 5–15% lower than the 2,300–2,500 Kcal recommended in America and Europe (Spady, 1980) to cover daily expenditure of children aged 10 to 12 years.

The time spent on heavier activities will have an effect on aerobic training for cardiopulmonary fitness in boys; in girls it was the total energy consumption which is related to recovery. The relationship between elevated activity and motor performances in girls was contradictory: positive for the long jump and negative for the run. In fact, the most active girls were the ones who worked more for their mothers and spent less time playing. They were heavier and were probably lacking in agility or technique, or perhaps practice, which would permit them to have a good start and faster run. On the other hand, they probably had the advantage of additional strength for jumping.

In general, the relation between activity and cardiovascular fitness in children is weak (Baranowski et al., 1992; Mirwald et al., 1981), even though a positive association was seen between the level of activity and physiological aptitude before puberty in European studies: It is interesting to note that these studies were based on children who maintain a high level of habitual activity, for example, by going to school by bicycle (Verschuur and Kemper, 1985; Rutenfranz et al., 1974; Sunnegardh et al., 1987).

The children in the present study show a slow growth rate, and this factor was largely responsible for mediocre motor performances and cardiopulmonary fitness compared to children in industrialized countries. The subjects, however, maintained activity levels absolutely compatible with the demands of their environment. However, using a positive connotation of adaptation to low supplies of energy in this context would be misleading because it is in fact the consequence of a nutritional stress continued throughout childhood. Waterlow (1985) has discussed this question in depth. The same children placed in favorable conditions in terms of better nutrition would have physical and motor functions at least equal to that of children in industrialized countries.

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