INTRODUCTION

Sleep is essential for infant growth and well-being and is particularly important for cognitive functioning. It also plays a key role in regulating emotions and behaviour. Healthy sleep is generally defined by adequate duration, appropriate timing and the absence of sleep disturbance. There is no definite consensus about what constitutes enough sleep at different ages. The National Sleep Foundation recommends that infants aged between 4 and 11 months should sleep for between 12 and 15 h during every 24-h cycle, with the normal range being 10–18 h. Studies have indicated that 10%–35% of parents report that their children have sleep problems, such as only sleeping for a short time, struggling to fall asleep or frequently waking up at night. These kinds of sleep problems do not just affect...
the children. They also have a profound effect on the way the family functions and the parents’ well-being\(^8\) and often increase their use of multiple health services.\(^8\)

Sleep–wake regulation and sleep states evolve rapidly during the first year of life, with continued maturation throughout childhood. In the first months of an infant’s life, their circadian rhythm has not yet been established and their sleep is normally characterised by short, fragmented periods of sleep with them waking up several times to feed. The circadian rhythm begins to emerge at around 10–12 weeks of age, and this is marked by reductions in night-time wakefulness during the first 6 months of life. It also decreases the amount that infants sleep, from 16–17 h at 0–3 months to 13–14 h by 6 months of age.\(^2\) However, sleep patterns vary between individuals, and they are explained by a complex interplay between genetic, environmental and social factors. These include family routines, parenting practices and expectations. Sleep problems are transient for most children and are likely to resolve naturally.\(^9\) However, some studies have suggested that sleep problems in infancy are related to negative development at a later age and emotional and behavioural problems.\(^10\)-\(^16\) The causal explanation for these associations are that sleep affects neurodevelopmental changes related to brain maturation, learning and memory consolidation.\(^17\) It may also have an impact on the brain circuits that underlie executive functions and the higher-order systems involved in cognition.\(^18\)

A systematic review of the relationship between sleep duration and health indicators from birth to 4 years of age found that a lack of age-adequate sleep was prospectively associated with mental health problems, such as anxiety, depression and poor emotional regulation. However, the evidence related to cognitive and motor development was not clear.\(^15\) Two large Norwegian birth cohort studies found an association between sleep problems in young children and social-emotional problems.\(^11\),\(^12\) Hysing et al studied 2014 children at 2 years of age. The authors found that less total sleep, prolonged sleep onset and frequent night waking corresponded with a greater risk of having concurrent social-emotional problems in toddlerhood. Similarly, Sivertsen et al\(^11\) studied 32 662 children and found that sleep problems at 18 months of age-predicted emotional regulation difficulties at 5 years of age. Few studies have focussed on sleep problems among infants below one year of age. A small longitudinal study of 117 American infants and toddlers, aged 6 to 18 months, reported limited relationships between sleep consolidation and social-emotional and cognitive development.\(^16\) The authors used the Ages and Stages Questionnaire (ASQ) and found no significant relationships between any sleep variables and developmental outcomes at 3 to 13 months, with regard to fine and gross motor skills, problem-solving and personal-social skills.\(^19\)

There is still a need for longitudinal studies to identify the long-term outcome of children’s behavioural sleep problems in the first years of life. The aims of the present study were threefold. First, we wanted to assess the prevalence of parent-reported sleep problems in a cohort of infants when they were 6, 12 and 24 months of age. Second, we aimed to investigate the concurrent relationships between infants’ behavioural sleep problems and motor, communication, problem-solving, personal-social and social-emotional skills at 6, 12 and 24 months. Third, we wanted to determine to what extent sleep problems at 6 months were related to changes in the developmental course from 12 to 24 months.

## 2 | METHODS

### 2.1 | Participants

The present study used data from the KVIK study, a Norwegian population-based longitudinal study of infants’ early development from birth to 2 years of age.\(^20\) Participants were recruited from 9 well-baby clinics in five municipalities in South-Eastern Norway, which served both urban and rural areas. Well-baby clinics are regularly attended by more than 95% of Norwegian parents and their children from birth to school age. The recruitment took place between May 2011 and May 2012. All families who were expecting a baby or who had recently given birth were invited to participate in the study by a midwife or a public health nurse at their first consultation, either during pregnancy or at the first home visit soon after birth. In total, 1555 (88.6%) of the families agreed to participate. The number of participants at each time point varied, mainly due to differences in the scheduled consultations at each well-baby clinic. Of the 1555 families who responded, 86.1% completed the ASQ at 6 months, 60.1% at 12 months and 48.7% at 24 months. The study had no specific exclusion criteria because the well-baby clinics offer services to all families with children below 5 years of age who live in the municipality.

### 2.2 | Procedure

The public health nurse or midwife at each of the 9 well-baby clinics provided oral and written information about the study to the families based on procedures approved by the Norwegian Regional Committee for Medical Health Research Ethics (2011/124/REK Sør Øst B). Written, informed consent was received from both parents who volunteered to
participate in the study. Background information on the parents and infants were recorded on enrolment, or at the first check-up after birth, and his included maternal educational level, ethnicity and the child’s gender and gestational age. Unfortunately, some background variables are missing due to failures in in collection routine.

The age-specific ASQ questionnaires were mailed to the participants’ home addresses two weeks before each well-baby visit at 6, 12 and 24 months. These were the second edition of the ASQ (ASQ-II) and the Social-Emotional version (ASQ:SE), which are explained later. Corrected ages were used for infants when these were completed.21 The mothers brought the completed questionnaires to the scheduled appointments and this information formed part of the overall clinical assessment during the consultation. The mothers completed two questions about their infant’s sleep at 6 months, 12 and 24 months postpartum in the well-baby clinics. These responses were used in the conversation between the public health nurse and the parents during the consultations. The public health nurses that participated in this study received lectures about early developmental psychology and infant sleep states and sleep cycles before the study started. They were encouraged to advise parents to observe their infant when they were sleeping during the day to learn the difference between deep and light sleep states. This could help them to avoid mis-interpreting light sleep as an early sign of awakening, which often encourages parental responses, such as starting to talk to the infant or lifting them up from their bed. All the infants and mothers with scores that indicated severe sleep or developmental problems were offered further in-depth evaluations or support within two weeks. The most severe cases were referred to specialists.

2.3 | Measures

2.3.1 | The ASQ questionnaires

Motor, communication, problem-solving and personal-social skills were assessed using the Norwegian version of ASQ-II.21,22 This is a 30-item, parent-reported screening instrument that assesses 5 areas of development: communication, gross motor, fine motor, problem-solving and personal-social. Each area consists of 6 age-specific items that can be used for children aged 4 to 60 months.22 Parents were asked to observe their child performing a number of specific skills and to rate whether the skill was observed often, sometimes or not yet, which scored 10, 5 and 0 points respectively. This resulted in total domain scores from 0 to 60. A Norwegian construct validity study found that the ASQ-II was an effective diagnostic tool for identifying developmental delays.23 In a Norwegian reference sample, the overall Cronbach’s alpha values ranged from 0.75 to 0.88.22 In the present study, the overall ASQ-II reliability ranged from 0.76 to 0.85 from 4 to 24 months.

The ASQ:SE is a brief parent-reported instrument that helps to identify developmental delays in children aged 6 to 60 months.24 Different forms are used depending on the child’s age and the number of scored items ranges from 19 at 6 months to 33 at 48 and 60 months. There are three possible responses for each item, rarely or never, sometimes and most of the time, which are scored 0, 5 and 10. An additional 5 points is added if the informant states that a specific behaviour worries them. A total difficulty score is calculated by adding all these points together. The ASQ:SE has been proven to be a valid and reliable tool.24

2.3.2 | Sleep

Nocturnal awakenings and daytime sleep were assessed by asking the parents how their child slept during the night and whether they slept during the day. Scores ranged from 5 points for very bad to 1 for very good. Sleep problems were defined as scores of 4 or 5 added together, either day or night, or both day and night.

2.4 | Statistical analysis

The prevalence of sleep problems was calculated at each time point. At 6, 12 and 24 months, two-sample Welch t-tests were used to compare the ASQ-II and ASQ:SE scores for infants with and without a defined sleep problem at 6 months. As a sensitivity analyses, these comparisons were repeated with adjustment for municipality, using robust standard errors. Linear mixed-effects models were used to study the relationships between sleep problems at 6 months with the ASQ-II scores and at 12 and 24 months with the ASQ:SE scores. The interaction between time and sleep problems was included to investigate possible relationships between sleep problems at 6 months and changes in the ASQ-II scores from 12 to 24 months. Time was included as a dichotomous variable, and the random effect was intercept only. As a sensitivity analysis, the models were repeated with adjustment for municipality.

3 | RESULTS

Of the 1555 families who responded, 86.1% (1339 families) completed the ASQ at 6 months, 60.1% (934 families) at 12 months and 48.7% (757 families) at 24 months. The background characteristics of the children and their mothers who took part and provided that data are presented in Table 1. A large proportion of the mothers had higher levels of education and were of Scandinavian ethnicity.

The prevalence of infants’ sleep problems was 152/1042 (14.6%) during the day and/or night at 6 months. Of these, 7.4% had difficulty sleeping during the day and 12.0% during the night. At 12 months, 37/501 (7.4%) of the infants had sleep problems during the day and/or night, 2.6% during the day and 7.0% during the night. At 24 months, 5/151 (3.3%) had difficulty sleeping during the day and/or night, 1.3% during the day and 3.3 during the night.

Table 2 shows concurrent differences in ASQ-II and ASQ:SE scores by sleep problems at 6, 12 and 24 months. There was generally no clear evidence of differences in ASQ-II and ASQ:SE scores.
by sleep problems at any of these measurement points. However, the ASQ-II mean scores were consistently lower for children with sleep problems at 6 and 12 months and slightly higher at 24 months, but these differences were not significant. In the sensitivity analysis with adjustment for municipality, there was also no clear evidence for differences.

The mixed-effects models showed some evidence of a relationship between sleep problems at 6 months and changes in ASQ-II communication scores from 12 to 24 months ($p$-value for interaction $0.024$), weaker evidence ($p$-value for interaction $0.053$) for ASQ-II problem-solving and no evidence for the other domains ($p$-values for interactions $\geq 0.136$). Results are shown in Table 3 and Figures 1 and 2. Sensitivity analyses adjusted for municipality were only slightly different.

### DISCUSSION

This large population-based study suggests that between 3.3% and 14.6% of infants between 6 and 24 months had parent-reported sleep problems, with the highest rate at 6 months and the lowest at 24 months. The results indicated a pattern of lower mean ASQ-II and ASQ:SE scores at 6 and 12 months for infants with parent-reported sleep problems, but, in general, these differences did not reach statistical significance at any time point. However, the results suggest a relationship between sleep problems at 6 months and positive changes in communication and problem-solving ASQ-II scores over time.

Our findings suggest that the prevalence of parent-reported infant sleep problems in the present study was lower than that found in previous studies of the same age group.\textsuperscript{3-5,25,26} However, drawing comparisons between studies is challenging for many reasons. Children's sleep duration is found to vary between countries and regions due to cultural factors,\textsuperscript{27} and a number of methodological issues make it difficult to compare prevalence rates because of variations in the definition of sleep problems, the type of sleep measures used and the age of the participants when sleep was measured. In our study, two single items based on parent reporting were used to measure sleep problems during daytime and night-time at 6, 12 and 24 months.

In their Norwegian Mother and Child cohort study, Hysing et al.\textsuperscript{3} found that at 18 months, 26.6% of infants ($n = 55,831$) had night-time awakenings based on the recommended hours of sleep per day (24 h), whereas only 9.4% of these infants' mothers endorsed a question indicating that their infant had a sleep problem. In our study, even fewer infants at 12 and 24 months had sleep problems during the night according to their mothers.

The results from the current study show a consistent pattern of slightly lower ASQ and ASQ:SE scores at 6 and 12 months,
Although not significantly lower, for infants with sleep problems. A Brazilian study reported findings that were consistent with our results. The study stated that there were no significant relationships between infants’ sleep and concurrent ASQ scores on communication, motor, problem-solving and personal-social development. However, our results show evidence of a relationship between sleep problems at 6 months and positive changes in communication and problem-solving scores from 12 to 24 months.

**Table 2** Differences in ASQ and ASQ:SE scores by sleep problems at 6, 12 and 24 months

| Time | ASQ/ASQ-SE | Sleep problems | No sleep problems | Difference | Confidence interval | p-value |
|------|------------|----------------|-------------------|------------|---------------------|--------|
| 6 months, 134 infants with sleep problems and 801 without | Communication | 50.45 | 50.46 | 0.01 | -1.39 to 1.40 | 0.991 |
| | Gross motor | 40.34 | 41.25 | 0.92 | -1.05 to 2.89 | 0.358 |
| | Fine motor | 50.00 | 51.48 | 1.48 | -0.24 to 3.20 | 0.091 |
| | Problem-solving | 54.96 | 55.09 | 0.12 | -1.09 to 1.34 | 0.839 |
| | Social-emotional | 74.46 | 75.50 | 1.04 | -0.49 to 2.57 | 0.183 |
| | | | | | | |
| | Adjusted | 0.07 | 0.07 | 0.07 | -1.32 to 1.46 | 0.917 |
| | | 0.96 | 0.96 | 0.96 | -0.99 to 2.91 | 0.332 |
| | | 1.57 | 1.57 | 1.57 | -0.07 to 3.22 | 0.061 |
| | | | | | | |
| | 12 months, 20 infants with sleep problems and 302 without | Communication | 41.00 | 44.49 | 3.49 | -2.97 to 9.94 | 0.274 |
| | Gross motor | 42.00 | 46.32 | 4.32 | -3.33 to 11.98 | 0.253 |
| | Fine motor | 53.25 | 55.07 | 1.82 | -1.32 to 4.95 | 0.241 |
| | Problem-solving | 48.25 | 51.16 | 2.91 | -3.21 to 9.03 | 0.334 |
| | Social-emotional | 78.46 | 78.14 | -0.33 | -4.88 to 4.23 | 0.884 |
| | | | | | | |
| | Adjusted | 3.86 | 3.86 | 3.86 | -2.15 to 9.88 | 0.207 |
| | | 3.71 | 3.71 | 3.71 | -3.51 to 10.94 | 0.312 |
| | | 2.72 | 2.72 | 2.72 | -2.87 to 8.31 | 0.339 |
| | | 2.63 | 2.63 | 2.63 | -1.80 to 7.05 | 0.231 |
| | | 2.70 | 2.70 | 2.70 | -1.43 to 6.75 | 0.201 |
| | | -0.33 | -0.33 | -0.33 | -1.06 to 1.30 | 0.842 |
| | | 0.86 | 0.86 | 0.86 | -0.89 to 2.61 | 0.333 |
| | | 1.19 | 1.19 | 1.19 | -0.32 to 2.70 | 0.123 |
| | 24 months, 3 infants with sleep problems and 91 without | Communication | 58.33 | 56.32 | -2.01 | -7.87 to 3.84 | 0.355 |
| | Gross motor | 56.67 | 58.35 | 1.68 | -12.41 to 15.78 | 0.664 |
| | Fine motor | 56.67 | 55.71 | -0.95 | -14.74 to 12.83 | 0.803 |
| | Problem-solving | 51.67 | 52.91 | -1.25 | -24.00 to 26.49 | 0.856 |
| | Social-emotional | 80.00 | 106.44 | 26.44 | | |
| | | | | | | |
| | | -2.67 | -2.67 | -2.67 | -5.66 to 0.32 | 0.080 |
| | | 1.51 | 1.51 | 1.51 | -3.75 to 6.77 | 0.570 |
| | | -1.40 | -1.40 | -1.40 | -6.46 to 3.66 | 0.583 |
| | | 0.37 | 0.37 | 0.37 | -9.09 to 9.82 | 0.939 |
| | | -2.71 | -2.71 | -2.71 | -16.19 to 10.77 | 0.504 |
| | | -3.10 | -3.10 | -3.10 | -9.61 to 3.42 | 0.348 |

Note: Number of children: 6 months, n = 152 with sleep problems, n = 890 without. At 12 months, n = 37 with sleep problems, n = 501 without and at 24 months, n = 5 with sleep problems, n = 146 without. Both questions employed a five-point scale from very bad (score 5) to very good (score 1). Sleep problems were defined as score 4 or 5, either day or night, or both day and night.

The Welch t-tests used throughout (not assuming equal standard deviations) in unadjusted analyses. Adjusted analyses, adjusted for municipality and based on robust standard errors.

*Only one child with sleep problems in this comparison, no test performed.*
For infants with sleep problems at 6 months, communication and problem-solving scores were lower than for those without sleep problems at 12 months but increased somewhat faster and were slightly higher, although not significantly higher, for infants with- out sleep problems at 24 months.

There are several potential mechanisms that may explain the finding of a relationship between sleep problems at 6 months and a slightly greater increase in communication and problem-solving scores over time. Sleep affects neurodevelopmental changes related to brain maturation, learning and memory consolidation, which are involved in cognition. Therefore, as sleep-wake cycles mature, children's abilities in terms of abstract reasoning, attention regulation and problem-solving will also increase. Although the maturation process concerning executive functions and other complex cognitive functions continues into early adulthood, this might be part of

| ASQ score                | Sleep problems, 12 months | Sleep problems, 24 months |
|--------------------------|---------------------------|---------------------------|
|                          | p, interaction            | estimate                  | lower 95% | upper 95% | p          | estimate | lower 95% | upper 95% | p          |
| Communication, unadjusted| 0.024                     | -2.01                     | -4.41     | 0.40      | 0.102      | 1.79     | -0.91     | 4.49      | 0.194      |
| Communication, adjusted  | 0.027                     | -2.05                     | -4.45     | 0.36      | 0.095      | 1.67     | -1.03     | 4.37      | 0.225      |
| Gross motor, unadjusted  | 0.495                     | 0.93                      | -1.50     | 3.37      | 0.452      | -0.21    | -2.93     | 2.52      | 0.882      |
| Gross motor, adjusted    | 0.477                     | 0.88                      | -1.56     | 3.33      | 0.478      | -0.31    | -3.05     | 2.43      | 0.826      |
| Fine motor, unadjusted   | 0.431                     | -0.88                     | -2.22     | 0.46      | 0.199      | -0.12    | -1.63     | 1.39      | 0.873      |
| Fine motor, adjusted     | 0.496                     | -0.95                     | -2.29     | 0.40      | 0.167      | -0.29    | -1.80     | 1.22      | 0.703      |
| Problem-solving, unadjusted| 0.053                   | -2.11                     | -3.89     | -0.33     | 0.020      | 0.16     | -1.83     | 2.14      | 0.878      |
| Problem-solving, adjusted| 0.059                     | -2.16                     | -3.94     | -0.38     | 0.018      | 0.05     | -1.94     | 2.04      | 0.963      |
| Personal-social skills, unadjusted | 0.136 | -1.41                     | -3.26     | 0.44      | 0.134      | 0.46     | -1.61     | 2.52      | 0.665      |
| Personal-social skills, adjusted | 0.144 | -1.31                     | -3.16     | 0.53      | 0.163      | 0.52     | -1.55     | 2.59      | 0.623      |

Note: p, p-value; interaction, interaction of time by sleep problems; estimate, estimated difference, sleep problems versus no sleep problems; lower 95% and upper 95%, lower and upper bounds for 95% confidence intervals.
the explanation. Other suggested mechanisms between sleep and development include overlapping genetic features and shared family and parenting factors. For example, the child’s environment may have an organising effect on both sleep–wake cycles and development. Mothers affected by their infants’ unconsolidated and fragmented sleep may provide less optimal stimulation or overall inadequate parental practices that may negatively affect both sleep and development in infants. In the opposite sense, when the infant’s sleep problems decrease, better sleep for the infant as well as for the parents may provide more stimulation and adequate parental practices. In turn, this can contribute to a catch-up in development. Since this study took place in the context of regular well-baby check-ups during the infants’ first two years, it can be assumed that parents who reported infant sleep difficulties most likely received advice and support that may have contributed to promoting healthy infant sleep patterns and thus a healthier development in general. Furthermore, systematic sleep assessment in the early months may have contributed to increased attention on topics relating to infant sleep and thereby a higher awareness among parents of the importance of promoting healthy sleep behaviour. This could also explain the lower prevalence rates of infant sleep problems in the current study.

Our findings extend the outcomes to a younger age group and underscore the importance of assessing infant sleep at an early age. Support should be provided to families throughout infancy and early childhood, including advice and information about sleep states, sleep cycles and the development of sleep behaviour. Public health nurses have a key role to play in supporting families with infants and children who experience sleep problems because they are directly involved with the families through child health programmes that are free and universally available. Information about sleep behaviour for parents can be beneficial in preventing further problems. Hence, efforts should be made in practice to protect and preserve infants’ sleep as much as possible.

The results from the present study must be interpreted by considering several methodological limitations. Firstly, an unintended intervention effect may have occurred by introducing systematic questioning and conversations about the infant’s sleep at daytime and night-time at several of the consultations at the well-baby clinics during the first year. Repeated conversations about infant sleep with the public health nurse likely provided the parents with increased knowledge on the topic. It may also have provided parents with concrete information that may have strengthened their ability to improve their infant’s sleep quality. That, in turn, may have facilitated corrections of negative sleep trends.

Secondly, we did not use a validated or objective measures of sleep, thus the subjective nature of the sleep question used in the present study may have affected the results. For example, night awakening or delayed sleep onset might be considered problematic by some parents but not others. Other variables that could have influenced the association, such as maternal depression or parenting practices, were left unexplored. However, most studies typically show that parental reports of a global sleep problem are usually confirmed by objective measures, and the sleep questions used in the current study are similar to those used by many physicians and public health nurses during routine clinic visits. Hence, the findings may still be of clinical relevance. Lastly, the results may have been affected by a selection bias due to high attrition rates in the study. The missing data were attributed to nonresponses, either due to differences among the individual municipality well-baby clinic programmes or that respondents moved to other municipalities or were unable to attend well-baby clinic consultations due to illness. Hence, the results should be interpreted with caution.

## 5 | CONCLUSION

This large representative regional-based study suggests a prevalence rate of parent-reported sleep problems between 3.3% and 14.6% in infants aged from 6 to 24 months, with the highest prevalence in the youngest age group. Mean ASQ-II global scores were consistently lower for children with sleep problems at 6 and 12 months. For infants with sleep problems at 6 months, communication and problem-solving scores were lower than for infants without sleep problems at 12 months but increased somewhat faster and were slightly higher for those without sleep problems at 24 months.

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### CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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