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Longitudinal sleep multi-trajectories from age 1 to 5.5 years and their early correlates:

Results from the ELFE birth cohort study

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ABSTRACT

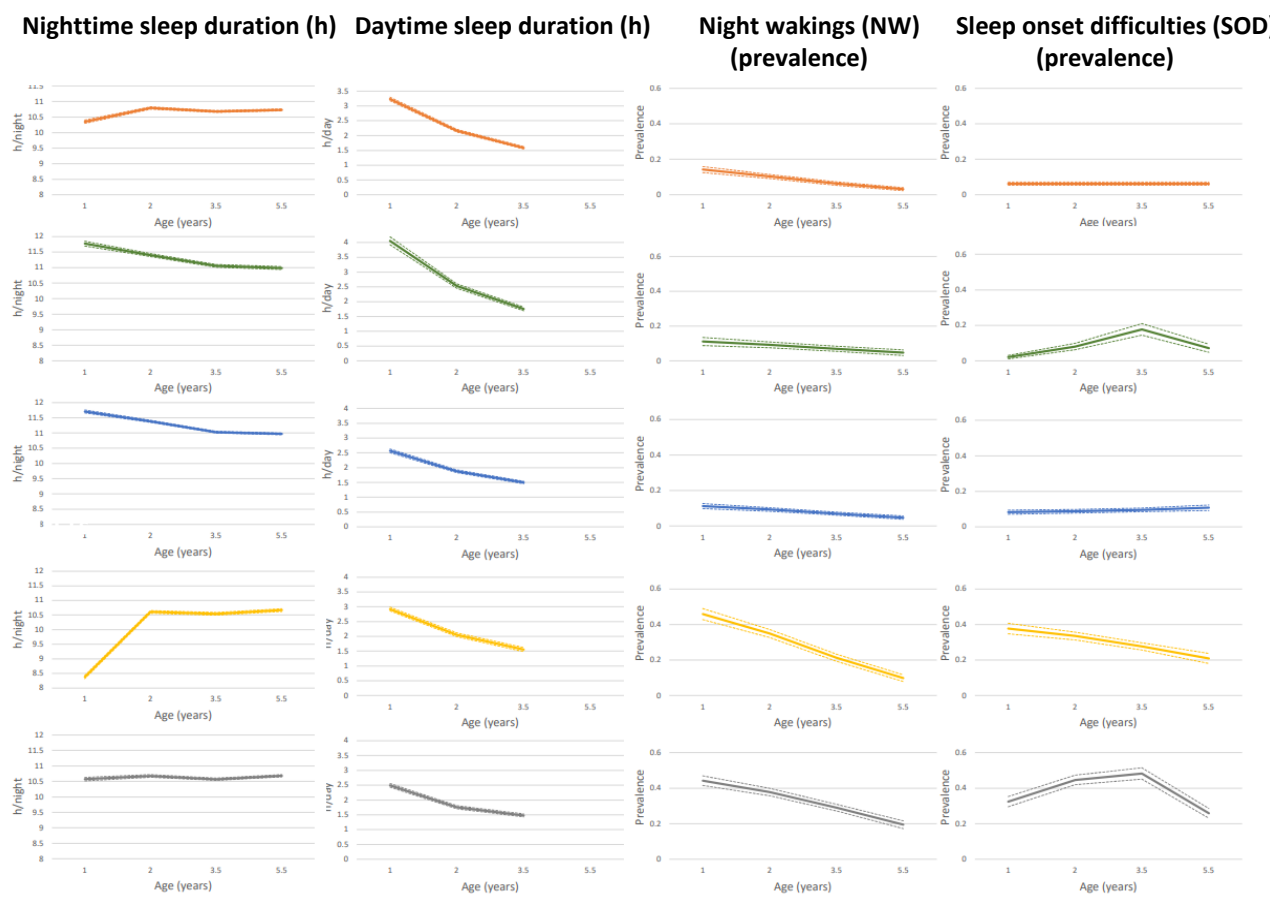
Study Objectives: Identifying sleep multi-trajectories in children from age 1 to 5.5 years and their early correlates.

Methods: We collected early family, maternal, and child characteristics, including children's nighttime (NSD) and daytime (DSD) sleep duration, night waking (NW), and sleep onset difficulties (SOD), by parental phone interviews at age 2 months and 1-, 2-, 3.5- and 5.5-years. Group-based multi-trajectory modeling identified sleep multi-trajectory groups. Multinomial logistic regression assessed associations with early factors.

Results: We identified five distinct sleep multi-trajectory groups for NSD, DSD, NW and SOD in 9,273 included children. The “Good sleepers” (31.6%) and “Long sleepers” (31.0%) groups had low NW and SOD prevalence and shorter NSD but longer DSD in “Good sleepers” than in “Long sleepers”. The “Good sleepers but few SOD” group (10.3%) had long NSD and DSD but a SOD peak at age 3.5 years; the “Improving NW and SOD” group (9.6%) showed short but rapidly increasing NSD to a plateau and high but decreasing NW and SOD; the “Persistent NW and SOD” group (17.5%) had persistent high NW and SOD. Maternal depression during pregnancy and sleep habits at age 1 (e.g., parental presence or feeding to fall asleep, sleeping at least part of the night away from own bed) were common risk factors associated with the most disordered sleep multi-trajectory groups.

Conclusions: We identified distinct sleep multi-trajectory groups and early life-associated factors in preschoolers. Most of the factors associated with the most sleep-disordered multi-trajectory groups are likely modifiable and provide clues for early prevention interventions.


Longitudinal sleep multi-trajectories from age 1 to 5.5 years and their early correlates: Results from the ELFE birth cohort study (N=9,237)



Good sleepers (G1)
31.7% (reference)

Good sleepers but few SOD (G2)
10.3%

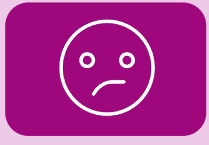
Long sleepers (G3)
31.0%



No or few sleep problems groups

Improving NW and SOD (G4)
9.6%


Persistent NW and SOD (G5)
17.5%




Frequent sleep problems groups


G2

G3






Sleep habits at age 1 year
(not getting asleep with parental presence, child having one's own room, start and finish sleep in one's own bed)




Daycare by family member




Young maternal age


G4

G5





Sleep habits at age 1 year
(parental presence or feeding required to fall asleep, sleeping at least part of the night away from own bed)



Maternal depression during pregnancy

Conclusion: We identified distinct groups of sleep multi-trajectories and early life-associated factors in preschoolers. Most of the factors associated with the most sleep-disordered multi-trajectory groups are likely modifiable and provide clues for early prevention interventions.

Key words: Group-based multi-trajectory modeling, sleep, children, preschool, sleep patterns, risk factors, longitudinal cohort study.

Statement of Significance

Sleep characteristics change rapidly during the early years of life. The present study is the first to investigate both sleep duration (nocturnal and diurnal) and quality and their evolution in children aged 1 to 5.5 years by identifying developmental sleep multi-trajectories in a national birth cohort study with a large sample size. In addition, this study identified specific early-life factors associated with the multi-trajectory groups with the most sleep disturbance that may be modifiable, providing clues for early behavioral prevention interventions.

1. Introduction

Healthy sleep is vital and essential for every person's overall health and wellbeing¹. It is characterized as adequate duration, appropriate timing and good quality without disturbances^{2,3}. Appropriate sleep durations (night sleep duration [NSD] and day sleep duration [DSD]) and sleep patterns vary with age^{3,4}. Sleep characteristics evolve rapidly during the first years of life, and changes in sleep patterns continue up to adulthood^{5,6}. For example, DSD gradually declines throughout childhood and is typically stopped by age 6 years⁷. However, sleep problems such as night waking (NW) and sleep onset difficulties (SOD) are frequent in young children^{8,9}. In fact, short sleep duration (SSD), frequent SOD and NW affect 20% to 30% of children under age 5 years¹⁰⁻¹². Early life sleep problems have been associated with child development and health, especially emotional^{13,14}, behavioral¹⁵⁻¹⁷ and intellectual development^{18,19}. Previous longitudinal studies showed that early life sleep troubles may persist in childhood and at later phases of life such as adolescence and adulthood^{10,20}.

Previous studies, mostly cross-sectional, have found several factors associated with sleep duration and quality. Child male sex^{7,8,21} and maternal depression²²⁻²⁴ were risk factors for both SSD and frequent sleep problems such as SOD and NW. Also, sleep habits up to the first 5 years of life such as co-sleeping (room or bed-sharing) and night sleep away from one's own bed were also found associated with SSD and sleep disturbances^{12,25,26}. Breastfeeding duration^{12,27} was found associated with SSD and NW¹². Demographic and maternal factors such as low income families^{7,28,29}, low educational level^{7,29}, older mothers at pregnancy (> 35 years)⁷ were suggested as risk factors for SSD from infancy up to 11 years. Regular exposure to passive smoking particularly in early years^{30,31} was found associated with frequent SOD and NW in childhood but also with sleep problems in adulthood³².

To our knowledge, only a few studies have assessed longitudinal sleep characteristics among children in large representative cohorts^{7,12,33–36}. Most of these studies defined sleep duration by global means or using predefined thresholds, usually those recommended by sleep societies, which might not be always the best way to describe the variability between infants and children over time. Even fewer studies, including ours, focused on sleep trajectories to identify groups with specific evolution of sleep characteristics over time, usually studying only one sleep characteristic^{20,31,33,37}. Only one recent study investigated the variations in night, day and total sleep trajectories among Asian children aged 3 months to 4.5 years³⁸ but studied each characteristic separately. Given that sleep undergoes various developmental patterns of change in duration and quality up to consolidation in the preschool years, studying each sleep characteristic one by one might not be accurate enough to assess the co-evolution of sleep patterns over time.

This study aimed to identify longitudinal sleep multi-trajectory patterns of NSD, DSD, frequent SOD and NW from age 1 to 5.5 years and identify specific early-life factors associated with these multi-trajectory patterns.

2. Methods

2.1. Study design and population

The ELFE birth-cohort profile and design have been previously published³⁹. Briefly, this national cohort was launched in metropolitan France in 2011. A total of 320 randomly selected maternity units participated. Inclusion criteria were infants born after 33 weeks of gestation to mothers ≥ 18 years old with no plan to leave metropolitan France within 3 years. Finally, 18,329 infants, born from mothers who agreed to participate, were recruited.

Participating mothers signed consent for themselves and their infant. Fathers signed consent for the infant's participation when present on inclusion days or were informed about their rights

to oppose. The ELFE study obtained approval from the Consultative Committee for the Treatment of Information for Health Research (CCTIRS), the national data protection authority (CNIL) and the National Council of Statistical Information (CNIS).

2.2. Data collection

Data for this study were collected from face-to-face questionnaires and medical records at the maternity wards and by parental phone-call interviews during the follow-up phases at child age 2 months and 1, 2, 3.5 and 5.5 years.

2.2.1. Sleep outcomes from age 1 to 5.5 years

NSD was assessed by the following questions: “What is your child’s total night sleep duration?” at age 1 year, and “Usually, at what time does your child go to bed?” and “Usually, at what time does your child wake up?” for weekdays and weekend days or holidays, respectively, at age 2, 3.5 and 5.5 years. DSD was assessed by the following question: “What is your child’s total daytime sleep duration including naps?” at age 1 and 2 years. At age 3.5 years, questions asked for both weekdays and weekend days or holidays were “Does your child take a nap?” and “What is your child’s total nap duration?”. Information on DSD was not asked at age 5.5 years. Mean NSD and DSD per day were calculated over the week in hours and minutes.

NW and SOD were respectively assessed by the same following questions at age 1, 2, 3.5 and 5.5 years: “How many nights did your child wake up during the night this week? (Never, 1 or 2 nights, 3 to 6 nights and always)” and “When you put your child in the bed, does he/she have difficulties falling asleep? For example, he/she calls or cries for a long time over 30 minutes? (Never, sometimes and often at age 1 and 2; never, sometimes, often and always at age 3.5 and 5.5).” Presence of NW and SOD was further considered when the answers were “3 to 6 nights a week” and “always” for NW and “often” and “always” for SOD.

2.2.2. Covariates

Sociodemographic and maternal characteristics were collected during the age 2-month phone interview and were completed by information collected at the maternity ward when missing. Characteristics included maternal birth place (France or abroad), single motherhood (yes/no), monthly household income in euros per consumption unit (€/month/CU) classified in quintiles (<1000, 1000-1385, 1385-1662, 1662-2078 and >2078), maternal education attainment (equal, below and above high school), crowded dwelling defined as number of rooms/people in the family ≤ 1 (yes/no), noisy dwelling (yes/no), maternal age at delivery, parity, maternal smoking during pregnancy (yes/no), maternal pre-pregnancy body mass index (BMI), maternal depressive symptoms during pregnancy (yes/no), and working mother at child age 1 (yes/no). For the latter, the “yes” answer included fully or partially working and being a student.

The child’s characteristics were collected from medical records and phone interviews and included sex, gestational age, birth weight, breastfeeding duration, medical problems from birth to age 1 year (none; medical consultation, i.e., more than the recommended ones for infants up to age 1 year and emergency or specialized consultation; and hospitalization), passive smoking exposure from age 2 months to 1 year. Main day-care arrangement (family members/partner; employed person, i.e., nannies inside or outside child’s home; and collective care) and sleep habits were collected at age 1 year. The latter habits included non-nutritive sucking (coded as none, thumb/finger only, pacifier only, both pacifier and thumb/finger), the use of a comforter (yes/no), parental presence needed when falling asleep (yes/no), room sharing (yes/no), and sleep arrangement (the infant falls asleep and ends in own bed/crib, falls asleep in own bed/crib but ends sleep in the parent’s bed, and falls asleep and ends sleep elsewhere than in own bed/crib).

2.3. Statistical analysis

Analyses were performed with SAS 9.4 (SAS Institute Inc, Cary, NC, USA). Characteristics of the included and excluded children were compared by chi-squared and Student *t* test for categorical and continuous variables, respectively.

Multi-trajectories of sleep characteristics were identified by using the group-based multi-trajectory modeling (GBMTM) method (PROC TRAJ procedure) developed by Nagin et al.⁴⁰. It allows for simultaneously modeling multiple measures of the same underlying phenomenon (NSD, DSD, NW and SOD). Trajectory shapes are modelled using polynomial functions of time. GBMTM handles missing values, and children were included in the multi-trajectories modeling if information on each sleep characteristic was available for at least two of four time points. Different models with up to five groups were computed and then compared based on the Bayesian Information Criteria. The final chosen model favored parsimony, and its quality was verified according to the recommended criteria: the average probability of belonging for each trajectory (≥ 0.7), the odds of correct classification (≥ 5) and the similarity between the model's estimation of the multi-trajectory prevalence and the actual prevalence⁴⁰. Children were then assigned to the trajectory group to which they had the highest possibility of belonging.

Covariates included in adjusted models were identified from the literature and were those described above. Multiple imputations of missing data for covariates (1.4%) involved using Fully Conditional Specification. Binary variables were imputed by logistic regression, nominal and ordinal variables by multinomial logistic regression, and continuous variables by linear regression. Twenty databases were imputed and analyzed. Estimates and confidence intervals were pooled to obtain overall results. Associations between covariates and sleep multi-trajectories were estimated by unadjusted (M1) and adjusted (M2) multinomial logistic regression models with a reference group, the one closest to the recommended sleep duration

and quality among children aged 1 to 5 years^{2,3}. As this is an exploratory analysis of factors associated with the multi-trajectory groups, the significant level was defined as $p < 0.05$. However, significant results after Benjamini-Hochberg adjusted p-value for multiple testing are with * in the tables.

3. Results

3.1. Characteristics of the study population

Among the 18,329 children included in ELFE cohort at birth, twins ($n=550$) and preterm infants ($n=756$) were excluded as were children with missing sleep outcomes at all time points ($n=3,538$) and those with very short or very long total sleep duration at age 1 year ($< 9\text{h/day}$, $n=1$; and $\geq 18\text{h/day}$, $n=3$) and missing data for the other time points. Among the 13,481 children with sleep data, 9,273 children had information for at least two of four time points for all sleep outcomes and were included in the sleep multi-trajectory modeling.

Maternal and child characteristics for excluded and included children are in Table 1. As compared with excluded children ($n=3,688$), included children ($n=9,273$) were significantly more frequently born to more educated mothers (41.7% vs. 17.1% >high school) with higher household income (47.9% vs. 25.3% >fourth quintile [$>1662\text{€}/\text{month}/\text{CU}$]), who were older at delivery (31.1 vs. 29.2 years), born in France (89.9% vs. 79.1%), non-smokers during pregnancy (82.5% vs. 72.7%), with lower pre-pregnancy BMI (23.4 vs. 23.8 kg/m^2), multiparous (34.2% vs. 31.8%), living in a couple relationship (96.8% vs. 89.0%), and working at 1-year post-delivery (79.3% vs. 58.0%). Also, included children significantly more frequently had higher gestational age (39.4 vs. 39.3 weeks), larger birth weight (3.4 vs. 3.3 kg), and longer breastfeeding duration (4.0 vs. 1.1 months). They less frequently lived in a crowded dwelling (18.6% vs. 32.3%) and were exposed to noises (10.5% vs. 15.8%) at age 2 months and more frequently experienced medical concerns (consultations or hospitalization) up to age

1 year (28.6% vs. 19%) than excluded children. Maternal depression during pregnancy and child sex did not differ by inclusion.

3.2. Sleep multi-trajectories description

We identified five distinct sleep multi-trajectory groups (Figure 1). NSD trajectories followed a quadratic shape in all groups except the second group, for which a cubic shape best explained the data. In all five groups, DSD and NW trajectories were best modeled by a cubic and linear relation, respectively. SOD shapes were more diverse. Groups 2 and 5 followed a cubic shape, groups 3 and 4 followed a decreasing linear shape and group 1 was constant.

Globally, all groups showed total sleep durations within the recommended sleep duration guidelines for children aged 1 to 5 years^{2,3} but with various shapes and distribution between night and day sleep (Table 2). In addition, all groups showed different prevalence of NW and SOD over time.

More specifically, children belonging to the first group had stable NSD, decreasing DSD and stable prevalence of SOD and NW (n=2,799, 31.6%). For children of this group, the mean sleep duration was 10h20/night at age 1 year with a slight increase of about 25 min/night in the following years. Mean DSD decreased from 3h15/day at age 1 year to 1h35/day at age 3.5 years, and frequent NW decreased from 14.3% at age 1 year to 2.8% at age 5.5 years, whereas frequent SOD was stable from 5.5% to 9.0% at all ages. This group was named “Good sleepers” and was the reference group for all analyses.

Globally, children belonging to the second group showed long sleep durations and moderate sleep quality from age 1 to 5.5 years (n=1,089, 10.3%). They presented long sleep durations especially at age 1 year, with mean NSD at 12h00/night and mean DSD at 4h00/day at age 1 year decreasing to 11h00/night and 1h35/day at age 5.5, respectively. Frequent NW decreased from 10.2% at age 1 year to 3.2% at age 5.5. Frequent SOD concerned 2.4% of children at age 1 year but peaked at 18.3% at age 3.5. This group was named “Good sleepers but few SOD”.

Children belonging to the third group showed slightly lower durations and higher SOD than children from “Good sleepers” (n=2,763, 31.0%). They showed a stable mean NSD between 11h00/night and 11h45/night from age 1 to 5.5 years. Mean DSD decreased from 2h30/day at age 1 year to 1h30/day at age 3.5. Frequent NW decreased from 11.2% at age 1 year to 3.9% at age 5. Few frequent SODs were noticed (\approx 8.0%) but with a peak of 13.7% at age 3.5 years. This group was named “Long sleepers”.

Children belonging to the fourth group showed an early sleep duration catch-up with a low but improving sleep quality (n=898, 9.6%). For children of this group, NSD strongly increased from 8h20/night at age 1 year to a plateau at about 10h40/night from age 2 to 5.5. Mean DSD decreased from 2h55/day at age 1 year to 1h30/day at age 3.5. Frequent NW and SOD were prevalent at age 1 year (48.4% and 40.9%, respectively) but decreased regularly to 10.9% for NW and 21.4% for SOD at age 5.5 after a plateau at about 30% from age 2 to 3.5. This group was named “Improving NW and SOD”.

Globally, children belonging to the last group showed shorter sleep duration with persistent low sleep quality (n=1,724, 17.5%). Children of this group had an average NSD of 10h40/night at all ages, and mean DSD decreased from 2h30/day at age 1 year to 1h28/day at age 3.5. Frequent NW was prevalent at age 1 year (42.7%) and decreased to 17% at age 5.5. Frequent SOD was prevalent at all ages, from 33.5% at age 1 year to a peak at 50% at age 3.5 and a decrease to 25.4% at age 5.5. This group was named “Persistent NW and SOD”.

Bedtimes were consistent within each group for all ages with collected information (2, 3.5 and 5.5 years). The groups “Good sleepers but few SOD” and “Long sleepers” showed the same earliest mean bedtimes (8:30 pm) followed by the group “Good sleepers” (mean bedtime 8:42 pm) and the groups “Improving NW and SOD” and “Persistent NW and SOD” with the latest mean bedtimes (8:54 pm) (Appendix 1).

3.3. Factors associated with sleep multi-trajectories between age 1 and 5.5 years

Unadjusted and adjusted multinomial logistic regressions are shown in the Appendix 2 and Table 3, respectively. Briefly, two subgroups emerged according to their trajectory characteristics: the groups of “Good sleepers but few SOD” and “Long sleepers” with longer NSD at age 1 year and small peak of SOD at age 3.5 as compared with children belonging to the group of “Good sleepers”, and the groups “Improving NW and SOD” and “Persistent NW and SOD” with shorter NSD, higher frequency of SOD and NW as compared with the group “Good sleepers”.

In adjusted models, as compared with the children from the group “Good sleepers”, the first subgroups (“Good sleepers but few SOD” and “Long sleepers”) were associated with younger maternal age, being cared for during the day by family members and less frequently having the sleep habits of falling asleep with parental presence, sharing their room and spending at least part of the night out of their own bed. However, several factors differentiated the children belonging to the group “Good sleepers but few SOD” and “Long sleepers” within this subgroup. Belonging to the group “Long sleepers” (longer sleep duration but higher frequency of SOD than “Good sleepers but few SOD”) was associated with female sex, lower maternal educational level and lower frequency of professional activity at age 1 year, and belonging to the group “Good sleepers but few SOD” was associated with having a primiparous mother, with higher pre-pregnancy BMI, who smoked during pregnancy, and more non-nutritive sucking behaviours.

As compared with children from the group “Good sleepers”, the second subgroup (“Improving NW and SOD” and “Persistent NW and SOD”) was associated with more maternal depressive symptoms during pregnancy, being cared for during the day by family members, having medical concerns and more frequently having the sleep habits of falling asleep with parental presence, sharing a room and spending at least part of the night in another bed. However,

several factors also differentiated the two groups “Improving NW and SOD” and “Persistent NW and SOD” within this subgroup. Indeed, belonging to the group “Persistent NW and SOD” (higher rates of NW and SOD from age 1 to 5.5 years) was associated with older maternal age, higher maternal educational level and more exposure to tobacco during and after pregnancy, and belonging to the group “Improving NW and SOD” was associated with lower maternal educational level and lower birth weight.

4. Discussion

To the best of our knowledge, this is the first study to describe both the quantity and quality of sleep patterns, identify longitudinal sleep multi-trajectories and evaluate their early correlates in children aged 1 to 5.5 years. We identified five distinct groups of children following different sleep duration and quality patterns over time.

When comparing our results to those for general population while studying global means or prevalence of each sleep characteristic one by one, our results showed that in all identified groups, mean total sleep durations were within the range of the daily sleep duration recommended by the American Academy of Sleep Medicine: 11h-14h/24h for children aged 1 to 2 years and 10h-13h/24h for those aged 3 to 5 years³, despite differences in day and night sleep distribution. Children belonging to groups “Good sleepers”, “Good sleepers but few SOD” and “Long sleepers” presented the highest sleep durations, especially for NSD for children in groups “Good sleepers but few SOD” and “Long sleepers” and DSD for children in groups “Good sleepers” and “Good sleepers but few SOD”. Children in the group “Improving NW and SOD” had the shortest total sleep duration at age 1, mainly due to short NSD but with a rapid catch-up afterward.

Despite these variations between sleep multi-trajectory groups, observed sleep duration trajectories were longer than in other studies reporting NSD trajectories and conducted among Canadian children aged 2.5-6 years¹⁹, Singaporean children aged 3-24 months⁴¹ and 3-54

months³⁸; and reporting NSD and DSD trajectories in Canadian children aged 3-24 months⁴². This observation may reflect overall higher sleep durations in French preschoolers as compared with their worldwide counterparts, as was also suggested in previous French study of the EDEN birth cohort³⁷. NW trajectories were more or less low and stable in three groups (“Good sleepers”, “Good sleepers but few SOD” and “Long sleepers”) and high but decreasing in children from group “Improving NW and SOD” and high but persistent in children from group “Persistent NW and SOD” (27% of the children) from age 1 to 5.5 years. These two kind of trajectory shapes have been reported for number of NWs per night among children aged 6 to 36 months in the United States⁴³ (34% in the high decreasing trajectory), in Chinese children aged 1 to 36 months (77% in the persistent NW group)²⁴ and in the French EDEN study³¹ in children 2 to 5.5 years old (23% belonging to the high prevalence trajectory). SOD trajectories were studied only in the EDEN birth cohort in children 2 to 5.5 years old (25% of the children)⁴⁴. Here we report a high prevalence of SOD in children from groups “Improving NW and SOD” and “Persistent NW and SOD” (27% of the children) with a decreasing shape for children from group “Improving NW and SOD” but a persistent one for children from group “Persistent NW and SOD” and a small peak (inverse U shape) at age 3.5 years in children from group “Good sleepers but few SOD” (10% of children), not explained by early bedtimes. This peak at age 3.5 years was already reported in the EDEN cohort⁴⁴ and might be explained by developmental changes and brain maturation occurring mainly during the first 2 years of life^{45,46}. However, further research is needed to address this issue and better explore sleep quality patterns, mainly SOD, during pre-school age.

Different early factors and sleep habits were associated with each multi-trajectory group of sleep characteristics. As compared with children from group “Good sleepers”, sleep multi-trajectories with long NSD and DSD and low NW and SOD (“Good sleepers but few SOD” and “Long sleepers”) were negatively associated with maternal age, child being care for by

someone else than a family member and several behaviors at age 1 year such as parental presence needed for the child to fall asleep and the child sleeping at least part of the night elsewhere than in their own bed. Conversely, sleep multi-trajectories with short NSD and DSD and high NW and SOD (“Improving NW and SOD” and “Persistent NW and SOD”) were positively associated with these same factors. These results agree with the literature^{7,29} and confirm our previous results obtained cross-sectionally in infants and longitudinally in preschoolers in another birth cohort^{12,31,42}. They suggest that early adequate sleep hygiene behaviors are beneficial for sleep patterns over time and that parental knowledge about sleep practices and needs should be reinforced⁴⁷. In addition, non-nutritive sucking (finger or pacifier) at age 1 year was positively associated with odds of belonging to group “Good sleepers but few SOD” (long sleep duration, relatively good sleep quality) and negatively with odds of belonging to group “Persistent NW and SOD” (short sleep duration, low sleep quality), which suggests that non-nutritive sucking habits may facilitate sleep initiation and maintenance. In a previous work, we showed that sucking a pacifier (with or without finger sucking) was associated cross-sectionally with more NW and SOD at age 1 year in infants from the ELFE cohort, and sucking only the finger/thumb was associated with fewer NW and SOD¹². This longitudinal analysis suggests that the observed effect at age 1 year does not persist when children grow up (i.e., when they are all able to find their pacifier within the bed and self-sooth)⁴⁸.

In the unadjusted models, the positive association between breastfeeding duration and belonging to groups “Improving NW and SOD” and “Persistent NW and SOD” (shortest sleep durations and highest NW and SOD) disappeared after adjustment, especially for parental sleep practices. This disappearance of the association in adjusted model suggests that, in our study population, breastfeeding or its duration by itself did not lead to sleep problems but rather than

sleep problems could result from parental sleep practices, related to nighttime breastfeeding and their maintenance after weaning.

This hypothesis was already suggested in our previous cross-sectional study of children at age 1 year¹². However, a recent publication of Asian children reported more frequent NW and longer sleep duration trajectories from age 3 to 54 months when the child was breastfed versus bottle-fed at age 3 months⁴⁹. The differences with our results might be explained by the higher prevalence of breastfed children in the Asian population (56%) than our population, the variable considered (breastfed at 3 months, yes/no, vs breastfeeding duration), the fact that we included NW and SOD in the multi-trajectory modelling and our additional adjustment on sleep practices.

In addition, the groups “Improving NW and SOD” and “Persistent NW and SOD” were associated with a mother presenting depressive symptoms during pregnancy and feeding the child to fall asleep at age 1 year. Maternal depression during the pre- and postnatal periods has been associated with an increase in both poorer child’s sleep quantity and quality of child’s sleep problems^{23,24,50,51}. A recent study reported that perinatal maternal depression was not associated with objectively measured sleep problems in children at age 1 year⁵², which suggests that maternal dysfunctional cognition, behavioral factors and sleep impairment observed in perinatal depression may affect the mother's impression of her infant's sleep and thus her reporting. However, several studies suggested that the link between maternal depression and shorter/lower sleep quality could be explained at least in part by an inappropriate strategy such as those to get the child go back to sleep, including feeding to fall asleep, as observed in the current study^{12,24,45,52}. This latter strategy, needing parental intervention, may also limit the child’s self-soothing capacities^{53–57}.

Maternal tobacco use during pregnancy was positively associated with groups having a peak of SOD at age 3.5 years (“Good sleepers but few SOD” and “Persistent NW and SOD”).

Passive smoking up to 1 year was also positively associated with odds of belonging to group “Persistent NW and SOD”, the group with the worst sleep multi-trajectories and in particular high persistent NW and SOD. Maternal smoking, especially during pregnancy, has been associated with sleep disturbances (duration, NW) in children^{30,31,37,58}. However, no study specifically investigated SOD. Several mechanisms might be involved, such as prenatal physiological modification involving hypoxia, as in sudden infant death syndrome⁵⁹, or by a direct increase of health problems such as asthma, lower respiratory function, and infections⁶⁰. In addition to factors already described, high infant birth weight was negatively associated with odds of belonging to group “Improving NW and SOD”. Low birth weight has been previously associated with sleep disturbances at later ages (e.g., shorter sleep duration at 18 months⁶¹, more sleep disturbances at age 7 years⁶² and shorter sleep duration and more frequent NW at age 18 months when born small for gestational age⁶³). In our study, preterm children were excluded; however, the short NSD and high NW and SOD especially at age 1 year and the global but incomplete sleep improvement up to age 5.5 in group “Improving NW and SOD” suggest specific attention paid to sleep patterns for children born with low birth weight.

This study has several strengths. The large nationwide sample of preschoolers from metropolitan France and the prospective design providing longitudinal data allowed us to assess overall sleep quantity and quality within the French general population of preschoolers with high accuracy, good statistical power and low memory bias. The longitudinal data along with the use of a novel multi-trajectory modeling method allowed for developmental analysis of early childhood sleep patterns over time. GBMTM⁴⁰ was particularly accurate in accounting simultaneously for both quality and quantity sleep characteristics and thus better characterizing sleep evolution over time. The large information collected at birth and up to age 1 year allowed for analyzing several possible factors associated with the identified sleep multi-trajectory groups.

This study has also some limitations. Sleep characteristics were assessed by parental questionnaires. Parental reports tend to overestimate true sleep-onset latencies⁵ and child nighttime sleep⁶⁴, because it reflects more time in bed, than exact sleep duration. In addition, reported NW might only be those events that bother the parents. Actigraphy would have been a more objective and better measurement but had not been considered because of cost and logistic reasons in this nationwide survey. However, parental reports of the child's sleep assessment are still widely used in epidemiology^{5,7,65} and have been shown to be reliable as compared with actigraphy^{66,67}. Finally, the studied population has high socioeconomic status, so generalization of the findings is not possible, especially to low socioeconomic classes, children with short breastfeeding duration, high exposure to tobacco or medical issues.

5. CONCLUSION

Using an original modeling method, this study provides new insights into childhood sleep development and highlights the large variability in sleep patterns among children from age 1 to 5.5 years. We identified five groups of sleep characteristics, including night and daytime sleep duration, frequent sleep onset difficulties and night waking. Early factors associated with the groups that include shorter sleep and lower sleep qualities were mostly related to behavior and sleep hygiene, which suggests that they could be accessible to potential modifications. All these risk factors would definitely help promote early prevention actions to manage sleep problems among at-risk children. However, further studies are warranted to investigate the relations between sleep multi-trajectories and subsequent health outcomes.

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The authors have no non-financial disclosures to declare.

Data Availability

The data underlying this article cannot be shared publicly due to the privacy of individuals who participated in the study. The data will be shared on reasonable request to the cohort scientific committee.

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Figure 1. Sleep multi-trajectories for the ELFE cohort children aged 1 to 5.5 years (N=9,273)

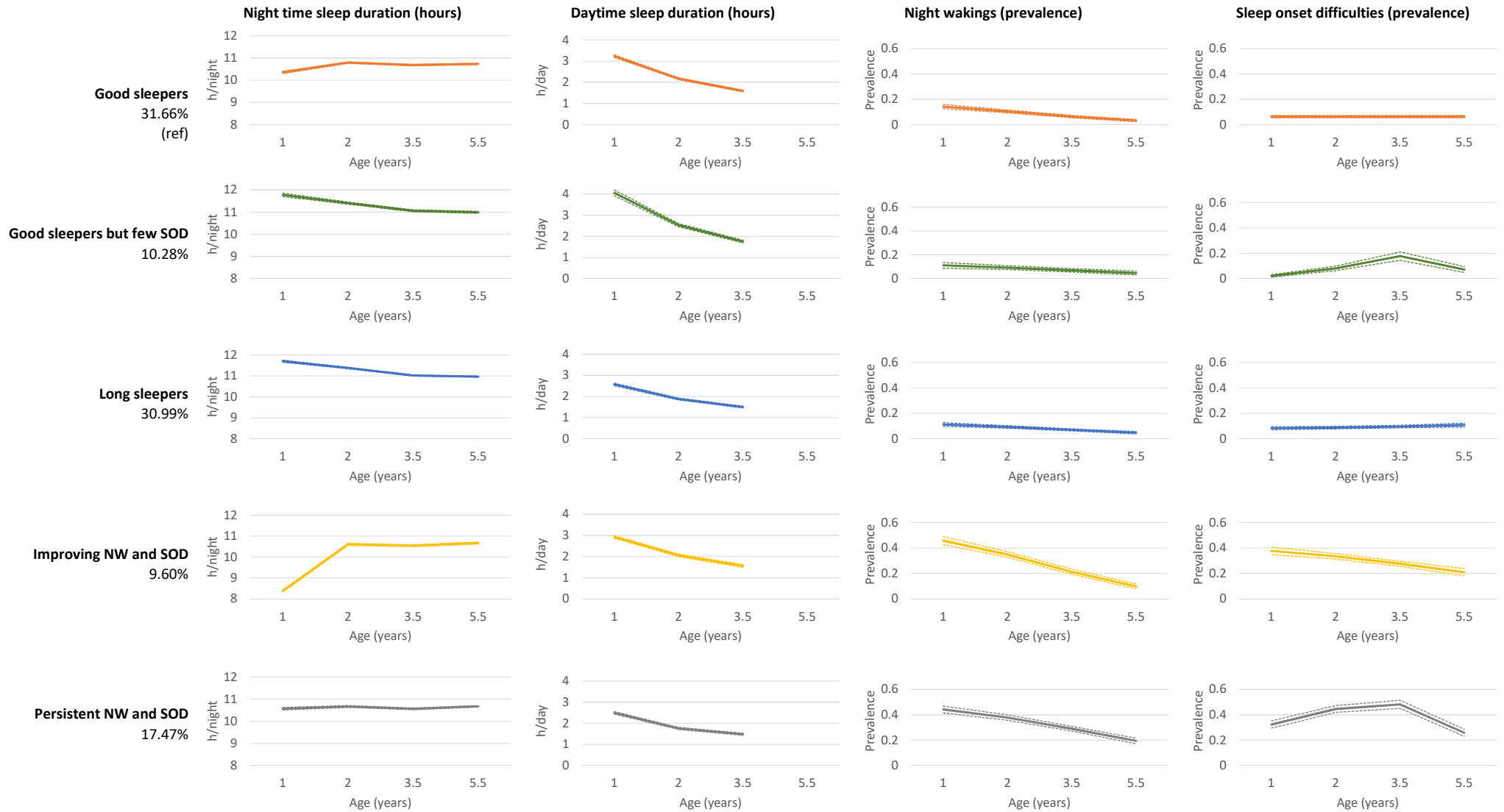


Table 1. Maternal and child characteristics (N=12,961)

	Excluded children	Included children	P-value	Missing data for included children	Missing data for excluded children
	% (n) or mean (SD) (n=3688)	% (n) or mean (SD) (n=9273)		n	n
Socio-demographic characteristics at 2 months					
Maternal education level			<.0001	11	963
< High school	16.5 (449)	23.6(2183)			
High school	66.4 (1810)	34.7 (3218)			
> High school	17.1 (466)	41.7 (3861)			
Household income (€/month/CU)			<.0001	466	1420
<1000	37.5 (851)	15.6 (1372)			
1000–1385	23.7 (538)	18.9 (1668)			
1385–1662	13.4 (305)	17.6 (1554)			
1662–2078	14.9 (339)	25.2 (2218)			
> 2078	10.4 (235)	22.7 (1995)			
Maternal characteristics					
Age at child birth (years)	29.2 (5.6)	31.1 (4.7)	<.0001	2	11
Born abroad	20.9 (767)	10.1 (938)	<.0001	0	20
Single mother	11.0 (404)	3.2 (298)	<.0001	7	19
Smoking during pregnancy	27.3 (992)	17.5 (1612)	<.0001	78	50
BMI before pregnancy (kg/m ²)	23.8 (5)	23.4 (4.7)	<.0001	90	99
Multiparous	31.8 (1167)	34.2 (3162)	0.011	20	21
Depressive symptom during pregnancy	12.9 (471)	12.1 (1114)	0.191	60	46
Working at 1 year post-delivery	58.0 (1575)	79.3 (7348)	<.0001	13	973
Child characteristics at birth and early factors at age 1 year					
Sex (boy)	51.7 (1907)	51.0 (4727)	0.443	0	1

Gestational age (weeks)	39.3 (1.1)	39.4 (1.1)	0.001	0	0
Birth weight (kg)	3.3 (0.5)	3.4 (0.4)	0.004	114	46
Breastfeeding duration (months)	1.1 (2.8)	4.0 (5.8)	<.0001	673	1355
Crowded dwelling at age 2 months	32.3 (843)	18.6 (1718)	<.0001	42	1079
Noisy dwelling at age 2 months	15.8 (337)	10.5 (972)	<.0001	30	1554
Medical problems between birth and age 1 year			<.0001	21	1237
None	80.9 (1984)	71.4 (6604)			
Consultation	6.0 (148)	13.5 (1251)			
Hospitalization	13.0 (319)	15.1 (1397)			
Passive smoking exposure up to age 1 year	10.1 (93)	4.1 (363)	<.0001	349	2764
Main day-care arrangement at age 1 year			<.0001	224	2529
Collective care	11.6 (134)	16.7 (1514)			
Cared by employed person	26.7 (309)	44.4 (4018)			
Cared by family members/partner	61.8 (716)	38.9 (3517)			
Child behaviors and sleep habits at age 1 year					
Sucking behaviors			<.0001	152	2582
Nothing	11.8 (131)	9.0 (818)			
Only finger	13.6 (150)	19.8 (1808)			
Only pacifier	52.9 (585)	48.0 (4378)			
Both finger and pacifier	21.7 (240)	23.2 (2117)			
Comforter to fall asleep	80.0 (859)	83.4 (7605)	0.005	151	2614
Parental presence to fall asleep	41.5 (511)	30.5 (2789)	<.0001	140	2457
Feeding to fall asleep	16.3 (175)	6.7 (610)	<.0001	164	2617
Room sharing	33.6 (424)	22.9 (2097)	<.0001	133	2426
Sleep arrangement			<.0001	156	2615
Sleep in one's own bed but ends up in parents' bed	18.1 (194)	13.6 (1239)			
Not sleeping in own bed	11.9 (128)	6.9 (626)			
Sleeping and finishing in own bed	70.0 (751)	79.5 (7252)			

SD: Standard deviation; **n:** number; **%:** percentage; **BMI:** body mass index; **CU:** consumption unit

Table 2. Distribution of sleep outcomes at each time point age (N=9,273)

	TSD		NSD		DSD		NW	SOD
	N	Mean (SD; range)	N	Mean (SD; range)	N	Mean (SD; range)	% (N)	% (N)
1 year	9004	13h42 (1h30; 7h45-17h30)	9061	10h46 (1h11; 7h00-16h00)	9097	2h58 (0h58; 0h00-6h00)	21.49 (7162)	14.25 (7801)
2 years	8842	13h00 (1h02; 9h00-16h30)	8873	11h00 (0h44; 9h00-13h00)	8900	2h02 (0h48; 0h00-10h00)	16.57 (7508)	15.48 (7609)
3.5 years	8001	12h13 (0h49; 9h13-16h38)	8001	10h47 (0h32; 9h05-12h00)	7540	1h33 (0h31; 0h00-5h00)	14.03 (7068)	20.98 (6508)
5.5 years	7639	10h49 (0h29; 9h30-13h24)	7639	10h49 (0h29; 9h30-13h24)	-	-	6.64 (7356)	11.75 (6963)

TSD: total sleep duration; NSD: night sleep duration; DSD: daytime sleep duration; NW: night waking occurring 3 to 6 nights per week or always; SOD: sleep onset difficulties occurring often or always; SD: standard deviation; N: Numbers; %: Frequencies

Table 3. Adjusted multinomial logistic regression for sleep multi-trajectories (N=9273). “Good sleepers” was the reference.

	Sleep multi-trajectory groups			
	Good sleepers but few SOD	Long sleepers	Improving NW and SOD	Persistent NW and SOD
	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Socio-demographic characteristics				
Maternal education level				
< High school	1.08 [0.87-1.34]	0.80 [0.69-0.93]*	1.45 [1.15-1.82]*	0.77 [0.64-0.92]*
High school	1.05 [0.86-1.28]	0.84 [0.73-0.96]*	1.16 [0.92-1.46]	0.76 [0.64-0.90]*
> High school	Reference	Reference	Reference	Reference
Household income (€/month/CU)				
< 1000	1.08 [0.78-1.50]	0.90 [0.71-1.12]	1.03 [0.73-1.44]	0.80 [0.62-1.04]
1000–1385	1.25 [0.95-1.65]	0.96 [0.80-1.16]	1.06 [0.77-1.45]	0.78 [0.62-0.97]*
1385–1662	1.12 [0.87-1.46]	1.02 [0.85-1.21]	0.93 [0.68-1.26]	0.88 [0.71-1.09]
1662–2078	1.24 [0.98-1.56]	0.97 [0.83-1.13]	0.90 [0.68-1.19]	0.90 [0.74-1.09]
> 2078	Reference	Reference	Reference	Reference
Maternal characteristics				
Age (years)	0.96 [0.95-0.98]*	0.98 [0.97-0.99]*	1.01 [0.99-1.02]	1.02 [1.01-1.04]*
Born abroad	1.05 [0.77-1.43]	0.89 [0.72-1.10]	1.24 [0.98-1.58]	1.03 [0.84-1.28]
Single mother	1.06 [0.64-1.74]	1.06 [0.75-1.49]	1.04 [0.70-1.55]	1.27 [0.89-1.81]
Smoking during pregnancy	1.26 [1.03-1.54]	1.12 [0.96-1.29]	1.06 [0.85-1.31]	1.20 [1.01-1.43]
BMI before pregnancy (kg/m ²)	1.01 [1.00-1.03]	0.99 [0.98-1.00]	1.00 [0.98-1.02]	0.98 [0.97-1.00]
Multiparous	0.75 [0.63-0.89]*	0.93 [0.83-1.06]	1.06 [0.87-1.28]	1.07 [0.92-1.25]
Depressive symptom during pregnancy	1.04 [0.82-1.31]	1.07 [0.90-1.26]	1.27 [1.01-1.60]	1.31 [1.08-1.58]*
Working at age 1 year	1.06 [0.84-1.35]	0.76 [0.64-0.90]*	0.96 [0.77-1.21]	0.90 [0.74-1.09]
Children characteristics and early factors at age 1 year				
Sex (boy)	0.90 [0.78-1.05]	0.75 [0.67-0.83]*	0.91 [0.77-1.07]	1.00 [0.88-1.13]
Gestational age (week)	0.95 [0.88-1.02]	1.00 [0.95-1.05]	0.99 [0.92-1.07]	1.01 [0.95-1.07]
Birth weight (kg)	1.02 [0.85-1.24]	1.00 [0.88-1.15]	0.75 [0.61-0.92]*	0.87 [0.73-1.02]
Breastfeeding duration (month)	0.99 [0.97-1.01]	0.99 [0.98-1.01]	1.00 [0.99-1.02]	1.00 [0.99-1.02]

Crowded dwelling at age 2 months	0.81 [0.64-1.03]	0.96 [0.81-1.12]	1.04 [0.83-1.29]	1.01 [0.84-1.22]
Noisy dwelling at age 2 months	0.83 [0.64-1.08]	0.95 [0.79-1.13]	0.88 [0.69-1.13]	0.92 [0.75-1.13]
Medical problems between birth and age 1 year				
Rare issue	Reference	Reference	Reference	Reference
Consultation	1.06 [0.84-1.33]	1.09 [0.93-1.28]	1.47 [1.18-1.84]	1.26 [1.05-1.52]
Hospitalization	1.14 [0.92-1.40]	1.13 [0.97-1.32]	1.16 [0.93-1.45]	1.13 [0.94-1.35]
Passive smoking exposure up to age 1 year	0.88 [0.57-1.35]	1.07 [0.80-1.43]	1.38 [0.96-1.98]	1.41 [1.03-1.93]
Main day-care arrangement at age 1 year	0.99 [0.97-1.01]	0.99 [0.98-1.00]	1.00 [0.99-1.02]	1.00 [0.99-1.01]
Collective care	0.56 [0.43-0.74]*	0.71 [0.60-0.84]*	1.00 [0.77-1.29]	1.02 [0.83-1.25]
Cared by employed person	0.67 [0.55-0.82]*	0.65 [0.56-0.75]*	0.65 [0.52-0.80]*	0.81 [0.68-0.96]*
Cared by family members/partner	Reference	Reference	Reference	Reference
Sleep habits at age 1 year				
Sucking behaviors				
Nothing	Reference	Reference	Reference	Reference
Only finger	2.21 [1.52-3.22]*	1.18 [0.94-1.48]	0.93 [0.67-1.28]	0.75 [0.58-0.97]
Only pacifier	1.55 [1.06-2.26]	0.96 [0.77-1.20]	1.00 [0.73-1.36]	0.79 [0.62-1.01]
Both finger and pacifier	1.30 [0.88-1.94]	0.90 [0.71-1.14]	1.06 [0.76-1.48]	0.89 [0.68-1.16]
Comforter to fall asleep	1.17 [0.90-1.51]	1.04 [0.88-1.23]	0.86 [0.68-1.09]	0.91 [0.75-1.11]
Parental presence to fall asleep	0.64 [0.51-0.81]*	0.80 [0.69-0.93]	2.89 [2.37-3.51]*	2.09 [1.79-2.45]*
Feeding to fall asleep	0.70 [0.46-1.07]	0.99 [0.77-1.26]	1.54 [1.18-2.02]*	1.40 [1.09-1.79]*
Room sharing	0.75 [0.60-0.94]*	0.72 [0.61-0.84]	0.99 [0.80-1.22]	1.03 [0.86-1.22]
Sleep arrangement				
Starts and finishes sleep in own bed	Reference	Reference	Reference	Reference
Starts in one's own bed but not finishing in it	0.61 [0.44-0.84]*	0.74 [0.61-0.90]*	1.80 [1.44-2.25]*	1.73 [1.44-2.09]*
Not sleeping in one's own bed	0.78 [0.46-1.30]	0.83 [0.61-1.13]	3.15 [2.36-4.20]*	2.26 [1.72-2.97]*

aOR: adjusted odds ratio; 95% CI: 95% confidence interval; BMI: body mass index; CU: consumption unit

In bold are significant results with p-value < .05.

* Significant results after Benjamini-Hochberg adjusted p-value for multiple testing

Appendix 1. Week average bedtime distribution by age and sleep multi-trajectory groups

	Sleep multi-trajectory groups										
	Good sleepers		Good sleepers but few SOD		Long sleepers		Improving NW and SOD		Persistent NW and SOD		Prob
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	
2 years	2854	20h42 (30min)	935	20h30 (30min)	2795	20h30 (30min)	847	21h54 (42min)	1564	20h54 (36min)	<.0001
3 years	2639	20h42 (30min)	844	20h30 (30min)	2556	20h30 (24min)	737	20h54 (36min)	1463	20h54 (30min)	<.0001
5.5 years	2486	20h42 (42min)	797	20h18 (42min)	2437	20h30 (48min)	696	20h48 (36min)	1386	20h48 (48min)	<.0001

Appendix 2. Unadjusted results for sleep multi-trajectories (M1) (N=9273). “Good sleepers” was the reference group.

	Sleep multi-trajectory groups			
	Good sleepers but few SOD	Long sleepers	Improving NW and SOD	Persistent NW and SOD
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
Socio-demographic characteristics at 2 months				
Maternal education level				
< High school	1.40 [1.18-1.66]*	0.95 [0.84-1.07]	2.18 [1.83-2.59]*	0.87 [0.75-1.00]
High school	1.23 [1.02-1.48]	0.89 [0.78-1.01]	1.15 [0.94-1.42]	0.70 [0.60-0.83]*
> High school	Reference	Reference	Reference	Reference
Household income (€/month/CU)				
<1000	1.29 [0.99-1.68]	0.96 [0.81-1.15]	2.98 [2.34-3.80]*	1.17 [0.96-1.42]
1000–1385	1.61 [1.27-2.04]*	1.00 [0.85-1.19]	1.76 [1.36-2.28]*	0.80 [0.66-0.98]
1385–1662	1.33 [1.04-1.70]*	1.00 [0.85-1.17]	1.25 [0.95-1.66]	0.84 [0.69-1.03]
1662–2078	1.37 [1.10-1.71]*	0.96 [0.82-1.12]	1.00 [0.77-1.30]	0.83 [0.70-0.99]*
> 2078	Reference	Reference	Reference	Reference
Maternal characteristics				
Age (years)	0.96 [0.95-0.98]*	0.97 [0.97-0.99]*	0.99 [0.98-1.01]	1.03 [1.02-1.04]*
Born abroad	0.70 [0.52-0.94]*	0.79 [0.65-0.96]*	2.64 [2.15-3.25]*	1.80 [1.49-2.17]*
Single mother	0.90 [0.56-1.45]	0.95 [0.68-1.32]	2.51 [1.75-3.58]*	1.87 [1.35-2.59]*
Smoking during pregnancy	1.39 [1.16-1.68]*	1.16 [1.01-1.33]	1.26 [1.04-1.53]*	1.17 [0.99-1.37]
BMI before pregnancy (kg/m ²)	1.01 [1.00-1.03]	0.99 [0.97-1.00]*	1.02 [1.01-1.04]*	0.99 [0.97-1.00]
Multiparous	0.84 [0.72-0.99]	1.03 [0.92-1.15]	0.91 [0.77-1.06]	0.98 [0.86-1.11]
Depressive symptom during pregnancy	1.05 [0.83-1.33]	1.05 [0.89-1.24]	1.52 [1.22-1.89]*	1.41 [1.18-1.70]*
Working at age 1 year	0.91 [0.75-1.12]	0.72 [0.63-0.83]*	0.42 [0.35-0.50]*	0.65 [0.56-0.76]*
Children characteristics and early factors at age 1 year				
Sex (boy)	0.88 [0.76-1.02]	0.74 [0.67-0.82]*	0.92 [0.79-1.07]	1.03 [0.91-1.16]
Gestational age (week)	0.95 [0.89-1.02]	1.00 [0.96-1.05]	0.93 [0.87-0.99]*	0.97 [0.92-1.03]
Birth weight (kg)	0.97 [0.82-1.14]	0.92 [0.82-1.04]	0.71 [0.60-0.84]*	0.84 [0.73-0.97]*
Breastfeeding duration (month)	0.97 [0.96-0.99]*	0.99 [0.98-1.00]	1.05 [1.03-1.06]*	1.04 [1.03-1.05]*

Crowded dwelling at age 2 months	0.69 [0.56-0.85]*	0.81 [0.71-0.93]*	1.87 [1.58-2.22]*	1.35 [1.16-1.57]*
Noisy dwelling at age 2 months	0.77 [0.59-0.99]	0.92 [0.78-1.09]	1.27 [1.01-1.60]	1.12 [0.92-1.36]
Medical problems between birth and age 1 year				
None	Reference	Reference	Reference	Reference
Consultation	1.02 [0.82-1.28]	1.07 [0.91-1.25]	1.58 [1.28-1.95]*	1.34 [1.12-1.60]*
Hospitalization	1.16 [0.95-1.43]	1.11 [0.96-1.29]	1.39 [1.13-1.71]*	1.18 [0.99-1.41]
Passive smoking exposure up to age 1 year	0.93 [0.61-1.41]	1.05 [0.80-1.39]	2.06 [1.48-2.88]*	1.55 [1.14-2.09]*
Main day-care arrangement at age 1 year				
Collective care	0.58 [0.46-0.74]*	0.77 [0.66-0.90]*	0.61 [0.49-0.75]*	0.93 [0.78-1.11]
Cared by employed person	0.76 [0.65-0.89]*	0.72 [0.64-0.80]*	0.33 [0.28-0.39]*	0.62 [0.54-0.71]*
Cared by family members/partner	reference	Reference	Reference	Reference
Sleep habits at age 1 year				
Sucking behaviors				
Nothing	reference	Reference	Reference	Reference
Only finger	2.47 [1.71-3.56]*	1.25 [1.01-1.56]	0.56 [0.42-0.75]*	0.56 [0.45-0.71]*
Only pacifier	1.96 [1.38-2.78]*	1.03 [0.85-1.26]	0.60 [0.47-0.77]*	0.55 [0.45-0.68]*
Both finger and pacifier	1.67 [1.15-2.41]*	0.97 [0.79-1.20]	0.66 [0.50-0.86]*	0.63 [0.51-0.79]*
Comforter to fall asleep	0.58 [0.39-0.87]*	0.92 [0.73-1.17]	3.11 [2.43-3.98]*	2.13 [1.70-2.68]*
Parental presence to fall asleep	0.52 [0.42-0.64]*	0.73 [0.64-0.83]*	5.53 [4.71-6.50]*	3.14 [2.76-3.58]*
Feeding to fall asleep	0.58 [0.39-0.87]*	0.91 [0.71-1.15]	3.06 [2.39-3.93]*	2.11 [1.68-2.66]*
Room sharing	0.69 [0.57-0.84]*	0.71 [0.62-0.81]*	1.84 [1.57-2.17]*	1.39 [1.21-1.60]*
Sleep arrangement				
Starts and finishes sleep in own bed	Reference	Reference	Reference	Reference
Starts in one's own bed but not finishing in it	0.45 [0.34-0.61]*	0.63 [0.53-0.75]*	3.70 [3.04-4.49]*	2.72 [2.31-3.21]*
Not sleeping in one's own bed	0.53 [0.33-0.85]*	0.71 [0.53-0.94]*	9.01 [7.03-11.54]*	4.28 [3.38-5.43]*

OR: odds ratio; **95% CI:** 95% confidence interval; **BMI:** body mass index; **CU:** consumption unit

In bold are significant results with p-value <.05. *

Significant results after Benjamini-Hochberg adjusted p-value for multiple testing.