Physical Fitness and Body Composition in Relation to Physical Activity in Prepubescent Senegalese Children

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ABSTRACT
Relationships among estimated body composition, habitual physical activity, and physical fitness were considered in Senegalese children 8.5–13.5 years of age. Anthropometric dimensions (arm and calf circumferences, trunk, and extremity skinfolds, body mass index), four motor performances (dash, standing long jump, throw, grip strength), a step-test (cardiorespiratory fitness), and heart rate (HR) monitoring (physical activity) were collected in 140 children (66 boys and 74 girls). Age and sex had a major effect on indicators of body composition and physical fitness. Height stunting used as an indicator of chronic undernutrition had a remarkable effect on body composition but only a limited influence on physical fitness. Physical activity, represented by percentage of time above the flex-HR (%fHR), did not vary with sex, age, and nutritional status. However, there was a low-to-moderate correlation between %fHR and several body composition indices, grip strength, and cardiorespiratory fitness. Comparisons of children in the upper and lower quartiles of %fHR indicated that better indices of body composition in boys, and better strength and cardiorespiratory fitness in girls were positively associated with a higher level of physical activity. Am. J. Hum. Biol. 10:385–396, 1998. © 1998 Wiley-Liss, Inc.

Body size and proportions of growing children are factors affecting physical performance (Malina, 1994). In developed countries, there is a special concern about fatness because of its negative influence on fitness (Parizkova, 1996). In the U.S., subcutaneous fat has increased over time (Bar Or and Malina, 1995). Physical inactivity is often considered a significant factor in overweight; however, inactivity is a relative concept and the level of activity needed by children to achieve and maintain fitness is not exactly known (Bar Or and Malina, 1995). Paradoxically, obese children expend more energy in physical activity per task than normal weight children, though not differing in the daily volume of physical activity (Gazzaniga and Burns, 1993). Results of studies on physical activity and adiposity are equivocal. However, it seems that obese adolescents are less active than their peers although their total energy expenditure is equal or even greater (Bar-Or and Baranowski, 1994). Further, the negative effect of adiposity on fitness is more apparent at the extremes ranges of fatness; a moderate increase of subcutaneous fat may have only a marginal effect on physical performance (Beunen et al., 1993; Malina et al., 1995).

The preceding are based on observations of children in developed countries. The majority of the world’s children, however, live under marginal nutritional and economic circumstances. Chronic undernutrition leads to stunted growth and reduced body size. Further, a high level of habitual physical activity may be needed for subsistence in many parts of the world. Competition between the physiological requirements of the
children during growth and maturation, and the social pressures for domestic or economic tasks may be assumed.

Studies of undernutrition and motor performance of children in developed countries have been done in Mexico (Malina and Buschang, 1985; Malina and Little, 1985; Malina et al., 1991), Brazil (Rocha da Ferreira et al., 1991; Matsudo, 1993; Anjos and Boileau, 1992), Zaïre (Chesiquière et al., 1984), and Senegal (Benefice, 1993). These studies generally show absolute lower performances compared with well-nourished children, but also stress the role of small body size in the outcomes. The same applies to maximal oxygen consumption, where absolute values are lower in malnourished children, but are quite equal after normalization for body weight or lean body mass (Spurr and Reina, 1989).

Physical activity is also a factor of variation in physical performance, especially for aerobic power. However, the effect of a high level of physical activity, like sport training, is less than in adults (Livingstone, 1994; Morrow and Freedson, 1994). Further, it is difficult to distinguish these effects from those of maturation during puberty (Malina, 1989).

Studies of physical activity of children in developing countries are scarce and the impact of malnutrition is not clear. The difference in physical activity levels between undernourished and normal children, expressed as %VO2 max, in Colombias is not significant (Spurr and Reina, 1990). However, in a previous study, these scientists showed that during a summer camp, activity was positively affected by a meal in undernourished children, but over a shorter period than in normal children (Spurr and Reina, 1988). Using a HR recording method, it was shown that physical activity levels in Bolivian children were more influenced by socioeconomic factors and nutritional status than by environmental factors such as altitude (Kemper et al., 1994; Slooten et al., 1994). In Senegal, physical activity, recorded with a direct observation method, revealed low to moderate correlations with performance and body composition (Benefice, 1993). In moderately undernourished children, the relationship between physical activity and performance is modest.

There are many gaps in the knowledge of the influence of physical activity and nutritional factors on growth and motor development of children from developing countries. The aim of this study is to describe variation in motor fitness of 8.5–13.5 year old Senegalese children in relation to anthropometric indices of muscle and fat mass, and estimated physical activity.

SUBJECTS AND METHODS

Sampling

The study was carried out in 3 villages of the district of Lambaye in the center of Senegal known as the "peanut basin" (14°45 north latitude and 17°30 west longitude). This area has a typical dry and hot Sahelian climate. Inhabitants are Muslim farmers cultivating millet and peanuts during an unique and brief rainy season (June to October). The nutritional situation is mediocre with an estimated per capita energy intake less than FAO/WHO/UNU requirements, and chronic undernutrition is widely prevalent (Chevassus and Ndiaye, 1981).

A sample of 140 children (66 boys and 74 girls) with a mean age of 11.3 years (SD = 1.4), ranging from 8.5–13.5 years of age, was drawn from a health and fitness survey in the area. Children were recruited after a preliminary home-to-home census was done in the villages. They were selected on the basis of 1) absence of clinically detectable abnormalities, especially in the orthopedic, neuromotor, or nutritional spheres; 2) known age after birth roles or determined with an accuracy of about 3 months using a local calendar of Muslim ceremonies and events; and 3) consent given by the parents. As parents were illiterate, after complete information about the aim and methods to be used in the survey, oral consent was given and the presence of a familiar person during the tests was required. The study was authorized by national and regional administrative authorities of Senegal.

Anthropometry

Children were measured according to techniques recommended by the International Biological Program (Weiner and Lourie, 1981). In addition to height and weight, arm circumference (AC, cm), calf circumference (CC, cm), and four skinfold thicknesses (mm) measured with a Holtain caliper on the left side: triceps (TSF), biceps, subscapular, and suprailliac are reported. Measurements were done three times and the average value was recorded. Extremity (triceps + biceps, Ext skf) and trunk (subscapular +...
suprailiac, Trunk skf) skinfolds were used as proxies for fat mass and distribution. CC and estimated arm muscle circumference (AMC) calculated after Gurney and Jelliffe (1975) as AMC = AC - π x TSF, were used as a proxy for limb muscle mass. The body mass index (BMI, weight/stature²) was also calculated.

**Motor fitness**

Motor fitness items included 3 trials of the following tests: 1) softball throw for distance (m); 2) standing long jump (m); and 3) hand grip strength measured by squeezing a rubber bulb connected to a manometer (Martin®, Tuttlingen). Values were pressure expressed in kilos Pascal (kPa). In addition, children had to run a distance of 33 m with time recorded in seconds (sec). They ran bare feet on a levelled sandy track. The children had no previous training. The day before testing, the tests were demonstrated and the children had an opportunity to practice. To estimate the reliability of the measures, test-retest correlations were calculated by measuring a subsample of 40 children after a one day interval. Coefficients were moderate for the dash (0.67), jump (0.73) and grip strength (0.71), and high for the throw (0.93). There was no significant difference between sexes.

**Cardiorespiratory fitness**

Cardiorespiratory fitness was estimated with a step-test with 3 two-step benches with different heights: 17, 23, and 30 cm. This allowed a gradual increase of effort. After 3 minutes rest in a sitting position, the children started going up and down the steps at a rhythm of 30 steps per minute, given by a metronome. They stepped for 3 minutes at each bench height; the total exercise time was thus of 9 minutes. They then rested for 5 minutes. The whole time of the test was 17 minutes (Figure 1). Heart rate frequency (HR, beat-per-minutes, bpm) was recorded every 5 seconds with a Sport Tester® monitor (Polar Electro Qy, Finland). Children were encouraged during the test by an assistant. The difference between HR recorded at the end of the exercise and the 1st minute of recovery was used as an index of cardiorespiratory endurance (1st-min recovery). Children were not familiar with the step-test, but a previous trial using an ergocycle show us that they were more comfortable with the stepping and more capable to produce a regular effort.

**Physical activity**

Physical activity was estimated from HR recording during the day. Initially it was decided that children should wear the Sport
ing occurred between 8-10 a.m. to 4-6 p.m.

Rather, the flex-HR (fHR) method (Spurr et al., 1988) was used. The flex-HR is the critical cut-off value of HR between resting measurements and the lowest HR recorded during exercise. The rationale is that during exercise there is a linear relationship between HR and VO\(_2\), whereas during resting activities the correlation is very low. In the present study, several measurements of HR at rest while lying and sitting, and while standing were done after at least 5 minutes of habituation time in a group of 40 children. Values are indicated in Table 1. It was estimated that fHR should be set between HR sitting and HR standing. For simplicity, fHR was calculated from the step-test as the average of the highest HR during the 3 minutes-rest in sitting position and the lowest HR at the beginning of stepping. Percentage of time over fHR was used as an overall index of activity (%fHR). To further explore the level of activity over fHR, the length of time spent in light-to-moderate, moderate-to-vigorous, and vigorous activity was calculated using the mean HR recorded during the step-test for the 1st (light activity), 2nd (moderate activity), and 3rd (vigorous activity) benches, as thresholds. Cut-off point values are also indicated in Table 1.

Four girls had incomplete data and were not included in this analysis. Forty children attended an elementary school; in these cases, data were collected during holidays. There were no differences in anthropometric indices, performances, or activity patterns between children attending or not attending school, and in consequence this factor was not taken into account in the analysis.

### Statistical analysis

Data were analysed using the BMDP statistical software (BMDP statistical software Inc., Los Angeles CA). Means, partial correlations, 3-way analysis of variance, and covariance analysis were used. A \( p \) value of .05 was accepted as significant.

### RESULTS

Compared with the World Health Organization reference (WHO, 1986), children were short in stature: median height-for-age (H/age) = -1.05 z-score (range -3.5-1.5) and underweighted: median weight-for-age (W/age) = -1.47 z-score (-2.86-1.29). About a quarter of the sample was below 2 standard deviations and less than 10% were above the median in both nutritional indices. These deficits could be attributed to mild-to-moderate malnutrition. Given the age of the subjects, this must be a chronic form of malnutrition and to take into account this effect, a height-for-age (H/age) less than 1 standard deviation (<1 z-score) was chosen as cut-off point. This divides the sample into undernourished (\( n = 74; \) mean H/age = -1.6 ± 0.5 z-score) and better nourished (\( n = 66; \) mean z-score = -0.12 ± 0.7 z-score) children, and allows for a mean difference greater than -1.5 z-score between the 2 groups. Children were also grouped according to the median age of the sample: over and below 11.3 years of age. Comparisons were done by age, sex, and nutritional group.

Girls have on average, greater values of the anthropometric body composition indices than boys (Table 2). There is a significant \( (p < 0.05) \), though small, interaction between age and sex for AC, AMC, and CC. Thus, comparisons were done again in the 2 age groups separately. Girls are still larger than boys. There is no age effect in skinfolds, and girls have larger values than boys. The trunk/extremity ratio is greater for boys. In the >11.3 year group, there is no significant trend for undernourished boys to

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**TABLE 1. HR values in different levels of activity (mean ± SD [range]) of prepubescent Senegalese children**

<table>
<thead>
<tr>
<th>Activity</th>
<th>HR (bpm)</th>
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<tbody>
<tr>
<td>Lying</td>
<td>76.0 ± 9.0 (56-99)</td>
</tr>
<tr>
<td>Sitting</td>
<td>94.6 ± 12.7 (66-129)</td>
</tr>
<tr>
<td>Standing</td>
<td>106.1 ± 14.6 (74-147)</td>
</tr>
<tr>
<td>Light activity</td>
<td>133.3 ± 13.6 (99.6-174.6)</td>
</tr>
<tr>
<td>Moderate activity</td>
<td>162.5 ± 14.9 (107-191)</td>
</tr>
<tr>
<td>Vigorous activity</td>
<td>162.8 ± 15.2 (116.3-194.6)</td>
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gain more trunk than extremity fat, as it is the case for well-nourished boys. In general, the undernourished children have lower indices than normal children, and girls have larger skinfolds than boys. The BMI is not different between the two Wage categories. However, Wage is different between sexes and age groups: girls are less stunted in stature than boys, and younger children are less stunted than older children.

Variations in motor fitness are shown in Table 3. Grip-strength values were log-transformed because the distribution was non-normal. Performances are better in older children (not significant for the cardiorespiratory endurance index), and boys have higher values than girls, except in grip strength and cardiorespiratory endurance. However, detailed analysis of HR during the step test shows that boys achieve significantly lower HR values than girls during exercise and 1st-min recovery (Figure 1). Nutritional group has only a limited effect in the dash and throw, where normal children perform better than undernourished children.

The average value of HR is lower in boys (99.6 ± 8.0 bpm) than in girls (105.0 ± 8.8 bpm), p < 0.001. There is no variation in % fHR by sex, age, and nutritional group: children spend 52.5% ± 29.7% of their daytime over the fHR value. However, the range of variation is wide (0.6–99.4%). Using the cut-off values of HR indicated in Table 1, it is apparent that children spend 48.6 ± 27.4% (0.3–96.4%) of their activity time without achieving 138.3 bpm and time spent in categories of activity over 138.3 bpm is low: light-to-moderate activities (138.2 bpm < HR < 152.5 bpm) = 2.5 ± 3.8% (range: 0–30.6%); time spent in moderate-to-vigorous activities (152.5 bpm < HR < 162.8 bpm) =
TABLE 3. Motor and physical fitness indicators (mean and SE) of Senegalese children

<table>
<thead>
<tr>
<th>Boys</th>
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<th>Girls</th>
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<tr>
<td>Age</td>
<td></td>
<td>Dash (sec)</td>
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</tr>
<tr>
<td>≤11.3</td>
<td>9</td>
<td>7.0 (0.51)</td>
<td>1.39 (0.11)</td>
</tr>
<tr>
<td>&gt;11.3</td>
<td>27</td>
<td>6.6 (0.54)</td>
<td>1.45 (0.17)</td>
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<td></td>
<td></td>
<td>&gt;11.3</td>
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<td></td>
<td></td>
<td>1.46 (0.23)</td>
<td>1.29 (0.27)</td>
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<td></td>
<td></td>
<td>1.46 (0.22)</td>
<td>1.38 (0.21)</td>
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<td>1.29 (0.27)</td>
<td>1.29 (0.16)</td>
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<td>1.39 (0.11)</td>
<td>1.45 (0.17)</td>
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<td>&gt;11.3</td>
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<td>1.46 (0.23)</td>
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<td>1.39 (0.11)</td>
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<td>&gt;11.3</td>
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<td></td>
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<td>15.6 (4.3)</td>
<td>10.0 (3.0)</td>
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<td></td>
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<td>17.2 (3.6)</td>
<td>13.6 (4.5)</td>
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<td>12.2 (2.3)</td>
<td>15.3 (3.0)</td>
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<td></td>
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<td>15.6 (4.3)</td>
<td>10.0 (3.0)</td>
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<td>17.2 (3.6)</td>
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<td>17.2 (3.6)</td>
<td>13.6 (4.5)</td>
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<td>15.3 (3.0)</td>
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<td>&gt;11.3</td>
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<td>4.58 (0.39)</td>
<td>4.46 (0.29)</td>
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<td>4.66 (0.25)</td>
<td>4.73 (0.29)</td>
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<td>4.46 (0.39)</td>
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<td>4.66 (0.25)</td>
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<td>14.6 (2.3)</td>
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<td>&gt;11.3</td>
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<td></td>
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<td>49.6 (20.2)</td>
<td>44.8 (12.3)</td>
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<td>50.8 (15.9)</td>
<td>49.7 (12.4)</td>
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<td>&gt;11.3</td>
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<td>44.8 (12.3)</td>
<td>44.8 (12.3)</td>
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<td>49.7 (12.4)</td>
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<tr>
<th>1 Min Recovery (bpm)</th>
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<tr>
<td>≤11.3</td>
<td>12.1 (7.0)</td>
<td>12.1 (7.0)</td>
</tr>
<tr>
<td>&gt;11.3</td>
<td>12.1 (7.0)</td>
<td>12.1 (7.0)</td>
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Effects: S = sex; A = age; N = nutritional group; ns = not significant.

DISCUSSION

Anthropometric indices of body composition of the Senegalese children varied with age, sex, and nutritional status. Age and sex differences in motor and cardiorespiratory fitness were also observed, but mild-to-moderate undernutrition had only a limited effect in the run and throw.

Girls had higher indices of fat mass than boys. It is known that at the beginning of puberty, maturation is associated with sex differences in muscle, fat mass, and relative fat distribution. Girls gain more subcutaneous fat on the extremities than boys, and the Trunk/Extremity ratio increases more in
Activity and Body Composition

a) Boys

Indices of body composition

Activity and Body Composition

b) Girls

Indices of body composition

Fig. 2. Activity and body composition (mean ± 1 SD): a) Senegalese boys; b) Senegalese girls.
Activity and Physical Performances

a) Boys

Physical performances

Activity and Physical Performances

b) Girls

Physical performances

Fig. 3. Activity and motor fitness (mean ± 1 SD): a) Senegalese boys; b) Senegalese girls.

boys (Malina, 1996). Hormonal regulation of growth differs between boys and girls and accounts for differences in fat mass. More-sensitive to nutritional influence; higher IGF1 in girls allows them to be better prepared for the metabolic demands of preg-
characteristics may give girls an advantage compared with boys during nutritional stress such as chronic undernutrition. This could explain why Senegalese pubescent girls have better %HR than boys; however this could also mean that these Senegalese girls are more advanced in pubertal growth than boys.

Girls had higher indices of muscle mass than boys; this may explain the similarity of grip strength in both sexes. Strength is proportional to the cross-sectional area of a muscle (Astrand and Rodhal, 1977), represented in this study by AMC. However, such relationships may not be observed in immature children, who are sometimes termed “metabolic non-specialists” (Bar Or, 1983). Actually, while having less arm muscle mass boys were better than girls in most motor fitness items, emphasizing that other factors such as skill, training, physical activity, and motivation play an important role.

The higher values of HRs of girls during exercise are consistent with other reports (Strong et al., 1990). They are sometimes attributed to the smaller lean body mass and low level of hemoglobin of girls compared with boys. It is also said that girls have a lower stroke volume and that autonomic cardiac regulation is different (Strong et al., 1990). HRs of girls paralleled those of boys and, as a result, there was no significant difference in the 1st-min recovery index. However, the lower HRs in boys at the end of exercise and during rest, suggested better cardiorespiratory efficiency.

Interindividual variation in maturation at the onset of puberty also needs to be considered because, especially in the case of boys; early matures tend to be stronger and better in motor performance than late matures (Malina, 1989). This could explain the limited effect of nutritional status on motor fitness in this study. The occurrence of puberty in this area of Senegal is delayed in comparison with Europe or North America (Simon et al., 1995). While the survey design did not permit the assessment of pubertal status, some children of both sexes were obviously more advanced than other. Because of the interrelation of growth and maturation events at the beginning of puberty, the use and interpretation of anthropometric indices of nutritional status like %HR or the BMI can thus be misleading.

Physical activity is a factor frequently involved in the explanation of sex differences in motor and aerobic fitness. The length of time spent in vigorous activity appears to be important (Verschuur and Kemper, 1985; Sunnegardh et al., 1987). In the present study, no differences in physical activity between sexes and by age and nutritional status were observed. This may be due to the lack of accuracy and precision of the HR method in evaluating physical activity in this population. It should be emphasized that children of this study were mildly or moderately, but not severely, undernourished and the difference in nutritional status between subjects may be too weak to affect levels of physical activity. Advantages and limitations of the HR method had been extensively reviewed (Saris, 1986; Verschuur and Kemper, 1985; Janz et al., 1992). The method is not considered accurate enough to estimate daily energy expenditure of individuals (Li et al., 1993). However, it is useful in group studies or for epidemiologic purposes (Kalkwarf et al., 1989; Spurr et al., 1988; Livingstone et al., 1992). Further, in West Africa, it is often difficult to investigate physical activity without interfering with subject behavior. HR recording appears to be an acceptable alternative method. The main limitation of the present study was the difficulty of monitoring HR for long periods. In developed countries, long periods of recording are necessary because there are substantial differences in activity levels between school days and holidays, and from one day to another (Falguerre et al., 1996). In rural Senegal, patterns of habitual physical activity are quite monotonous. In another study of physical activity using an observational method, no changes in intensity between days and also between different seasons of the year were observed, while nature of tasks changed dramatically because children were involved in agricultural tasks during the rainy season (Benefice, 1993). A popular way to express physical activity from HR is to determine fixed limits to separate mild, moderate, and vigorous activity, for example 140 and 160 bpm (Amstrong and Bray, 1991); in contrast, individually calibrated indicators have the advantage of taking into account the underlying cardiorespiratory fitness of the child (Panter Brick et al., 1996). However, it must be emphasized that %HR values do not provide direct estimates of physical activity; rather, the reflect individual adaptation to physical activity (Panter Brick et al., 1996).
As a rule, the overall level of activity of the Senegalese children was low. While they spent 50% of their time over the fHR, they had less than 10 min per day in moderate to vigorous activity. This is consistent with other observations from Senegal: in a previous study, children spent only 4% of their time above 140 bpm, with differences between sexes (Bénéfice, 1992); Diakah and colleagues (1992) noticed in a rural district closed to this area that children achieved 140 bpm during only 2.4% of the day for girls and 2.8% for boys. The present study was done at the end of the dry season where only a few agricultural tasks were executed and where heat was torrid. This could favor a sedentary behavior. However, extreme heat is not rare in this area and never prevents people to be normally active. Similar low levels of HR patterns were observed in children from other developing countries (Panter Brick et al., 1996). A low level of activity was also reported in industrialized countries using the HR method; school children experienced relatively short periods of intense activity (Amstrong and Bray, 1991; Gilliam et al., 1981). This may reflect a bias in the method because in children, vigorous activity occurs in short bouts of time, perhaps less than 10 sec, and the habitual recording period of 1 min. may be too long to detect small changes. Further, children have the ability to recover quickly after exercise (Livingstone et al., 1992).

The low relationships between estimated physical activity and motor fitness variables may also be the consequence of a ceiling effect due to the lack of variation in physical activity in this sample. As a rule however, such relationships are weak during childhood, especially in the case of cardiorespiratory fitness (Livingstone, 1994). Interestingly, habitual physical activity seems to be a greater predictor of cardiorespiratory fitness in obese children than in normal children (Taylor and Baranowski, 1991). When Senegalese children were contrasted according to the lower and higher quartiles of fHR, relationships between activity and AC, extremity skinfolds, and the BMI were observed in boys but not in girls. More active boys appeared to have more subcutaneous fat and estimated total fatness. This implies perhaps that active boys were in better nutritional status than inactive boys. Conversely, a low level of activity may be a way for undernourished boys to meet their energy requirements. In the case of undernourished girls, it is likely that their important participation in domestic tasks does not permit a reduction in habitual activity to the same extent (Bénéfice, 1993).

In both sexes grip strength is greater in active children. Cardiorespiratory fitness is influenced by activity in girls, but not in boys. This could mean that boys were fit enough and their level of activity was insufficient to cause a further increase in cardiorespiratory performance. In contrast, lower cardiorespiratory fitness of girls make them more sensitive to the training effect of higher physical activity.

This study suggests that physical activity in Senegalese children, as in children from industrialized countries, is not an important determinant of cardiorespiratory fitness and motor fitness. However, better nutritional status in boys, and motor fitness in both sexes are positively associated with a higher level of activity.

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LITERATURE CITED

Bénéfice E (1993) Physical activity, cardiorespiratory


