Growth spurt, relative fat distribution and physical activity of Senegalese rural male adolescents

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Growth spurt, relative fat distribution and physical activity of Senegalese rural male adolescents

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Abstract

This study examines the height growth spurt of a group of 378 adolescent boys from rural Senegal (West Africa), along with their subcutaneous fat changes through puberty. Habitual physical activity was qualitatively estimated in a subsample of 40 adolescents via a questionnaire; it was quantitatively assessed by an accelerometer worn for 3 consecutive days. Using the Preece-Baine model, a delay of about 3 years in the growth spurt was discernable compared with CDC reference data. Despite this delay, older adolescents reached a final stature of around the 50^{th} percentile of the reference. Subcutaneous fat increased after the age at take-off, with substantial trunk fat deposition. These adolescents appeared to be fairly active, spending 38% of their time during the day performing vigorous activities. These results are in line with other African studies describing a slow and prolonged growth process. The fat regional deposition pattern also conformed to that of adolescents from industrialized countries. No significant relationship between physical activity and nutritional status was evidenced.

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Introduction

A pattern of slow but continuous growth was described several years ago in rural African children (Little and Johnson 1987). This resulted in a blunted spurt which was even more pronounced in boys than in girls (Little and Johnson 1987; Simondon and others 1997). Sexual maturity was also frequently delayed (Cameron and others 1993; Campbell and others 2005). A profile of leanness and slow growth would appear to be habitual in populations living in the dry savannahs of Africa (Glew and others 2003; Gray and others 2004). Likewise, more than two decades ago, a phenomenon of catch-up growth at the end of puberty was reported (Kulin and others 1982) and was later confirmed in rural Mali (Pawloski 2003). This phenomenon, sometimes termed "compensatory growth", was concomitant with an increase in fatness, occurring mainly after the peak of height velocity (Cameron and others 1994).

Among the causes frequently advanced to explain this slow growth, chronic undernutrition is most often cited (Martorell and others 1992). Global energy dietary deprivation is widespread in rural Africa; however, certain micronutrient deficiencies (essential amino acids and zinc) could also lead to stunting (Golden 1991). This might be the case in Senegalese agricultural communities at the end of the dry season (Benefice and Simondon 1993). Indeed, physical activity is a potent regulator of energy balance and hence of nutritional status. In rural Africa, adolescents and children are continuously involved in daily tasks at the household level, and this may represent a high level of energy expenditure. This is especially evident in the case of adolescent girls (Benefice and others 2001a). Studies among African rural boys are less common, and there is a need to provide new information (Larsen and others 2004).

A paradoxical long-term consequence of stunting is the possible existence of a link with fatness or obesity (Sawaya and Roberts 2003). This was recently described in South Africa (Kruger and others 2004), especially in urbanized areas where a process of nutritional transition is in progress (Mukuddem-Petersen and Kruger 2004). Likewise, an association between stunting during infancy and higher subsequent trunk fat accumulation was also reported among adolescent girls (Benefice and others 2001b). One plausible explanation could be a lower rate of fat oxidation in previously malnourished children (Sawaya and Roberts 2003).

Causes and long-term consequences of stunting are complex and not fully understood. More investigations are needed, especially in the most severely affected areas, so as to better evaluate this condition and provide appropriate recommendations for public health policies. Hence, the main objective of the present study was to analyze the pubertal growth spurt in a sample of Senegalese boys exposed to chronic malnutrition, in relation to fat deposition patterns. In addition, the role of physical activity as a possible modulator of nutritional status and growth was studied.

Subjects and methods

Ecological setting

The study was performed in the Niakhar district of Senegal 120 km southeast of the capital city Dakar. It belongs to the ancient kingdom of the Siin in the so-called "groundnut basin". This district comprises 33,000 inhabitants mainly belonging to the Sereer ethnic group; 74% of them are Muslims and 23% Christians. The climate is Sahelian, with a long dry season and a short rainy season (June to October). The productive activity consists of groundnut and millet cultivation. The study was carried out between March and June 2000.

Sampling

From the demographic database of the Niakhar project: (http://www.ird.sn/activites/niakhar/presentation/index.html), 3427 boys 10-to-17-years-old were censused. A total of 400 were randomly drawn to participate in the study. The final sample included 378 boys who were measured.

Ethic

The study protocol was approved by the review board of the Institut de Recherche pour le Développement (IRD, Centre de Dakar) and by an annual agreement on the part of the Senegalese Ministry of Research. The aims of the study were individually explained to the boys, their parents and village leaders. Oral consent was requested, since most subjects were illiterate. The study followed the principles of the Helsinki Declaration.

Anthropometric measurements and indices

The following measurements were carried out in accordance with standardized recommended techniques (Lohman and others 1988): 1) body weight (kg), lightly clothed and barefoot with an electronic scale (accuracy 100 g); standing height (cm) with a

Harpenden ® anthropometer; measurement of 7 subcutaneous fatfolds (in mm) with a Holtain ® caliper at the tricipital (tric), bicipital (bic), subscapular (sca), supra-iliac (sil), umbilical (umb), anterior thigh (thigh) and media-calf (calf) sites. Measurements were done in duplicate after marking the sites. A mean of 2 measurements was used to minimize variance. In addition, mid-arm circumference (MAC, cm) was measured with an unstretchable tape.

Indices of malnutrition were calculated according to the World Health Organization (WHO 1995) height for age (H-age) and weight for age (W-age). They were computed using Anthro software and expressed as z-scores (Centers for Diseases Control: http://www.cdc.gov). BMI was calculated as weight (kg) /stature (m) ^{2}.

The Preece and Baines model (Preece and Baines 1978) was used to fit a height velocity curve. This model allows for calculation of the following indices: age at height take-off (TO; years), velocity at TO (cm/year); age at peak height velocity (PHV; years); velocity at PHV (cm/year); and prediction of adult final stature (cm). Since it was not possible under field conditions to accurately assess the sexual maturity of the boys, age at TO and age PV were used as proxies for pubertal maturity.

The sum of the 7 skinfolds (sum 7 SKF, mm) was used as an index of subcutaneous fat mass and as a proxy for total fat mass. Principal component analysis (PCA) was performed on the 7 skinfold measurements to assess relative fat distribution. It followed the protocol of Healy and Tanner (Healy and others 1981) modified by Mueller (Mueller and others 1982). As a first step, each skinfold was transformed into its natural log and then each log-transformed skinfold was regressed on the mean of the six log-transformed skinfolds. Residuals of regressions were used in PCA. The first step eliminated the total subcutaneous fatness component which usually accounts for 80% of variance (Baumgartner and others 1986). Factor scores obtained for each adolescent were generated and then used for group comparisons.

Because two measurers participated in the surveys, standardization was carried out at the beginning based on 25 children. The technical error in measurement and the variation coefficient were calculated (Lohman and others 1988). The technical error was very small (0.1 to 0.5). Variability between observers was also weak: 0.3% for longitudinal measurements. Variability was higher for subscapular skinfolds (5.7%) but was within the limits published in the specialized literature (Malina 1995a).

Physical activity

Physical activity was studied in a subsample of 40 subjects with the same age range, geographic location and familial characteristics as the main sample. Physical activity was quantitatively studied using a CSA accelerometer. Accelerometers are small (5 * 4 * 1.5 cm), light (42.5 g) electronic monitors attached at the left hip in a small pouch. We used the CSA (Computer Science and Applications Inc, Shalimar, Florida) model 7164. It has a single vertical piezoelectric sensor which generates a signal at each body center mass acceleration. It can record accelerations ranging from 0.05 to 2 Gs. The interval time was set at one minute and the instrument was worn for 72 consecutives hours (3 complete days and 3 nights). This interval of time was chosen because no significant improvement in data reliability was manifest after 3 days of observation (Benefice and Cames 1999). Data were collected through an interface unit connected to a personal computer. Activity intensity was expressed as numbers of counts per minute (counts/minute or cpm). We used 2 cut-off points: 613 bpm (corresponding to 3 Mets) and 941 bpm (6 Mets), established from a regression equation between observation scores and accelerometry counts in a group of girls(Benefice and Cames 1999). These thresholds enable dividing activity intensity into 3 levels. Activity below 3 Mets was considered to be light or sedentary; activity between 3 and 6 Mets as moderate; and activity over 6 Mets as vigorous. The complete daily cycle was divided into 3 periods: morning from 7:00 to 12:59; afternoon from 13:00 to 18:59; and night from 19:00 pm to 6:59.

Statistical analysis

All data were entered in duplicate and quality control was performed with Epi Info software. Accelerometry counts were transferred to an Excel file. Statistical analyses were done using NCSS software, release 2004 (http://www.ncss.com/). Variables were checked and normality of distribution verified. For comparison purposes, a simple Student test or one-way analysis of variance was used. Scheffe's multiple comparison post hoc tests were used. In case of abnormally distributed variables, a log transformation was applied. If the distribution continued to be abnormal, the Kruskall-Wallis one-way ANOVA non-parametric test was employed. Associations between variables were studied using Pearson or Spearman rank correlations.

Results

Adolescents were divided into 3 age groups; anthropometric characteristics appear in Table 1. As indicated by H-age and W-age indices, boys were below the international references, and the growth delay was apparently greater in older boys. BMI values were under the 3rd percentile in children older than 13 years of age and just at the 10th percentile for younger boys.

Figure 1 provides an illustration of growth delays. Mean stature at all ages was at or just below the 5th percentile. Figure 2 shows distance and velocity curves calculated using the Preece and Baines' model (Preece and Baines 1978). In addition, mean height values for age from the NCHS/CDC database were also computed. An examination of the velocity curves revealed that Senegalese adolescents were characterized by a delay in age at peak velocity (PHV) of more then 3 years. The peak was smooth and the maximum velocity attained was lower than the reference. Interestingly, distance curves fitted from the model appeared to be quite similar after a shift of 3 years. Table 2 gives more details on biological parameters of the growth spurt and on differences between Senegalese adolescents and the CDC reference. The differences in height attained at PHV (10.8 cm) and adulthood (1.1 cm) suggest that lower velocity goes hand in hand with a prolonged time of positive growth velocity, allowing for a catch-up in early adolescence.

Table 1 reveals a clear increase in total fat mass (as represented by the sum of 7 skinfolds; Sum 7 skf) with age. The difference was statistically significant ($F=19.0$, $p<0.0001$). In order to examine the influence of pubertal growth, boys were divided into 3 groups:

- Group 1 =age < TO (< 11.2-years-old) or "prepubertal" group (n=55).
- Group 2= between TO and PHV (11.2<age<16.4) or "pubertal" group (n=244).
- Group 3= older than age at PHV (>16.4-years-old) or "end of puberty" group (n=80).

Total fatness was significantly greater in “pubertal” and “end of puberty” than in “prepubertal” children (non-parametric one-way analysis of variance, Kruskall-Wallis test: χ^2=32.0, p<0.0001). However, there was no difference between “pubertal” and “end of puberty” children.

Fat regional deposition during puberty was evaluated through a principal component procedure as presented above. Two principal components with an Eigen value greater then 1 emerged, explaining respectively 36.2% and 19.8% of total variance in subcutaneous fatness. The first principal component (PC1) contrasted the trunk (positive loading) with member (negative loading) fatness. It was termed “trunk-members”. The second component (PC2) contrasted arm (negative loading) to leg (positive loading) fatness. It was termed “leg-arm”. Comparisons according to pubertal growth groups are indicated in Figure 3. For PC1, differences were significant between groups 1-2 and group 3 (F=29.9, p<0.0001), implying that “prepubertal” and “pubertal” children had less trunk fat deposition then “end of puberty” children. For PC2, differences were significant between group 1 and groups 2-3 (F=4.3, p<0.001): “prepubertal” children had smaller leg deposits of fat than “pubertal” or “end of puberty children”.

The subsample of children monitored for habitual activity (n=40) belonged to the pubertal group. It did not differ from the other children with respect to age and anthropometric characteristics. There was no day-to-day variability in levels of activity. The 3 days of monitoring were thus pooled. During the day, boys spent 41% of their time engaged in personal activities (such as resting, visiting, eating, bathing); 5% in leisure or sports activities; 23% in traveling (walking for personal or domestic purposes); 2.3% in light domestic activity; 1.3% in handicraft or small trading; and 7.5% in agricultural tasks (carrying grain, harvesting, clearing fields, caring for animals). A detailed description of these activities has already been published in a master’s thesis (Vanacker 2000). Figure 4 shows the activity profile according to accelerometry counts. Boys awoke early in the morning, before 7:00 am and as early as 5:00 am in some case. In the morning, levels of activity were not as high as during the afternoon, where they peaked between 18:00 and 19:00. There was a period of low activity or rest between 1:00 and 2:00.

Table 3 presents the distribution of activity intensity averaged at 3 levels. On the whole during the day, adolescents spent the same percent of time engaged in both light and vigorous activities. Interestingly, they also spent 10% of their time at vigorous activities in the evening. The latter concerned activity (sports, playing or dancing) between 19:00 and 22:00 hours.

Interestingly, the relationship between activity and age was negative ($r=-0.34$, $p<0.02$). The same trend was noted with stature, but without reaching a significance level. Finally, relationships between physical activity and body build and nutritional status of adolescents were explored. There existed a non-significant trend toward stronger adolescents being more active (correlation between BMI and total activity: $r=0.21$, $p=0.10$).

Discussion

To our knowledge, this is the first study reporting fat patterns related to growth spurt in West African adolescents. While the present study largely confirms the pattern of slow growth during puberty already reported in Africa (Little and Johnson 1987; Pawloski 2003; Simondon and others 1997), it also provides new elements. Chronic malnutrition, represented by H-age and W-age Z-scores under the international reference, is an indisputable fact. Among the 372 boys in the sample, a total of 72% were below the -1 z-score and 36.8% below the -2 z-score of the H-age index. The apparent increase with age in the prevalence of growth retardation can no doubt be explained by a delay in the adolescent growth spurt and a difference between the chronological and biological age. The peak of height velocity, while smooth in comparison with populations from Europe and the USA (Hamill and others 1979; Tanner and others 1966), was nevertheless clearly marked. Interestingly, this growth profile is close to that observed in Turkana boys: velocity at PHV is quite similar (5.6 versus 5.5 in Turkana boys, cm/year); however, Senegalese boys take off earlier (11.2 versus 14.0 years) and reach the PHV at an earlier age (16.4 versus 17.0 years in Turkanas) (Little and Johnson 1987; Walker and others 2006). Finally, predicted adult size in Senegal (176.9 cm) was similar to that observed in Tukanas (175 cm). It should be noted that both populations were native to a dry savannah environment, and their predominant economic activities involved herding and agriculture. Recent theory has proposed an evolutionary process and environmental pressure to explain growth trajectories within a life-history framework (Little and Johnson 1987; Walker and others 2006). It could be assumed that the same causes produced the same growth effects in these African boys living in a dry environment and exposed to chronic energy deficiency. One limitation of these observations is that they are based on cross-sectional data that tend to blunt variability. However, a recent longitudinal analysis performed in girls from the same district confirmed the slow growth tempo reported here (Garnier and others 2005). While the final stature reached by adult men is not precisely known, in adolescents older then 17 years of age the 75th percentile was 173.8 cm, and the 90th was 176.2 cm. This indicates that older adolescents were apparently recovering a stature corresponding to roughly one 50th of the international NCHS/CDC reference. These findings support the hypothesis of "compensatory growth" during puberty through prolonged growth and positive velocity (Cameron and others 1994).

Another important facet of this study was the increase in fat accretion and trunk fat patterning through puberty. These adolescents underwent a steep rise in total fatness occurring after TO. This is in line with other studies indicating that fat accretion occurred during the growth spurt and was influenced by the rhythm of puberty (Malina and others 1999). Similarly, the pattern of adult fat deposition emerges during adolescence and is related to the puberty tempo (Koziel and Malina 2005). Indeed, principal component analysis indicates that adolescents accrue more fat at the trunk and leg during PHV. Likewise, a longitudinal study from Belgium confirmed that in male adolescents, early maturers tended to accumulate more fat in the trunk than in the extremities (Beunen and others 1994). The authors concluded that late maturers were somewhat protected from metabolic diseases during adulthood because of the relationship between elevated abdominal fatness and metabolic complications (Alberti and others 2005). In some ways, our adolescents could be considered late maturers. We cannot exclude the possibility of a relationship between fat patterning and metabolic risk in a chronically malnourished population presumed to be free of lipid-related diseases. Indeed, there is some evidence relating stunting during infancy and childhood with later overweight and obesity (Sawaya and Roberts 2003). The explanation could lie in a low rate of fat oxidation in stunted children (Hoffman and others 2000). However, up until now, this hypothesis has not been fully supported by empirical evidence (Sichieri and others 2003). The risk exists only in countries, mainly Asian or Latin American, which are undergoing nutritional transition. In the case of Sahel countries like Senegal, food security continues to be a major problem.

The subsample of children monitored for physical activity proved to be fairly active: they spent 14 h to 16 h a day in movement and 38% in vigorous activity. As a whole, this represents an activity volume greater than that observed in girls (601.0 ± 22.3 bpm in boys versus 385.5 ± 6.7 bpm in girls) (Benefice and Cames 1999). Girls spent 50% of the daytime in sedentary activities and 25% in vigorous activities, versus 38.2% and 38.0%, respectively in boys. Girls tended to decrease their activity at the beginning of puberty, while boys maintained a high level up to the end of puberty (Malina 1995b). In the present study area, for example, boys were adept at fierce sports like soccer, wrestling, tree-climbing and racing, while girls were more peaceful. Boys were also in charge of somewhat heavier agricultural tasks like planting and hoeing, and had to care for small animals. Indeed, the trend toward a decrease in the activity volume with age is in line with the general literature (Malina 1995b). Due to the small sample size and lack of variance, we were unable to find a clear-cut relationship between activity, body build and fatness. There existed a non-significant trend with BMI. This positive correlation was unexpected; however, BMI in lightweight children is more an indicator of heaviness and muscle mass than of fatness.

In the present paper, we report new data on physical growth and activity of adolescent males from Senegal. They presented a growth spurt which was delayed for more than 3 years compared to children from industrialized countries, while apparently reaching a final stature in line with the international reference. While being classified as "chronically malnourished", these adolescents displayed a high level of activity. This indicates that international reference data should be interpreted with caution after 10 years of age in the absence of indicators of pubertal status. Hence, the growth trajectory of these Senegalese adolescents appeared to successfully evolve concomitant with the environmental constraints they endured.

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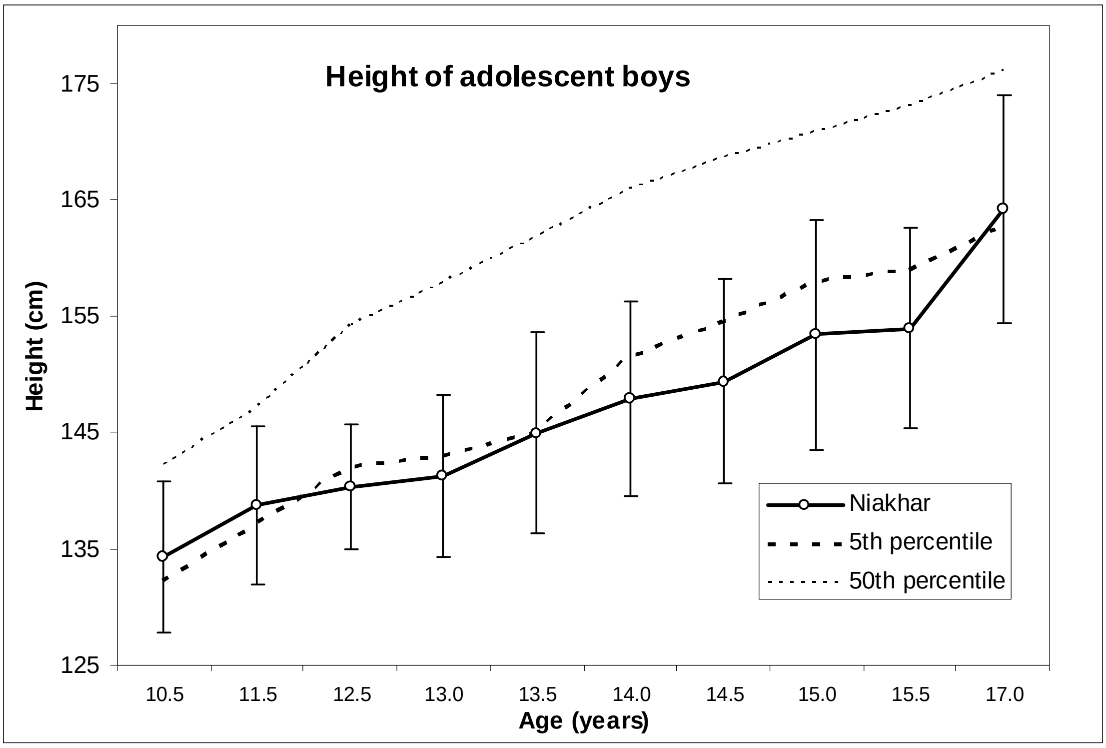


Figure 1: Growth of Senegalese adolescent boys in comparison with percentiles of the international CDC/NCHS reference

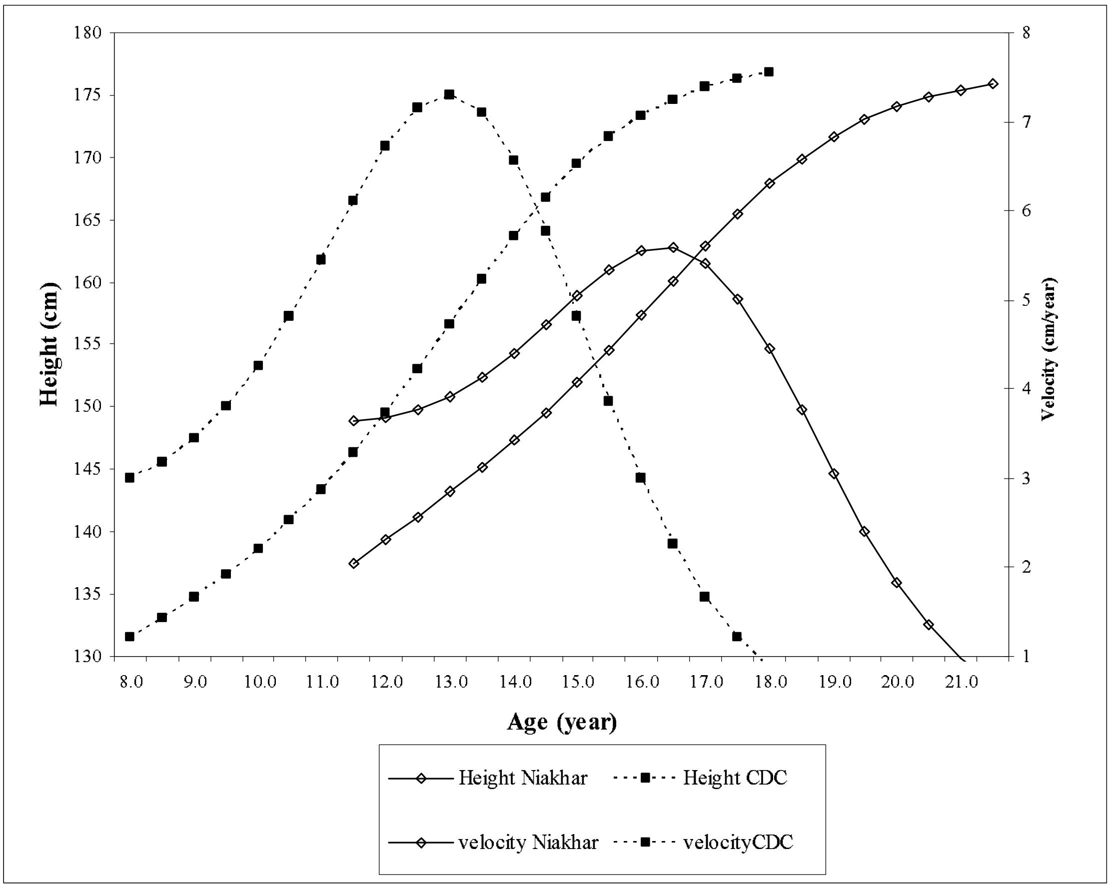
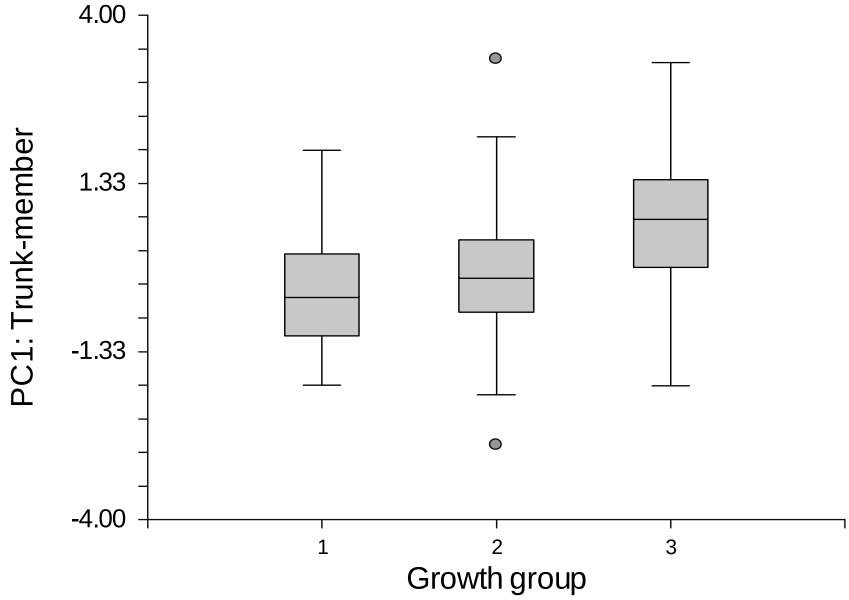


Figure 2: Curves of height velocity and distance of Senegalese boys compared with CDC/NCHS reference values



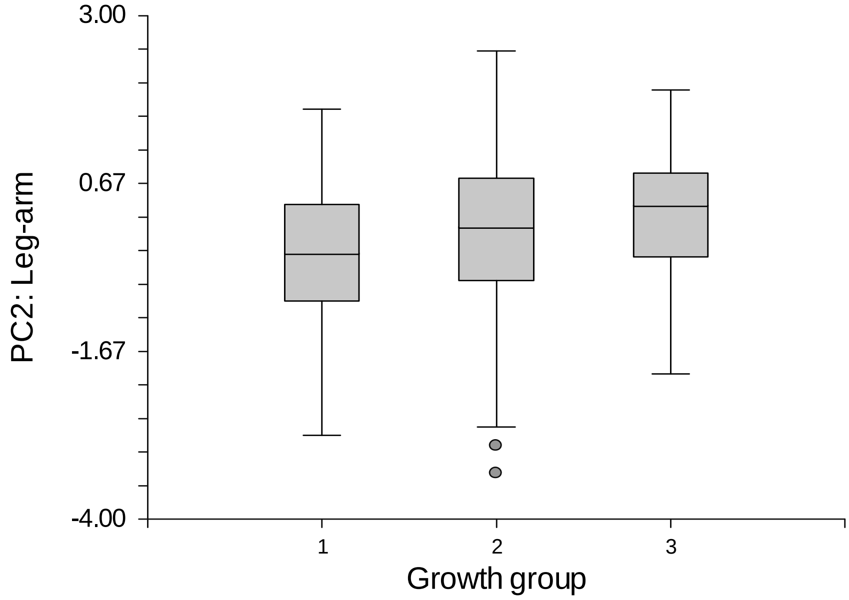


Figure 3: Factor scores in 1st and 2nd principal component according to growth group (1: pre-pubertal; 2: pubertal; 3: end of puberty)

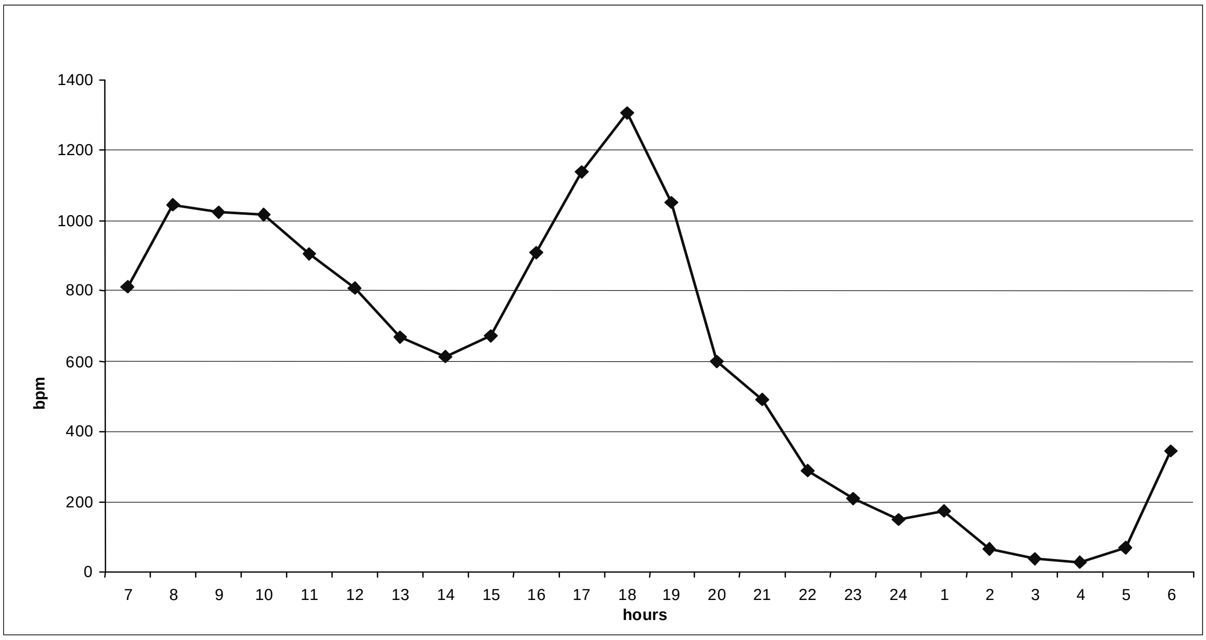


Figure 4: Twenty-four hour activity profile in Senegalese adolescents derived from accelerometry counts

Table 1 Anthropometric characteristics of adolescent Senegalese boys

Weight (kg)	Age (years)	Mean	SD
n=142	10 to 13	29.17	3.79
n=98	13.1 to 15	35.59	6.26
n=139	>15	44.53	8.80
Height (cm)	10 to 13	137.58	7.16
	13.1 to 15	147.39	9.09
	>15	160.16	10.54
MAC (cm)	10 to 13	17.95	1.29
	13.1 to 15	19.54	1.75
	>15	21.56	2.31
Sum 7 skf (mm)	10 to 13	37.67	8.06
	13.1 to 15	41.15	7.95
	>15	44.02	9.61
H-age (z-score)	10 to 13	-1.30	0.94
	13.1 to 15	-1.89	1.01
	>15	-2.09	1.34
W-age (z-score)	10 to 13	-1.43	0.61
	13.1 to 15	-1.95	0.73
	>15	-2.25	0.86
BMI (kg/m^2)	10 to 13	15.35	0.98
	13.1 to 15	16.25	1.28
	>15	17.25	1.68

Table 2 Biological parameters of growth in Senegalese boys (adjusted with the Preece and Baine's model)

Parameters	Niakhar	CDC/NCHS	Absolute value of difference
Age take-off (year)	11.2	5.9	5.3
Velocity take-off (TO; cm/year)	3.6	2.7	0.9
Age at peak velocity (PV; year)	16.4	13.0	3.4
Velocity PV (cm/year)	5.6	7.3	1.7
Dist TO-PV (cm)	22.8	30.7	7.9
Acceleration TP-PV (cm^2/year)	2.0	4.6	2.6
Height value at TO (cm)	136.5	125.8	10.8
% Adult stature	72.2	70.6	1.6
Height value at PHV (cm)	159.3	156.5	2.9
% Adult stature	90.1	87.9	2.2
Dist PV-adult (cm)	17.6	21.6	4.0
Adult value (cm)	176.9	178.0	1.1

Table 3: Percent of time spent during the day and at night in different levels of activity of Senegalese adolescents

Period	Light	Moderate	Vigorous	Total (%)
Morning	36.0	24.4	39.6	100.0
Afternoon	40.4	23.2	36.4	100.0
Total day	38.2	23.8	38.0	100.0
Night	81.4	8.2	10.4	100.0

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