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Sleep Duration in Adolescence and Its Prenatal, Perinatal, and Health Determinants in a Large Population-based Cohort Followed from Birth

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Abstract

Objective To investigate sleep duration and its associated factors in adolescents aged 11 years from the 2004 Pelotas (Brazil) Birth Cohort Study.

Methods Sleep duration was assessed using a self-report sleep habits. Independent variables included perinatal, sociodemographic, behavioral, and health characteristics. The associations were estimated using multiple linear regression.

Results The mean sleep duration of 3,179 adolescents was 9.3 hour (SD =1.7 hour). Longer sleep duration was associated with lower socioeconomic status at birth (β: 0.37, 95% CI: 0.12; 0.61), lower mother's education level ($p < 0.001$), and being female (β: 0.19, 95% CI: 0.06; 0.33). Shorter sleep duration was associated with cesarean section delivery (β: −0.16, 95% CI: −0.31; -0.02); having classes in the morning shift (β: −1.38, 95% CI: −1.51; -1.26), and lower terciles of physical activity ($p = 0.04$).

Conclusions The mean sleep duration observed in this study was consistent with the international recommendations for this age range. Adolescents from lower income families, who are more active, study in shifts other than morning, girls, and those born through vaginal delivery presented higher sleep duration than their counterparts.

Keywords
- sleep
- adolescent
- sleep deprivation
- epidemiology

Introduction

Sleep is an essential biological process for an individual's physical and mental development. Changes in sleep patterns and duration have been observed not only in adults but also in children and adolescents.[1] Sleep duration tends to decrease during the transition from childhood to adolescence, which is related to biological (including puberty and hormonal changes), psychological, and sociocultural factors.[2] Sufficient sleep time is vital to maintain adequate cognitive and behavioral function, and alertness during the day.[3] According to international recommendations, teenagers should sleep 8–10 hour every 24 hour.[4,5] The average total nighttime sleep measured by actigraphy and reported in a recent systematic review (age: 0–18 years) and meta-

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analysis of studies (age: 3–18 years) were 8.85 hours in 9–11 years old, 8.05 hours in 12–14 years old, and 7.40 hours in the 15–18 years.[6]

Insufficient sleep can cause tiredness in the morning, drowsiness, impaired functioning of daytime tasks, mood disturbances, decreased motivation, as well as physical (such as cardiovascular disease) and mental (such as depression and anxiety) problems during adolescence.[7] In addition, long-term consequences can be observed, such as diseases in adulthood, e.g., increased risk of cardiovascular disease.[7]

The possible determinants of shorter sleep duration in adolescence are prenatal maternal factors (such as smoking, alcohol consumption, depression, and anxiety during pregnancy)[8]; individual characteristics, such as sex[9]; early characteristics, such as hyperactivity until the age of 5 years[8]; lifestyle habits resulting from the availability of computers and televisions in the bedroom[10]; and socioeconomic characteristics in adolescence (lower socioeconomic status has been associated with shorter sleep time).[11] However, studies evaluating these factors showed inconsistent results, opposite results, or an absence of association.

Most studies evaluating the sleep duration determinants were conducted in high-income countries, which may not reflect the reality of the sleep pattern and duration of adolescents in low- and middle-income countries.[11,12] Sleep duration can be related to environmental factors, such as the season of the year, number of hours that an individual is exposed to natural sunlight, and cultural factors.[1,2] Thus, the social and demographic factors can play different roles in sleep duration in adolescents from different countries.[11,12]

Given the importance of sleep to the adolescents' health and development and considering that this is a critical period for determining health in adulthood,[7] it is important to identify the sleep duration and its determinants. Although population-based studies have been conducted to investigate the sleep duration among adolescents,[13] research on duration and its determinants, especially the early factors, remain scarce. Thus, this study aimed to describe sleep duration in adolescents who participated in the 2004 Pelotas Birth Cohort Study and to investigate its association with socioeconomic, demographic, behavioral, and health characteristics.

Material and Methods

Study Design and Sample

This cross-sectional study used the data of the 2004 Birth Cohort Study from Pelotas, RS, Brazil. The original cohort population consists of 4,231 children born between January 1 and December 31, 2004, whose mothers resided in the urban area of Pelotas and Jardim América (currently Capão do Leão municipality). The mothers were interviewed shortly after birth (perinatal study). Follow-ups were performed at 3 months and at 1, 2, 4, 6, 11, and 15 years. In the present study, the data collected during the perinatal period and the follow-up data obtained from children aged 4 and 11 years were used (follow-up rates of 99.2%, 90.2% and 86.6%, respectively). Twins were excluded, and only those with complete data on sleep duration were included. After reviewing the data, those sleeping <4 hour or >15 hour per night were excluded, since they were considered implausible values ($n = 16$ participants). More detailed information about the cohort can be accessed in other publications.[14,15]

Outcome

Sleep duration was assessed based on the adolescents' answers to the questions related to bedtime and waking hours, as well as latency time. The relevant questions were as follows: "During the past month, what time have you usually gone to bed at night?," "How long (in minutes) has it usually taken for you to fall asleep each night?," and "What time have you usually got up in the morning?" Sleep time was calculated as the period between the time the adolescent reported going to bed at night and waking up in the morning subtracted by the latency time. These questions were extracted from the Pittsburgh Sleep Quality Index, developed by Buysse,[16] and validated in Brazil in adolescent population by Passos.[17]

Exposures

The exposure variables were socioeconomic and demographic, health, and behavioral characteristics.

Variables Collected in the Perinatal Study

The variables obtained in the perinatal study were as follows: socioeconomic index (National Economic Indicator [IEN]), was established by performing a main component analysis of the 12 consumer goods and education levels of the head of the family (subsequently categorized into quintiles)[18]; mother's education (completed years of education), which was divided into four categories (0, 1–4, 5–9, or >9 years); mother's age in full years (divided into three categories: <20, 20–34, or ≥ 35 years); maternal smoking status during pregnancy, which was determined by the answering the question, "Did you smoke during pregnancy?"; alcohol consumption during pregnancy, which was determined by asking the mother if she used to drink alcohol during pregnancy; presence of depression or nervous problem during pregnancy, which was determined by the answering the question, "Did you have depression or any emotional problems during pregnancy?"; type of delivery (-vaginal/cesarean); gestational age, which was identified using the Dubowitz method[19] (prematurity: <37 weeks); adolescent sex (woman/man); adolescent's skin color (-white/black/others); birth weight (recorded in the birth certificate) (low birth weight (LBW): $<2{,}500$ g); and 5-minute Apgar score (dichotomized into <7 points or ≥ 7 points).

Variables Collected in Other Follow-ups

At the four-year follow-up, mothers were asked about the total time they had breastfed their child, which were later categorized into five groups: ≤ 1, 1.01–3, 3.01–6, 6.01–12, and >12 months).

The body mass index (BMI) of the 11-year-old adolescent was calculated by dividing the weight (measured with a scale coupled to the air displacement plethysmography device

[BodPod®] by height in meters squared (using a Harpenden® portable stadiometer). BMI was analyzed according to the specific recommendation for age and sex: ≥5th percentile and <85th percentile (normal weight), ≥85th percentile and <95th percentile (overweight), and ≥95th percentile (obesity).[20] The variable physical activity of the adolescent was assessed for 5 full days using an accelerometer (a device placed on the adolescent's dominant arm) and measured in bouts (periods with predefined durations, in consecutive minutes) of 5 minute/d and categorized into tertiles. Data on the participants' school shift was used to analyze whether the adolescent studied or not in the morning. Room sharing was assessed by asking the mother whether the teenager slept alone or not. The presence of psychiatric disorders was assessed at the age of 11 years using the Portuguese version of the Development and Well-Being Assessment tool (DAWBA), which has been cross-culturally adapted and validated for using in Brazil.[21] Mothers or guardians were interviewed by trained psychologists. Psychiatric disorders were assessed based on the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), and the relevant questions were answered by yes or no. The clinical evaluation of the total sample was performed by a psychologist. A second independent psychologist evaluated 10% of the study sample. Both were trained in how to apply the DAWBA, in a standardized manner. The inter-rater agreement was 91.2% for the presence of any psychiatric disorder. More detailed information about the training and the application of DAWBA can be obtained elsewhere.[22]

Statistical Analysis

First, a descriptive analysis was performed. The mean sleep duration, their standard deviations (SDs) and their corresponding 95% confidence intervals (95% CI) were presented according to the exposure variables. Multiple linear regression analyses by hierarchical levels were conducted to investigate the factors associated with sleep duration.[8] The hierarchical model was organized into three levels. Level 1 included the socioeconomic index, maternal education and age, maternal smoking and alcohol consumption, and mental health during pregnancy. Level 2 included the type of delivery, gestational age, teenager' sex and skin color, birth weight, 5-minute Apgar score, and duration of breastfeeding. Level 3 included teenager's BMI, physical activity level, school shift, room sharing status, and mental health. All variables were included following the hierarchical level in the adjusted analysis using the stepwise backward selection method. The inclusion of variables was made according to a statistical criterion (p value of <0.20). The significance level was set to 5%, and tests were two-tailed. STATA 15.0 software (Stata Corp., College Station, TX, USA)[23] was used to perform all analyses.

Ethics

All follow-ups of the 2004 Pelotas Birth Cohort Study were approved by the Research Ethics Committee of the School of Medicine of the Federal University of Pelotas. In addition, an informed consent form was signed by the adolescent's mother or guardian, authorizing participation in each stage of the study. Teenagers aged 11 years were also asked to sign a consent form prior to their participation in the study.

Results

After excluding twins ($n = 84$), 3,179 adolescents with valid responses to the question related to sleep duration were included in the present study. ►**Table 1** shows the description of the sample and the comparison between individuals included and those who were not included in the study, according to the perinatal variables. A difference was found between individuals included and those who were not included in terms of socioeconomic index (IEN) and maternal education (higher proportions of adolescents from the lowest quintile of IEN and children of less educated mothers among those not included), maternal age (lower proportions of older mothers among those not included). There was a higher proportion of mothers who had depression or emotional problems during pregnancy; of preterm infants, infants with LBW, and infants with a 5-minute Apgar score <7 among those not included.

Of the total participants, 45.7% were born from mothers with ≥9 years of education, while 66.9% were born from mothers aged 20–34 years. The prevalence of mothers who smoked, consumed alcohol, and had depression or emotional problems during pregnancy were 26.7%, 3.3%, and 23.9%, respectively. Approximately 12.3% of the participants were born preterm, 7.7% had LBW, and 1.3% had a 5-minute Apgar score <7 (►**Table 1**). About one-third (33.2%) of the participants were breastfed for >12 months. Regarding to the characteristics of participants aged 11 years, more than half (55.3%) had adequate BMI, 49.7% studied in the morning shift, 41.0% shared a room with another person, and 12.5% was the prevalence of any psychiatric disorder (►**Table 1**).

The mean sleep duration of participants aged 11 years was 9.3 hour (SD = 1.7 hour; median = 9.25; 95% CI: 9.22–9.35). ►**Table 2** shows the mean, SD, and 95% CI of sleep duration, according to the variables studied. Adolescents belonging to families in the lowest (poorest) income quintile had, on average, nighttime sleep duration of 33.6 minute longer compared with adolescents in the richest quintile (9.63 hour, SD 1.83 hour versus 9.07 hour, SD 1.59). Children of uneducated mothers had 1 hour and 6 minutes more sleep per night compared with those of mothers with ≥9 years of education. Compared with those born through cesarean section, adolescents born vaginally, as well as girls, those with normal weight, and those who shared a room with another person showed longer mean sleep duration. Furthermore, the mean sleep duration of adolescents who studied in the morning was 1 hour and 22 minute shorter than that of adolescents who studied in other shifts (8.59, SD = 1.55 hour versus 9.96 hour, SD = 1.64).

►**Table 3** shows the results of crude and adjusted analyses of sleep duration, according to the exposure variables. In the crude analysis, the lower the income quintile and the lower the maternal education, the longer the sleep duration of

Table 1 Sample characterization according to exposure variables and comparison between participants included and not included in the study according to perinatal period variables ($N = 4,147$) *. 2004 Pelotas Birth Cohort Study

Variables	Included sample ($n = 3,179$) % (95% CI)	Not included ($n = 968$) % (95% CI)**
Variables collected at the perinatal period		
Familiar Socioeconomic Index (IEN) ($n = 3,202$)		
Quintile 1 (poorest)	19.1 (17.6–20.7)	31.4 (27.9–35.0)
Quintile 2	18.8 (17.4–20.4)	19.5 (16.7–22.8)
Quintile 3	20.2 (18.7–21.8)	16.7 (14.0–19.7)
Quintile 4	21.4 (19.8–23.0)	14.2 (11.8–17.1)
Quintile 5 (richest)	20.5 (19.0–22.1)	18.2 (15.4–21.3)
Maternal education (years of study) ($n = 4,104$)		
0	0.8 (0.5–1.2)	1.9 (1.2–3.0)
1–4	13.1 (12.0–14.4)	19.0 (16.6–21.6)
5–8	40.4 (38.7–42.2)	43.7 (40.6–46.9)
9 or more	45.7 (43.9–47.4)	35.4 (32.5–38.5)
Maternal age (years) ($n = 4,143$)		
< 20	18.9 (17.6–20.3)	19.6 (17.2–22.2)
20–34	66.9 (65.3–68.5)	69.7 (66.7–72.5)
≥ 35	14.2 (13.0–15.4)	10.7 (8.9–12.8)
Maternal smoking during pregnancy ($n = 4,145$)		
Yes	26.7 (25.2–28.2)	30.4 (27.6–33.4)
Alcohol consumption during pregnancy ($n = 4,145$)		
Yes	3.3 (2.7–4.0)	3.7 (2.7–5.1)
Depression or nervous problems during pregnancy ($n = 4,143$)		
Yes	23.9 (22.4–25.4)	28.9 (26.1–31.8)
Cesarean section ($n = 4,145$)		
Yes	45.52 (43.8–47.3)	42.24 (39.2–45.4)
Preterm birth ($n = 4,133$)		
<37 weeks	12.3 (11.2–13.5)	17.6 (15.3–20.1)
Adolescent's biological sex ($n = 4,147$)		
Male	51.3 (49.6–53.1)	54.1 (51.0–57.3)
Adolescent skin color ($n = 3,596$)		
White	68.1 (66.4–69.7)	65.2 (61.1–69.1)
Black	12.4 (11.3–13.7)	12.2 (9.7–15.2)
Other[a]	19.5 (18.1–20.9)	22.7 (19.3–26.4)
Low birth weight (< 2500 g) ($n = 4,142$)		
Yes	7.7 (6.8–8.7)	13.2 (11.2–15.5)
5th minute APGAR score ($n = 4,118$)		
< 7 points	1.3 (0.9–1.7)	4.9 (3.7–6.5)
Variables collected at the 4-year follow-up		
Breastfeeding duration (in months) ($n = 3,167$)		
≤ 1	13.4 (12.2–14.6)	–
1.01–3	20.5 (19.1–21.9)	–
3.01–6	14.4 (13.2–15.7)	–

(*Continued*)

Table 1 (*Continued*)

Variables	Included sample ($n = 3,179$) % (95% CI)	Not included ($n = 968$) % (95% CI)**
6.01–12	18.6 (17.2–20.0)	–
> 12	33.2 (31.6–34.8)	–
Variables collected at the 11-year follow-up		
Body Mass Index (BMI) ($n = 3,118$)		
Eutrophic	55.3 (53.5–57.0)	–
Overweight	22.6 (21.2–24.1)	–
Obesity	22.1 (20.6–23.6)	–
Physical activity (minutes/day) ($n = 3,000$)		
1° tercile (less active group)	33.3 (31.7–35.0)	–
2° tercile	33.3 (31.7–35.0)	–
3° tercile (more active group)	33.3 (31.7–35.0)	–
Morning shift school ($n = 3,164$)		
Yes	49.7 (48.0–51.5)	–
Bedroom sharing ($n = 3,172$)		
Yes	41.0 (39.3–42.7)	–
Any psychiatric disorder (DSM-5) ($n = 3,174$)		
Yes	12.5 (11.4–13.7)	–

Abbreviations: 95% CI, 95% confidence interval; BMI, Body Mass Index; DSM-5, Diagnostic and Statistical Manual of Mental Disorders; IEN, National Economic Indicator.

*Eighty-four twins were excluded from the total ($n = 4,231$) of cohort participants.

[a]Other: skin color other than white or black.

adolescents ($p < 0.001$ for linear trend tests). Girls had longer sleep duration (β: 0.21; 95% CI: 0.09–0.33) compared with boys. Children born through cesarean section −0.25; 95% CI: (−0.37 to −0.13). had shorter sleep duration compared with those born through vaginal delivery. Adolescents who were in the adequate BMI category had shorter sleep duration ($p = 0.001$ for linear trend test) compared with those from the overweight and obesity categories; when going from the least physically active tertile to the most active tertile, sleep duration increased (linear trend $p = 0.044$). Adolescents who studied in the morning (β: −1.37; 95% CI: −1.48 to −1.26) and who shared a bedroom with another person (β: −0.21; 95% CI: −0.34 to −0.09) had lesser sleep duration (►**Table 3**).

After adjusting for confounding factors, adolescents belonging to families in the lowest income quintile had a longer sleep duration (β: 0.37; 95% CI: 0.12–0.61) compared with those in the highest (richest) income quintile. Children whose mothers had a lower education level had a longer sleep duration ($p < 0.001$ for linear trend test). Girls (β: 0.19; 95% CI: 0.06–0.33) had longer sleep duration compared with boys. Adolescents born through cesarean section (β: −0.16; 95% CI: −0.31 to −0.02), who were in first tertile of physical activity (β: −0.25; 95% CI: −0.42 to −0.08), and studied in the morning (β: −1.38; 95% CI: −1.51 to −1.26) had fewer hours of sleep than those born through vaginal delivery, who were more physically active, and did not study in the morning respectively (►**Table 3**).

Discussion

Principal Findings and Interpretation

This study assessed the sleep duration of and its association with sociodemographic, behavioral, and health characteristics in Brazilian adolescents. Adolescents slept an average of 9.3 hour at night. Sleep duration was longer in the lower-income adolescents, children of uneducated mothers, and girls. It was shorter in children who were born through cesarean section, performed fewer physical activities, and studied in the morning.

The mean sleep duration observed in our study is within the recommended time for adolescents[5,24] and it was higher than the reported in the literature for this age group. The sleep duration observed in a multicenter study, which included 117,888 adolescents from 11 European countries (Austria, Estonia, France, Germany, Hungary, Ireland, Israel, Italy, Romania, Slovenia, and Spain), with a mean age of 14.9 years, reported a mean sleep duration of 7.7 hour per night.[25] In a study including 15,701 American teenagers, the mean sleep duration was 8.5 hour for those aged 13 years.[26] In another North American study conducted in 9,251 adolescents, the mean sleep duration for weekdays and weekends

Table 2 Means of sleep duration (in hours), standard deviation (SD) and 95% confidence interval (95%CI), according to the exposure variables ($N = 3{,}179$), 2004 Pelotas Birth Cohort Study

Variables	Sleep duration	
	Mean (SD)	95% CI
Variables collected at the perinatal period		
Familiar Socioeconomic Index (IEN)		
Quintile 1 (poorest)	9.63 (1.83)	9.47; 9.80
Quintile 2	9.36 (1.80)	9.20; 9.52
Quintile 3	9.20 (1.66)	9.06; 9.34
Quintile 4	9.27 (1.75)	9.12; 9.42
Quintile 5 (richest)	9.07 (1.59)	8.93; 9.20
Maternal education (years of study)		
0	10.19 (1.59)	9.53; 10.84
1–4	9.67 (1.77)	9.50; 9.84
5–8	9.36 (1.77)	9.26; 9.45
9 or more	9.09 (1.68)	9.01; 9.18
Maternal age (years)		
< 20	9.30 (1.68)	9.17; 9.44
20–34	9.28 (1.77)	9.20; 9.35
≥ 35	9.29 (1.66)	9.14; 9.44
Maternal smoking during pregnancy		
No	9.27 (1.69)	9.21; 9.34
Yes	9.32 (1.87)	9.19; 9.44
Alcohol consumption during pregnancy		
No	9.29 (1.73)	9.23; 9.35
Yes	9.19 (1.91)	8.82; 9.57
Depression or nervous problems during pregnancy		
No	9.27 (1.72)	9.20; 9.33
Yes	9.35 (1.79)	9.23; 9.48
Type of delivery		
Vaginal	9.40 (1.74)	9.32; 9.48
Cesarean section	9.15 (1.72)	9.06; 9.24
Preterm birth (< 37 weeks)		
No	9.28 (1.68)	9.12; 9.45
Yes	9.29 (1.75)	9.22; 9.35
Adolescent's biological sex		
Male	9.18 (1.75)	9.10; 9.27
Female	9.39 (1.72)	9.31; 9.48
Adolescent's skin color		
White	9.25 (1.69)	9.18; 9.32
Black	9.30 (1.78)	9.12; 9.48
Other[a]	9.44 (1.88)	9.29; 9.59
Low birth weight (< 2500 g)		
No	9.35 (1.67)	9.14; 9.56
Yes	9.28 (1.74)	9.22; 9.34
5^{th} minute APGAR score (< 7)		
No	9.17 (1.94)	8.55; 9.79
Yes	9.29 (1.74)	9.23; 9.35
Variables collected at the 4-year follow-up		
Breastfeeding duration (in months)		
≤ 1	9.29 (1.80)	9.12; 9.46
1.01–3	9.32 (1.81)	9.18; 9.46
3.01–6	9.17 (1.71)	9.01; 9.33
6.01–12	9.28 (1.73)	9.14; 9.42
> 12	9.32 (1.68)	9.22; 9.42
Variables collected at the 11-year follow-up		
Body Mass Index (BMI)		
Eutrophic	9.38 (1.70)	9.30; 9.46
Overweight	9.17 (1.71)	9.04; 9.30
Obesity	9.13 (1.81)	9.00; 9.27
Physical activity (minutes/day) ($n = 3{,}000$)		
1° tercile (less active group)	9.20 (1.71)	9.10; 9.31
2° tercile	9.28 (1.76)	9.17; 9.39
3° tercile (more active group)	9.36 (1.75)	9.25; 9.47
Morning shift school		
No	9.96 (1.64)	9.88; 10.04
Yes	8.59 (1.55)	8.52; 8.67
Bedroom sharing		
No	9.37 (1.78)	9.29;9.45
Yes	9.16 (1.66)	9.07; 9.25
Any psychiatric disorder (DSM-5)		
No	9.29 (1.71)	9.23; 9.36
Yes	9.24 (1.90)	9.05; 9.43

Abbreviations: BMI, Body Mass Index; DSM-5, Diagnostic and Statistical Manual of Mental Disorders; IEN, National Economic Indicator.
[a]Other: skin color other than white or black.

observed in adolescents aged 11 years were 9 hour 26 minute and 10 hour 17 minute, respectively.[27] In Brazilian adolescents belonging to the 1993 Pelotas Birth Cohort, the sleep duration of those aged 11 years was 9.7 hour, which was similar to that observed in the present study.[28]

Adolescents with more socioeconomic vulnerability slept longer in the present study. Existing literature did not show a consistent relationship between sleep and socioeconomic conditions.[29] Low economic level was associated with short sleep duration in many studies (possibly because low-income homes are less organized and noisier, and families have less knowledge on sleep hygiene).[11,30] However, as in the present study, 11-year-old adolescents from the 1993 Pelotas

Table 3 Crude and adjusted analyses of associations between exposure variables and sleep duration ($N = 3,179$), 2004 Pelotas Birth Cohort Study

Variables	Sleep duration			
	Crude Analysis		Adjusted Analysis***	
	β (95% CI)**	p*	β (95% CI)**	p*
Variables collected at the perinatal period				
Familiar Socioeconomic Index (IEN)		**< 0.001**		**0.029**
Quintile 1 (poorest)	0.57 (0.35; 0.78)		0.37 (0.12; 0.61)	
Quintile 2	0.30 (0.08; 0.51)		0.14 (-0.09; 0.38)	
Quintile 3	0.13 (-0.08; 0.34)		0.05 (-0.17; 0.27)	
Quintile 4	0.20 (-0.01; 0.41)		0.16 (-0.05; 0.37)	
Quintile 5 (richest)	0.00		0.00	
Maternal education (years of study)		**< 0.001#**		**< 0.001#**
0	1.10 (0.41; 1.78)		1.24 (0.46; 2.03)	
1–4	0.58 (0.39; 0.77)		0.47 (0.24; 0.70)	
5–8	0.26 (0.13; 0.39)		0.23 (0.07; 0.40)	
9 or more	0.00		0.00	
Maternal age (years)		0.960		0.346
< 20	0.02 (-0.14; 0.18)		-0.11 (-0.30; 0.07)	
20–34	0.00		0.00	
≥ 35	0.01 (-0.17; 0.19)		-0.11 (-0.30; 0.09)	
Maternal smoking during pregnancy		0.557		0.160
No	0.00		0.00	
Yes	0.04 (-0.10; 0.18)		-0.11 (-0.27; 0.05)	
Alcohol consumption during pregnancy		0.590		0.347
No	0.00		0.00	
Yes	-0.09 (-0.43; 0.25)		-0.19 (-0.57; 0.20)	
Depression or nervous problems during pregnancy		0.222		0.759
No	0.00		0.00	
Yes	0.09 (-0.05; 0.23)		0.02 (-0.13; 0.18)	
Type of delivery		**< 0.001**		**0.023**
Vaginal	0.00		0.00	
Cesarean section	-0.25 (-0.37; -0.13)		-0.16 (-0.31; -0.02)	
Preterm birth (< 37 weeks)		0.977		0.537
No	0.00		0.00	
Yes	-0.00 (-0.19; 0.18)		-0.06 (-0.27; 0.14)	
Adolescent's biological sex		**0.001**		**0.004**
Male	0.00		0.00	
Female	0.21 (0.09; 0.33)		0.19 (0.06; 0.33)	
Adolescent's skin color		0.058		0.682
White	0.00		0.00	
Black	0.05 (-0.14; 0.24)		-0.07 (-0.28; 0.14)	
Other[a]	0.19 (0.03; 0.35)		0.04 (-0.14; 0.22)	
Low birth weight (< 2500 g)		0.547		0.490
No	0.00		0.00	
Yes	0.07 (-0.16; 0.30)		0.10 (-0.19; 0.39)	

Table 3 (*Continued*)

Variables	Sleep duration			
	Crude Analysis		Adjusted Analysis***	
	β (95% CI)**	p*	β (95% CI)**	p*
5th minute APGAR score (< 7)		0.682		0.839
No	0.00		0.00	
Yes	-0.11 (-0.66; 0.43)		0.06 (-0.56; 0.69)	
Variables collected at the 4-year follow-up				
Breastfeeding duration (in months)		0.602		0.807
≤ 1	-0.03 (-0.23; 0.16)		-0.02 (-0.25; 0.20)	
1.01–3	0.00 (-0.17; 0.17)		-0.04 (-0.23; 0.15)	
3.01–6	-0.15 (-0.34; 0.04)		-0.14 (-0.35; 0.08)	
6.01–12	-0.04 (-0.22; 0.13)		-0.04 (-0.24; 0.16)	
> 12	0.00		0.00	
Variables collected at the 11-year follow-up				
Body Mass Index (BMI)		**< 0.001#**		0.307
Eutrophic	0.00		0.00	
Overweight	-0.21 (-0.36; -0.06)		-0.12 (-0.28; 0.04)	
Obesity	-0.25 (-0.40; -0.10)		-0.02 (-0.18. 0.15)	
Physical activity (minutes/day) (*n* = 3,000)		**0.044#**		**0.004#**
1° tercile (less active group)	-0.16 (-0.31; -0.00)		-0.25 (-0.42; -0.08)	
2° tercile	-0.08 (-0.23; 0.07)		-0.14 (-0.30; 0.02)	
3° tercile (more active group)	0.00		0.00	
Morning shift school		**< 0.001**		**< 0.001**
No	0.00		0.00	
Yes	-1.37 (-1.48; - 1.26)		-1.38 (-1.51; -1.26)	
Bedroom sharing		**0.001**		0.069
No	0.00		0.00	
Yes	-0.21 (-0.34; -0.09)		-0.12 (-0.26; 0.01)	
Any psychiatric disorder (DSM-5)		0.570		0.844
No	0.00		0.00	
Yes	-0.03 (-0.12; 0.06)		-0.01 (-0.11; 0.09)	

Abbreviations: BMI, Body Mass Index; DSM-5, Diagnostic and Statistical Manual of Mental Disorders; IEN, National Economic Indicator.
[a]Other: skin color other than white or black.
#Linear trend test p-value.
*p-value of the Wald's heterogeneity test.
**β (95% CI): linear regression coefficient with 95% confidence interval.
***adjusted analysis using a p-value <0.20 as a criterion for variable inclusion.

Birth Cohort, who belonged to families in the highest income quintile, showed shorter sleep duration.[13] The present study also found that lower maternal education was associated with longer sleep duration. In a systematic review, worse social indicators (lower family income and parents' education levels) were associated with shorter sleep duration, worse sleep patterns, and poor sleep quality in adolescents. The only contradictory study in this review was also performed in Brazilian adolescents, which was in accordance with our findings.[11] Socioeconomic factors might be associated in various ways in different cultural contexts, and these should be better explored in future studies. A possible explanation for the present finding could be the increased light stimulation in the bedroom, coming from certain devices like televisions and cell phones, which affected the nighttime sleep of adolescents of higher socioeconomic status. Another hypothesis is that adolescents from higher socioeconomic levels, whose parents are more educated, might have more extracurricular tasks, need to postpone bedtime, having, therefore, less sleep duration.[11]

The present study reported that teenage girls had a longer sleep duration than boys, which is supported by differences

in sleep neurophysiology reported between boys and girls.[31] A recent study, conducted in 165,793 adolescents from 24 countries in Europe and North America, showed that boys in most countries had slightly longer sleep duration (<10 minute) on school days, while girls in all countries slept more on weekends.[12] The present study was not able to investigate the sleep duration separately on weekdays and weekends, as this information was not collected; hence, this issue needs to be explored in future studies.

Regarding to the school shift, those adolescents who studied in the morning had a mean sleep duration of >1 hour shorter than those who studied in other shifts. This finding corroborated with those reported in the literature.[32] Several studies showed that the school shift, starting early in the morning, is not in line with the biological nature of the adolescent and contributes to the reduction in the sleep duration.[32–34] Adolescents undergo changes in circadian and/or homeostatic processes, delaying the onset of sleep propensity.[35] Therefore, the fact that adolescents feel sleepy later is physiological and independent of cultural issues or geographic location.[36] Thus, the morning shift prevents the adolescent getting enough sleep, which can affect school performance, as sleep patterns have an impact on an individual's intellectual capacity.[33]

In the present study, sleep duration was shorter in adolescents born through cesarean section. Previous studies suggested that the type of delivery could influence sleep in the early postnatal period, with advantages for vaginal delivery, as it causes less disturbance in the sleep of babies in the first two days of life.[37] Similar to the present study, in a study conducted in 3-month-old Canadian babies, those born by emergency cesarean section were reported to sleep an hour less than those born through vaginal delivery.[38] The type of delivery has already been related to the differences in infant's intestinal microbiota; when passing through the vaginal canal, the baby has the advantage of being colonized by the mother's beneficial bacteria.[39] The formation of the intestinal microbiota is important role in sleep regulation.[40]

The present study also found that adolescents who performed fewer physical activities had shorter sleep duration. This association can be partially explained by the fact that increased energy expenditure, resulting from the practice of physical exercise during wakefulness, would lead to the need for more hours of sleep, as a means of repairing energy balance.[41] These findings corroborated with those of epidemiological and clinical studies, which showed a positive association between the performance of physical exercise and sleep, with physical activity being a form of non-pharmacological intervention to improve the quality and duration of sleep.[42] A review conducted by Back et al.[43] pointed out that aerobic physical activity can function as a non-photic synchronizer, capable of affecting the circadian timing system and interfering with the regulation of sleep schedules.[43]

It is important to highlight some associations that were not verified in this sample, although the directions of the results were in accordance with the expected findings. This was the case of the association of sleep duration with psychiatric disorders and nutritional status. Disrupted sleep might be a contributory causal factor in the occurrence of major types of mental health disorders, even though this relationship may be considered bidirectional.[44] As for nutritional status, short sleep duration can lead to changes in the hypothalamic-pituitary-adrenal axis, deregulating hormones that are involved in controlling hunger and satiety and leading to overeating and poor food choices.[45] Bidirectionality in this relationship is also a possibility, considering that excess body fat can result in sleep dysregulation.[46]

Strengths and Limitations

Some limitations should be considered when interpreting the results of this study. The first limitation is the differences between the included and unincluded individuals. As losses were greater for adolescents belonging to families from the lowest socioeconomic quintile, the mean sleep duration observed may be shorter than the actual duration. Second, the magnitude of most associations found was relatively small, and some intervals were close to nullity. Third, adolescentś pubertal status was not obtained. Moreover, as it was a cross-sectional study, the associations observed with the 11-year-old exposure variables, such as physical activity and nutritional status, may be susceptible to reverse causality bias. Another limitation may be related to the probable difficulty of 11-year-old adolescents in answering questions related to their bedtime and waking hours. Although it is possible that 11-year-old adolescents are too young to recognize their sleep pattern, the sleep-related questions were extracted from an instrument validated in adolescents.[17] Furthermore, it was not possible to separately determine the sleep duration on school days and on weekends, which is particularly relevant in this age group.[12]

Nonetheless, this study fills an important gap in the literature regarding the sleep duration of adolescents from low- and middle-income families. In addition, the study used data from a population-based birth cohort, with a large sample size and a low rate of losses to follow-ups. Furthermore, variables from the perinatal period were used, which is less explored in the literature.

Conclusions

The present study showed that adolescents aged 11 years had an adequate mean sleep duration. The mean sleep durations were longer in adolescents with worse socioeconomic conditions, teenage girls, and more physically active participants, while they were shorter among those born through cesarean section and who studied in the morning.

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References

1 Bartel KA, Gradisar M, Williamson P. Protective and risk factors for adolescent sleep: a meta-analytic review. Sleep Med Rev 2015;21:72–85. http://www.ncbi.nlm.nih.gov/pubmed/25444442[Internet]
2 Carskadon MA. Sleep in adolescents: the perfect storm. Pediatr Clin North Am 2011;58(03):637–647
3 Van Dongen HP, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. Sleep 2003;26(02):117–126. http://www.ncbi.nlm.nih.gov/pubmed/12683469[Internet]
4 Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's updated sleep duration recommendations: final report. Sleep Health 2015;1(04):233–243. http://www.ncbi.nlm.nih.gov/pubmed/29073398[Internet]
5 Paruthi S, Brooks LJ, D'Ambrosio C, et al. Recommended Amount of Sleep for Pediatric Populations: A Consensus Statement of the American Academy of Sleep Medicine. J Clin Sleep Med 2016;12(06):785–786. http://www.ncbi.nlm.nih.gov/pubmed/27250809[Internet]
6 Galland BC, Short MA, Terrill P, et al. Establishing normal values for pediatric nighttime sleep measured by actigraphy: a systematic review and meta-analysis. Sleep 2018;41(04):http://www.ncbi.nlm.nih.gov/pubmed/29590464[Internet]
7 Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. Appl Physiol Nutr Metab 2016;41(6, Suppl 3)S266–S282
8 Fatima Y, Doi SAR, Najman JM, Al Mamun A. Continuity of sleep problems from adolescence to young adulthood: results from a longitudinal study. Sleep Health 2017;3(04):290–295. http://www.ncbi.nlm.nih.gov/pubmed/28709517[Internet]
9 Keyes KM, Maslowsky J, Hamilton A, Schulenberg J. The great sleep recession: changes in sleep duration among US adolescents, 1991-2012. Pediatrics 2015;135(03):460–468. http://www.ncbi.nlm.nih.gov/pubmed/25687142[Internet]
10 Mei X, Zhou Q, Li X, et al. Sleep problems in excessive technology use among adolescent: a systemic review and meta-analysis. Sleep Science Practice 2018;2(09). Doi: 10.1186/s41606-018-0028-9
11 Felden EP, Leite CR, Rebelatto CF, Andrade RD, Beltrame TS. [Sleep in adolescents of different socioeconomic status: a systematic review]. Rev Paul Pediatr 2015;33(04):467–473. http://www.ncbi.nlm.nih.gov/pubmed/26298657[Internet]
12 Gariepy G, Danna S, Gobiņa I, et al. How Are Adolescents Sleeping? Adolescent Sleep Patterns and Sociodemographic Differences in 24 European and North American Countries. J Adolesc Health 2020;66(6S) [Internet]S81–S88. http://www.ncbi.nlm.nih.gov/pubmed/32446613
13 Wehrmeister FC, Wendt A, Tavares PS, et al. Short and long sleep duration and associated factors in pre-adolescence and early adulthood: evidence from the 1993 Pelotas birth cohort study. Sleep Med 2020;75:477–483. http://www.ncbi.nlm.nih.gov/pubmed/33007718[Internet]
14 Santos IS, Barros AJ, Matijasevich A, Domingues MR, Barros FC, Victora CG. Cohort profile: the 2004 Pelotas (Brazil) birth cohort study. Int J Epidemiol 2011;40(06):1461–1468. http://www.ncbi.nlm.nih.gov/pubmed/20702597[Internet]
15 Santos IS, Barros AJ, Matijasevich A, et al. Cohort profile update: 2004 Pelotas (Brazil) Birth Cohort Study. Body composition, mental health and genetic assessment at the 6 years follow-up. Int J Epidemiol [Internet]. 2014;43(05):1437–1437a-f. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25063002
16 Buysse DJ, Reynolds CF III, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28(02):193–213. http://www.ncbi.nlm.nih.gov/pubmed/2748771[Internet]
17 Passos MH, Silva HA, Pitangui AC, Oliveira VM, Lima AS Araújo RC. Reliability and validity of the Brazilian version of the Pittsburgh Sleep Quality Index in adolescents. J Pediatr (Rio J) 2017;93(02):200–206. http://www.ncbi.nlm.nih.gov/pubmed/27520731[Internet]
18 Barros AJ, Victora CG. [A nationwide wealth score based on the 2000 Brazilian demographic census]. Rev Saude Publica 2005;39(04):523–529. http://www.ncbi.nlm.nih.gov/pubmed/16113899[Internet]
19 Dubowitz L, Mercuri E, Dubowitz V. An optimality score for the neurologic examination of the term newborn. J Pediatr 1998;133(03):406–416. http://www.ncbi.nlm.nih.gov/pubmed/9738726[Internet]
20 de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 2007;85(09):660–667. http://www.who.int/bulletin/volumes/85/9/07-043497.pdf[Internet]
21 Fleitlich-Bilyk B, Goodman R. Prevalence of child and adolescent psychiatric disorders in southeast Brazil. J Am Acad Child Adolesc Psychiatry 2004;43(06):727–734
22 La Maison C, Munhoz TN, Santos IS, Anselmi L, Barros FC, Matijasevich A. Prevalence and risk factors of psychiatric disorders in early adolescence: 2004 Pelotas (Brazil) birth cohort. Soc Psychiatry Psychiatr Epidemiol 2018;53(07):685–697
23 StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC
24 Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health 2015;1(01):40–43. http://www.ncbi.nlm.nih.gov/pubmed/29073412[Internet]
25 Sarchiapone M, Mandelli L, Carli V, et al. Hours of sleep in adolescents and its association with anxiety, emotional concerns, and suicidal ideation. Sleep Med 2014;15(02):248–254
26 Maslowsky J, Ozer EJ. Developmental trends in sleep duration in adolescence and young adulthood: evidence from a national United States sample. J Adolesc Health 2014;54(06):691–697. http://www.ncbi.nlm.nih.gov/pubmed/24361237[Internet]
27 Leger D, Beck F, Richard JB, Godeau E. Total sleep time severely drops during adolescence. PLoS One 2012;7(10):e45204. http://www.ncbi.nlm.nih.gov/pubmed/23082111[Internet]
28 Schäfer AA, Domingues MR, Dahly DL, et al. Correlates of self-reported weekday sleep duration in adolescents: the 18-year follow-up of the 1993 Pelotas (Brazil) Birth Cohort Study. Sleep Med 2016;23:81–88. http://www.ncbi.nlm.nih.gov/pubmed/27692281[Internet]
29 Dollman J, Ridley K, Olds T, Lowe E. Trends in the duration of school-day sleep among 10- to 15-year-old South Australians between 1985 and 2004. Acta Paediatr 2007;96(07):1011–1014. http://www.ncbi.nlm.nih.gov/pubmed/17524028[Internet]

30 Bøe T, Hysing M, Stormark KM, Lundervold AJ, Sivertsen B. Sleep problems as a mediator of the association between parental education levels, perceived family economy and poor mental health in children. J Psychosom Res 2012;73(06):430–436
31 Markovic A, Kaess M, Tarokh L. Gender differences in adolescent sleep neurophysiology: a high-density sleep EEG study. Sci Rep 2020;10(01):15935. http://www.ncbi.nlm.nih.gov/pubmed/32985555[Internet]
32 Bowers JM, Moyer A. Effects of school start time on students' sleep duration, daytime sleepiness, and attendance: a meta-analysis. Sleep Health 2017;3(06):423–431
33 Hansen M, Janssen I, Schiff A, Zee PC, Dubocovich ML. The impact of school daily schedule on adolescent sleep. Pediatrics 2005;115 (06):1555–1561. http://www.ncbi.nlm.nih.gov/pubmed/15930216 [Internet]
34 Temkin DA, Princiotta D, Ryberg R, Lewin DS. Later Start, Longer Sleep: Implications of Middle School Start Times. J Sch Health 2018;88(05):370–378. http://www.ncbi.nlm.nih.gov/pubmed/29609217[Internet]
35 Crowley SJ, Acebo C, Carskadon MA. Sleep, circadian rhythms, and delayed phase in adolescence. Sleep Med 2007;8(06):602–612
36 Hagenauer MH, Perryman JI, Lee TM, Carskadon MA. Adolescent changes in the homeostatic and circadian regulation of sleep. Dev Neurosci 2009;31(04):276–284. http://www.ncbi.nlm.nih.gov/pubmed/19546564[Internet]
37 Freudigman KA, Thoman EB. Infants' earliest sleep/wake organization differs as a function of delivery mode. Dev Psychobiol 1998;32(04):293–303
38 Matenchuk BA, Tamana SK, Lou WYW, et al;CHILD Study Investigators. Prenatal depression and birth mode sequentially mediate maternal education's influence on infant sleep duration. Sleep Med 2019;59:24–32. http://www.ncbi.nlm.nih.gov/pubmed/31153013[Internet]
39 Fouhy F, Ross RP, Fitzgerald GF, Stanton C, Cotter PD. Composition of the early intestinal microbiota: knowledge, knowledge gaps and the use of high-throughput sequencing to address these gaps. Gut Microbes 2012;3(03):203–220. http://www.ncbi.nlm.nih.gov/pubmed/22572829[Internet]
40 Matenchuk BA, Mandhane PJ, Kozyrskyj AL. Sleep, circadian rhythm, and gut microbiota. Sleep Med Rev 2020;53:101340
41 Oliveira LMFT, Silva AOD, Santos MAMD, Ritti-Dias RM, Diniz PRB. Exercise or Physical Activity: Which Is More Strongly Associated with the Perception of Sleep Quality by Adolescents? Rev Paul Pediatr 2018;36(03):322–328. http://www.ncbi.nlm.nih.gov/pubmed/30365813[Internet]
42 Legnani RFS, Legnani E, Gasparotto Gda S, Bacil EDA, da Silva MP, de Campos W. Sleep habits and physical activity in students: a systematic review. Journal of Physical Education 2015;26(01): 147–156
43 Back FA, Fortes FS, Santos EHR, Tambelli R, Menna-Barreto LS, Louzada FM. Sincronização não-fótica: o efeito do exercício físico aeróbio. Revista Brasileira de Medicina do Esporte 2007;13(02): 138–142
44 Freeman D, Sheaves B, Waite F, Harvey AG, Harrison PJ. Sleep disturbance and psychiatric disorders. Lancet Psychiatry 2020;7 (07):628–637
45 Felső R, Lohner S, Hollódy K, Erhardt É, Molnár D. Relationship between sleep duration and childhood obesity: Systematic review including the potential underlying mechanisms. Nutr Metab Cardiovasc Dis 2017;27(09):751–761. http://www.ncbi.nlm.nih.gov/pubmed/28818457[Internet]
46 Collings PJ, Ball HL, Santorelli G, et al. Sleep Duration and Adiposity in Early Childhood: Evidence for Bidirectional Associations from the Born in Bradford Study. Sleep 2017;40; (02):zsw054. http://www.ncbi.nlm.nih.gov/pubmed/28364513 [Internet]

