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Are nocturnal awakenings at age 1 predictive of sleep duration and efficiency at age 6: Results from two birth cohorts

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ABSTRACT

Objective: To investigate the association of nighttime awakenings at 12 months with the duration and efficiency of nighttime sleep at 6 years of age.
Methods: Data from two population-based prospective studies (The Pelotas 2004 and The Pelotas 2015 Birth Cohorts) were used. Information on nighttime awakenings was provided by mothers during the 12-month follow-up interview. Infants who awakened >3 times after sleep onset at 12 months were considered frequent wakeners. Sleep duration and sleep efficiency were obtained by actigraphy at the 6-year follow-up. Children wore the device at the wrist of the non-dominant arm continuously for 3–7 days, including at least one weekend day. Unadjusted and adjusted beta coefficients were obtained by linear regression for each cohort separately.
Results: 2500 children from the 2004 and 2793 from the 2015 cohort had full information on nighttime awakenings at 12 months and actigraphy at 6 years and were analyzed. Prevalence of frequent wakeners was 6.3 % and 5.9 % in the 2004 and 2015 cohort, respectively. Mean bedtime and wake-up time at 6 years were, respectively, 23:23 and 08:41 h in the 2004 cohort, and 00:10 and 09:00 h int the 2015 cohort. Nighttime sleep lasted on average 7.54 and 7.24 h respectively in the 2004 and the 2015 cohort, and the sleep efficiency was 81.1 and 82.5 % respectively. In adjusted analyses, no associations were found between awakening at 12 months and sleep duration or sleep efficiency at 6 years of age.
Conclusion: In both cohorts sleep duration and efficiency were below the recommendation for school-age children (respectively 9–11 h and 85 %). There was no relationship between the number of nighttime awakenings at 12 months and sleep duration or efficiency at 6 years.

1. Introduction

Adequate sleep duration is essential for physical and mental health across the lifespan [1,2]. In children and adolescents, shorter sleep duration is associated with excess adiposity, poorer emotional regulation and academic achievement, and lower quality of life/well-being [3–5]. Nonetheless, evidence suggests that the number of hours of sleep per night has been decreasing by at least 1 h in pediatric groups over the last century [6], due to increasingly later bedtime but unchanged wake time across decades [7]. Artificial light, late-night screen time, physical inactivity, caffeine use, no bedtime rules in the household, and the increased availability of information and communication technologies are current factors to which this decline has been generally ascribed [8].

Besides short sleep duration, epidemiologic studies have demonstrated a high prevalence of sleep disturbances in various age groups from infancy to adolescence [9,10]. A nationally representative cohort including 5107 infants aged 0–1 years in Australia showed that nighttime awakenings were the most common type of sleep disturbance until the end of the first year of life (40.8 %), steadily decreasing through ages 10–11 years (5.7 %) [11]. The frequency of sleep disturbances in early childhood, including nighttime awakenings, and their consequences on body composition, emotional regulation, growth, and cognition have been the subject of several studies [12,13]. Also, three or more nocturnal awakenings at 6 moths showed to be related to short sleep duration (<13 h) at 18 months of age [14]. In addition, past publications suggested that signaled night awakening (night awakenings after initial sleep onset that are signaled to parents, for example by crying, and which require parental assistance) [15] could be a precursor of later sleep difficulties [9,16]. Thus, this study aimed to investigate the association of nighttime awakenings at 12 months with the duration and efficiency of nighttime sleep at 6 years of age. The hypothesis being tested was that frequent nighttime awakenings at 12 months was associated with short sleep duration and poor sleep efficiency at 6 years of

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age. Studies that elucidate the longitudinal association between sleep disturbances in infancy and sleep quality later on in childhood, using consistent measures, may help to define the focus and timing of future intervention efforts.

2. Methods

This study employed data from two longitudinal studies: The Pelotas 2004 and the Pelotas 2015 Birth Cohorts.

2.1. - The Pelotas 2004 and 2015 birth cohorts

From 1 January to 31 December in 2004 and 2015, all maternity hospitals in the city of Pelotas were visited daily, and all urban women giving birth were invited to join the study (perinatal study). Pelotas is a medium-sized city in the state of Rio Grande do Sul, located in the south of Brazil, near the Uruguayan border. According to the Brazilian Institute of Geography and Statistics, the municipal population reached 325,685 inhabitants in 2022, of whom 93.3 % were urban residents. Primary data collection was conducted using standardized questionnaires to obtain information on socioeconomic, environmental, demographic, nutritional, behavioral, and other health-related characteristics. Detailed methodological information on each cohort is available elsewhere [17–19].

The cohorts continue to be followed up regularly up to the present time, but the analyses in this study refer to the first year and the 6 years of life. After the perinatal study in hospitals, all children from the 2004 and 2015 cohorts were visited at home at the ages of 3 and 12 months and at a research clinic at 6 years of life.

At the inception of the cohorts and at all follow-ups of both cohorts, data collection was carried out by trained research team members. Mothers were interviewed using standardized, pre-coded questionnaires. To standardize data collection, the team members were trained before each round of fieldwork. The training included general orientations on each question and pre-coded options, and instructions on how to approach the mother and the family in a polite manner. During the follow-up visits, quality control measures included repetition by a supervisor of a subset of interview questions for 5 % of the whole sample, including key variables such as age, smoking, education, etc.

The total number newborns enrolled in the 2004 and 2015 cohorts were 4231 and 4,275, respectively. Refusal rates at the perinatal interview, when all urban women giving birth were invited, were 0.8 % and 1.3 %, respectively, in the 2004 and the 2015 cohort. Response rates at the 12-month and 6-year interviews were, respectively, 94.3 % and 90.2 % in the 2004 cohort, and 95.4 % and 90.5 % in the 2015 cohort.

2.2. - Outcomes

The nighttime sleep and wakefulness status were defined by actigraphy at 6 years of age. In the 2004 cohort children wore GENEActiv® device continuously at the wrist of the non-dominant arm for 4–7 days, including at least one weekend day. In the 2015 cohort participants wore the Actigraph-GT3x® device also continuously at the non-dominant wrist for 3–6 days. Both accelerometers are waterproof and measure acceleration in three axes (x, y, z) with high sample frequencies (GENEActiv was set at 85.7 Hz and Actigraph at 60Hz). Mothers/caregivers were instructed not to remove the device from the child arm not even during the bath. Comparisons between the raw data of the two devices are available elsewhere [20,21]. In both cohorts, raw data was processed in R software with GGIR package (version 2.2–0). The algorithm implemented for sleep detection was proposed by Van Hess [22], which is based on changes in wrist angle (z axis) to classify sleep periods. Time windows of 5 min were assessed and changes in angle of 3° were used in this study. Validation studies comparing actigraphy to polysomnography, direct observation or videosomnography in children demonstrated that actigraphy has a high sensitivity (ability to detect sleep) of 82–90 % and a relatively low specificity (ability to detect wake) of 51–73 %, with a tendency to overestimate sleep time and underestimate wake after sleep onset [23].

Two outcomes were considered: nighttime sleep duration and sleep efficiency. Sleep duration (the total amount of sleep minus arousals) [24], was defined as the total time in bed until waking up the next day, discounting the latency time and the total duration of nighttime awakenings, as directly provided by the algorithm. Sleep efficiency is the percentage of sleep time achieved between bedtime and wake-up times [24].

2.3. - Exposure

The main exposure was the number of nighttime awakenings at 12 months of age as informed by the mother/caregiver through face-to-face interview. Data collection on nighttime awakenings was slightly different in the two cohorts. At the 2004 cohort, the mother/caregiver was asked whether the child had woken in the middle of the night in the last fifteen days, and at the 2015 cohort, the question was whether the child used to wake up in the middle of the night. In both cases, the positive answer was followed-up by a question asking how many times per night the child used to wake up. Children who presented more than 3 awakenings during nighttime sleep were considered frequent wakeners [25].

2.4. - Potential confounders

Except information on child ethnicity, that was self-reported by the mother at the 6-year follow-up, all other potential confounders were collected at the perinatal study and at the 3-month and 12-month follow-ups. The official Brazilian classification of ethnicity is based on skin color and includes three frequent categories (white, black, or brown) in addition to the less frequent indigenous and yellow (Asian origin) groups.

From the perinatal study, the following variables were employed: family monthly income (in quintiles, in which the first quintile was composed of the poorest families and the fifth, of the wealthiest), maternal age (in complete years), maternal ethnicity (self-reported by the mother as white, black, brown/indigenous/yellow), maternal education (complete years of formal education), smoking during pregnancy (at least one cigarette per day in any trimester of pregnancy) (yes/no), alcohol consumption during pregnancy (any amount at any time during pregnancy) (yes/no), parity (0, 1 or $\geq$2 previous deliveries), and daily caffeine consumption from coffee and *maté* drinking (a caffeine-rich beverage highly consumed in South Brazil) in the third trimester of pregnancy ($\geq$300 mg/day) (yes/no). Type of delivery (vaginal/cesarean section), sex of the participant (male/female), low birth weight (<2500g) (yes/no), preterm birth (<37 weeks of gestation) (yes/no), 5th minute APGAR (<7 and $\geq$ 7), and whether the participant required neonatal intensive care (yes/no), were also collected at the perinatal study.

From the 12-month follow-up, the variables habitual room-sharing (including bed- and non-bed sharing) (yes/no), bed-sharing with the mother for nighttime sleep (yes/no), current breastfeeding (yes/no), use of a pacifier (yes/no), maternal work outside the home (yes/no), and maternal depressive symptoms (yes/no) were used. Maternal depression was assessed using the Edinburgh Postnatal Depression Scale – EPDS) [26] at the cutoff $\geq$8, according to a validation study carried out in Brazil [27].

2.5. - Data analysis

Data analysis was performed with STATA statistical package version 17.0 [28]. The two cohorts were analyzed separately. To check for selection bias due to follow-up losses, the analyzed sample of each cohort was firstly compared with the original sample at the perinatal study.

Mean and 95 % confidence intervals (95%CI) were used to describe continuous variables. Categorical variables were described as proportions with 95%CI. The prevalence of >3 nighttime awakenings at 12 months was calculated, with the respective 95%CI.

The two outcomes were analyzed as continuous variables. The amount of awakenings/night at 12 months was tested as a continuous variable and as a categorical variable (≤3 awakenings as the reference category). Linear regression models, providing unadjusted and adjusted beta (β) coefficients were used. Adjusted analysis followed-up a hierarchical model built by the authors. The first level was composed of the family income and maternal variables collected at the perinatal study. The second level comprised the variables of the child at birth. The third level included the variables collected at the 12-month follow-up. Variables were entered in the multivariable analyses according to the hierarchical model described above. Starting with the inclusion of the variables from the first level, the regressions were performed by stepwise backward, removing one-by-one those with higher p-values. Variables associated with the outcome at $p < 0.20$ were maintained in the model for adjustment. In each level, variables were adjusted for variables from the same level and for those of the previous levels that were kept in the model. Associations with two-tailed $p < 0.05$ were considered statistically significant.

As breastfeeding has been associated with a higher frequency of nighttime awakenings [29] and evidence for the impact of preterm birth on sleep beyond the neonatal period is mixed [30,31], sensitivity analyses according to breastfeeding at 12 months (yes/no) and gestational age (<37 or ≥37 weeks of gestation) were carried out.

2.6. Ethical issues

All visits of the 2004 cohort were approved by the Research Ethics Committee of the Faculty of Medicine of the Federal University of Pelotas, affiliated with the National Research Council (CONEP). The perinatal study/3-month follow-up, the 12-month and the 6-year follow-ups were approved under the approval protocol number 034/2003, 35/10 and 3,554,667, respectively. The visits of the 2015 cohort were approved by the Ethics Committee of the School of Physical Education of the Federal University of Pelotas, affiliated with the National Research Council (CONEP) under the approval protocol number 26746414.5.0000.5313. In both cohorts, written informed consent was signed by the mother before the perinatal, 3-month, 12-month, and 6-year interviews.

3. Results

The 2004 cohort enrolled 4231 newborns and the 2015 cohort 4275. Table 1 presents the description of the analyzed sample and of the original cohort (perinatal study). The prevalence of frequent nighttime awakenings at 12 months in the 2004 and in the 2015 cohort, according to the independent variables is also shown in Table 1.

3.1. - Description of the samples

Due to the limited number of actigraphy devices available, only 2592 of the 3722 children of the 2004 cohort followed-up at six years had their sleep objectively assessed. Two children were excluded due to aberrant results: Mean total time in bed of 23.6 h and 2.5 h and mean sleep duration of 14.6 h and 2.15 h, respectively. The analyzed sample comprised 2500 participants with full information on nighttime awakenings at 12 months and actigraphy. The attributes at birth, family income and maternal characteristics of the analyzed sample were similar to the original cohort. Mean age at the 6-year follow-up was 6.7 years (standard deviation - SD: 0.2), 51.6 % were males, 40.7 % were firstborns, 8.8 % were low birth weight, 10.1 % were preterm, and 5.2 % had needed intensive neonatal care.

Of the 3867 children of the 2015 cohort followed-up at six years, 2877 had their sleep objectively assessed. Five children were excluded due to aberrant results: 3.7–3.9 h of mean total time in bed and 2.2–3.2 h of mean sleep duration. The analyzed sample was composed of 2793 cohort participants with full information on actigraphy and nighttime awakenings at 12 months. There was no difference between the analyzed sample and the original cohort regarding family monthly income, maternal and child characteristics at birth. Mean age at the 6-year follow-up was 6.8 years (SD: 0.3), 50.6 % were males, 50.0 % were firstborns, 10.1 % were low birth weight, 15.5 % were preterm, and 7.2 % had needed intensive neonatal care.

3.2. - Nighttime awakenings

In the 2004 cohort, a total of 1561 infants (62.4 %) woke in the middle of the night at the two weeks before the interview (Table 2). The wakeners woke on average 2.0 times per night. The prevalence of >3 nighttime awakenings for the whole sample was 6.3 % (95%CI 5.4–7.3 %) (Table 2) and was associated with family income (higher in children from families in the second and fourth quintiles), those born with ≥2500 g, who were breastfed at 12 months, who did not use a pacifier, and whose mothers presented depressive symptoms (Table 1).

In the 2015 cohort, 49.4 % of the infants (N = 1380) used to awaken in the middle of the night. The wakeners woke on average 2.1 times across the night (Table 2). The prevalence of >3 nighttime awakenings was 5.9 % (95%CI: 5.1–6.9 %) (Table 2) and was higher in children from mothers who consumed alcoholic beverages in pregnancy, who had older siblings, bed-shared with the mother, who were breastfed, who did not use a pacifier, and whose mothers presented depressive symptoms (Table 1).

3.3. - Sleep duration and efficiency

At 6 years of age, the children from the 2004 cohort went to bed on average at 23:23 h and woke up at 08:41 h (Table 2). Discounting the latency time and nighttime waking episodes, the mean sleep duration was 7.54 h and the sleep efficiency 81.1 %. Children from the 2015 cohort went to bed and woke up later than those from the 2004 cohort (respectively, 00:10 h and 09:00 h. Mean sleep duration in the 2015 cohort was shorter than in the 2004 cohort (7.24 h) and the sleep efficiency was higher (82.5 %).

3.4. - Association between nighttime awakenings at 12 months, sleep duration and sleep quality at 6 years

The results from the analyses of association between nighttime awakenings at 12 months, sleep duration and sleep quality at 6 years among children from the 2004 and 2015 cohorts are presented in Table 3 and Table 4, respectively. Among children from the 2004 cohort, unadjusted analysis showed that every nighttime awakening at 12 months was related to a decrease of 0.13 min (95%CI -1.50; 1.25) in sleep duration and 0.1% points in sleep efficiency at 6 years, without statistical significance (Table 3). In the 2015 cohort, the decrease was of 0.98 min (95%CI -2.47; 0.51) in sleep duration, and the sleep efficiency was practically not affected by nighttime awakenings in early life (β: 0.0; 95%CI -0.1; 0.2) (Table 4). The adjusted analyses did not change the results in both cohorts.

Frequent wakeners (>3 awakenings) from the 2004 (Table 3) and the 2015 cohorts (Table 4) slept on average, respectively, 6.25 and 4.93 min less than their counterparts who were not frequent wakeners, but the difference was not statistically significant. The adjustment for covariables did not change the results: 5.96 (95%CI -14.11; 2.20) in the 2004 cohort, and −3.50 (95%CI -12.18; 5.17) in the 2015 cohort.

In the unadjusted analysis, sleep efficiency in the 2004 cohort was 0.2% points lower in frequent wakeners than in their counterparts, without statistical significance. Sleep efficiency in the 2015 cohort was practically the same among wakeners and non-wakeners. In full adjusted

Table 1
Description of the analyzed sample in comparison with the original cohort, prevalence of frequent nighttime awakenings at 12 months (>3/night), and associated factors at the Pelotas 2004 and the Pelotas 2015 Birth Cohorts.

Characteristics	2004 cohort					2015 cohort				
	Analyzed sample N (%)	Original cohort N (%)	p[a]	Prevalence of frequent nighttime awakenings at 12 months % (95%CI)	p[a]	Analyzed sample N (%)	Original cohort N (%)	p[a]	Prevalence of frequent nighttime awakenings at 12 months % (95%CI)	p[a]
Family monthly income (quintile)			0.726		0.034			0.493		0.081
1st	482 (19.3)	871 (20.6)		5.4 (3.7–7.8)		560 (20.1)	846 (19.8)		6.4 (4.7–8.8)	
2nd	514 (20.6)	854 (20.2)		9.0 (6.8–11.7)		588 (21.1)	859 (20.1)		4.8 (3.3–6.8)	
3rd	481 (19.2)	816 (19.3)		4.8 (3.2–7.1)		564 (20.2)	853 (20.0)		5.5 (3.9–7.7)	
4th	529 (21.2)	858 (20.3)		7.0 (5.1–9.5)		566 (20.2)	856 (20.0)		5.0 (3.4–7.1)	
5th	494 (19.8)	830 (19.6)		5.1 (3.4–7.4)		514 (18.4)	859 (20.1)		8.4 (6.3–11.1)	
Maternal age (years)			0.953		0.800			0.756		0.078
< 20	476 (19.1)	799 (18.9)		5.9 (4.1–8.4)		539 (19.3)	804 (18.8)		6.1 (4.4–8.5)	
20-24	656 (26.3)	1148 (27.2)		6.7 (5.0–8.9)		694 (24.9)	1022 (23.9)		5.2 (3.8–7.1)	
25-29	573 (22.9)	959 (22.7)		5.6 (4.0–7.8)		650 (23.3)	1045 (24.5)		4.9 (3.5–6.9)	
30-34	454 (18.2)	758 (17.9)		7.3 (5.2–10.1)		599 (21.5)	918 (21.5)		6.0 (4.4–8.2)	
≥35	340 (13.6)	563 (13.3)		5.9 (3.8–8.9)		310 (11.1)	485 (11.4)		9.4 (6.6–13.1)	
Maternal skin color			0.414		0.932			0.451		0.502
White	1556 (62.9)	2581 (61.7)		6.4 (5.3–7.7)		1971 (70.7)	3024 (70.9)		6.2 (5.2–7.3)	
Black	413 (16.7)	689 (16.5)		6.0 (4.1–8.8)		461 (16.5)	667 (15.6)		4.8 (3.2–7.1)	
Brown/other**	505 (20.4)	911 (21.8)		5.9 (4.2–8.4)		356 (12.8)	577 (13.5)		6.2 (4.1–9.2)	
Maternal schooling (years)			0.566		0.625			0.993		0.589
0-4	364 (14.7)	654 (15.6)		6.9 (4.7–10.0)		255 (9.2)	391 (9.2)		7.1 (4.5–10.9)	
5-8	1045 (42.3)	1731 (41.4)		6.6 (5.2–8.3)		712 (25.5)	1095 (25.6)		5.3 (3.9–7.3)	
≥9	1064 (43.0)	1801 (43.0)		5.7 (4.5–7.3)		1825(65.4)	2788 (65.2)		6.0 (5.0–7.2)	
Smoking in pregnancy			0.595		0.552			0.221		0.727
No	1828 (73.1)	3067 (72.5)		6.5 (5.4–7.7)		2361 (84.6)	3567 (83.5)		6.0 (5.1–7.0)	
Yes	672 (26.9)	1162 (27.5)		5.8 (4.3–7.8)		430 (15.4)	705 (16.5)		5.6 (3.8–8.2)	
Alcohol consumption in pregnancy			0.670		0.962			0.532		0.007
No	2422 (96.9)	4089 (96.7)		6.3 (5.4–7.3)		2574 (92.2)	3957 (92.6)		5.6 (4.8–6.6)	
Yes	78 (3.1)	140 (3.3)		6.4 (2.7–14.5)		217 (7.8)	315 (7.4)		10.1 (6.8–14.0)	
Caffeine 3rd trimester pregnancy (mg/day)			0.707		0.916			0.834		0.908
<300	2076 (83.1)	3522 (83.5)		6.3 (5.3–7.4)		2564 (91.9)	3925 (92.1)		6.0 (5.1–7.0)	
≥300	422 (16.9)	698 (16.5)		6.4 (4.4–9.2)		225 (8.1)	338 (7.9)		5.8 (3.4–9.7)	
Parity			0.565		0.382			0.960		0.010
0	1017 (40.7)	1665 (39.4)		5.6 (4.3–7.2)		1395 (50.0)	2136 (50.0)		4.7 (3.7–6.0)	
1	644 (25.8)	1110 (26.2)		7.3 (5.5–9.6)		869 (31.1)	1320 (30.9)		7.8 (6.2–9.8)	
≥2	838 (33.5)	1453 (34.4)		6.3 (4.9–8.2)		527 (18.9)	817 (19.1)		6.1 (4.3–8.5)	
Type of delivery			0.959		0.127			0.531		0.508
Vaginal	1366 (54.6)	2308 (54.6)		7.0 (5.7–8.4)		993 (35.6)	1489 (34.8)		6.3 (5.0–8.0)	
Cesarean	1134 (45.4)	1921 (45.4)		5.5 (4.3–7.0)		1799 (64.4)	2785 (65.2)		5.7 (4.7–6.9)	
Child sex			0.800		0.405			0.342		0.056
Male	1289 (51.6)	2154 (51.9)		6.7 (5.4–8.2)		1381 (49.5)	2164 (50.6)		6.8 (5.6–8.3)	
Female	1211 (48.4)	2036 (48.1)		5.9 (4.7–7.3)		1412 (50.5)	2111 (49.4)		5.1 (4.1–6.4)	
Preterm			0.053		0.110			0.106		0.088
No	2237 (89.9)	3672 (88.4)		6.6 (5.6–7.7)		2399 (85.9)	3612 (84.5)		6.3 (5.4–7.3)	
Yes	251 (10.1)	483 (11.6)		4.0 (2.2–7.2)		394 (14.1)	663 (15.5)		4.1 (2.5–6.5)	
Low birth weight			0.074		0.046			0.328		0.130
No	2279 (91.2)	3796 (89.2)		6.6 (5.6–7.7)		2532 (90.7)	3830 (89.9)		6.2 (5.3–7.2)	
Yes	221 (8.8)	430 (10.2)		3.2 (1.5–6.5)		261 (9.3)	428 (10.1)		3.8 (2.1–7.0)	

(*continued on next page*)

Table 1 (*continued*)

Characteristics	2004 cohort Analyzed sample N (%)	2004 cohort Original cohort N (%)	p[a]	2004 cohort Prevalence of frequent nighttime awakenings at 12 months % (95%CI)	p[a]	2015 cohort Analyzed sample N (%)	2015 cohort Original cohort N (%)	p[a]	2015 cohort Prevalence of frequent nighttime awakenings at 12 months % (95%CI)	p[a]
Apgar 5th minute			0.240		0.634			0.058		0.237
≥7	2443 (98.2)	4110 (97.8)		6.3 (5.4–7.3)		2764 (99.2)	4206 (98.7)		6.0 (5.1–6.9)	
<7	44 (1.8)	92 (2.2)		4.6 (1.1–16.4)		22 (0.8)	54 (1.3)		–	
Intensive neonatal care			0.161		0.664			0.089		0.159
No	2368 (94.8)	3960 (94.0)		6.3 (5.4–7.4)		2620 (93.8)	3956 (92.8)		6.1 (5.3–7.1)	
Yes	130 (5.2)	254 (6.0)		5.4 (2.6–10.9)		172 (6.2)	307 (7.2)		3.5 (1.6–7.5)	
Mother-child bed-sharing at 12 months			0.167		0.054			0.869		0.001
No	1162 (50.6)	1874 (52.5)		5.6 (4.4–7.1)		1508 (54.0)	2177 (54.2)		4.6 (3.7–5.8)	
Yes	1133 (49.4)	1697 (47.5)		7.6 (6.2–9.3)		1285 (46.0)	1840 (45.8)		7.6 (6.2–9.1)	
Breastfeeding at 12 months			0.763		<0.001			0.800		<0.001
No	1559 (62.4)	2451 [7,62]		3.7 (2.8–4.7)		1600 (57.3)	2313 (57.6)		2.3 (1.7–3.2)	
Yes	941 (37.6)	1456 (37.3)		10.6 (8.8–12.8)		1193 (42.7)	1703 (42.4)		10.8 (9.2–12.7)	
Room-sharing at 12 months			0.822		0.067			0.473		0.712
No	147 (5.9)	235 (6.0)		2.7 (1.0–7.0)		231 (8.3)	352 (8.8)		6.5 (4.0–10.5)	
Yes	2353 (94.1)	3671 (94.0)		6.5 (5.6–7.6)		2562 (91.7)	3664 (91.2)		5.9 (5.0–6.9)	
Pacifier use at 12 months			0.791		<0.001			0.931		<0.001
No	960 (38.4)	1513 (38.8)		9.5 (7.8–11.5)		1046 (37.5)	1510 (37.6)		9.9 (8.2–11.8)	
Yes	1539 (61.6)	2392 (61.2)		4.3 (3.4–5.4)		1747 (62.5)	2508 (62.4)		3.6 (2.8–4.6)	
Mother works outside home at 12 months			0.849		0.162			0.516		0.368
No	1508 (60.3)	2366 (60.6)		6.8 (5.7–8.2)		1408 (50.8)	2054 (51.6)		6,4 (5.2–7.8)	
Yes	992 (39.7)	1541 (39.4)		5.4 (4.2–7.0)		1362 (49.2)	1924 (48.4)		5.6 (4.5–7.0)	
EPDS			0.736		0.007			0.701		0.011
<8	1475 (59.9)	2283 (59.5)		5.3 (4.3–6.6)		1619 (58.6)	2346 (59.1)		5.0 (4.0–6.2)	
≥8	987 (40.1)	1555 (40.5)		8.0 (6.5–9.9)		1144 (41.4)	1626 (40.9)		7.3 (6.0–9.0)	

[a] Chi-square test; ** "Other" includes indigenous and yellow (Asian origin) groups; EPDS: Edinburgh Post-natal Depression Scale [27].

Table 2
Sleep parameters at 12 months and 6 years of age among children from the Pelotas 2004 and the Pelotas 2015 Birth Cohorts.

	2004 cohort N = 2500	2015 cohort N = 2793	p
At 12 months			
Number nighttime awakenings,* mean (95% CI)	2,0 (1.9–2.1)	2.1 (2.0–2.2)	0.035
>3 nighttime awakenings, % (95%CI)	6.3 (5.4–7.9)	5.9 (5.1–6.9)	0.607
At 6 years			
Bedtime (hh:mm), mean (95%CI)	23:23 (23:20–23:26)	00:10 (00:06–00:13)	<0.001
Wake-up time (hh:mm), mean (95%CI)	08:41 (08:38–08:45)	09:00 (8:57–09:04	<0.001
Sleep duration, mean(95% CI)	7.54 (7.51–7.57)	7.24 (7.20–7.27)	<0.001
Sleep efficiency, mean (95% CI)	81.1 (80.8–81.3)	82.5 (78.7–85.8)	<0.001

*Non-wakeners not included; hh:mm: hours:minutes; 95%CI: 95 % confidence interval.

models these results were unchanged both in the 2004 (β: 0.00; 95%CI -0.10; 0.90) and in the 2015 cohort (β: 0.1; 95%CI -0.7; 0.10).

The sensitivity analyses after stratifying to breastfeeding status at 12 months and prematurity (Figs. 1 and 2) did not show any difference in sleep duration or efficiency as a function of frequent awakenings at 12 months.

4. Discussion

With a prospective design, the main finding of this study was that, in the two cohorts, the number of awakenings at 12 months were not predictive of short or poor sleep efficiency at 6 years. Across the eleven-year period, the prevalence of frequent awakeners remained stable (around 6 %), while overnight sleep duration declined in about half an hour (in part due to a shift to later bedtime, which was delayed in 47 min, not fully compensated by a 19 min later wake-up time), and the sleep efficiency slightly increased over time (although still below the recommended cutoff of ≥85 %) [32]. The consistency of the results from the two cohorts strengths the validity of our findings.

A previous study showed that, compared to trouble getting to sleep and not happy to sleep alone, waking overnight was associated with the highest odds of having a concomitant sleep problem from infancy to age 6–7 years [11]. Longitudinal studies seeking to relate childhood sleep problems to sleep problems later in childhood however are uncommon. The reason for lack of association in our study, even when stratifying the samples for breastfeeding status at 12 months and prematurity, is possibly due to the different kind of mechanisms underlying frequent awakenings in infancy and regulation of sleep duration and efficiency in school age. Frequent awakenings in infancy are a type of behavioral sleep disturbance [33] mostly dependent on parent-infant nighttime interaction style. The shift from externally imposed calming and activating strategies to self-soothing results in part from social interactions with the parents, and, in part, from a variety of other contextual (room- and bed-sharing, number of checks a parent makes on a sleeping infant), parent psychological well-being and responsivity, breastfeeding, and individual factors of the child (age, sex, temperament, and use of a sleep-aid) [34,35]. On the other hand, sleep duration and efficiency at

Table 3
Crude and adjusted beta (β) coefficients for sleep duration and sleep efficiency according to nighttime sleep awakenings at 12 months at the Pelotas 2004 Birth Cohort (N = 2500).

	Sleep duration (minutes)		Sleep efficiency (%)	
	β coefficient (95%CI)	p	β coefficient (95%CI)	p
Number of nighttime awakenings				
Unadjusted analysis	−0.13 (−1.50; 1.25)	0.857	−0.1 (−0.2; 0.1)	0.243
Adjusted analysis				
Model 1	−0.13 (−1.51; 1.26)	0.859◆	−0.1 (−0.2; 0.1)	0.396[a]
Model 2	0.01 (−1.36; 1.39)	0.985◆◆	−0.1 (−0.2; 0.1)	0.505[b]
Model 3	−0.23(-1.67; 1.20)	0.747◆◆◆	−0.1 (−0.2; 0.1)	0.369[c]
>3 nighttime awakenings				
Unadjusted analysis	−6.25 (−14.23; 1.72)	0.125	−0.2 (−1.1; 0.8)	0.702
Adjusted analysis				
Model 1	−6.35 (−14.39; 1.70)	0.122[d]	−0.2 (−1.1; 0,8)	0.752ˆ
Model 2	−6.27 (−14.25; 1.70)	0.123**	−0.1 (−1.0; 0.8)	0.820ˆˆ
Model 3	−5.96 (−14.11; 2.20)	0.152***	−0.0 (−1.0; 0.9)	0.918ˆˆˆ

◆Model 1: Maternal schooling; ◆◆Model 2: Model 1 plus child sex, 5th minute APGAR, and neonatal intensive care; ◆◆◆Model 3: Model 2 plus mother-child bed-sharing and mother works outside home at 12 months.
ˆModel 1: Maternal schooling, caffeine 3rd trimester of pregnancy and parity; ˆˆModel 2: Model 1 plus child sex; ˆˆˆModel 3: Model 2 plus mother-child bed-sharing and pacifier use at 12 months.
[a] Model 1: Maternal age (years), maternal schooling, caffeine 3rd trimester of pregnancy, and parity.
[b] Model 2: Model 1 plus child sex.
[c] Model 3: Model 2 plus mother-child bed-sharing and pacifier use at 12 months.
[d] Model 1: Maternal schooling; **Model 2: Model 1 plus child sex, 5th minute APGAR, and neonatal intensive care; *** Model 3: Model 2 plus mother-child bed-sharing and mother works outside home at 12 months.

Table 4
Crude and adjusted beta (β) coefficients for sleep duration and sleep efficiency according to nighttime sleep awakenings at 12 months at the Pelotas 2015 Birth Cohort (N = 2793).

	Sleep duration (minutes)		Sleep efficiency (%)	
	β coefficient (95%CI)	p	β coefficient (95%CI)	P
Number of nighttime awakenings				
Unadjusted analysis	−0.98 (−2.47; 0.51)	0.198	0.0 (−0.1; 0.2)	0.923
Adjusted analysis				
Model 1	−1.01 (−2.50; 0.48)	0.184◆	−0.0 (−0.2; 0.1)	0.952[a]
Model 2	−0.96 (−2.44; 0.53)	0.206◆◆	−0.0 (−0.2; 0.1)	0.950[b]
Model 3	−0.93 (−2.41; 0.56)	0.220◆◆◆	0.0 (−0.1; 0.2)	0.825[c]
>3 nighttime awakenings				
Unadjusted analysis	−4.93 (−13.64; 3.78)	0.267	0.0 (−0.8; 0.9)	0.957
Adjusted analysis				
Model 1	−4.24 (−12.92; 4.44)	0.339[d]	0.1 (−0.7; 0.9)	0.892 ˆ
Model 2	−4.20 (−12.86; 4.47)	0.342**	0.1 (−0.8; 0.9)	0.984 ˆˆ
Model 3	−3.50 (−12.18; 5.17)	0.428***	0.1 (−0.7; 1.0)	0.747ˆˆˆ

◆Model 1: Maternal skin color, maternal age, alcohol consumption in pregnancy, and parity; ◆ Model 2: Model 1 plus child sex, 5th minute APGAR and low birth weight; ◆◆◆Model 3: Model 2 plus mother-child bed-sharing.
ˆModel 1: Family monthly income, alcohol consumption in pregnancy, caffeine 3rd trimester of pregnancy, and parity; ˆ ˆ Model 2: Model 1 plus child sex, low birth weight and 5th minute APGAR; ˆ ˆ ˆ Model 3: Model 2 plus mother-child bed-sharing, breastfeeding at 12 months and pacifier use at 12 months.
[a] Model 1: Family monthly income, alcohol consumption in pregnancy, caffeine 3rd trimester of pregnancy, and parity.
[b] Model 2: Model 1 plus child sex, low birth weight and 5th minute APGAR.
[c] Model 3: Model 2 plus mother-child bed-sharing, breastfeeding at 12 months and pacifier use at 12 months.
[d] Model 1: Maternal skin color, maternal age, alcohol consumption in pregnancy, and parity; ** Model 2: Model 1 plus child sex, 5th minute APGAR and low birth weight; ***Model 3: Model 2 plus mother-child bed-sharing.

school age are more the result of influential environmental factors like school schedules, family routines and cultural practices, besides individual differences in genetic make-up influencing sleep/wake regulation. Nonetheless, the observed lack of association may be reassuring for parents experiencing fragmented sleep in their infants.

According to international guidelines, the recommended sleep duration for school-aged children (6–13 years of age) is 9–11 h/24 h, although 7–8 h and 12 h may be considered appropriate [36]. In our study, the children from both cohorts slept a little more than 7 h a night (thus at the lower border of the sleep duration recommendations) and the mean efficiency was below the cut-off point for good-sleep quality (≥85 %) [32]. Sleep duration recommendations are based on the best available evidence and expert consensus, and are largely reliant on observational studies using self-reported sleep duration [8], which is known to overestimate actual sleep duration [37]. Nonetheless, in a meta-analysis published in 2018, including 79 studies that involved children aged 3–18 years from 17 countries, the pooled mean estimate for overnight sleep duration, as measured with actigraphy, was 8.98 h for the 6–8 years age band, thus close to the current international guidelines. In the same way, a multinational, cross-sectional study conducted in 12 countries from all major world regions, with 9- to 11-year-old children, mean (standard deviation) sleep duration measured by actigraphy was 8.8 (0.9) hours/day [38]. Another meta-analysis of 83 studies, including a total of 9068 healthy children between the age of 0 and 18 years and published in 2018 with sleep parameters assessed by actigraphy reported a pooled mean sleep duration of 7.92 h (95%CI 7.69–8.16) and 87.4 % sleep efficiency (95%CI 86.4–88.3 %) [39]. On the other hand, a meta-analysis of objectively assessed sleep from childhood to adulthood to determine normative sleep values across the lifespan, in which 65 studies representing 3577 healthy individuals aged 5–102 years were included, the total sleep time significantly decreased with age in adults, while it was the case in children and adolescents only in studies performed on school days [8]. This pattern suggests that, in children and adolescents, the decrease in total sleep time is not related to maturation but to other factors such as earlier school start times, use of electronics or lack of bedtime routine. Cultural and parental styles may also contribute for differences in sleep behavior in different settings [40].

As the 6-year follow-up of the 2015 cohort was carried out between November of 2021 and December of 2022, the potential role of the COVID-19 pandemic on sleep quality of children from this cohort needs to be considered. A systematic review planned to assess the influence of COVID-19 on sleep quality in children and adolescents found an increase in sleep duration and later bedtime during the pandemic, when compared with the previous period, and a trend toward reduced sleep efficiency [41]. Our findings went in an opposite direction given that in the 2015 cohort the sleep duration was shorter, and sleep efficiency was higher than in the 2004 cohort. Almost all studies included in the review had been conducted during the first semester of 2020, when schools were closed in most countries, and lockdown measures precluded outside home activities. On the contrary, by the end of 2021, the vaccine against the Sars-CoV-2 had already been available in Brazil for about a year, isolation measures had progressively been relaxed, and schools' closure was not universal in Pelotas, giving way to online and presential classes.

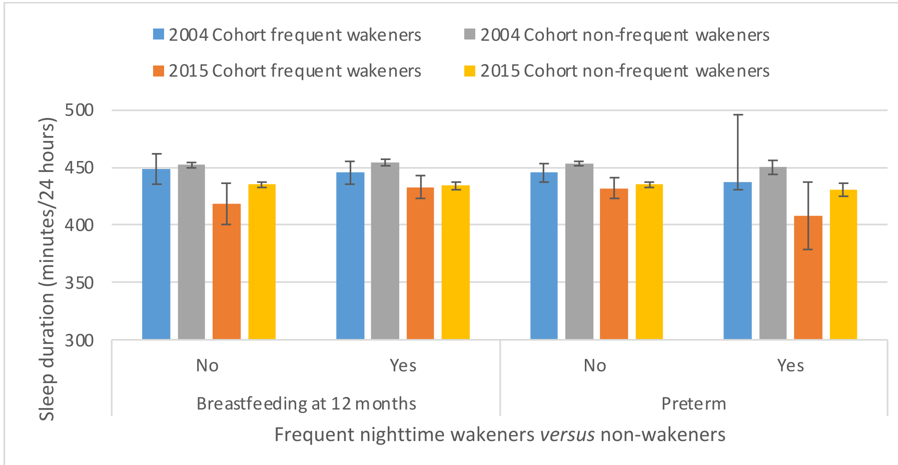

Fig. 1. Sleep duration (in minutes/24 h) at 6 years and frequent nighttime awakenings at 12 months in the Pelotas 2004 and the Pelotas 2015 Birth Cohorts by breastfeeding at 12 months and prematurity.

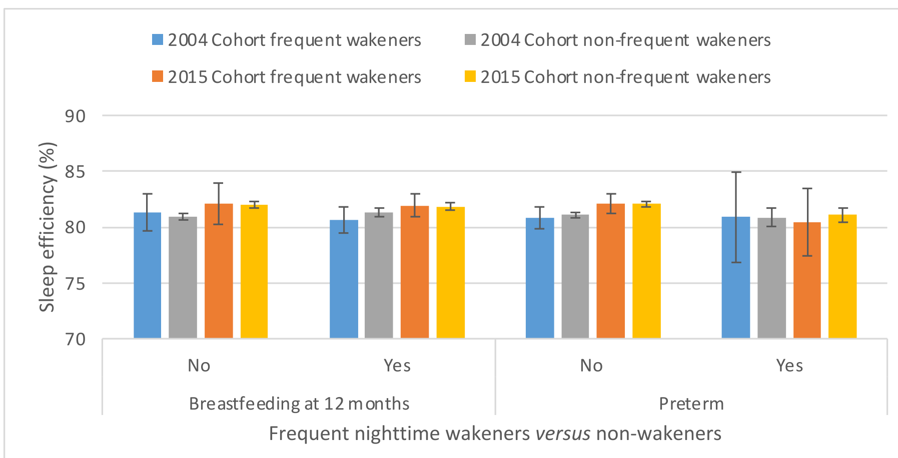

Fig. 2. Sleep efficiency (total sleep time/time in bed) at 6 years and frequent nighttime awakenings at 12 months in the Pelotas 2004 and the Pelotas 2015 Birth Cohorts by breastfeeding at 12 months and prematurity.

This study has several strengths and limitations that warrant discussion. Major strengths include the large sample of children from two population-based birth cohorts, carried out at the same city, eleven years apart, employing similar logistic and data collection methodologies. The longitudinal nature of the study, the highly standardized measurement protocol, and the rigorous quality control program ensure high quality data. As highlighted by a systematic review, an important observation of the available evidence in this field of research is the lack of use of objective measures for sleep duration, emphasizing the need for more accurate measures in future studies [3]. Our study contributes to fill this gap. Although polysomnography is considered the gold standard technique in laboratory experiments, actigraphy is gaining popularity for the assessment of sleep in epidemiologic research, providing a good objective estimate of sleep duration. Additionally, sleep duration can differ in children depending on the day of the week (school versus weekend night) [24]; therefore, it is essential to analyze both periods, as we have done here.

Among the limitations, the sleep was objectively assessed by actigraphy only at 6 years of age. Nighttime awakenings at 12 months were based on maternal report. The reported awakenings are thus the signaled nighttime awakenings that were identified by the parents, and the results cannot be generalized to other brief awakenings that were not signaled. Also, as actigraphy is highly accurate to identifying sleep periods, but less accurate in identifying wake after sleep [23], the total sleep time and the sleep efficiency may have been overestimated. Additionally, the type of actigraphy device used at the cohorts were different, and to comply with other objectives of the cohorts, we employed the Van Hess (2015) algorithm to assess the sleep parameters. The most widely used algorithm to calculate accelerometer sleep outcomes in children is the Sadeh algorithm [39]. Within the actigraphy field, there is lack of standardization of scoring rules for sleep, made difficult by the variety of proprietary hardware used utilizing different sampling rates and algorithms [42]. A systematic review and meta-analysis aiming to establish normative estimates of child nighttime sleep, including any algorithm, points that the adequate sleep duration for children aged 6–8 years should be around 8.24 h (95%CI 7.83–8.65) and the sleep efficiency for those aged 3–14 years 86.3 % (95%CI 84.4–88.2 %) [42]. This meta-analysis was replicated including an additional 2.5 years of literature and focusing on outcomes produced exclusively with the Sadeh algorithm and the mean values for sleep duration were very similar to the previous review, although only 17 out of our 83 studies were included in both meta-analyses [39]. Sleep efficiency for children aged 6–12 years (87.0 %; 95%CI 82.0–92.0 %) was similar to that reported by the first meta-analysis with children aged 3–14 years.

5. Conclusion

In both cohorts sleep duration and efficiency were below the recommendation for school-age children (respectively 9–11 h and 85 %). In our two cohorts, at 6 years of age, the sleep duration was shorter and efficiency was poorer than reported by meta-analysis of studies conducted in several countries [39,42]. Although the prevalence of frequent nighttime wakeners was high, we found no association between high nighttime awakenings and sleep duration or efficiency at school age, thus reassuring the parents who experience fragmented sleep in their infants.

CRediT authorship contribution statement

Ina S. Santos: Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Priscila Echevarria:** Writing – review & editing, Writing – original draft, Software, Formal analysis. **Luciana Tovo-Rodrigues:** Writing – review & editing, Writing – original draft. **Alicia Matijasevich:** Writing – review & editing, Writing – original draft. **Marlos R. Domingues:** Writing – review & editing, Writing – original draft. **Pedro C. Hallal:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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