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Running title: Sleep habits of Senegalese adolescent girls

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Abstract

Objective: To study the relationship between sleep habits, nutritional status, growth and maturation in a group of African adolescent girls. The main hypothesis to be tested was that sleep length could be an effective way to spare energy, and thus malnourished girls sleep longer than normal girls.
Design: Three repeated yearly surveys (1997 to 1999) on a sub- sample of girls drawn from a larger study cohort on growth at adolescence.
Setting: The Niakhar district in the central part of Senegal.
Subject: 40 girls were initially drawn. Missing girls were replaced at each round by girls having the same characteristics and belonging to the same cohort.
Intervention: At each round data on pubertal development (breast stages and occurrence of menarche), growth and nutritional status were collected. Adolescents wore an accelerometer for 3 or 4 consecutive nights and days at each round.
Results: At the beginning of the survey, girls were 13.3 ± 0.5 yo. They were under international reference values in weight and height. Their mean sleep duration was 8.5 ± 0.9 hours. Their puberty status did not influence their sleep habits; however, they slept more in March than in June which was related to the seasonal change in daylight. There was a significant relationship between BMI and sleep habits: thinner girls slept a longer time and more quietly than the more corpulent girls.
Conclusion: The nutritional status of these girls influenced their sleep habits: this may have been either a direct causal relationship or a consequence of a protective attitude on the part of the mothers towards the frailer girls.

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Introduction

There is great interest in studying the sleep habits of children and adolescents, since they appear to be linked to somatic disorders such as respiratory diseases (Camhi *et al.*, 2000), injuries (Valent *et al.*, 2001), overweight or obesity (Gupta *et al.*, 2002), psychological conditions including anxiety, depression, and aggressive behavior (Meijer *et al.*, 2000); alcohol or substance consumption and social and family disturbances (Stein *et al.*, 2001; Vignau *et al.*, 1997). Many adolescents complain about too short a sleep length, difficulties in falling asleep and waking up, and sleepiness during the daytime (Vignau *et al.*, 1997). This is worrisome because of the negative association with daytime functioning, and especially school performance (Mantz *et al.*, 2000; Wolfson and Carskadon, 1998).

Sleep pattern is affected by developmental changes during childhood and puberty (Mercer *et al.*, 1998; Wolfson and Carskadon, 1998). Many studies indicate a decrease in total sleep length throughout puberty, mainly related to school schedules (Lee *et al.*, 1999; Mercer *et al.*, 1998). However, physiological sleep needs are not reduced during puberty; it is even possible that an increase is needed due to changes in the phase delay of the biological clock (Laberge *et al.*, 2001). A prospective study demonstrated that, without restriction, spontaneous length of sleep remained fairly constant throughout pubertal stages with a median time of 9.2 hours (Carskadon *et al.*, 1980). In industrialized countries, despite a noteworthy variability, studies report a longer sleep duration during the weekend (Mantz *et al.*, 2000; Meijer *et al.*, 2000; Mercer *et al.*, 1998; Shinkoda *et al.*, 2000; Thorleifsdottir *et al.*, 2002; Wolfson and Carskadon, 1998).

However, these studies do not summarize the sleep habits of all adolescents. It must be considered that, in many parts of the world, sleep length is not regulated by school schedules but by working activities inside or outside the household. This is the case in West Africa where many domestic tasks assigned to women and adolescent girls, like pounding millet or rice, or fetching and carrying water, take place early in the morning (Garnier and Bénéfice, 2001). In addition, these tasks are often strenuous, requiring an important energetic investment (Bleiberg *et al.*, 1980). They are also time- consuming, leaving very few occasions for women to have leisure time or rest during the day (Levine *et al.*, 2001). Moreover, in this context, sleeping or resting longer time during the weekend is a chimera, since many tasks have to be repeated day after day (Avotri and Walters, 1999).

In developing countries all children and adolescents are enrolled in daily subsistence tasks, but girls are required to play a greater role in domestic tasks and generally work longer than boys (Vanacker, 2000; Yamanaka and Ashworth, 2002). They participate more frequently in heavy duties at home and have shorter rest and sleep times than girls from industrialized countries (Torun *et al.*, 1996). Furthermore, insufficient dietary intake and malnutrition are prevalent in developing countries. Thus, high work loads and low energy intakes could lead to an energy imbalance with a waste of muscle mass impairing exercise tolerance (Shetty, 1999; Spurr, 1990). In these conditions, sleep length could be an effective way to spare energy and the physiological need for sleep could be even greater in active adolescents from developing countries than in adolescents from industrialized countries.

While the daily physical activity and energy expenditure of children from developing countries has been reasonably well studied up to now (Torun, 2002), far less is known about their rest and sleep habits. Hence the purpose of this study was to present data on sleep habits of a group of Senegalese adolescent girls. It specifically examines their sleep pattern according to age, growth, pubertal maturation and season of observation, and looks at the possible influence of nutritional status.

Subjects and Methods

Study area

Since 1995, our group has been performing a follow-up study on growth and maturation throughout puberty in a sample of approximately 390 adolescents, including almost all girls in the district of Niakhar (Center of Senegal) born in 1983 and 1984 (Bénéfice *et al.*, 2001b). We hypothesized that growth and maturation delays observed in these adolescent girls were linked to high daily energy expenditure due to an excessive workload that may create competition between familial and social pressure to work and the satisfaction of their nutritional and energy needs. Physical activity was thus quantitatively assessed using an electronic accelerometer and was monitored during 3 consecutive rounds from 1997 to 1999. Some results have already been published (Bénéfice and Cames, 1999; Bénéfice *et al.*, 2001a).

The study area belongs to the Sahelian climatic bend of West Africa, characterized by a long dry season (November to June) and a short rainy season (July to October). Farming and herding are the main productive activities. Farmers grow millet and cowpeas for food and peanuts for cash. Infant mortality and under-5 mortality rates dramatically decreased from 1963 to 1999 (213 per thousand to 80 per thousand and 485 per thousand to 213 per thousand, respectively) but they still remain high (Delaunay *et al.*, 2001). More than 25% of preschool children are chronically undernourished (stunted growth) and 7% are wasted according to the WHO Database on Child Growth and Malnutrition (http://www.who.int/nutgrowthdb/). There is a recurrence of food shortages at the end of the dry season and during the rainy season (Simondon *et al.*, 1993).

Selection of adolescent girls

Our purpose was to follow up, for 3 consecutive years encompassing puberty changes, a sub-sample of adolescents for in-depth studies of physical activity. Thus, forty girls were drawn in June 1997 from the initial cohort of adolescents present all year round in the area (mean age at inclusion: 13.3 ± 0.5 years). Economic difficulties generally force women and adolescent girls to temporarily migrate to cities to work as maids. As a consequence, it was not always possible to find the same girls from one year to another. When a girl was absent, she was replaced by another girl of the same age, living close by and belonging to the overall sample of 390 adolescents. This shift affected 9 to 10 girls at each round, leading to a coverage rate of 50%.

Objectives of the study and methods used were individually explained to the girls and their parents and to the leaders of the villages. Their oral consent was requested since they are illiterate. The study was approved by the review board of the IRD (French Institute for Research and Development) and by the yearly convention between the Ministry of Research of Senegal and the IRD. Further development of the study was approved by the newly installed ethic committee of Senegal under the presidency of the "Direction des Etudes de la Recherche et de la Formation" (DERF) of the Senegalese Ministry of Health.

Measurements

Adolescent girls were visited over 3 consecutive years: June 1997, June 1998 and March 1999. At each round they were weighed (kg) with an electronic scale accurate to 100g and their height (cm) measured with a portable Harpenden anthropometer. Deviations from the mean of the WHO/NCHS population were computed and expressed in z-score (WHO, 1983). The body mass index (BMI = weight/ height ^{2}, kg/m^2) was also calculated.

The triceps skinfold (mm) was measured at mid distance between the acromion and olecraneon with a Holtain calliper and the arm circumference (cm) was taken at the same site with a plastic tape. Measurements were done in duplicate and were averaged to minimize the variance. Inter- and intra- observer coefficients of variation were low (Bénéfice *et al.*, 2001b)

Sexual maturity was determined after inspection of breast development (Tanner, 1962). Maturation status was divided into 3 groups: prepubertal and onset of puberty (breast stages 1 and 2); mid-puberty (breast stages 3 and 4); end of puberty (breast stage 5). Girls were asked about the occurrence of their first menstruation. In some cases, they did not understand the question, and their mothers were asked instead.

Physical activity was evaluated using accelerometers to give accurate, objective values and by direct observation. Detailed description of the method has already been published elsewhere

(Bénéfice and Cames, 1999). Briefly, accelerometers are small (5 * 4 * 1.5 cm) and light (42.5 g) electronic monitors worn 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 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 4 consecutives days during the first round (June 1997) and 3 days during the subsequent round. The reason for this change was that we did not observe significant improvement in data reliability after 3 days of observation (Bénéfice and Cames, 1999).

In the present study, activity intensity was simply expressed as mean counts per minute (counts.min $^{-1}$) and resting time (min) was defined as the number of zero counts during the day, arbitrarily defined as 7 a.m. to 9 p.m. Rest was also expressed as the percent of time spent at zero counts during the same period.

To determine sleep length, accelerometry counts recorded between 20:00 and 8:00 were examined. Generally, the onset of sleep was straightforward, and appeared as a consecutive sequence of zero counts. Smooth movements with values under 20 counts.min^{-1} were frequently recorded during the sleep. Waking- up time was also evident, in the form of the steep onset of a succession of counts over 100. Determination of sleep duration was done manually for each night and each girl. Results were then computed for all adolescents and summarized in a unique file using Excel^{R} macro programming (Visual Basic ^{R}).

The following parameters were calculated:

- Mean length of sleep time, expressed in minutes and hours.
- Mean counts per minute (counts.min $^{-1}$), during sleep time. This was considered as an index of depth of sleep and hence of sleep quality.
- Standard deviations in mean counts during the sleeping period. This was taken as an index of variability in sleep quality.
- Time of falling asleep (h: min).
- Time of waking up (h: min).
- Mean counts per minute (counts.min $^{-1}$) during awakening.
- Mean length (min) of rest and percent of time spent resting during day.

Time of falling asleep was distinguished from bedtime, which was not recorded here. Both indices are presumed to be very closed in a normal situation. Total sleep duration was exactly calculated (sequences of zero counts sometimes interrupted by short periods < 25 counts.min) and thus was not simply the difference between the time of falling asleep in the evening and that of waking up in the morning. During the night certain girls woke up and performed activities such as caring for small domestic animals or carrying water (it occurred that water taps are opened for only a few hours at night). These activities were taken into account in the calculation and were removed from the total sleep length.

Statistical analysis

Normality of distributions was checked for each variable (D'Agostino, Martinez-Iglewicz tests or Kolmogorov-Smirnov tests) and could be assumed except for mean counts during wakefulness. In this case, a non-parametric test (Kruskal-Wallis) was used to study differences between groups. Student t-test, analysis of variance and co-variance were used to compare means or adjusted means of variables between visits. Post hoc, multiple comparisons were performed with a Newman-Keuls test. Repartition of discrete variables (breast development, menarche) was analysed with a Chi-square test. The association between sleep parameters taken as dependent variables and individual characteristics of girls taken as independent variables was studied with partial correlation and multiple regression procedures. Statistical analyses were performed using the NCSS software package (Hintze, 2000).

The nature of the surveys was not strictly longitudinal. Only 10 girls were completely followed up and while we carefully replaced the missing girl by a girl having the same characteristics and belonging to the cohort followed up since 1995, it possible that this affected the comparisons. This may occur if the variables of interest in girls followed up during the 3 rounds differ systematically from those of the girls not followed up. This hypothesis is tested in Table 1 by a 2-way analysis of variance analysing the cohort effect between categories of girls (those completely involved in the 3-round survey and those not involved) and the visit effect. This was not the case: there were no differences in age, nutritional status or sleep parameters between the 2 categories of girls and no interaction between category and round number. In the analysis, the successive samples were thus considered to be independent.

Reliability of accelerometry counts between nights of monitoring was estimated on the basis of the Cronbach alpha coefficient of consistency. It was moderately low ($r = 0.52$) but was considered to be acceptable under natural life conditions. Values were thus pooled over the 3 or 4 nights of monitoring.

Results

The adolescent girls studied here were undergoing a period of accelerated growth and sexual maturation at puberty. This is clearly apparent from Table 2 indicating changes in body dimensions during the 3 years of observation. It is interesting to note that while girls presented an increase in weight and height, their growth remained steady and below the median, in relation to their age group of the international WHO/NCHS reference. About a quarter of the girls (24.5%) had a height-age index below 2 z-scores and could be considered as stunted; this proportion did not change during the course of study. Only 30% had normal growth, above –0.5 z-score. Hence, 70% of the girls exhibited some degree of stunting. These girls displayed an increase in BMI and arm circumference, but not in triceps skinfold. There was a significant trend toward more sexual maturation throughout the study: about 80% of adolescents were pubescent at the end. However, only 10 girls experienced menarche at the end of the study (Table 3).

Differences in sleep parameters between subjects can be affected by individual characteristics. Since a subgroup of 10 girls had been visited on 3 occasions, it was possible to check the reliability of sleep indices. This was done by calculation of intraclass correlation coefficients (ICC) in the 3 rounds of study. The ICC was equal to 0.73 for sleep duration ($F= 3.77$, $p<0.01$); 0.58 for accelerometry counts during sleep ($F=2.5$, $p=0.06$); and 0.63 for variability in counts during sleep ($F=2.7$, $p<0.04$). From this limited sample, it could be assumed that sleep characteristics tracked well from one round to another and that, for the purpose of the present study, within-subject variability did not affect group comparisons.

There was a significant increase in sleep length during the course of the study (Table 4 a). This difference corresponded to roughly 30 minutes between the first and last visit. It must be emphasized that these values correspond to the true sleep duration, not to time spent in bed.

There was no difference in resting time during the day from one visit to another. Interestingly, the quality of sleep, as exemplified by movements during sleep and their standard deviations, improved in the sense that the values lowered. However, activity during periods of wakefulness did not change (table 4 b). When indices of sleep or rest were compared according to breast stage development or menarche, after adjusting for round differences, no significant differences were detected (Table 5). In a similar way, it could be demonstrated that no difference according to menarcheal status was noticeable (not shown here).

When looking at the trend of differences between visits, post-hoc tests indicate that the main difference occurred between the first two visit and the 3rd. Introducing age as a co-variable did not modify this relation. This is understandable, since a missing girl was replaced by her counterpart having the same age. Roughly speaking, age and visit number carry the same meaning and have the same effect on sleep parameters. Age alone had a limited but significant influence on sleep length ($r=0.23$, $p<0.01$), but this disappeared after adjusting for round number ($r = 0.01$, n.s). Because the first 2 rounds took place in June (end of the dry season) and the 3rd in March (mid dry season), we hypothesized that these differences might be linked to a difference in day/night length, rather than to aging. Indeed, in Senegal, the difference between March and June in the time of sunrise is 45 minutes (June: 06:35; March 07:20). It is 17 minutes for sunset (June 19:30 and March 19:13). Table 6 shows that girls fell asleep and woke up earlier in June than in March; they also slept more quietly and deeply in March. However, there were no changes according to rest time during the day and awakening time at night.

Correlations between age, anthropometric characteristics of the girls' sleep length, activity during the night and their rest during the day, partialized for a visit effect, are presented in Table 7.As expected, age was not correlated with any of sleep parameters. There were significant negative relationships between anthropometric variables and sleep length: the more corpulent, taller girls had a shorter sleep length than the thinner girls. No relationship was observed with triceps skinfold, nor with rest length. There were no significant relationships between activity counts during sleep and any of the anthropometric variables. However, rest during the day was negatively correlated with activity during the night: a longer rest meant less movement at night and hence better sleep quality.

To further explore our results, a model was built using a limited set of variables. Since there were redundancies between variables, for example, between weight and BMI, or height and

H-age, selection was performed using a step by step regression procedure. Only variables resulting in a significant increase in percent of variance explained were retained. After that, the predictive power of retained variables was tested with a multiple regression procedure (Table 8). Dependent variables included sleep length and sleep quality (accelerometry counts during sleep). Independent variables included age, BMI, index of nutritional status, H-age as an indicator of growth, and rest during the day. The NCSS package enabled treatment of one categorical variable, which was the month of survey (termed here "season") was also entered into the set of independent variables. The model explaining sleep length was significant ($p<0.0001$) (see Table 8 a) . Residuals were normally distributed and were not autocorrelated.(the Durbin-Watson value was 1.79 and there was no probability for positive or negative serial correlations). The model explained 23% of variance. BMI, but not H-age, was a significant predictor and had a negative regression coefficient. Seasonal effect was significant: June (end of dry season) had a negative effect compared with March (beginning of dry season). Whatever their age, more corpulent, i.e. better nourished adolescent girls, had a shorter sleep duration.

The coefficient of determination of the model for activity counts during the night (sleep quality) was lower ($R^2= 0.14$) but still significant ($p<0.005$). The model was not biased by autocorrelation of residuals (Durbin-Watson value = 2.11, no probability for positive or negative serial correlation). H-age and BMI did not predict body movements during sleep. Again, there was a significant season effect: accelerometry counts at night were higher in June compared with March. As noted in Table 7, rest duration during the day was negatively associated with accelerometry counts and hence positively with sleep quality. The effect was modest, though significant.

Discussion

As far as we are aware, this is the first study which has focused on sleep habits of adolescent girls living in a rural African milieu. Most of our knowledge of the topic stems from research carried out in industrialized countries. In those studies, the importance of sleep as a component of daily energy expenditure was seldom considered, apart from its relationship to obesity (Gupta *et al.*, 2002) or sports participation (Ribeyre *et al.*, 2000). However, in a developing country like Senegal where food insecurity is widespread and dietary intakes insufficient at certain periods (Simondon *et al.*, 1993), sleep and rest may act as a buffer mechanism to spare energy. In other words, a longer sleep time would permit lowering the total energy expenditure and preserving the energy balance. This could be the case in the present study: smaller, thinner girls slept longer and perhaps more deeply than the more corpulent girls.

Adolescent sleep patterns have been investigated in clinical settings using laboratory methods such as electrophysiological recordings. For epidemiological purposes, most studies rely on questionnaires either self-administered (Laberge *et al.*, 2001; Lee *et al.*, 1999; Mantz *et al.*, 2000; Meijer *et al.*, 2000; Mercer *et al.*, 1998; Sorensen and Ursin, 2001; Wolfson and Carskadon, 1998) or proposed to parents (Gulliford *et al.*, 1990), or else a diary kept by the subject (Thorleifsdottir *et al.*, 2002). In these studies, differences between time spent in bed and effective sleep duration are difficult to ascertain. Only a few studies have relied on objective methods such as accelerometry (Gupta *et al.*, 2002; Kramer *et al.*, 1999). In the present study, it was not possible to use questionnaires or diaries for practical reasons (the girls did not have a precise knowledge of time) and direct observation of behaviour implied an unacceptable intrusion into the adolescents' privacy. Use of the accelerometer was thus a good solution: it allowed for an objective and quantitative analysis of sleep length. It was also possible to monitor movements when awake or asleep. In epidemiological studies, accelerometer counts are considered to accurately and reliably reflect general activity (Trost, 2001). We had already used accelerometry to evaluate physical activity during day (Bénéfice and Cames, 1999; Bénéfice *et al.*, 2001a).

The main purpose here was to examine the effects of environmental or nutritional factors on the sleep of adolescents. In addition to these effects, individual variability is important and there exist substantial differences between "short" and "long" sleepers which are regulated by internal physiological factors (Aeschbach et al., 2003). However, good reliability in sleep duration during the course of the study was observed in the sub sample of girls having fully participated in the 3 rounds . It could thus be assumed that individual sleep characteristics did not change in the course of the survey and were not likely to interact with the variables of interest.

Did these Senegalese girls present different sleep habits from those of girls from developed countries? A longitudinal laboratory study showed that without constraints, sleep length is approximately 9.2 hours and remains constant throughout puberty (Carskadon *et al.*, 1980). This figure is only slightly higher than values from the present study (*8.55 ± 0.9 hours*). Sleep lengths extracted from questionnaire studies during school time range from a minimum of 449 ± 66 minutes (7:29 hours) (Wolfson and Carskadon, 1998) to 620 ± 63 minutes (10 :20 hours) (Gulliford *et al.*, 1990). Hence, results presented here hold a median range within these values (Gulliford *et al.*, 1990; Laberge *et al.*, 2001; Lee *et al.*, 1999; Mantz *et al.*, 2000; Meijer *et al.*, 2000; Mercer *et al.*, 1998; Sorensen and Ursin, 2001; Wolfson and Carskadon, 1998). Comparisons are only tentative, since the meaning of indicators is not always the same (time in bed versus sleep length) and the method may differ. However, it can be stated that free-living Senegalese did not differ markedly from other adolescents worldwide. Specifically, they did not *seem* to lengthen their sleep time in order to recover from fatigue, effort or high-level activity during the day. Such behaviour would have been plausible in view of the heavy burden of activities reported in previous studies (Bénéfice and Cames, 1999; Bénéfice *et al.*, 2001a). However, it has been reported that in rural areas their time schedule is less constrained than in the cities: adolescent rural girls apparently slept a longer time than rural girls working as maids (Garnier and Bénéfice, 2001).

At first glance, it appeared that sleep length increased throughout the course of study and hence with age (visits were done yearly at 10 to 12 month intervals). Though, a close inspection of data reveal that this age effect hide a marked seasonal effect. The difference between sunset and sunrise is 1:02 hours between March and June. The difference is greater in the morning (sunrise occurs 45 minutes earlier in June) than in the evening (sunset is 17 minutes later in June). These changes are partially reflected by the sleep habits of adolescent girls: they fall asleep 17 ± 44 minutes earlier in March than in June and wake up 12 ± 28 minutes later (Table 4). Activities are limited in the evening for obvious reasons (there is no electrical supply in the villages) and have to be performed by fire or kerosene lamp lights. Because domestic tasks are compulsory, women and girls take advantage of sunlight and generally do not prolong their sleep after 6:30 whatever the season. It must also be emphasized, that the torrid heat of the afternoon – especially at the end of the dry season- forces the population to perform strenuous tasks such as pounding millet or fetching water early in the morning or in the evening. Environmental constraint such as this weather effect need to be taken into account. Another plausible constraint not addressed here, is the heat of rooms during the night that could disturb sleep and its peacefulness. Insect bites obviously did not affect sleep quality here, since the mosquito concentration is low during the dry season.

Indeed nutritional status represented here by anthropometric indices, had a consistent and independent effect on sleep length and sleep quality. Thinner girls slept a longer time and also more deeply than normal or corpulent girls. Calculations indicates that a one- standard-deviation difference in BMI between girls (BMI < 15.5 kg/m^2 versus BMI > 17.5 kg/m^2) results in a 25- minutes difference in sleep length. Two interpretations could be proposed. First, a longer sleep length and quality is required by the malnourished girls in order to fulfil their daily tasks. In this sense, sleep length is an effective way to regulate energy expenditure or to recover after heavy exercise. It is known that body dimensions and muscle mass in marginally malnourished children are key determinants of their activity levels (Spurr, 1990). Spurr and colleagues demonstrated that during a summer day-camp, moderately malnourished boys were able to increase their level of activity, but they could not sustain their effort for more than 2 hours (Spurr and Reina, 1988). In the adolescents studied here, a previous study reported a significant effect of the nutritional state (BMI) on their total activity volume. High BMI girls were also more active during the night and the day than low BMI girls (Bénéfice et al., 2001a). It is thus tempting to hypothesize that malnourished girls need a longer time to fully recover after effort than normal girls, and this is reflected by a longer sleep duration. While low BMI girls did not rest more than the others during the day, there was a negative relationship between rest and sleep quality. This is suggestive of a general disposition of certain girls to be more agitated than others. The absence of an association between nutrition status and rest could be explain by a "peer pressure" effect during the day as described by Spurr (Spurr and Reina, 1988) and by the involvement of these girls in compulsory domestic tasks. Such an association has nevertheless been suggested in a study of energy balance of active Nepalese women in whom herding animals, a task that involves long periods of rest, resulted in less body mass variation than farming, during the season of peak agricultural work (Panter-Brick, 1996)

An alternative explanation would be that the longer sleeping time which was allowed to the thinner girls was due to the compassion of their mothers. The stunted, thin girls look younger than their real age and elicit a protective attitude on the part of their parents. An example of such solicitude has been reported in this district in the case of breastfeeding of malnourished babies (Simondon *et al.*, 2001). It is clearly evident that in rural Africa, women are overburdened by the different roles they must assume (Avotri and Walters, 1999; Levine *et al.*, 2001; McGuire and Popkin, 1988). They need to be helped by their daughters. However, sharing of tasks within the household according to the competence and fitness of the members is likely to occur (Bénéfice *et al.*, 2001a). Allowing the frailer girls to sleep longer is an effective means of alleviating their efforts. It should be underlined that such a protective attitude does not exist in the cities, where migrant girls work as maids and are forced to accomplish their duties whatever their age or nutritional status (Garnier and Bénéfice, 2001).

Finally, the relationship observed between growth represented by height or height-for-age, and sleep length (Table 6), does not hold true in the multiple regression procedure. Laboratory studies suggested that growth hormone is released during the night, precisely during the slow-wave phase of sleep (Van Cauter and Copinschi, 2000). However, the link between short stature and a sleep pattern has not been fully demonstrated. Moreover, one study specifically addressing this topics found an inverse relationship (Gulliford et al., 1990). Similarly there were no relationships between sexual maturity and sleep pattern. It may be observed that these Senegalese girls displayed a noticeable delay in puberty compared with girls from industrialized countries: only 10 girls (25%) experienced menarche at 15 years of age. This figure is in agreement with values reported in the same area: the median age at menarche was estimated to be 16.2 years using a probit analysis in sample of 1126 girls (Simondon et al., 1997).

In conclusion, this group of adolescent Senegalese girls, who were surveyed in their true life conditions, present a sleep length within the median range reported in the literature. Environmental constraints (seasonal variation in daylight), but not age or pubertal maturity, were significant determinants of their sleep pattern, and a relationship between nutritional status and sleep length, either as a cause or a consequence, was established.

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Table 1: Analysis of the cohort effect and of the visit effect in girls followed up at each round compared to girls not followed up.

Variables	Differences between categories [1] of adolescent girls (A) F (2,114)	Differences between visit (B) F (1,114)	Interaction between A and B F (1,114)
Age (year)	3.0 [2]	101.2	0.12
	n.s [3]	0.0001	n.s
BMI (kg/m2)	0.03	5.61	0.29
	n.s	0.04	n.s
H-age (z-score)	0.28	2.12	0.16
	n.s	n.s	n.s
Sleep length	0.12	4.17	0.42
(min)	n.s	0.01	n.s

[1] category 1: girls followed up at each round (n=10); category 2: girls not followed up at each round.
[2] F value
[3] probability (n.s : not significant)

Table 2: Anthropometric characteristics of adolescent girls according to round number (n= 40 at each round)

Variables	Rounds	Mean	SD[1]	F (2, 119)	p [2]
Age (years)	1	13.3	.53	137.8	.000
	2	14.3	.57		
	3	15.2	.47		
Total		14.3	.96		
Weight (kg)	1	35.4	6.1	11.1	.000
	2	40.3	9.1		
	3	43.2	7.0		
Total		39.7	8.1		
Height (cm)	1	149.1	7.2	9.2	.000
	2	152.0	8.8		
	3	156.6	7.6		
Total		152.6	8.4		
Arm circumference (cm)	1	20.7	2.0	3.7	.026
	2	21.1	2.8		
	3	22.1	2.1		
Total		21.3	2.4		
Triceps skinfold (mm)	1	8.6	3.6	1.2	n.s
	2	9.8	4.1		
	3	9.6	3.5		
Total		9.4	3.7		
Body mass index (kg/m2)	1	15.8	1.9	6.3	.002
	2	17.2	2.8		
	3	17.5	2.0		
Total		16.9	2.4		
H-age (z-score)	1	-1.30	1.18	2.7	n.s
	2	-1.30	1.28		
	3	-.78	1.16		
Total		-1.14	1.22		
W-age (z-score)	1	-1.56	.83	.4	n.s
	2	-1.41	1.03		
	3	-1.37	.87		
Total		-1.44	.91		

[1] SD: standard deviation
[2] p value for significance; n.s.: not significant

Table 3: Sexual maturation of adolescent girls according to round number (expressed in percent of total; n= 40 at each round)

Variable	Round 1	Round 2	Round 3	χ^2 (p)
Breast stage				
1: beginning	62.5	50.0	19.0	20.2
2: mid- puberty	32.5	42.5	54.8	(p<0.001)
3 adult appearance	5.0	7.5	26.2	
Total (%)	100.0	100.0	100.0	
Menarche				
1: yes	5.0	22.5	25	6.2
2: no	95.0	77.5	75	(p<0.04)
Total (%)	100.0	100.0	100.0	

Table 4 a: Sleep (night) and rest (day) parameters of adolescent girls, according to round number (n=40 at each round)

Variables	Round number	Mean	SD [1]	F (2, 119)	Multiple comparisons [2]
Sleep length (min)	1	499	52	5.21	3 <1,2
	2	506	44	p<0.006	
	3	535	59		
Total		513	54		
Sleep length (hours)	1	8.31	0.87	5.19	3 < 1, 2
	2	8.43	0.74	p<0.006	
	3	8.90	0.98		
Total		8.55	0.91		
Counts during sleep	1	13.1	4.7	4.18	3 < 1,2
($counts.min^{-1}$)	2	13.9	6.6	p < 0.01	
	3	10.2	5.8		
Total		12.4	6.2		
Variability in counts	1	90.8	54.3	6.11	3 < 1,2
during sleep	2	91.7	44.4	p < 0.003	
	3	60.3	37.0		
Rest length during the day (min)	1	93	54	1.04	
	2	111	65	n.s	
	3	103	51		
Total		102	57		
% of time resting during the day	1	11.8	6.9	1.45	
	2	14.2	8.3	n.s	
	3	14.3	7.0		
Total		13.5	7.5		

[1] SD: standard deviation

[2] Newman-Keuls post hoc test

Table 4 b: Activity counts during wakefulness of adolescent girls, according to round number (Kruskal Wallis test)

Variables	Round number	Median	Mean rank	$\chi 2$
Counts during wakefulness	1	620.26	66.40	1.97
($counts.min^{-1}$)	2	532.80	55.60	n.s
	3	531.50	59.40	

Table 5: Sleep (night) and rest (day) lengths of adolescent girls, according to puberty
status (adjusting for age at visit)

	Puberty status	Mean	SD	F (2,116)	p
Sleep length (min)	1	519	52.3	0.61	ns
	2	508	55.6		
	3	509	57.7		
Counts during sleep (counts.min^{-1})	1	12.1	5.2	0.10	n.s
	2	12.7	7.1		
	3	12.6	6.3		
Rest duration during the day (min)	1	111	57.6	0.99	ns
	2	95	57.7		
	3	96	61.1		

Table 6 a: Seasonal variation in sleep (night) and rest (day) lengths of adolescent girls

Variable	Season	Mean	SD	t-value	p
Falling asleep time	June	21:57	0:41	2.32	0.02
	March	21:37	0:48		
Waking time	June	6:24	0:27	2.39	0.02
	March	6:38	0:31		
Sleep length (min)	June	502	48	3.18	0.001
	March	535	59		
Counts during sleep ($counts.min^{-1}$)	June	13.5	6.2	2.83	0.05
	March	10.2	5.8		
Variability in counts	June	91.3	49.3	3.50	0.0006
	March	60.3	37.1		
Rest length (min)	June	102	60	0.14	n.s
	March	103	51		

Table 6 b: Seasonal variation in activity counts during wakefulness (Mann-Whitney test)

	Season	Median	95% LCL	95% UCL	Z-Value	p
Counts during wakefulness ($counts.min^{-1}$)	June	578	519	621	0.22	ns
	March	532	478	642		

Table 7: Partial correlations between sleep length, anthropometric parameters and rest length (controlling for visit effect)

	sleep length	Counts during sleep
Age	0.01	0.10
	n.s	n.s
Weight	-0.36	-0.12
	0.00	ns
Height	-0.18	-0.14
	0.05	ns
Arm circumference	-0.27	-0.09
	0.00	ns
Triceps skinfold	-0.15	0.00
	ns	ns
BMI	-0.36	-0.08
	0.00	ns
H-age	-0.18	-0.15
	0.05	ns
W-age	-0.35	-0.16
	0.00	0.09
Rest during day	0.16	-0.19
	ns	0.04

Table 8 a: Summary of a multiple regression analysis between sleep length and rest length, season, age, BMI, and H-age (independent variables).

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	R^2	T-Value to test H0:B(i)=0	Prob Level
Age	8.90	7.00	0.01	1.27	n.s
H-age	-6.07	3.98	0.02	-1.53	n.s
BMI	-6.85	2.05	0.08	-3.35	0.00
Rest length	0.13	0.08	0.02	1.66	n.s
Season	-30.17	13.71	0.03	-2.20	0.03

R^2	0.23
Coefficient of Variation	0.09

Table 8 b : Summary of a multiple regression analysis between activity counts during sleep and rest length, season, age, BMI, and H-age (independent variables).

Independent Variable	Regression Coefficient b(i)	Standard Error Sb(i)	R^2	T-Value to test H0:B(i)=0	Prob Level
Age	1.23	0.86	0.02	1.44	n.s
H-age	-0.30	0.49	0.00	-0.62	n.s
BMI	-0.32	0.25	0.01	-1.29	n.s
Rest length	-0.02	0.01	0.04	-2.27	0.03
Season	4.56	1.68	0.06	2.72	0.01

R^2 (model)	0.14
Coefficient of Variation	0.48