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Physical activity patterns of rural Senegalese adolescent girls during the dry and rainy seasons measured by movement registration and direct observation methods

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Objective: To study the physical activity patterns and daily estimates of energy expenditure (EE) of rural adolescent Senegalese girls.
Design: Physical activity was monitored using a portable accelerometer during four consecutive days and within the same time, by direct observation during two consecutive days. Adolescent girls were followed during the dry season (June, $n = 40$) and again during the rainy season (September, $n = 30$)
Setting: The Niakhar district in the central part of Senegal.
Subjects: Forty adolescents (13.3 ± 0.5 y) drawn from a sample of 221 rural girls followed as part of a longitudinal study on growth and nutrition during puberty.
Results: Reliability of movement counts was acceptable (intraclass correlation, $R = 0.71$). There was a linear relationship between movement counts and observed scores. Predicted physical activity levels were high: 1.90 ± 0.12 Mets (EE: 9.03 ± 0.77 MJ). Physical activity levels derived from movement counts during the day are higher in the rainy season than during the dry season. This coincided with a depression in nutritional indicators during the rainy season apparent in the overall sample. Sleep duration appeared to be short in both seasons (6–6.5 h per night). Senegalese adolescents participated in daily household tasks but time spent in productive activities, agricultural or handicraft, was less than 1 h per day.
Conclusions: Estimates of activity-related EE of Senegalese adolescents were greater than those of adolescents from developed countries but closed to recent estimates for rural areas in developing countries. Energy requirements drawn from developed countries do not necessarily apply to African adolescent girls.
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Descriptors: physical activity levels; energy expenditure; accelerometer; factorial method; puberty, seasonality; Senegal

Introduction

The contribution of physical activity to daily energy expenditure (EE) is important in everyday life and could reach 20% of total EE (Dauncey, 1989). In children, the estimate is higher, respectively 31% for boys and 25% for girls (Spady, 1980). Physical activity is important because of its great variability and potential health consequences. In industrialized countries, the link between low levels of physical activity and the risk of obesity, metabolic and cardiovascular diseases, cancer and overall mortality is a primary concern (DiPietro, 1995). These potential health negative consequences are also a matter of concern in children and adolescents (Goran & Sun, 1998), though the relationships are less evident than in adults (Malina, 1995; Bar-Or & Baranowski, 1994).

In less developed countries concerns about physical activity are quite different. A high prevalence of under-nutrition is common, and hard physical labor is often required for daily subsistence in non-mechanized societies. Therefore, there exists a risk of energy imbalance, and nutritional status could be a limiting factor in household productivity (Spurr, 1988). Children are regularly involved in domestic or productive tasks in many developing countries, and their efforts contribute to the maintenance of the household (Munroe *et al*, 1984). Young women and girls are especially involved in relatively heavy work loads (Walker, 1997). Knowledge about children and adolescents physical activity in industrialized countries is increasing (Pate *et al*, 1994; Caspersen *et al*, 1998). More recently, it was demonstrated that geographical location, cultural condition or season may influence EE and should be taken into consideration (Goran *et al*, 1995, 1998). However, in developing countries information remains insufficient. Though, there exist a few studies from Nigeria indicating a low level of physical activity among university students (Cole & Ogungbe, 1987; Cole & Ogbe, 1987), data for pubescent girls are lacking. As a consequence, current recommendations for energy intake are uncertain. There is a need for more specific studies on free-living populations in different ecological settings (Torún *et al*, 1996).

For epidemiological purposes there is a need for accurate, objective, non-invasive and cheap methods to measure physical activity. Questionnaires are reliable in adults (Baecke *et al*, 1982). However, in children, especially in developing countries, reliance on interviews or self-report

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questionnaires is doubtful. Several objective methods have been proposed, including observation methods (Montoye & Taylor, 1984), heart-rate monitoring which has been recently validated in children (Bitar *et al*, 1996) and electronic devices such as accelerometers (Meijer *et al*, 1991).

Accelerometry has different rationale than other usual methods such as HR recording. It measures accelerations of the body due to movement and thus relies on mechanical laws of Newton. In contrast, direct or indirect calorimetric methods rely in thermodynamic laws (Meijer *et al*, 1991). An important limitation of accelerometry is that it does not measure static work, like load bearing. Fortunately, most daily activities have dynamic properties and there is a direct relationship between body acceleration and energy expenditure (Meijer *et al*, 1989).

Accelerometry has been used to measure habitual physical activity in children and is valid, objective and reliable (Janz, 1993). Because of limitations of measuring physical activity and energy expenditure in African children, electronic accelerometers could be a valuable option. Hence, the aim of this study is to report an estimation of habitual physical activity and EE in a group of 40 adolescent Senegalese girls during two seasons of the year. The data are based on accelerometry counts and direct minute-by-minute observations of physical activity.

Sampling and methods

The study was carried out in the Niakhar district of Senegal, 150 km east of the capital city Dakar. It is a rural area where millet and peanut are the main products. It has a Sahelian type of climate with a long dry season (November to June) and a unique short rainy season (July to October). The population of 29 104 inhabitants belongs to the Sereer ethnic group. Infant mortality rate is decreasing but remains rather high (77 per 1000) as well as the mortality rate under 5 y (182 per 1000), denoting unfavorable health and nutrition conditions (Delaunay, 1998).

Sampling

The adolescents are a subsample of a larger sample of 406 girls born in 1983 and 1984, who were measured during the first few years of life and again in 1995 (Simondon *et al*, 1998). Since then, they have been followed as part of a longitudinal study of growth and maturation during puberty. Of the 406 girls, 342 were relocated in 1997 and measured at three periods of the year: April (dry season), August-September (rainy season) and December (post-harvest season). Most of those not located had moved out of area with their family or had temporarily migrated to Dakar, and it was impossible to locate them. The sample of 342 included 221 girls who remained all the year round in the Niakhar area and 121 who stayed in Dakar during the dry season. The 40 girls were drawn from the 221 rural girls. The sample was similar in age, maturational status (breast development) and anthropometric characteristics relative to the whole sample (see Table 2).

Parents were illiterate; complete information was given to them and to the girls about the aims and methods of the study and oral consent was obtained. Until now no ethical committee exists in Senegal, and the study was authorized by the national and local administration as a part of a general agreement concerning health studies in the Niakhar area.

Procedures

The physical activities studies were undertaken in June (end of dry season) and September (rainy season) 1997. The same girls were seen at each round. However, because there was a rain shortage, parents of 10 girls decided to send them to the city until mid October. These 10 girls were seen again when they came back, but were removed from the data set because their work loads and activities differed markedly from the previous months. Hence, this analysis concerns 40 girls in June and 30 in September.

Anthropometric measurements were made every four months. Of 221 rural girls present in April, 11 were missing in August and 13 in December. Adolescents were weighed barefoot and lightly dressed with an electronic scale accurate ±100 mg. Stature was measured with an Harpenden^R portable anthropometer; mid-arm circumference was measured on the left arm with a nonstretchable tape, and the triceps skinfold was measured at the same level with a Holtain^R caliper. The body mass index (BMI, kg/m^2) was calculated. Sexual maturity was assessed as breast development (Tanner, 1962). Girls, or their mother when they were unable to answer, were asked on the occurrence of their first menstruation. Measures were taken by the same team at each round.

Physical activity was recorded in two ways. Firstly, with a minute-by-minute direct observation method during 12 h for two consecutive days; and second, wearing a CSA^R accelerometer for four consecutive days. The two days of observation occurred within the four days of monitoring.

Eight young women observers were recruited and specifically trained to observe the girls. They lived in the Niakhar district and were well accepted by the girls and their families. Each observation day was divided in two six hour intervals (7 a.m. to 1 p.m.; 1 p.m. to 7 p.m.). Survey teams changed every six hours. A supervisor regularly monitored the observers and assisted them when necessary. A training period was organized before each survey where different observers coded the same children. Inter-observer agreement in excess of 90% was obtained. In all, 1680 h of observations were recorded. Surveyors rated physical activity levels (PAL) every minute. They watched the girls at a distance so as not to interfere with their usual behavior for approximately 50 s and during the remaining time reported the dominant activity on a special sheet. Activity was recorded according to levels of intensity using a 10 point simplified scale ranging from lying down to maximum effort. This scale was based on Bouchard *et al* (1983). Energetic equivalents expressed as multiples of basal metabolic rate (Mets) were compiled from published specific activities by Bleiberg *et al* (1980), Torun *et al* (1989), FAO/WHO/UNU (1985) (Table 1).

The nature and location of activities was also recorded within 15 min intervals. Activities were classified into six principal categories: (1) leisure, personal and social activities, school; (2) moving and walking; (3) light domestic tasks; (4) tedious domestic tasks; (5) agricultural tasks; and (6) handicraft and small trading. Each of these principal activities was sub-divided into secondary activities, thus permitting a simple and precise description of all chores undertaken by the girls. For example, tedious domestic tasks included cutting wood (for cooking), fetching water, carrying water, carrying loads, washing sheets or heavy clothes, sweeping the yard, and ironing clothes (with a charcoal iron). With this double digit coding system, a total of 46 habitual activities could be recorded quickly. In

Table 1 Categories of activities and metabolic cost expressed as multiples of basal metabolic rate (BMR)

Score	*Multiples of BMR*[a]	*Examples of activities*
1	1.0	Sleeping, lying in the bed
2	1.5	Sitting quietly without activities or with very light activity (eating, washing)
3	1.8	Light activity while sitting (cooking, washing plates, plaiting hair, bolting...)
4	2.3	Light activity while standing (bathing, preparing food, winnowing grain...)
5	2.8	Walking, light activity in movement (dressing, cutting straw, weaving, dish washing, care of children)
6	3.3	Light manual work (cleaning, sweeping, gathering wood, washing clothes, winnowing, sowing, carrying light load)
7	4.8	Manual work at a moderate pace (fetching water, cutting wood, loading a cart, stirring a big pot of millet porridge, harvesting sorghum)
8	5.6	Manual work at a sustained pace (grinding grain, pounding, hoeing, carrying heavy loads, harvesting peanuts, football)
9	6.0	Physical activity of high intensity (digging earth, uprooting manioc, land clearing, walking steeply, dancing)
10	7.0	Physical activity of very high intensity (very fast dance, sprinting)

[a]Compiled from Bleiberg *et al* (1980); Torún *et al* (1989); FAO/WHO/UNU (1985).

addition, observers noted simple descriptions of the task undertaken in the record sheet. The task inventory was based on previous experiences in other parts of the country (Bénéfice, 1993) and on a pilot survey performed during the training of the observers. Locations for observation included staying inside the room, in the yard, by the compound, in the village or hamlet, in the bush, and outside the district area. This information was principally used to look at the consistency of the data records.

CSA accelerometer

The CSA Model 7164 accelerometer (Computer Science and applications Inc., Shalimar Florida, 32579, USA) was chosen. It is a small ($5 \times 3.8 \times 1.5$ cm) and light (60 g) apparatus. It has a single vertical piezoelectric sensor which generates a signal proportional to the strain acting on it. It is designed to record accelerations ranging to 0.05–2 Gs. It has a band limited response from 0.25–2.5 hertz. A 34 kb non volatile RAM permits the storage of data; power is supplied with a lithium battery. Battery life is in excess of 4000 h. When the interval of time is set at one minute, more than 22 consecutive days of data could be down loaded. Data could be collected through an interface unit connected to a personal computer. A dynamic calibration was performed under laboratory conditions by the manufacturer. This is done with a free swinging pendulum with control of the decay rate. Instrument reliability and between-unit variability is excellent (Tryon & Williams, 1996).

Adolescents wore the accelerometer packed in its small nylon pouch within a linen belt, firmly fitted at the level of the left hip. Good functioning of the accelerometer was regularly checked by the supervisor using the small magnet bar provided by the manufacturer. Girls were instructed how to fasten and unfasten the belt for toilet or bathing. However, they wore the accelerometer during the night. Movement monitoring encompassed the two days of direct observation, therefore permitting a cross-check of data. On a few occasions were data lost for a couple of hours and had to be dropped because abnormalities occurred (as an excess of movement counts). This was due to a badly tied belt or a prank by a girl. In all, 5616 h of activities were recorded.

Statistical analysis

Descriptive statistics for anthropometric characteristics, count movements and observed scores were calculated. Average daily physical activity indices, observed scores as well as movement counts were expressed on a minute basis (sum of 1-min scores or movements divided by the number of minutes).

Reliability of physical activity indices was estimated on the basis of intraclass correlations from a one-way analysis of variance. It is reported as the reliability of the movement counts for each subject during the four days R_2 ($R_1(MS_b - MS_w)/MS_b$) where MS_b = mean square between subjects and MS_W = mean square within subjects. The reliability of movement counts for a single day, R_1, is $(MS_b - MS_w)/MS_b + MS_w$. Interclass correlation and Cronbach's alpha reliability coefficient was used to test internal consistency of observed scores. Validity of CSA counts was estimated by examining the relationships with observed scores using Pearson correlation and regression analysis. Student *t*-tests and analyze of variance and co-variance were used to compare means or adjusted-means. When normality of distribution could not be assumed non-parametric tests were used (Wilcoxon ranked test and Kruskal–Wallis one-way analysis of variance). The Chi square test was used to analyze the classification of discrete variables. Analyzes were done with the NCSS 97 statistical software (Hintze, 1997).

Results

Anthropometric characteristics of the adolescent girls are given in Table 2. They are between the 3rd and 5th percentiles of the NCHS reference data for body mass but closed to the 10th percentile for stature (Hamill *et al*, 1979). As a consequence the BMI is below the 5th

Table 2 Anthropometric characteristics of rural Senegalese adolescent girls

Variables	*Adolescents studied (n = 40)*	*Other adolescents (n = 181)*	*t*	*P*
Age (y)	13.3[a]	13.4	0.19	ns
	0.5[b]	0.6		
Body weight (kg)	34.3	33.5	0.82	ns
	5.0	5.9		
Stature (cm)	148.3	146.8	1.1	ns
	7.1	8.6		
BMI (kg/cm^2)	15.5	15.4	0.4	ns
	1.6	1.6		
Arm Circumference (cm)	20.4	20.4	0.1	ns
	1.6	1.9		
Triceps skinfold (mm)	7.9	7.9	0.05	ns
	2.8	2.6		

[a]Mean.
[b]Standard deviation.

percentile of a well nourished reference population (Must *et al*, 1991).The triceps skinfold is also just at the 5th percentile of American children (Johns *et al*, 1981). The girls show a marked degree of underweight and stunting compared with adolescents from developed countries. This is a general characteristic of the area since there are no differences between the 40 girls and the total sample.

In June, 12 adolescents (30%) were prepubertal (breast stage 1: B1); 13 (32.5%) were just in the onset of puberty (B2); 12 (30%) were in mid-puberty (B3) and only 3 (7.5%) were in B4 or B5. These proportions did not change from the first to the second observation period ($\chi^2 = 1.79$, ns). Two of the girls just experienced their first menstruation.

There was a not-significant trend for lower anthropometric values during the rainy season among the 40 studied girls. This could be due to the smallest of the sub-sample. Comparisons were done again with the total rural girls sample. In such conditions, there was a significant increase in all anthropometric measurements, except BMI, from one round to another (Table 3, upper part). Mean increase reach 3.1 cm for stature and 1.8 kg for body mass. However, because puberty is a time of accelerated linear growth and therefore a potential confusing factor, comparisons were repeated after adjusting for age change through a covariance analysis (Table 3, lower part).

Differences in age-adjusted weight and height are no longer significant. Values for arm circumference and triceps skinfold are significantly lower during the rainy season (August).The lower BMI in December could be explained by a small but not significant, increase in age-adjusted stature (+1 cm). There is a noticeable recovery in arm circumference and triceps skinfold during the subsequent post-harvest season.

Mean movement counts and scores during 12 h of observation per day (720 min) are presented in Table 4. There are no statistically significant differences in counts per minute between days (Levene test for equality of variance is accepted; $F = 0.5$, ns). Intraclass correlations indicate that reliability for movement counts during only one day of monitoring is moderate ($R_1 = 0.55$) but increased to 0.71 for four days.

Table 4 Day-to-day variability and repeatability of movements counts

	Day 1	*Day2*	*Day3*	*Day4*	*Total*	*F*	R_1[a]	R_2[b]
Movement counts	638.6[c]	663.0	613.0	640.1	638.78	0.25[e]	0.55	0.71
	236.5[d]	264.4	242.4	224.7	195.6	ns		

[a]R_1: reliability based on intraclass correlation given one day of observation.
[b]R_2: reliability with 4 d averaged.
[d]Mean.
[c]Standard deviation.
[e]*F* ratio of one-way analysis of variance.

Subjects were monitored by observers during two consecutive days. The difference between days using a paired Student *t*-test is significant (score day 1: 3.51 ± 0.57 ; score day 2: 3.71 ± 0.55; $t = 2.4$, $P < 0.02$). Pearson correlation between the two days is significant ($r = 0.59$, $P < 0.0001$); Cronbach's alpha coefficient is equal to 0.74 indicating moderate but acceptable reliability.

Individual correlation coefficients between movement counts and observed physical activity levels range from $0.30 - 0.98$. The mean coefficient for the raw data is 0.62 (± 0.15). After averaging the data across the two days of observation within each subject, the correlation is 0.50 ($P < 0001$). There is a significant linear increase of movement counts with observed scores, expressed as Mets to give a practical meaning (Figure 1).

The standard error of estimate is 0.22 Mets and the mean error between observed and predicted PALs is $7.7 \pm 5.8\%$. The difference between observed PAL during 12 h of a day and predicted from movement counts is not statistically significant (Observed PAL: 2.30 ± 0.25 Mets; predicted PAL: 2.44 ± 1.2 Mets; $P = 0.9$, Wilcoxon signed-rank).

There were no significant relationships between anthropometric dimensions and observed PALs or movement

Table 3 Seasonal variation in anthropometric characteristics of rural Senegalese adolescent girls

Variables	*Dry season (April)* n = *210*	*Rainy season (August)* n = *208*	*Post harvest (December)*	*F*	*P* n = *221*
Body weight (kg)	35.4[a]	35.6	37.2	5.8	0.003
	0.3[b]	0.4	0.4		
Height (cm)	147.5	148.4	150.6	11.1	0.0001
	0.4	7.7	7.6		
BMI (kg/cm^2)	16.1	16.0	16.3	0.7	ns
	0.1	0.1	0.1		
Arm circumference (cm)	21.1	20.8	21.9	12.6	0.0001
	0.1	0.1	0.1		
Triceps skinfold (mm)	9.4	9.3	11.3	16.9	0.0001
	0.2	0.3	0.2		
Comparisons after adjustment for age changes through analysis of covariance					
Body weight (kg)	36.2	35.5	35.9	0.9	ns
	0.3	0.4	0.4		
Height (cm)	148.3	148.2	149.3	1.3	ns
	0.4	0.5	0.5		
BMI (kg/cm^2)	16.4	16.0	15.9	3.1	04
	0.1	0.1	0.1		
Arm circumference (cm)	21.4	20.8	21.4	7.5	0.0006
	0.1	0.1	0.1		
Triceps skinfold (mm)	9.8	9.3	10.8	7.1	0.001
	0.2	0.2	0.3		

[a]Mean.
[b]Standard error of the mean.

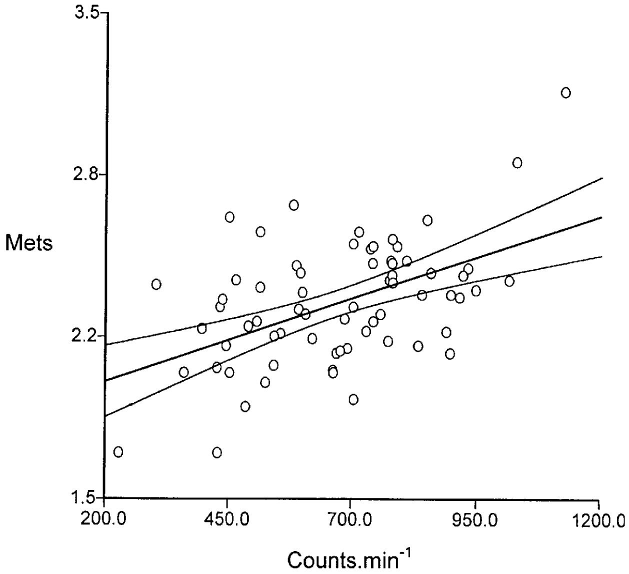

Figure 1 Scatter plot, regression and confident interval of the mean ($\alpha = 5\%$) lines of observed mean levels of physical activity during day (expressed as Mets) and accelerometry counts. Data for all subjects are pooled. PAL (mets) $= 6.8.10^{-4}$ (counts.min^{-1}) + 1.85; $n = 70$; $r = 0.50$ ($P < 0.0001$); SEE = 0.22.

counts. Age, pubertal status or occurrence of menstruation do not account for variation in physical activity indices.

Since the survey was designed to evaluate seasonal variation in activity, movement counts, during the day (7 a.m. to 7 p.m.) and night (8 p.m. to 6 a.m.) were compared between June and September (Table 5).

Differences are statistically significant during the day but activity level does not change during the night. It is interesting to consider the metabolic significance of the differences. For this purpose, daily counts.min^{-1} were converted in multiples of basal metabolic rate (BMR) using the regression equation in Figure 1. Although individual equations could have been calculated, we rather used a single equation obtained in pooling data for all subjects. BMR was estimated using the equation established by Henry & Rees (1991) for adolescent girls. This equation is established for people living in tropical areas. Individual weights measured at the time of survey were used in the equation. Movement counts under 25 counts.min^{-1} occur when lying without movement or during sleep; in such cases EE was set at one BMR instead of using the regression equation. Total daily EE (TEE) is higher during the rainy season (1.95 ± 0.12 Mets) than during the dry season (1.89 ± 0.14 Mets) ($P < 0.03$). The corresponding estimated EE will be 8.85 ± 0.80 MJ (2116.1 ± 170 Kcals or 58.0 ± 6.5 Kcals.kg^{-1}) during the dry season and 9.29 ± 0.67 MJ (2220.3 ± 170 Kcals or 59.2 ± 7.7 Kcals.kg^{-1}) during the rainy season.

Table 5 Mean and standard deviation for movement counts across 4 d, in the dry and rainy seasons

	Dry season	*Rainy season*	*Test*	*P*
Activity during day (counts.min^{-1})	582.9[a]	731.6	2.2[c]	0.02
	209.0[b]	330.9		
Activity during night (counts.min^{-1})	40.7	37.9	1.9[d]	ns
	111.0	39.5		

[a]Mean.
[b]Standard deviation.
[c]Value of the Student test.
[d]Wilcoxon Rank-sum.

Table 6 Percentage of time spent during 12 hours of a day in 3 levels of activity according to season

Activity levels	*Dry season*	*Rainy season*	*Total*
< 613 counts min^{-1}	53.8	42.5	50.0
Light-to-moderate 613−940 counts min^{-1}	24.5	28.2	25.8
Moderate-to-vigourous > 940 counts min^{-1}	21.7	29.3	24.3
	100.0	100.0	100.0

$\chi^2 = 38.6$, (DF = 2) $P < 0.0001$.

The percentage of time spent at different levels of activity is another way to evaluate the intensity of activity and work loads. Two cut-off points were chosen for movement counts: 613 counts.min^{-1} corresponding to 3 Mets and 940 counts.min^{-1} corresponding to 6 Mets. Activities below 3 Mets are considered sedentary; activities between 3 and 6 Mets are light-to-moderate, and activities over 6 Mets are moderate-to-vigorous. In general, adolescents spend 50% of their day time (6 h in sedentary activities, 25% (3 h) in light-to-moderate and 25% (3 h) in moderate-to-vigorous activities. This breakdown changes with season: time spent in sedentary activities is longer in the dry season, whereas time spent in vigorous activities is longer during the rainy season (Table 6).

The daily pattern of movement counts, averaged per hour, is illustrated by Figure 2. Differences in peaks between seasons are all statistically significant. Adolescents begin to work earlier during the rainy season than during the dry season, but stop early doing their activities. It should be noted that there are no seasonal differences in sleep length; the girls always went to bed at about 22 p.m. and awakened very early, at 5 a.m. They slept 54.1% of the night time in the dry season (6.5 h) and 50.7% in the rainy season (6.0 h), ($\chi^2 = 2.4, \mathrm{DF} = 1, \mathrm{ns}$).

The purpose of adolescent activities is an important question. Table 7 summarizes the breakdown of activity into different categories during the dry and rainy seasons. The main differences are in time spent in personal or social activities (shorter in rainy season) and in light domestic chores (longer in rainy season). More detailed analysis indicates that the average time spent at school is 1.6 h per day, but less than one-half of the sample attended school regularly. Adolescents rested an average of 4.9 h, more in rainy season than in dry season. Agricultural tasks were apparently longer at the end of the dry season; in June girls participate in clearing the fields for sowing. But, agricultural work represented less than 1 h per day for each adolescent (0.6 h).

Discussion

The Senegalese adolescent girls studied here appear to have a considerable level of physical activity. According to cut-off points suggested by Torún *et al* (1996), they would fall in the 'heavy activity' category with an estimated total daily energy expenditure above 1.88 Mets. There are no relationships between physical activity indices and age, physical characteristics, or maturational status of the adolescent girls. EE per kg of body mass usually decreases with age (Rowland, 1990) and more abruptly in girls than

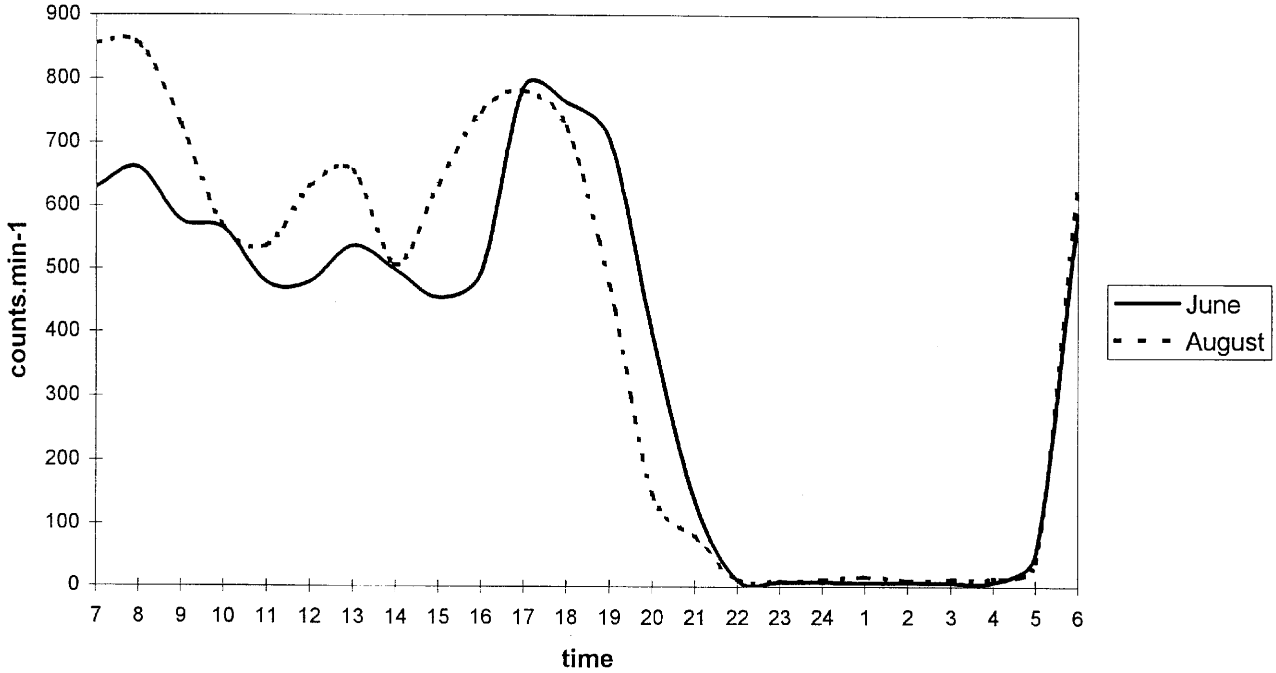

Figure 2 Seasonal variation of movement counts.

Table 7 Percentage of time spent during the day in different groups of activities in the dry and rainy seasons

Activity group	*Dry season*	*Rainy Season*	Total *(%)*	Total *(h)*
Social and personal activities; school	53.9	50.6	52.2	6.2
Moving, walking	11.3	11.4	11.3	1.3
Domestic chores: light	17.2	23.8	20.5	2.5
Domestic chores: heavy	11.7	9.4	10.6	1.3
Agriculture	5.8	4.7	5.2	0.6
Handicraft, trading	0.1	0.1	0.1	0.1
Total (%)	100	100	100	
Total hours observed)	(960)	(960)	(1920)	(12)

$\chi^2 = 60.9$, (ddl = 6) $P < 0.0000$.

in boys by stage of puberty (Janz & Mahoney, 1997). The homogeneity of the sample with regards to these variables, combined with the monotonous and repetitive nature of the daily compulsory tasks minimizes the variation in PA levels and may explain the lack of contrast among girls.

The accelerometer is not a new instrument, but as far as we are aware, this may be the first time that it was used in a sample of children from a developing country. However, calculation of energy expenditure (EE) either from accelerometer counts or from observational method is based upon approximations that need to be clearly stated. Firstly, CSA is not primarily designed to estimate EE in a biological sense but with a physical meaning in terms of changes in kinetic energy (Tyron & Williams, 1996). Therefore, static work such as lifting a load is not monitored. This is not negligible since in the present sample, time spent in carrying water or other loads represents 37 min per day. Part of this effort is taken into account via walking, especially as the impact of the foot on the floor changes and in turn the resulting pattern of accelerations is modified. Unfortunately alterations in movement counts is difficult to quantify. Secondly, calculation of EE from observed activity also has a major weakness since there are few data for this age group, and metabolic values for everyday tasks of African children such as fetching water, pounding millet or digging earth simply do not exist. They have to be based on limited measurements on adult women (Bleiberg *et al*, 1980).

The ability of the CSA model as well as other types of accelerometers to determine EE has been tested under laboratory condition using ergometric exercises (Meijer *et al*, 1989; Melanson & Freedson, 1995), whole-room calorimeter (Bray *et al*, 1994); and doubly-labeled water (Bouten *et al*, 1996). As a rule, count movements are well correlated with EE. Correlations are higher under laboratory conditions than in the fields and are increased if variables such as vibration during transport are taken into account or if the energy output is adjusted for body mass (Bouten *et al*, 1996). Relative error is also variable, from 7–30%, depending on the type of activity (Bray *et al*, 1994). All of the authors concluded positively about the usefulness and accuracy of accelerometry in estimating and in discriminating different levels of EE in field conditions. In children, cut-off values during a treadmill exercise with indirect calorimetry has been recently proposed (Dowda *et al*, 1997). Recruitment of children and conditions of testing seem too different to allow these cut-off points to be used in the present study. Accelerometry gives a better prediction of EE for low intensity exercises than simple HR monitoring (Meijer *et al.* 1989). Combining the flex-HR method, which takes into account differences in HR at rest and during exercise (Spurr & Reina, 1989), with movement counts improves the prediction of EE determined in a room calorimeter (Moon & Butte, 1996). Finally, individual calibration and regression lines do not result in improvement of the prediction (Bouten *et al*, 1996). If proved, such property will be of great interest in field studies.

The CSA accelerometer has been used with healthy American children and compared to heart rate (HR) telemetry (Janz 1993). The correlations between HR and movement counts range from 0.50–0.64. Day-to-day stability appears to be insufficient over 3 d, and is better with 4–6 d (Janz *et al*, 1994). Reliability, in fact clinical repeatability because instrument reliability is checked under strictly controlled laboratory conditions (Tryon & Williams, 1996), represented by intraclass correlations is equal to 0.75 for 4 d. Interestingly, the present study performed under very different conditions, gives a similar result ($R = 0.71$). The CSA accelerometer also discriminates between different levels of activity (Janz *et al*, 1994; Janz & Mahoney, 1997). In this present study, low correlations between movement counts and observed scores occurred on two occasions because of synchronization errors. The low to moderate correlations could also be due to inaccuracy of the observation coding. A simple 10 levels scale limits the occurrence of errors, but decreases sensitivity. The choice of a simple scale, however, was dictated by practical reasons.

In this present study, the CSA was a valid instrument to estimate activity-related EE in field conditions, and our purpose was to show its usefulness in describing physical activity patterns of rural Senegalese adolescent girls. Accelerometers could be worn over several days and results of this study show that better clinical repeatability is achieved after 4 d. It would be difficult to have a HR record for such long time period because of electrode displacements, discomfort due to heat or excessive dryness of the skin (Bénéfice, 1998). On the other hand, direct monitoring of activities by observer is expensive and time consuming in training, data acquisition and analysis. It is also intrusive even when great attention is paid to this aspect. Youth may alter habitual behavior if they know that they are being observed. Thus, in the rural context of Senegal where other simple methods such as questionnaires or self reports are not reliable, accelerometery appears to be a valuable method.

Only few studies on EE have been done at the beginning of adolescence. This period is very important to consider because growth and maturational processes are associated with an increase in energy requirements. Also, in rural Africa, this is a time when girl changes into a young women with different reproductive and productive roles. Knowledge of physical activity patterns, energy expenditure and energy requirements are thus crucial factors to consider when establishing health and nutritional policy. For Senegalese girls the present estimates of $0.24 \pm 0.029\,\text{MJ.kg}^{-1}$ ($58.5\,\text{kcal.kg}^{-1}$) is higher than those recorded in developed countries (Bandini *et al*, 1990; Wong, 1994) but closed to the estimates of Torún *et al* (1996). Estimates of EE are very often calculated on the basis of 8 h of sleep. However, when carefully measured, as is the case in the present study, sleep duration is considerably shorter (6 h). Sleep and rest are important components of EE that need to be cautiously evaluated, even in developed countries. Studies from Nigeria indicate that young students spent most of their day time in sitting or resting activity (Cole & Ogungbe, 1987; Cole & Ogbe, 1987). A recent study from the same country, suggests that in young men increased time spent in resting activity could be a way to adapt to insufficient food intakes and to sustain high levels of energy expenditure (Onimawo, 1998).

An indirect evidence of a high level of physical activity arises from comparisons with American studies using the CSA accelerometer. The cut-off point chosen by Janz *et al* (1994) for moderate activity ($500\,\text{counts.min}^{-1}$) on basis of HR recording ($130\,\text{b.min}^{-1}$) is lesser than in the present study ($613\,\text{counts.min}^{-1}$) based on direct observation. Average daily counts for American girls at midpuberty are lower than those of Senegalese adolescents: $108.1 \pm 16.3\,\text{counts.min}^{-1}$ *vs* $582.9-731.6\,\text{counts.min}^{-1}$ depending on the season (Table 6). It should be emphasized that high levels of physical activity have been already reported in Senegal. In an area close to Niakhar, using the same observational method, an EE during day of 2.28 ± 0.2 Mets was noted (Bénéfice, 1993), quite similar to the value reported here: 2.30 ± 0.25 Mets. With the doubly-labeled method Diaham *et al* (1997) found a high 24 h EE in prepubertal ($\text{EE} = 1.82 \pm 0.09$ Mets) and pubertal adolescents girls ($\text{EE} = 2.29 \pm 0.12$ Mets). It is interesting to note that results for prepubertal girls are similar to our own estimates. Unfortunately age, maturity status and body mass are not given for the pubertal adolescents.

This study provides some insights into the nature of works performed by Senegalese adolescents. They spent 31% of the day time in domestic tasks, more in light than in heavy tasks; 52% of the time is for personal activities. This gives impression that the work load is not excessive. High activities occur at specific hours of the day (7 a.m., 12 a.m., 18 p.m.), corresponding to the preparation of meals. There are seasonal differences in peak activity related to the seasonal differences in day length and field work. Apart from meal preparation, day activities could be classified as light-to-moderate. However, it is known that cumulative counts of light activities could greatly increase total EE (Dauncey, 1989). As already stated, in this study the short duration of sleep is also an important factor for high estimated total EE.

The higher level of physical activity during the rainy seasons coincide with a depression in arm circumference, triceps skinfold and BMI in the total sample. In West Africa, such effect is generally linked to a seasonal food shortage (Annegers, 1973; Bénéfice *et al*, 1984). It has already been described in the Niakhar area (Simondon *et al*, 1993). Interestingly in this present study, seasonal depression does not result in a slow down of linear growth, but rather in changes in body composition (fat mass and fat free mass). These body adjustments together with a relatively modest increase in work loads may be considered protective toward the adolescent growth spurt.

Conclusions

Senegalese adolescent girls show a high level of physical activity and differ sharply from adolescents in developed countries. Application of energy requirements based on observations from developed countries may thus be questionable. More information is needed on the activity of adolescents in different settings and seasons, with details of their health, growth, and maturational status.

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