Are New Zealand children meeting the Ministry of Health guidelines for sleep?

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Policy summary

The Ministry of Health recommends that children in Aotearoa/New Zealand (NZ) have sufficient, good quality sleep, in conjunction with adequate physical activity and nutrition, to support health and wellbeing (Ministry of Health, 2017b). Current Ministry of Health sleep duration guidelines are based on US National Sleep Foundation (NSF) recommendations, developed by a multidisciplinary panel of experts (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015). Thus, the Ministry recommend that toddlers (1 – 2 year olds) sleep 11 to 14 hours per day and preschoolers (3 – 4 year olds) sleep 10 to 13 hours per day, which may include naps. In addition, NSF sleep quality guidelines, based on an expert panel review, indicate that waking once or less at night is 'appropriate', waking twice is 'uncertain' and waking three or more times is 'not appropriate' for good quality sleep of toddlers or preschoolers (Ohayon et al., 2017).

However, limited data are available on how many children in NZ are meeting sleep duration and sleep quality guidelines and the factors associated with a greater or less likelihood of children having good sleep health in the early years. The *Growing Up in New Zealand* (GUiNZ) contemporary longitudinal study of child development in Aotearoa/New Zealand (NZ) (Morton et al., 2013) provided an ideal platform to investigate this identified gap in knowledge. Consequently, this study of sleep in early childhood is the largest of its kind in NZ (n = 6,490).

Sleep durations and night wakings of children in GUiNZ were analysed cross-sectionally at 24 months and 45 months, and longitudinally across these two time points. A range of analytical techniques were used, including Bayesian linear regression, Bayesian negative binomial multiple regression and Bayesian growth curve models, which enabled variation and uncertainty in each child's day-to-day sleep to be taken into account and probabilistic estimation of the prevalence of children in NZ meeting, or not meeting, sleep guidelines to be calculated.

The estimated prevalence of 24 month old children in NZ having short, appropriate or long sleep was 15.6%, 70.2% and 14.2% respectively; and the estimated prevalence of 24 month olds in NZ having an appropriate, uncertain or not appropriate number of night wakings was 84.6%, 11.6% and 3.8% respectively, after adjusting for a host of sociodemographic factors. At 45 months, the estimated prevalence of children in NZ having short, appropriate or long sleep was 14.1%, 80.5% and 5.4% respectively; and having an appropriate, uncertain or not appropriate number of night wakings was 91.7%, 7.0% and 1.3% respectively, after adjusting for a range of sociodemographic variables. While these results indicate that the majority of children in NZ are meeting sleep guidelines, they equate to 29.8% of two year olds and 19.5% of 45 month olds having a high probability of inappropriate sleep durations, and

15.4% of two year olds and 8.3% of 45 month olds having a high probability of potentially compromised sleep quality.

Results of this study also indicate that some groups of children are at greater risk of sub-optimal sleep durations or more disturbed sleep than others. At one or both time points, girls, Māori, Pacific and Asian children, and children living in more socioeconomically deprived areas had a high probability of shorter or more disturbed sleep compared to boys, European/Other children and children living in areas with least deprivation. Sleep trajectories differed by these key sociodemographic factors, but as data were only available at two time points it is not yet known how sleep does, or does not, differ between groups as children grow older. However, findings build on recent research which provides evidence that ethnic and socioeconomic inequities exist in preschoolers' sleep durations in NZ (Muller, Paine, Wu, & Signal, 2019a).

In addition, sociodemographic factors at the neighbourhood-, household- and child-level that were independently associated with sub-optimal sleep durations or night wakings at 24 or 45 months of age included living in an urban area; living in an area with heavy traffic; living in a household with low material standard of living; being overweight; having poor health; and using visual media 2 or more hours a day.

This study focusses on two (of four) of the Government's health priorities, namely 'child wellbeing' and 'achieving equity in health outcomes' (Ministry of Health, 2018). Study findings provide support for the inclusion of sleep as a child wellbeing indicator in the government's first Child and Youth Wellbeing strategy (Department of the Prime Minister and Cabinet, n.d.) and for taking political action to address the drivers of ethnic and socioeconomic inequities in child sleep via social and economic policy, given evidence linking sleep to health and other wellbeing outcomes. The study findings indicate areas that, if addressed, could support improved sleep in young children and consequent improvements in wellbeing, and potentially reduce child health inequities. This includes tackling root causes of social inequities, including structural racism, and targeted interventions to ensure all families with young children have access to sufficient financial and material resources, living conditions and support to enable all children to have good sleep health from an early age and across the lifecourse. Results also support tackling obesogenic environments and providing visual media guidelines. In addition to the factors associated with poor sleep health, raising awareness of the contribution that sleep makes to children's health, wellbeing and development is important.

Executive summary

Sufficient, good quality sleep is imperative for child health and development (El-Sheikh & Sadeh, 2015). Short sleep duration and poor sleep quality is negatively associated with children's mental and physical health and behaviour (Chaput et al., 2017; Reynaud, Vecchierini, Heude, Charles, & Plancoulaine, 2018). In Aotearoa/New Zealand (NZ) the Ministry of Health advise that children obtain sufficient, good quality sleep, including the recommendation that 1 to 2 year olds sleep 11 to 14 hours per day and 3 to 4 year olds sleep 10 to 13 hours per day (Ministry of Health, 2017b). In addition, the US National Sleep Foundation (NSF) guidelines indicate that, for toddlers and preschoolers, waking once or less during the night is 'appropriate', waking twice is 'uncertain' and waking 3 or more times is 'not appropriate' for good sleep quality (Ohayon et al., 2017).

The aim of this study was to assess parentally-reported sleep in a large group of children in NZ to answer two key questions: 1) how many NZ children are meeting the Ministry of Health guidelines for sufficient good quality sleep over time?; and 2) what social and demographic factors are associated with NZ children meeting, or not meeting, the sleep guidelines?

Data on sleep durations and night wakings of children in the *Growing Up in New Zealand* (GUiNZ) longitudinal study collected via face-to-face interviews when children were 24 months and via telephone interviews when children were 45 months old were analysed, in conjunction with a range of sociodemographic variables available in the GUiNZ dataset.

Descriptive statistics indicated that 82.8% of children in GUiNZ met sleep duration guidelines at 24 months (11.9% short; 5.3% long) and 90.6% met sleep duration guidelines at 45 months (6.2% short; 3.2% long). This reduced to 77.3% of children meeting sleep duration guidelines at both 24 and 45 months. In regard to sleep quality, 83.1% of children in GUiNZ met guidelines for appropriate night wakings at 24 months (12.1% uncertain; 4.7% not appropriate) and 92.9% at 45 months (5.6% uncertain; 1.5% not appropriate). Whereas, 79.4% of children had an appropriate number of night wakings at both time points.

At 24 months, gender, ethnicity, area-level socioeconomic deprivation, heavy traffic and body size were significantly associated with how long children slept, after controlling for other sociodemographic factors of interest (rurality, material standard of living, neighbourhood safety, household structure, maternal paid work, childcare, time outside and health). Ethnicity, rurality, material standard of living, traffic and health also remained significant predictors of the number of times children usually woke at night at 24 months of age, after controlling for all other variables. Based on Bayesian statistical modelling, the estimated prevalence of 24 month olds in NZ having a high probability of short, appropriate or long sleep was 15.6%, 70.2% and 14.2% respectively; and the estimated

prevalence of two year olds in NZ having a high probability of an appropriate, uncertain or not appropriate number of night wakings was 84.6%, 11.6% and 3.8% respectively, after adjusting for all sociodemographic variables.

At 45 months of age, fewer sociodemographic variables were available to investigate in relation to sleep. At the univariate level, the proportion of children in GUiNZ having appropriate sleep durations and/or night wakings differed significantly by ethnicity, area-level socioeconomic deprivation, household structure, maternal paid work, child's sleep location and duration of visual media use. Gender was significantly associated with sleep duration, after controlling for ethnicity, area-level deprivation, rurality, household structure, maternal paid work and visual media use. Whereas, ethnicity and visual media use were significantly associated with the number of times children usually woke at night, after factoring in all other variables. The resulting estimated prevalence of 45 month olds in NZ having a high probability of short, appropriate or long sleep was 14.1%, 80.5% and 5.4% respectively; and having a high probability of appropriate, uncertain or not appropriate number of night wakings was 91.7%, 7.0% and 1.3% respectively, after adjusting for all sociodemographic variables in multivariate models.

Growth curve models indicated that sleep trajectories from 24 to 45 months of aged differed by gender, ethnicity and area-level socioeconomic deprivation. Considered together, findings of this study indicate that a substantial proportion of children in NZ have a high probability of not meeting sleep guidelines and that ethnic and socioeconomic inequities exist in young children's sleep. In addition, a number of factors at the neighbourhood-, household- and child-level contribute to an increased risk of poor sleep health in early childhood.

Introduction

Sufficient, good quality sleep is vital for child health and development (El-Sheikh & Sadeh, 2015). In contrast, short sleep in the early years of life is associated with concurrent and longitudinal poor physical and mental health outcomes (Chaput et al., 2017) including behavioural difficulties (Reynaud et al., 2018), increased risk of injury (Boto et al., 2012; Koulouglioti, Cole, & Kitzman, 2008) and overweight and obesity (Cappuccio et al., 2008; Carter, Taylor, Williams, & Taylor, 2011; Fatima, Doi, & Mamun, 2015; Miller, Kruisbrink, Wallace, Ji, & Cappuccio, 2018; Monasta et al., 2010; Porter et al., 2018; Wu, Gong, Zou, Li, & Zhang, 2017). In adults, both habitual short and long sleep durations are risk factors for mortality and mental and physical health morbidity (Bin, Marshall, & Glozier, 2013). In young children, prolonged sleep durations may negatively influence development via reduced exploration of physical and social environments (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Adams Hillard, et al., 2015). Reduced sleep quality due to night waking in young children is associated with poorer health related quality of life, behavioural problems, emotional difficulties and hyperactivity (Hiscock, Canterford, Ukoumunne, & Wake, 2007; Reynaud et al., 2018).

In Aotearoa/New Zealand (NZ), the Ministry of Health recommends that toddlers (1 to 2 year olds) obtain 11 to 14 hours, and preschoolers (3 to 4 year olds) obtain 10 to 13 hours, of good quality sleep across 24 hours each day to support health and wellbeing (Ministry of Health, 2016, 2017b). These recommendations are based on guidelines developed by a multidisciplinary panel of experts for the US National Sleep Foundation (NSF) (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Adams Hillard, et al., 2015; Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015). In addition, NSF sleep quality guidelines indicate that for toddlers and preschoolers, waking once or less during the night is indicative of good quality sleep (Ohayon et al., 2017).

Despite having guidelines for sleep, we don't know how many children in NZ are meeting these nor are we able to identify those children who are at the greatest risk of poor sleep health. Such information is vital for informing health and social policy to support all children to experience good sleep health.

In NZ, inequities exist in adult sleep health. The prevalence of short sleep is greater for Māori than non-Māori adults, sleep disturbances are more prevalent for Māori than European adults, and area-level socioeconomic deprivation is a risk factor for short or disturbed sleep independent of ethnicity (Paine & Gander, 2013, 2016; Paine, Harris, Cormack, & Stanley, 2016). While less is known about the social patterning of young children's sleep, recent research indicates that ethnic and socioeconomic inequities exist in sleep health as early as 3 to 4 years of age in NZ, with Māori preschoolers and preschoolers from families who hold low socioeconomic position experiencing the greatest risk of short sleep (Muller et al., 2019a). Further understanding of the relationships between

ethnicity, socioeconomic position and sleep health trajectories across early childhood will inform policy to support equitable sleep health early in the lifecourse.

A review of recent international literature on social and environmental determinants of sleep health identified significant associations between the neighbourhood context, family factors, media use and child sleep (Hale, Emanuele, & James, 2015). Identifying factors at the neighbourhood-, household- and child-level that are predictive of young children in NZ meeting, or not meeting, current sleep guidelines can be used to guide policy that supports good sleep health in early childhood.

GUiNZ is the largest contemporary longitudinal study of child development in NZ (Morton et al., 2013). Commencing in 2008, pregnant women living in the Auckland, Counties-Manukau and Waikato District Health Board areas were recruited, resulting in a sample comprising 6,846 children born between March 2009 and May 2010 (Morton et al., 2015). Strengths of GUiNZ include the large sample size, longitudinal design, lifecourse approach and the ethnic and socioeconomic diversity of participants (Morton et al., 2013; Morton et al., 2015). GUiNZ provides a valuable opportunity to investigate how long and how well young children in NZ are sleeping and to investigate social and environmental predictors of good and poor sleep health early in the lifecourse. This information can inform policy to support child health and wellbeing.

Study aims

The aim of this study was to assess parentally-reported sleep in a large group of children in New Zealand to answer two key questions:

1. How many New Zealand children are meeting the Ministry of Health guidelines for sufficient good quality sleep over time?
2. What social and demographic factors are associated with New Zealand children meeting or not meeting the sleep guidelines?

Method

This study utilised sleep and sociodemographic GUiNZ data that were collected, predominantly, during face-to-face interviews when children were 24 months of age and brief telephone interviews when children were 45 months old.

Ethics

Ethics approval for the GUiNZ study was granted by the Ministry of Health Northern Y Regional Ethics Committee (Morton et al., 2013). The project in this report has been evaluated by peer review and judged to be low risk (Massey University Human Ethics Notification: 4000018816). Consequently it has not been reviewed by one of the University's Human Ethics Committees. The

researchers named in this document are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you want to raise with someone other than the researchers please contact Dr Brian Finch, Director (Research Ethics), email humanethics@massey.ac.nz.

Measures

Based on published sleep health literature and the availability of data collected in the GUiNZ study, the following measures were analysed for this report:

Sleep measures

Information on children's sleep duration and night wakings collected during both the GUiNZ 24 month and 45 month data collection waves (Table 1) were analysed. This included maternal reports of children's usual sleep duration at night (*night sleep*) and usual sleep duration during the day (*day sleep*), which were summed to create a *total sleep time* (TST) across 24 hours variable.

TST was then categorised to indicate if children had sleep durations deemed '*appropriate*', not appropriate '*short*' or not appropriate '*long*' for their age, based on NSF sleep duration recommendations (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015). NSF 'not recommended' short (Age 1 to 2 years = <9 hours; Age 3 to 5 years = <8 hours) and 'may be appropriate' short (Age 1 to 2 years = 9 – 10 hours; Age 3 to 5 years = 8 – 9 hours) durations were collapsed to form the 'short' category. NSF 'not recommended' long (Age 1 to 2 years = >16 hours; Age 3 to 5 = >14 hours) and 'may be appropriate' long (Age 1 to 2 years = 15 – 16 hours; Age 3 to 5 years = 14 hours) durations were collapsed to form the 'long' category.

Mothers also reported the number of times their child usually woke at night (*night wakings*). These were summed and categorised using NSF sleep quality guidelines to indicate 'appropriate' (not waking or waking once), 'uncertain' (2 night wakings) or 'not appropriate' (3 or more wakings) number of night wakings (Ohayon et al., 2017).

In order to determine the proportion of children that shifted between categories for TST and night waking over time, sleep trajectories from 24 months to 45 months were created using NSF sleep duration and sleep quality categories (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015; Ohayon et al., 2017).

Table 1: Sleep information from the GUiNZ 24 month and 45 month data collection waves

Sleep Variable	Description	GUiNZ Question or Derived Variable
Night sleep	Sleep duration at night (hours)	*On average, how much time does [NAME] spend asleep at night in total?*
Day sleep	Sleep duration during the day (hours)	*On average, how much time does [NAME] spend asleep during the day?*
Total sleep time (24hrs)	Usual total sleep time (TST) across 24 hours, in hours	Sum of night sleep and day sleep
Total sleep time: categories	TST categorised as 3 levels, based on NSF sleep duration guidelines	24 months: Short = <11hr Appropriate = 11-≤14hr Long = >14hr 45 months: Short = <10hr Appropriate = 10-≤13hr Long = >13hr
Night wakings	Number of wakings during the night, used as a measure of sleep quality	*On average how many times does [NAME] wake at night?*
Night wakings: categories	Night wakings categorised, based on NSF sleep quality guidelines	Appropriate = 0 to 1 Uncertain = 2 Not appropriate = ≥3
Sleep duration trajectories	Trajectories of usual TST from 24 months to 45 months	Based on TST categorical variables, from 24 months to 45 months: Short → short Short → appropriate Short → long Appropriate → short Appropriate → appropriate Appropriate → long Long → short Long → appropriate Long → long

Table 1 (continued): Sleep information from the GUiNZ 24 month and 45 month data collection waves

Sleep Variable	Description	GUiNZ Question or Derived Variable
Night waking trajectories	Trajectories of night wakings from 24 months to 45 months based on night waking categories	Based on categorical night waking variables, from 24 months to 45 months: Appropriate → appropriate Appropriate → uncertain Appropriate → not appropriate Uncertain → appropriate Uncertain → uncertain Uncertain → not appropriate Not appropriate → appropriate Not appropriate → uncertain Not appropriate → not appropriate

Sociodemographic measures

A number of sociodemographic variables were investigated in relation to children's sleep at 24 months (Table 2). While most of these were measured during the 24 month face-to-face interview, information on child gender was collected 6 weeks post-partum via telephone interviews and child ethnicity was based on maternal report of child ethnicity during face-to-face interviews at 9 months.

As per Ministry of Health ethnicity data protocols, prioritised ethnicity was reported (Table 2). Each child was allocated to a single ethnic group, based on the ethnic group(s) that their mother identified them as belonging to, in prioritised order of Māori, Pacific, Asian and European/Other (Ministry of Health, 2004, 2017a). Socioeconomic position at 24 months was measured using the New Zealand Index of Deprivation 2006 (NZDep2006; Salmond, Crampton, & Atkinson, 2007) which is an area-level composite measure of socioeconomic deprivation. Material standard of living (*how does your [and your partner's combined] total income meet your everyday needs?*) was also included as a measure of socioeconomic position due to it reflecting deprivation at the household-level.

Rurality, neighbourhood safety, neighbourhood traffic, household structure and maternal paid employment were examined as potential predictors of how long

and how well children slept at 24 months (Table 2). This was based on previous research showing relationships between living in more urban environments and shorter sleep in 1 year olds (Bottino et al., 2012); living in unsafe neighbourhoods and single mother households and increased odds of inadequate sleep in school children and adolescents (Singh & Kenney, 2013); road traffic noise and poorer sleep quality in school children (Ohrstrom, Hadzibajramovic, Holmes, & Svensson, 2006); and maternal paid employment and differences in sleep patterns in 5 to 7 year olds (Kalil, Dunifon, Crosby, & Su, 2014; Magee, Caputi, & Iverson, 2012). We also investigated childcare attendance; two measures of child wellbeing (general health and body size) and time spent outside, which was conceptualised as a proxy for outdoor light exposure which is known to play a role in sleep regulation (Wright et al., 2013).

Table 2: Sociodemographic information at 24 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Gender	Child gender	*Did you have a boy or a girl*[a]
Ethnicity	Child ethnicity	*What ethnic group does your baby [do your babies] belong to?* Prioritised child ethnicity derived by allocating each child to a single ethnic group based on the ethnicities that mothers identified, in prioritised order:[b,c] Māori Pacific Asian European/Other
Socioeconomic deprivation	NZDep2006[d] area-level measure of deprivation	NZDep2006 quintiles derived from NZDep2006 deciles: 1 = decile 1 and 2 2 = decile 3 and 4 3 = decile 5 and 6 4 = decile 7 and 8 5 = decile 9 and 10

[a]Collected at 6 weeks post-partum via phone interviews; [b]Collected at 9 months via face-to-face interviews; [c]Prioritised ethnicity based on Ministry of Health ethnicity data protocols for the health and disability sector (Ministry of Health, 2004, 2017a); [d]NZDep2006 (Salmond et al., 2007) collected at 24 months via face-to-face interviews

Table 2 (continued): Sociodemographic information at 24 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Rurality	Whether child lives in a rural or urban area	Derived from address: Rural area Urban area
Material standard of living	Material standard of living in child's household, reflective of deprivation at the household-level	*How does your (and your partner's combined) total income meet your everyday needs?* Categorised as: Not enough money Just enough money Enough money More than enough money
Neighbourhood safety	Perceived safety of child's neighbourhood	*To what extent do you agree or disagree with these statements about your neighbourhood? This is a safe neighbourhood* Dichotomised as: Disagree (combined 'strongly disagree' and 'disagree') Agree (combined 'strongly agree' and 'agree'
Neighbourhood traffic	Heavy traffic in child's neighbourhood	*There is heavy traffic on my street or road* Dichotomised as: Disagree (combined 'strongly disagree' and 'disagree') Agree (combined 'strongly agree' and 'agree')
Household structure	Composition of adults in child's household	Derived from information provided about child's family and categorised: Parent alone Two parents Parent/s with others (combined 'parent(s) with extended family' and 'parent(s) living with non-kin')

Table 2 (continued): Sociodemographic information at 24 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Mother's paid work	Whether or not child's mother in in paid employment	*Do you have a paid job at the current time?* Yes No
Childcare	Whether or not child is in childcare	*Over the past 1 month has [your child/have your children] been looked after at regular times during the week by anyone other than your partner?* Yes No
Time outside week	Usual time outside on week days, as a proxy for light exposure	*Thinking about the last 4 weeks, approximately how many hours has child spent outdoors on an average week day?* Categorised as: <1 hour and none 1 to <2 hours 2 to <3 hours 3 to <4 hours 4 to <5 hours ≥5 hours
Time outside weekend	Usual time outside on weekends, as a proxy for light exposure	*Thinking about the last 4 weeks, approximately how many hours has child spent outdoors on an average weekend day?* Categorised as: <1 hour and none 1 to <2 hours 2 to <3 hours 3 to <4 hours 4 to <5 hours ≥5 hours
General health	Child's general health	*In general how would you say [child's] current health is?* Poor Fair Good Very good Excellent

Table 2 (continued): Sociodemographic information at 24 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Body size	Child's body mass index (BMI)	BMI = [weight (kg)/height (m)]^2 Categorised as: Thin (<15.24 boys; <14.96 girls) Healthy weight (15.24 to <18.36 boys; 14.96 to <18.09 girls) Overweight (18.36 to <19.99 boys; 18.09 to <19.81 girls) Obese (≥19.99 boys; ≥19.81 girs)[e,f]

[e]Children without accurate measures of height and/or weight were excluded; [f]Categorised using International Obesity Taskforce child BMI cut-offs for 2 year olds (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007; Cole & Lobstein, 2012), to align with NZ Ministry of Health indicators https://minhealthnz.shinyapps.io/nz-health-survey-2017-18-annual-data-explorer/_w_a04772ad/_w_6b7888c4/#!/explore-indicators

Sociodemographic variables that were analysed in relation to children's sleep at 45 months are outlined in Table 3. Variables relevant to this study collected during the GUiNZ 45 month data collection wave included children's rurality, household structure and whether or not mothers were in paid employment. In addition, a *visual media use* variable was created by combining usual daily television and electronic media use duration, and categorised based on the current Ministry of Health recommendation that 2 to 5 year olds have less than one hour of screen time per day (Ministry of Health, 2017b). As per variables analysed in relation to sleep at 24 months, gender was based on data collected at 6 weeks post-partum and ethnicity was based on maternal report of child ethnicity at 9 months. Area-level deprivation (NZDep2013; Atkinson, Salmond, & Crampton, 2014) was not measured during the 45 month telephone interviews. Therefore, the decision was made to use NZDep2013 measured at 54 months to reflect children's socioeconomic position at 45 months, as this was the closest timepoint that NZDep was collected.

Table 3: Sociodemographic information at 45 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Gender	Child gender	*Did you have a boy or a girl*[a]
Ethnicity	Child ethnicity	*What ethnic group does your baby [do your babies] belong to?* Prioritised child ethnicity derived by allocating each child to a single ethnic group based on th ethnicities that mothers identified in prioritised order:[b,c] Māori Pacific Asian European/Other
Socioeconomic deprivation	NZDep2013[d] area-level measure of deprivation	NZDep2013 quintiles derived from NZDep2013 deciles: 1 = decile 1 and 2 2 = decile 3 and 4 3 = decile 5 and 6 4 = decile 7 and 8 5 = decile 9 and 10
Rurality	Whether child lives in a rural or urban area	Derived from address: Rural area Urban area
Household structure	Structure of child's household	Based on family information provided in the interview and categorised as: Parent alone = parent alone Two parents = two parents Parent(s) with others = parent(s) with extended family; parent(s) living with non-kin

[a]Collected at 6 weeks post-partum via phone interviews; [b]Collected at 9 months via face-to-face interviews; [c]Prioritised ethnicity based on Ministry of Health ethnicity data protocols for the health and disability sector (Ministry of Health, 2004); [d]NZDep2013 (Atkinson et al., 2014) collected at 54 months via face-to-face interviews

Table 3 (continued): Sociodemographic information at 45 months

Sociodemographic Variable	Description	GUiNZ Question or Derived Variable
Mother's paid work	Whether or not child's mother is in paid employment	*Do you have a paid job at the current time?* Yes No
Child's sleep location	Where child usually sleeps	*What is the current sleeping arrangement you have for [NAME] most of the time in your home?* Categorised as: Separate room alone = in a separate room alone Shared room = in a separate bed in a shared room with sibling(s)/ other children; parents; other adults Shared bed = in a shared bed with sibling(s)/other children; parents; other adults Other = other
Visual media use	*Usual amount of time child spends using visual (screen) media on weekdays*	*Thinking about a usual weekday, approximately how many hours does [NAME] spend at home… Watching television programming including free-to-air, online, and pay TV or DVDs either on TV or other media? Using electronic media e.g. computer or laptop, including children's computer systems such as Leapfrog, ipads, tablets, smart phones and any electronic gaming devices?* Duration of TV and electronic media summed and categorised as: <1 hour[e] 1 to <2 hours 2 to <3 hours ≥3 hours

[e]Based on Ministry of Health recommendation that children between the ages of 2 and 5 years have less than 1 hour of screen time per day (Ministry of Health, 2017b)

Data analysis

Data were analysed using R software (version 3.4.3) (R Core Team, 2017) and *p* values of <.05 were interpreted as statistically significant. As per a pre-determined data analysis plan, cross-sectional descriptive statistics were produced for child sleep variables using GUiNZ data collected at ages 24 months and 45 months (mean [standard deviation] and proportions) and percentages of children meeting current sleep duration and sleep quality recommendations from 24 months to 45 months were calculated. Univariate associations between sociodemographic factors and the proportion of children in the sample meeting sleep guidelines at 24 months and 45 months were described using percentages and 95% confidence intervals. Linear regression and Poisson regression models were run to examine univariate predictors of children's TST and number of night wakings at 24 and 45 months respectively.

Independent cross-sectional sociodemographic predictors of sleep durations and night wakings of children in NZ at 24 months and 45 months were investigated using Bayesian linear regression and Bayesian negative binomial multiple regression models. There are several advantages to utilising a Bayesian paradigm of modelling (Berger, 2013; Bernardo & Smith, 2009; Wagenmakers et al., 2018). For example, this approach produces measures of uncertainty for estimated parameters and can model complex problems with numerous latent variables, unlike more traditional modelling approaches. A probabilistic estimate for each parameter was obtained from Bayesian models using Markov chain Monte Carlo (MCMC) simulations, which allowed us to identify the probability of each child falling above or below the NSF guidelines for sleep duration at each age and the probability of having 'appropriate', 'uncertain' or 'not appropriate' number of wakings during the night.

Only one parentally-reported (subjective) measure of sleep duration and usual number of night wakings was measured at each data collection wave, which does not allow the estimation of children's day-to-day variability in sleep. However this subjective value, plus some uncertainty around it, is expected to capture the true value of TST and wakings. For every child at each data collection wave we assumed a normal distribution of TST with a mean value and common standard deviation, which was a reasonable assumption in the absence of repeated measures at each time point. The mean was equal to a linear combination of the predictors and one intercept. The standard deviation was obtained from the reciprocal of the variance (precision) and a non-informative prior distribution was used for the precision. In other words, using this approach enabled the data to 'speak for itself'. We opted for modelling TST as a continuous variable rather than using a binary one (appropriate versus not appropriate short or not appropriate long) so that we did not lose information and were able to obtain estimates in the regression model that could be easily interpreted. We also used Bayesian regression for the number of night wakings,

but considered the outcome variable to have a negative binomial distribution. This model also produced a night waking distribution for each child.

Trajectories of children's sleep durations and night wakings from 24 to 45 months were analysed using Bayesian growth curve models. Growth curve modelling is a flexible analytical technique suited to analysing longitudinal data, accounting for change at both the group- and individual-level (Hesser, 2015; Oravecz & Muth, 2018).

Results

Data were collected on sleep durations and night wakings of 6,308 children at 24 months and 6,186 children at 45 months. A total 6,004 children had sleep information at both time points and 6,490 children had at least some sleep information available at either 24 or 45 months. Within the total sample (n=6,490; 48.2% girls, 51.8% boys), almost half of children were categorised as belonging to the 'European/Other' ethnic group (22.4% Māori, 12.9% Pacific, 13.4% Asian, 45.2% European/Other, 6.1% missing data) and, at 24 months of age, nearly one quarter of children lived in areas with the highest deprivation scores (NZDep2006 quintiles: 1 (least deprived)=17.4%, 2=17.6%, 3=16.9%, 4=19.1%, 5 (most deprived)=23.9%, missing data=5.3%).

Description of sleep at 24 months

At 24 months of age, children slept an average of approximately ten and a half hours at night and two hours during the day and half of children in the sample did not usually wake during the night (Table 4 and Figures 1 and 2). The majority (82.8% and 83.1% respectively) of children were meeting Ministry of Health and NSF sleep duration and night waking guidelines (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Adams Hillard, et al., 2015; Ministry of Health, 2017b; Ohayon et al., 2017) (Table 4).

Table 4: Average sleep durations in hours and proportions of children waking at night, at 24 months of age (n=6,308)

Sleep Variable	Mean (SD) or %
Night sleep duration	10.55 (1.34)
Day sleep duration	1.80 (0.79)
Total sleep time (24hrs)	12.36 (1.51)
Number of night wakings: 0 1 2 3 or more	 50.70% 32.42% 12.14% 4.74%
Total sleep time: Short (<11hr) Appropriate (11-≤14hr) Long (>14hr)	 11.86% 82.80% 5.34%
Night wakings: Appropriate (0-1) Uncertain (2) Not appropriate (≥3)	 83.12% 12.14% 4.74%

Figure 1: Total sleep time in 24 hours, sleep at night and sleep during the day for children aged 24 months

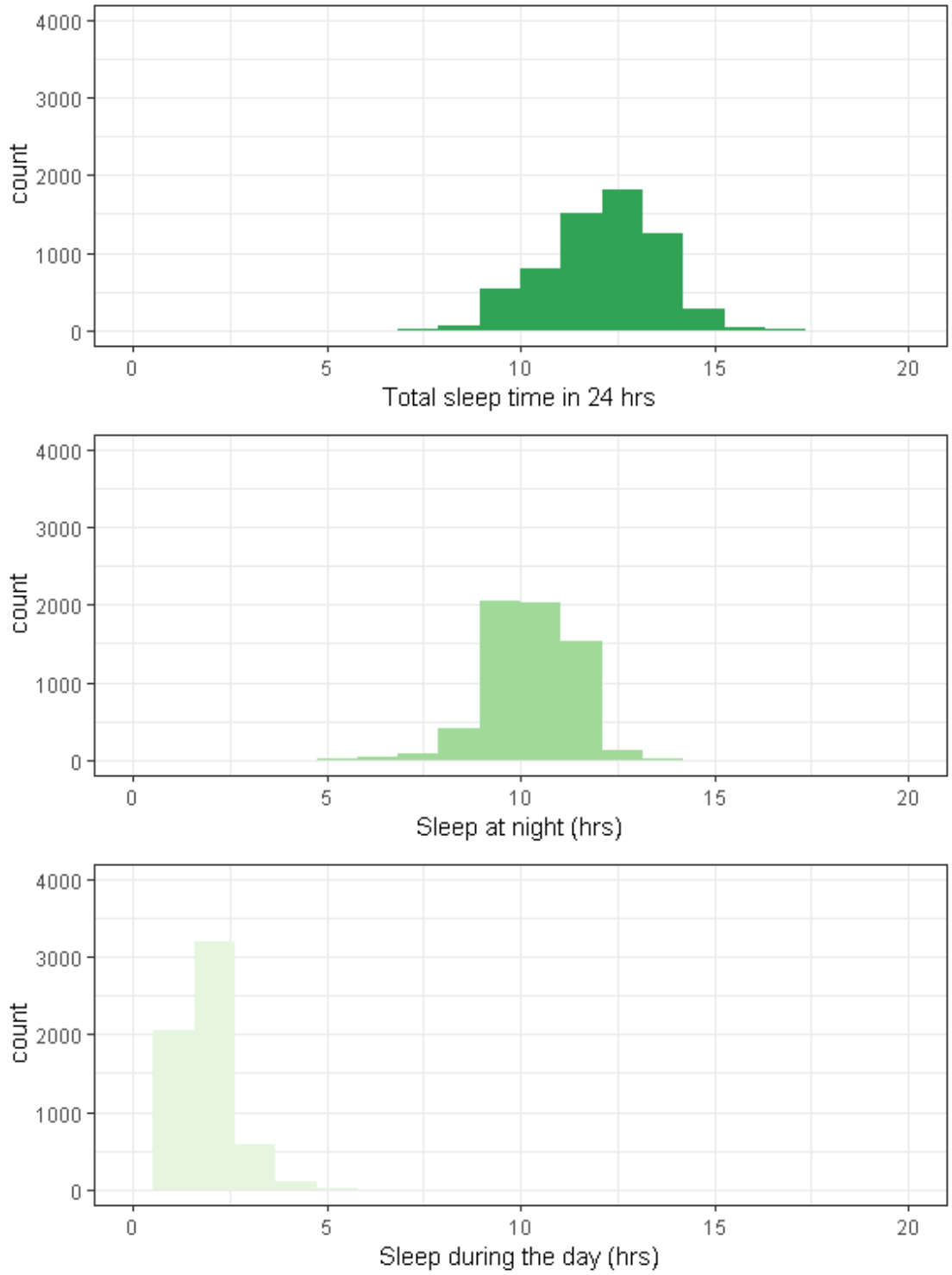
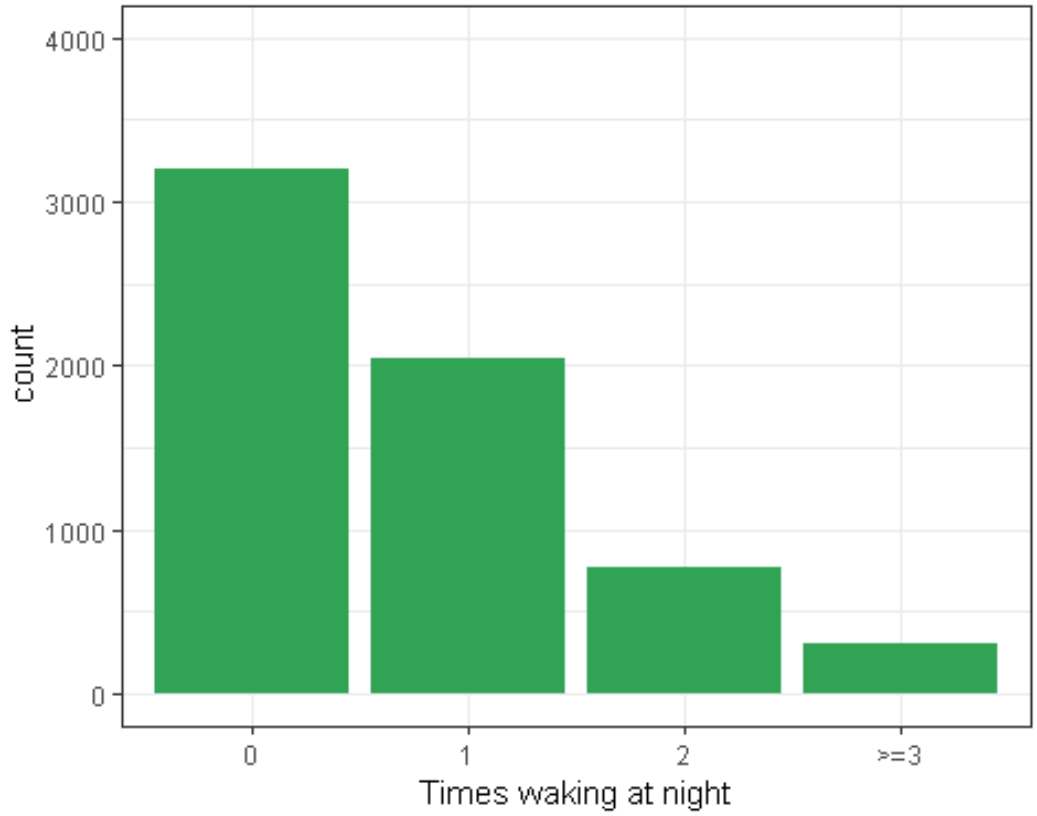


Figure 2: Frequency of children waking at night at 24 months of age



As indicated by 95% confidence intervals (i.e. intervals that overlap indicate no difference and intervals that do not overlap indicate a difference between groups), there was no statistically significant difference between the proportion of girls and the proportion of boys meeting, or not meeting, sleep duration and sleep quality (night waking) guidelines at 24 months of age (Table 5).

However, differences were observed by ethnicity (Table 5). A larger percentage of Māori, Pacific and Asian children had short sleep and a smaller percentage of Asian children had long sleep, compared to children in the European/Other group. In addition, a larger proportion of Pacific children had short sleep compared to Māori and Asian children. A smaller proportion of Māori children had appropriate sleep durations compared to Asian children. Regarding night waking, a smaller proportion of Māori, Pacific and Asian children met guidelines for an appropriate number of night wakings at 24 months, compared to children in the European/Other group, and a larger proportion of Māori children than Asian children woke an appropriate number of times.

Table 5: Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 24 months of age, stratified by sociodemographic factors (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<11hr)	Appropriate (11 - ≤14hr)	Long (>14hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Gender:						
Girl	12.76 (11.57-13.94)	82.42 (81.07-83.77)	4.82 (4.06-5.58)	83.73 82.42-85.04)	11.97 (10.82-13.12)	4.30 (3.58-5.02)
Boy	11.02 (9.94-12.09)	83.15 (81.87-84.44)	5.83 (5.03-6.63)	82.54 (81.24-83.84)	12.30 (11.18-13.43)	5.15 (4.40-5.91)
Ethnicity:						
Māori	16.26 (14.37-18.16)	78.57 (76.46-80.68)	5.17 (4.03-6.31)	82.15 (80.18-84.12)	12.06 (10.38-13.74)	5.79 (4.59-6.99)
Pacific	25.39 (22.44-28.33)	69.61 (66.49-72.72)	5.01 (3.53-6.48)	81.29 (78.65-83.93)	13.59 (11.27-15.91)	5.13 (3.63-6.62)
Asian	12.33 (10.14-14.51)	83.99 (81.55-86.43)	3.69 (2.43-4.94)	76.15 (73.32-78.99)	17.40 (14.87-19.92)	6.45 (4.82-8.09)
European/Other	5.49 (4.66-6.31)	88.48 (87.32-89.64)	6.03 (5.17-6.89)	86.33 (85.09-87.58)	9.92 (8.84-11.00)	3.75 (3.06-4.44)
NZDep2006 quintiles:						
1 (least deprived)	5.06 (3.78-6.34)	89.43 (87.64-91.23)	5.51 (4.17-6.84)	85.35 (83.28-87.41)	11.55 (9.68-13.41)	3.11 (2.09-4.12)
2	7.45 (5.93-8.97)	86.59 (84.61-88.57)	5.96 (4.59-7.33)	84.66 (82.57-86.75)	10.34 (8.57-12.11)	5.00 (3.73-6.26)
3	9.23 (7.52-10.95)	85.10 (82.99-87.21)	5.67 (4.30-7.04)	83.09 (80.87-85.31)	11.88 (9.97-13.80)	5.03 (3.73-6.32)
4	13.99 (12.05-15.92)	82.05 (71.91-84.19)	3.96 (2.87-5.05)	82.30 (80.17-84.42)	12.69 (10.84-14.55)	5.01 (3.80-6.23)
5	19.57 (17.60-21.55)	74.74 (72.58-76.91)	5.68 (4.53-6.84)	80.75 (78.79-82.71)	13.63 (11.92-15.34)	5.62 (4.47-6.77)

Table 5 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 24 months of age, stratified by sociodemographic factors (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<11hr)	Appropriate (11 - ≤14hr)	Long (>14hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Rurality:						
Rural	8.68 (6.23-11.13)	84.22 (81.05-87.39)	7.10 (4.86-9.34)	87.38 (84.49-90.27)	9.66 (7.09-12.24)	2.96 (1.48-4.43)
Urban	11.97 (11.12-12.81)	82.84 (81.86-83.82)	5.19 (4.62-5.77)	82.66 (81.67-83.65)	12.36 (11.50-13.21)	4.98 (4.41-5.55)
Material standard of living:						
Not enough	15.72 (12.92-18.52)	78.43 (75.26-81.59)	5.86 (4.05-7.66)	77.97 (74.78-81.15)	15.56 (12.77-18.35)	6.47 (4.58-8.36)
Just enough	14.54 (13.02-16.06)	80.72 (79.03-82.42)	4.73 (3.82-5.65)	80.63 (78.93-82.33)	13.53 (12.05-15.00)	5.85 (4.83-6.86)
Enough	11.31 (10.01-12.60)	83.24 (81.71-84.77)	5.46 (4.53-6.39)	84.68 (83.20-86.15)	11.35 (10.05-12.65)	3.97 (3.17-4.77)
More than enough	6.39 (5.05-7.74)	87.77 (85.96-89.57)	5.84 (4.55-7.13)	87.13 (85.29-88.98)	9.47 (7.86-11.08)	3.39 (2.40-4.39)
Neighbourhood safety:						
Disagree	16.33 (13.25-19.42)	78.04 (74.58-81.50)	5.63 (3.70-7.55)	81.85 (78.63-85.07)	11.25 (8.61-13.89)	6.90 (4.78-9.01)
Agree (safe)	11.39 (10.57-12.21)	83.33 (82.36-84.29)	5.28 (4.70-5.86)	83.22 (82.25-84.19)	12.25 (11.40-13.10)	4.53 (3.99-5.07)

Table 5 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 24 months of age, stratified by sociodemographic factors (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<11hr)	Appropriate (11 - ≤14hr)	Long (>14hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Neighbourhood traffic:						
Disagree	10.78 (9.84-11.73)	84.00 (82.88-85.12)	5.22 (4.54-5.90)	84.17 (83.05-85.28)	11.65 (10.67-12.63)	4.18 (3.57-4.79)
Agree (traffic)	13.83 (12.36-15.29)	80.57 (78.89-82.25)	5.60 (4.63-6.58)	81.18 (79.52-82.83)	13.08 (11.65-14.51)	5.74 (4.76-6.73)
Household structure:						
Parent alone	16.09 (12.04-20.13)	78.86 (74.37-83.36)	5.05 (2.64-7.46)	82.02 (77.79-86.25)	11.04 (7.59-14.49)	6.94 (4.14-9.74)
Two parents	9.70 (8.82-10.59)	85.14 (84.07-86.21)	5.16 (4.49-5.82)	84.60 (83.52-85.68)	11.46 (10.51-12.42)	3.94 (3.35-4.52)
Parent/s with others	16.08 (14.32-17.84)	78.14 (76.16-80.12)	5.78 (4.66-6.89)	79.69 (77.77-81.61)	14.00 (12.34-15.66)	6.31 (5.15-7.48)
Maternal paid work:						
Yes	10.19 (9.16-11.22)	85.38 (84.18-86.58)	4.43 (3.73-5.13)	84.09 (82.84-85.33)	11.60 (10.51-12.69)	4.31 (3.62-5.00)
No	13.70 (12.46-14.94)	79.93 (78.48-81.37)	6.38 (5.50-7.26)	82.05 (80.67-83.43)	12.75 (11.55-13.95)	5.20 (4.40-5.99)
Childcare:						
Yes	9.91 (8.92-10.90)	85.64 (84.48-86.80)	4.45 (3.77-5.14)	84.29 (83.09-85.50)	11.56 (10.51-12.62)	4.14 (3.48-4.80)
No	14.30 (13.00-15.60)	79.25 (77.74-80.76)	6.45 (5.53-7.36)	81.66 (80.22-83.10)	12.86 (11.61-14.11)	5.48 (4.63-6.32)

Table 5 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 24 months of age, stratified by sociodemographic factors (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<11hr)	Appropriate (11 - ≤14hr)	Long (>14hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Time outside week:						
0 - <1hr	18.02 (14.17-21.86)	74.93 (70.59-79.28)	7.05 (4.49-9.61)	79.90 (75.88-83.91)	12.79 (9.45-16.14)	7.31 (4.70-9.92)
1 - <2hr	12.92 (10.75-15.10)	81.49 (78.97-84.01)	5.59 (4.10-7.08)	82.69 (80.24-85.15)	12.05 (9.94-14.16)	5.26 (3.81-6.71)
2 - <3hr	9.98 (8.64-11.32)	85.21 (83.62-86.80)	4.81 (3.85-5.76)	83.80 (82.15-85.45)	11.60 (10.16-13.03)	4.60 (3.66-5.54)
3 - <4hr	10.73 (9.05-12.41)	84.52 (82.56-86.48)	4.75 (3.60-5.91)	84.29 (82.32-86.27)	11.42 (9.69-13.14)	4.29 (3.19-5.39)
4 - <5hr	11.23 (9.07-13.40)	82.42 (79.81-85.02)	6.35 (4.68-8.02)	85.47 (83.06-87.88)	9.89 (7.85-11.93)	4.64 (3.20-6.08)
≥5hr	13.98 (11.69-16.27)	80.57 (77.95-83.18)	5.45 (3.95-6.95)	80.00 (77.36-82.64)	15.80 (13.39-18.21)	4.20 (2.88-5.53)
Time outside weekend:						
0 - <1hr	20.98 (15.65-26.31)	71.88 (65.99-77.76)	7.14 (3.77-10.52)	79.02 (73.69-84.35)	12.50 (8.17-16.83)	8.48 (4.83-12.13)
1 - <2hr	15.88 (12.50-19.27)	79.42 (75.67-83.17)	4.70 (2.74-6.66)	79.19 (75.43-82.96)	14.32 (11.07-17.56)	6.49 (4.20-8.77)
2 - <3hr	10.48 (8.83-12.13)	83.56 (81.56-85.55)	5.96 (4.68-7.23)	84.46 (82.51-86.41)	11.24 (9.54-12.94)	4.30 (3.21-5.39)
3 - <4hr	9.26 (7.72-10.81)	86.69 (84.89-88.50)	4.04 (3.00-5.09)	83.01 (81.02-85.01)	12.94 (11.16-14.73)	4.04 (3.00-5.09)
4 - <5hr	10.51 (8.85-12.18)	84.50 (82.53-86.46)	4.99 (3.81-6.17)	84.34 (82.37-86.32)	10.51 (8.85-12.18)	5.14 (3.94-6.34)
≥5hr	13.75 (12.07-15.44)	80.15 (78.20-82.10)	6.10 (4.93-7.27)	82.95 (81.11-84.79)	12.69 (11.07-14.32)	4.36 (3.36-5.35)

Table 5 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 24 months of age, stratified by sociodemographic factors (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<11hr)	Appropriate (11 - ≤14hr)	Long (>14hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
General health:						
Poor	28.12 (12.55-43.70)	62.50 (45.73-79.27)	9.38 (0.00-19.47)	65.62 (49.17-82.08)	6.25 (0.00-14.64)	28.12 (12.55-43.70)
Fair	16.91 (11.80-22.01)	79.71 (74.23-85.19)	3.38 (0.92-5.84)	68.60 (62.28-74.92)	18.84 (13.51-24.17)	12.56 (8.05-17.07)
Good	15.51 (12.76-18.27)	80.72 (77.72-83.72)	3.77 (2.32-5.21)	79.52 (76.45-82.59)	13.86 (11.23-16.48)	6.63 (4.73-8.52)
Very good	11.87 (10.49-13.25)	82.91 (81.30-84.51)	5.22 (4.27-6.17)	82.29 (80.66-83.92)	12.58 (11.17-14.00)	5.13 (4.19-6.07)
Excellent	10.64 (9.59-11.70)	83.54 (82.27-84.80)	5.82 (5.02-6.62)	85.48 (84.27-86.68)	11.13 (10.05-12.20)	3.40 (2.78-4.01)
Body size:						
Thin	16.81 (9.92-23.71)	78.76 (71.22-86.30)	4.42 (0.63-8.22)	79.65 (72.22-87.07)	17.70 (10.66-24.74)	2.65 (0.00-5.62)
Healthy weight	8.17 (6.92-9.43)	86.01 (84.42-87.60)	5.81 (4.74-6.89)	84.64 (82.99-86.30)	10.59 (9.17-12.00)	4.77 (3.79-5.75)
Overweight	13.56 (10.85-16.27)	82.68 (79.68-85.68)	3.76 (2.25-5.26)	83.50 (80.56-86.44)	12.42 (9.81-15.03)	4.08 (2.52-5.65)
Obese	12.07 (7.88-16.26)	82.76 (77.90-87.62)	5.17 (2.32-8.02)	83.19 (78.38-88.00)	14.22 (9.73-18.72)	2.59 (0.54-4.63)

As outlined in Table 5, greater area-level socioeconomic deprivation was associated with an increasing percentage of children having short sleep or 'not appropriate' night wakings. Similar patterns were observed between material standard of living, children's health and sleep at 24 months, with higher levels of income and better health aligned with increasing proportions of children having sleep durations and night wakings categorised as being appropriate for this age.

Differences in the proportion of children meeting, or not meeting, sleep guidelines at 24 months were also found in relation to other sociodemographic factors at the community-, household- and child-level (Table 5). A larger percentage of children living in a rural area had an appropriate number of night wakings compared to children living in an urban area, but no difference in the proportion of children meeting sleep duration guidelines was observed by rurality. A larger proportion of children living in areas with heavy traffic had short sleep and a smaller proportion of children living in heavy traffic areas had appropriate sleep durations and appropriate night wakings, compared to children not living near heavy traffic. A smaller proportion of children living in two parent households had short sleep compared to children in households comprising sole parents or parent/s with other adults. A larger proportion of children from two parent households also had appropriate night wakings compared to children from homes with parent/s and other adult household members.

A greater proportion of children who spent less than an hour outside during the week had short sleep compared to children who spent between 2 and less than 5 hours outside on week days (Table 5). This difference was not seen when time outside during the week was 5 hours or more. In addition, a larger proportion of children who spent 5 hours or more outside during the week usually woke twice during the night, compared to children who spent between 2 and less than 5 hours outside on week days.

A larger proportion of children with very good or excellent health had appropriate sleep durations and a larger proportion of children with excellent health had appropriate night wakings, compared to children with poor health in the sample.

The proportion of children with an 'appropriate', 'uncertain' or 'not appropriate' number of night wakings at 24 months of age did not differ by neighbourhood safety, maternal paid work, childcare, or body size (Table 5). However, a smaller proportion of children who lived in a safe neighbourhood, whose mother was in paid work, who were in childcare, or who had a healthy weight had short sleep durations, compared to children living in an unsafe neighbourhood, whose mother was not employed, who were not receiving childcare or who were overweight or thin.

Description of sleep at 45 months

At the age of 45 months, children slept an average of approximately ten and three quarter hours at night and half an hour during the day, and around two thirds of children in the sample did not usually wake during the night (Table 6 and Figures 3 and 4). Over ninety percent of children met guidelines for sleep duration and night waking (Table 6).

Table 6: Average sleep durations in hours and proportions of children waking at night, at 45 months of age (n=6,186)

Sleep Variable	Mean (SD) or %
Night sleep duration	10.69 (1.08)
Day sleep duration	0.51 (0.85)
Total sleep time (24hrs)	11.21 (1.18)
Number of night wakings: 0 1 2 3 or more	 62.01% 30.86% 5.64% 1.49%
Total sleep time: Short (<10hr) Appropriate (11-≤13hr) Long (>13hr)	 6.21% 90.61% 3.18%
Night wakings: Appropriate (0-1) Uncertain (2) Not appropriate (≥3)	 92.87% 5.64% 1.49%

Figure 3: Total sleep time in 24 hours, sleep at night and sleep during the day for children aged 45 months

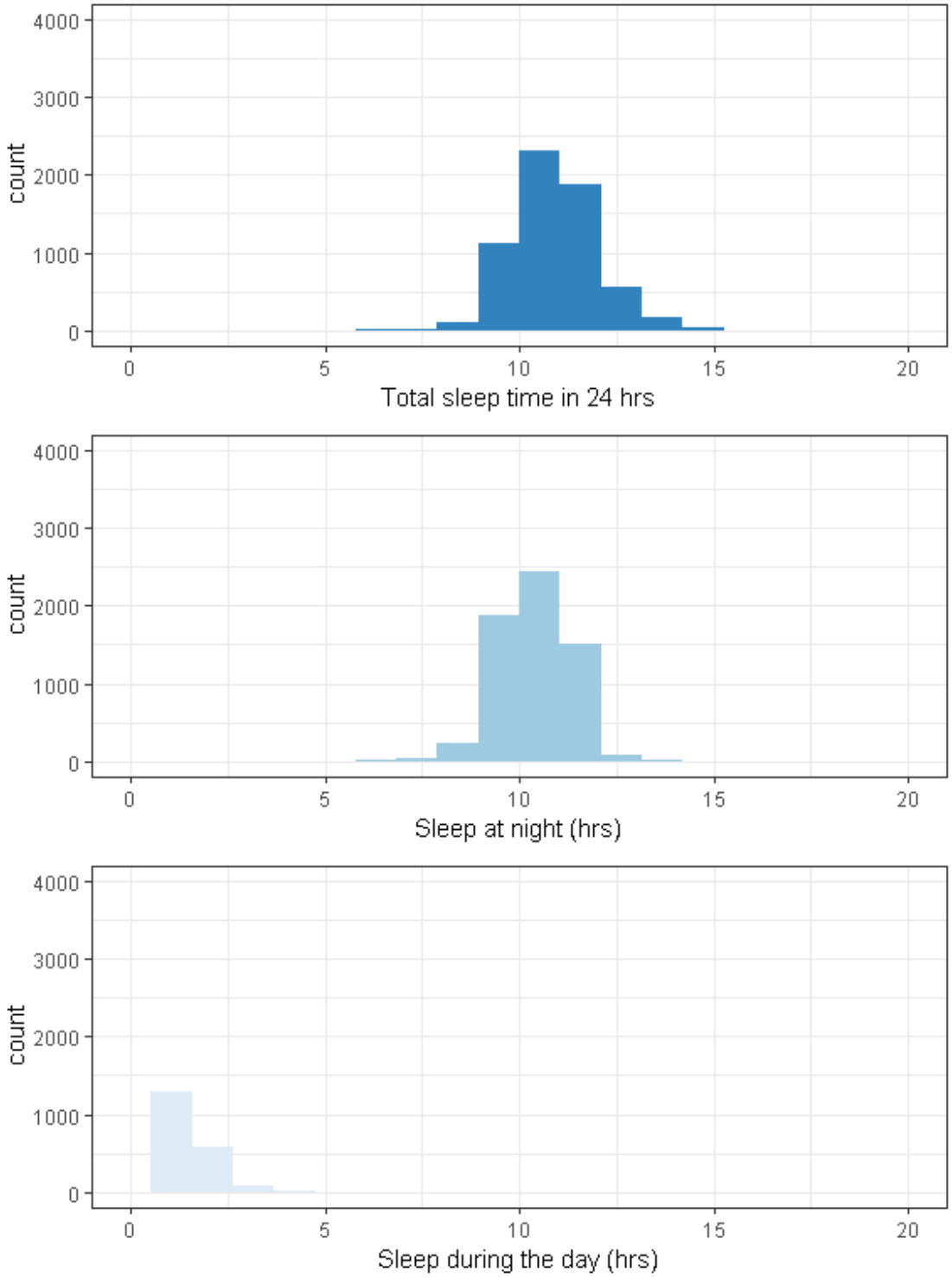
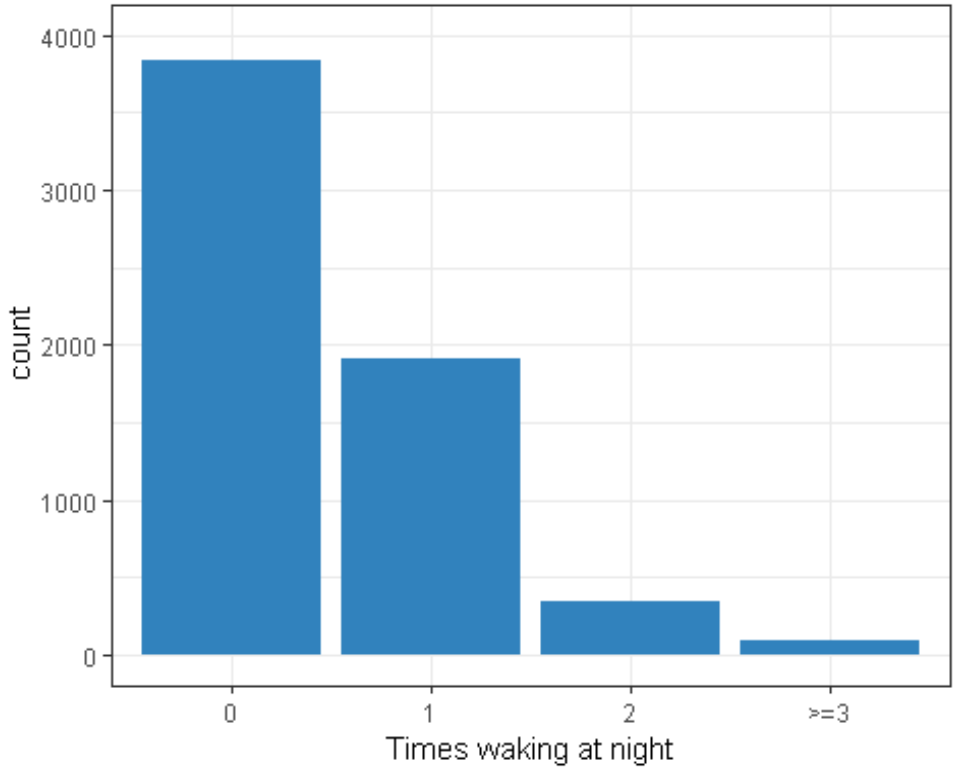


Figure 4: Frequency of children waking at night at 45 months of age



The proportion of children meeting sleep guidelines at 45 months did not differ by gender or rurality, but did differ by ethnicity (Table 7). A larger proportion of Māori, Pacific and Asian children had short sleep, long sleep, usually woke twice ('uncertain') or three or more times ('not appropriate') during the night compared to European/Other children. Greater area-level deprivation was associated with increasing proportions of children having short sleep, long sleep, and waking twice during the night. A similar pattern was observed for visual media use and sleep, with longer durations of visual media use associated with increasing proportions of children having short sleep and with decreasing proportions of children having appropriate sleep durations and night wakings.

A smaller percentage of children living in two parent households had short sleep compared to children in households with one parent or with parent/s and other adults (Table 7). A larger proportion of children whose mothers were in paid work had appropriate sleep durations, and a smaller proportion of children whose mothers were in paid work had long sleep, compared to children whose mothers were not in paid work. A smaller percentage of children who slept in a separate room alone had short sleep compared to children who shared a room or a bed and a smaller proportion of children who shared a room had short sleep compared to children who shared a bed. A larger percentage of children who shared a bed had long sleep, compared to children who slept in a separate room alone. Similarly, a greater proportion of children who slept in a separate room alone or who shared a room had an appropriate number of night wakings compared to children who shared a bed.

Table 7: Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 45 months of age, stratified by sociodemographic factors (n=6,186)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<10hr)	Appropriate (10 - ≤13hr)	Long (>13hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Gender:						
Girl	6.57 (5.68-7.45)	90.55 (89.50-91.60)	2.88 (2.28-3.48)	92.33 (91.37-93.28)	6.00 (5.14-6.85)	1.68 (1.21-2.14)
Boy	5.87 (5.06-6.69)	90.66 (89.65-91.67)	3.47 (2.83-4.10)	93.38 (92.52-94.24)	5.31 (4.53-6.09)	1.31 (0.92-1.71)
Ethnicity:						
Māori	8.56 (7.07-10.05)	87.90 (86.16-89.63)	3.54 (2.56-4.53)	90.48 (88.92-92.04)	7.16 (5.79-8.53)	2.36 (1.55-3.17)
Pacific	10.43 (8.24-12.62)	84.22 (81.61-86.84)	5.35 (3.74-6.96)	91.71 (89.74-93.69)	6.68 (4.89-8.47)	1.60 (0.70-2.50)
Asian	9.47 (7.47-11.46)	88.23 (86.03-90.43)	2.31 (1.28-3.33)	90.66 (88.67-92.64)	7.77 (5.94-9.59)	1.58 (0.73-2.43)
European/Other	2.74 (2.14-3.33)	95.01 (94.22-95.81)	2.25 (1.71-2.79)	94.81 (94.00-95.62)	4.09 (3.36-4.81)	1.11 (0.73-1.49)
NZDep2013 quintiles:						
1 (least deprived)	3.37 (2.36-4.38)	94.33 (93.03-95.63)	2.30 (1.46-3.14)	93.76 (92.40-95.11)	4.60 (3.42-5.78)	1.64 (0.93-2.36)
2	4.64 (3.39-5.88)	93.36 (91.89-94.83)	2.00 (1.17-2.83)	93.09 (91.59-94.59)	5.09 (3.79-6.39)	1.82 (1.03-2.61)
3	4.83 (3.51-6.15)	92.61 (91.00-94.22)	2.56 (1.59-3.53)	93.30 (91.76-94.84)	5.62 (4.20-7.03)	1.08 (0.45-1.72)
4	6.71 (5.14-8.29)	90.29 (88.42-92.15)	3.00 (1.92-4.07)	92.77 (91.14-94.40)	5.48 (4.04-6.91)	1.76 (0.93-2.58)
5	10.33 (8.70-11.96)	84.58 (82.64-86.52)	5.09 (3.91-6.27)	91.02 (89.48-92.55)	7.41 (6.01-8.81)	1.57 (0.90-2.24)

Table 7 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 45 months of age, stratified by sociodemographic factors (n=6,186)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<10hr)	Appropriate (10 - ≤13hr)	Long (>13hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Rurality:						
Rural	4.26 (2.56-5.96)	92.96 (90.81-95.12)	2.78 (1.39-4.16)	93.89 (91.87-95.91)	4.44 (2.71-6.18)	1.67 (0.59-2.75)
Urban	6.30 (5.63-6.97)	90.60 (89.80-91.40)	3.10 (2.62-3.58)	92.60 (91.88-93.32)	5.83 (5.18-6.47)	1.57 (1.23-1.91)
Household structure:						
Parent alone	8.25 (5.83-10.67)	87.12 (84.18-90.07)	4.63 (2.78-6.47)	92.76 (90.48-95.04)	5.63 (3.61-7.66)	1.61 (0.50-2.72)
Two parents	4.89 (4.26-5.53)	92.41 (91.62-93.19)	2.70 (2.22-3.18)	93.18 (92.44-93.93)	5.35 (4.69-6.02)	1.46 (1.11-1.82)
Parent/s with others	9.72 (8.11-11.32)	86.07 (84.20-87.95)	4.21 (3.12-5.30)	91.81 (90.33-93.30)	6.66 (5.31-8.01)	1.53 (0.86-2.20)
Maternal paid work:						
Yes	5.83 (5.06-6.59)	91.69 (90.79-92.60)	2.48 (1.97-2.99)	93.17 (92.34-94.00)	5.55 (4.80-6.30)	1.28 (0.91-1.65)
No	6.71 (5.75-7.68)	89.12 (87.92-90.32)	4.17 (3.40-4.94)	92.48 (91.46-93.49)	5.79 (4.89-6.69)	1.74 (1.23-2.24)
Child's sleep location:						
Separate room alone	3.65 (2.95-4.35)	93.75 (92.85-94.65)	2.60 (2.01-3.20)	94.72 (93.89-95.56)	4.19 (3.45-4.94)	1.08 (0.70-1.47)
Shared room	6.78 (5.71-7.86)	90.06 (88.78-91.34)	3.15 (2.40-3.90)	93.36 (92.29-94.43)	5.49 (4.52-6.47)	1.15 (0.69-1.60)
Shared bed	10.62 (8.94-12.30)	84.88 (82.93-86.84)	4.50 (3.37-5.63)	88.29 (86.54-90.05)	8.99 (7.43-10.55)	2.71 (1.83-3.60)
Other	11.76 (0.93-22.59)	85.29 (73.39-97.20)	2.94 (0.00-8.62)	88.24 (77.41-99.07)	5.88 (0.00-13.79)	5.88 (0.00-13.79)

Table 7 (continued): Proportions and 95% confidence intervals of children meeting sleep duration and night waking guidelines at 45 months of age, stratified by sociodemographic factors (n=6,186)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Short (<10hr)	Appropriate (10 - ≤13hr)	Long (>13hr)	Appropriate (0 – 1 waking)	Uncertain (2 wakings)	Not appropriate (≥3 wakings)
Visual media use:						
<1hr	3.81 (2.68-4.94)	93.56 (92.11-95.01)	2.63 (1.68-3.57)	94.11 (92.72-95.50)	4.53 (3.31-5.76)	1.36 (0.68-2.04)
1 - <2hr	4.43 (3.56-5.30)	92.68 (91.58-93.78)	2.89 (2.18-3.60)	93.89 (92.88-94.91)	4.85 (3.94-5.76)	1.26 (0.79-1.73)
2 - <3hr	6.05 (4.85-7.26)	91.29 (89.86-92.71)	2.66 (1.85-3.47)	92.69 (91.37-94.00)	5.65 (4.48-6.82)	1.66 (1.02-2.31)
≥3hr	10.88 (9.27-12.49)	84.52 (82.65-86.39)	4.60 (3.52-5.69)	90.59 (89.07-92.10)	7.67 (6.29-9.05)	1.74 (1.07-2.42)

Description of sleep trajectories from 24 to 45 months

Approximately three quarters of children consistently met sleep duration and night waking guidelines at both 24 months and 45 months (Tables 8 and 9). Close to fourteen percent of children went from having either short or long sleep at 24 months to meeting sleep duration guidelines at 45 months, two percent of children had consistently short sleep and less than one percent of children had consistently long sleep durations (Table 8). Approximately six percent of children went from having appropriate sleep durations at 24 months to either short or long sleep at 45 months and <0.5% went from short sleep at 24 months to long sleep at 45 months, or vice versa (Table 8).

Approximately thirteen percent of children went from waking two or more times a night at 24 months to meeting night waking guidelines at 45 months (Table 9). Around four percent of children went from meeting night waking guidelines at 24 months (not waking or waking only once) to waking two or more times per night at 45 months. Approximately three percent of children were consistently outside the appropriate range of night waking at both 24 months and 45 months.

Table 8: Sleep duration trajectories from 24 months to 45 months (n=6,004)

	45mth: Short (<10hr)	45mth: Appropriate (10-≤13hr)	45mth: Long (>13hr)
24mth: Short (<11hr)	2.03%	8.98%	0.35%
24mth: Appropriate (11-≤14hr)	3.91%	77.33%	2.12%
24mth: Long (>14hr)	0.15%	4.56%	0.57%

Table 9: Night waking trajectories from 24 months to 45 months (n=6,004)

	45mth: Appropriate (0-1 waking)	45mth: Uncertain (2 wakings)	45mth: Not Appropriate (≥3 wakings)
24mth: Appropriate (0-1)	79.43%	3.18%	0.63%
24mth: Uncertain (2)	10.24%	1.37%	0.37%
24mth: Not appropriate (≥3)	3.18%	1.10%	0.50%

Factors associated with children meeting sleep guidelines at 24 months

Univariate relationships between sociodemographic factors and sleep at 24 months

At the univariate level, linear regression and Poisson regression models showed statistically significant relationships between sociodemographic characteristics and the duration of children's sleep across 24 hours and the number of times children woke during the night at 24 months of age (Appendices 1 and 2). There was a small but statistically significant difference in sleep duration by gender, with girls sleeping approximately 4 minutes less than boys. There were also significant univariate differences in children's sleep by ethnicity. Māori children slept 33 minutes less, Pacific children slept 58 minutes less and Asian children slept 39 minutes less than European/Other children, who slept an average of 12.72 hours across 24 hours. On average, Māori children woke 1.2 times more, Pacific children woke 1.2 times more and Asian children woke 1.4 times more than European/Other children who woke an average of 0.6 times per night. There was a dose response relationship between area-level socioeconomic deprivation and sleep duration. Children living in least deprived areas had an average TST of 12.65 hours, compared to children living in NZDep2006 quintile areas 2, 3, 4 and 5 who slept an average of 2 minutes, 12 minutes, 23 minutes and 40 minutes less respectively. In addition, children living in most deprived areas woke 1.1 times more than children living in least deprived areas, who woke an average of 0.7 times per night.

As per Appendices 1 and 2, children living in urban areas slept an average of 16 minutes less and woke 1.2 times more than children from rural areas. There was a dose response relationship between parents reporting having 'enough' income to meet every day needs and sleep. Children from households with 'enough' and 'more than enough' slept 10 minutes more and 23 minutes more respectively, compared to children from households with 'not enough'. Children from homes with 'enough' and 'more than enough' income to meet daily needs tended to wake less (0.2 times and 0.3 times less respectively) than children from homes with 'not enough'. Children who lived in safe neighbourhoods slept an average of 20 minutes more and woke an average 0.1 times less than children living in unsafe neighbourhoods and children living in areas with heavy traffic slept an average of 12 minutes less and woke 1.1 times more than children from areas without heavy traffic. A similar pattern was found for maternal work, with children of mothers not in paid work sleeping slightly less (by 5 minutes) and waking slightly more (1.1 times) than children of mothers in paid work. Children living in two parent households tended to sleep 20 minutes longer and wake 0.1 times less than children living in sole parent households. Whereas, children in childcare slept an average 18 minutes more and woke slightly (0.1 times) less than children not in childcare.

Univariate relationships were also found between time outside, children's health and body size, and sleep at 24 months (Appendices 1 and 2). Children who spent less than an hour outside on weekdays had an average TST of 12.12 hours and woke an average 0.8 times, whereas children who spent 2 to <3 hours, 3 to <4 hours or 4 to <5 hours outside slept an average 20, 16 and 18 minutes more respectively. Children who spent 3 to <4 hours and 4 to <5 hours outside on weekdays also woke slightly less (average 0.1 and 0.2 fewer times) than children who spent less than an hour outside. Similarly, time outside on weekends was associated with differences in sleep at the univariate level. Children who spent two or more hours outside on weekends had significantly longer average sleep durations (2-<3hrs = 28 minutes, 3-<4hrs = 25 minutes, 4-<5hrs = 24 minutes, ≥5hrs = 17 minutes) than children who spent less than an hour outside on weekends. More time outside on the weekend was also associated with fewer night wakings. Children who spent 2 to <3 hours, 4 to <5 hours and ≥5 hours outside had an average 0.2 fewer night wakings than children who spent less than an hour outside. Children with excellent health slept an average 37 extra minutes than children with poor health. Children with good, very good or excellent health tended to wake less (an average 0.4, 0.4 and 0.5 fewer wakings) than children with poor health. Overweight or thin children slept an average of 11 minutes and 23 minutes less than children with a healthy weight.

Multivariate relationships between sociodemographic factors and sleep at 24 months

Results of Bayesian multivariate linear regression and Bayesian negative binomial multiple regression models of children's TST and night wakings at 24 months respectively are summarised in Table 10. These models assume uncertainty around parentally-reported mean sleep measurements and take into account individual variation in sleep durations and night wakings for each child. All of the sociodemographic variables that were analysed at the univariate level (Appendices 1 and 2) were included in the models simultaneously, with the exception of the *time outside weekend* variable. This was highly correlated with the *time outside week* variable, therefore the decision was made to include the latter due to this variable relating to a greater number of days during the week.

After controlling for all sociodemographic factors in the model, gender, ethnicity, area-level socioeconomic deprivation, heavy traffic and body size were associated with children's TST at 24 months of age (Table 10). Girls' sleep durations were, on average, approximately 8 minutes shorter per night than boys'. Sleep durations of Māori, Pacific and Asian children were significantly shorter by an average of 20, 43 and 38 minutes respectively, compared to sleep durations of European/Other children. Children living in areas with greatest socioeconomic deprivation (NZDep2006 quintile 5) slept approximately 16 minutes less than children living in least deprived areas (NZDep2006 quintile 1). Children who lived in neighbourhoods with heavy traffic slept approximately 11

minutes less than children who lived in areas without heavy traffic. Children who were overweight also tended to sleep an average of 10 minutes less than children who were a healthy weight.

In contrast, gender, area-level socioeconomic deprivation and body size were not significant predictors of the number of times children woke at night at 24 months of age, after controlling for other sociodemographic characteristics (Table 10). Ethnicity and heavy traffic were significant in both models and rurality, material standard of living, household structure and child health were significantly associated with the number of night wakings, but not with children's TST. On average, Asian children woke 1.3 times more at night than European/Other children; children living in urban areas woke 1.3 times more at night than children living in rural areas; children living in areas with heavy traffic woke 1.2 times more at night than children living in areas without heavy traffic; and children living in households comprising parent/s and other adult/s woke 1.4 times more at night than children living in two-parent households. Whereas, children living in households with enough income to meet every day needs had an average of 0.2 fewer night wakings than children living in households with not enough income and children with excellent health woke approximately 0.4 times less than children with poor health.

Table 10: Associations between sociodemographic factors and child sleep durations and night wakings at 24 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Intercept	12.93 (0.42)	12.15-13.77	Significant	0.65 (0.40)	-1.03 – 0.09	Non-significant
Gender:						
Boy	Baseline			Baseline		
Girl	-0.14 (0.05)	-0.25 – -0.04	Significant	0.97 (0.05)	-0.12 – 0.97	Non-significant
Ethnicity:						
European/Other	Baseline			Baseline		
Māori	-0.33 (0.07)	-0.48 – -0.19	Significant	1.10 (0.07)	-0.04 – 0.23	Non-significant
Pacific	-0.71 (0.10)	-0.90 – -0.51	Significant	1.07 (0.09)	-0.11 – 0.24	Non-significant
Asian	-0.63 (0.08)	-0.80 – -0.47	Significant	1.33 (0.07)	0.14 – 0.43	Significant
NZDep2006 quintiles:						
1	Baseline			Baseline		
2	0.07 (0.08)	-0.09 – 0.23	Non-significant	1.11 (0.08)	-0.04 – 0.26	Non-significant
3	0.01 (0.09)	-0.15 – 0.18	Non-significant	1.12 (0.08)	-0.04 – 0.26	Non-significant
4	-0.10 (0.09)	-0.27 – 0.06	Non-significant	1.01 (0.08)	-0.14 – 0.17	Non-significant
5	-0.27 (0.09)	-0.45 – -0.08	Significant	1.06 (0.09)	-0.11 – 0.23	Non-significant
Rurality:						
Rural	Baseline			Baseline		
Urban	-0.13 (0.10)	-0.31 – 0.06	Non-significant	1.27 (0.10)	0.04 – 0.43	Significant

Note: SD = standard deviation; HDI = highest density interval

Table 10 (continued): Associations between sociodemographic factors and child sleep durations and night wakings at 24 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Material standard of living:						
Not enough	Baseline			Baseline		
Just enough	-0.08 (0.10)	-0.28 – 0.12	Non-significant	0.96 (0.09)	-0.21 – 0.12	Non-significant
Enough	0.04 (0.10)	-0.16 – 0.24	Non-significant	0.81 (0.09)	-0.37 – -0.03	Significant
More than enough	0.11 (0.11)	-0.11 – 0.32	Non-significant	0.74 (0.10)	-0.50 – -0.11	Significant
Neighbourhood safety:						
Disagree	Baseline			Baseline		
Agree (safe)	-0.16 (0.11)	-0.37 – 0.05	Non-significant	0.96 (0.09)	-0.22 – 0.15	Non-significant
Neighbourhood traffic:						
Disagree	Baseline			Baseline		
Agree (traffic)	-0.18 (0.06)	-0.29 – -0.06	Significant	1.15 (0.05)	0.04 – 0.24	Significant
Household structure:						
Parent alone	Baseline			Baseline		
Two parents	0.14 (0.14)	-0.13 – 0.40	Non-significant	1.19 (0.14)	-0.09 – 0.47	Non-significant
Parent/s with others	0.05 (0.14)	-0.22 – 0.32	Non-significant	1.38 (0.14)	0.06 – 0.63	Significant
Maternal paid work:						
Yes	Baseline			Baseline		
No	0.01 (0.06)	-0.11 – 0.13	Non-significant	1.00 (0.06)	-0.12 – 0.12	Non-significant
Childcare:						
No	Baseline			Baseline		
Yes	0.05 (0.06)	-0.07 – 0.17	Non-significant	1.07 (0.06)	-0.05 – 0.18	Non-significant

Note: SD = standard deviation; HDI = highest density interval

Table 10 (continued): Associations between sociodemographic factors and child sleep durations and night wakings at 24 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,308)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Time outside week:						
0 - <1hr	Baseline			Baseline		
1 - <2hr	0.01 (0.13)	-0.24 – 0.25	Non-significant	1.08 (0.11)	-0.12 – 0.29	Non-significant
2 - <3hr	0.19 (0.12)	-0.04 – 0.42	Non-significant	1.02 (0.10)	-0.18 – 0.22	Non-significant
3 - <4hr	-0.13 (0.12)	-0.37 – -0.10	Non-significant	1.04 (0.11)	-0.17 – 0.25	Non-significant
4 - <5hr	0.11 (0.13)	-0.15 – 0.36	Non-significant	0.96 (0.12)	-0.28 – 0.18	Non-significant
≥5hr	-0.08 (0.13)	-0.34 – 0.01	Non-significant	1.16 (0.12)	-0.09 – 0.37	Non-significant
General health:						
Poor	Baseline			Baseline		
Fair	-0.24 (0.37)	-0.97 – 0.44	Non-significant	1.04 (0.23)	-0.40 – 0.51	Non-significant
Good	-0.12 (0.35)	-0.83 – 0.52	Non-significant	0.75 (0.22)	-0.70 – 0.16	Non-significant
Very good	0.08 (0.34)	-0.61 – 0.72	Non-significant	0.69 (0.21)	-0.77 – 0.07	Non-significant
Excellent	0.14 (0.34)	-0.55 – 0.77	Non-significant	0.59 (0.21)	-0.92 – -0.09	Significant
Body size:						
Healthy weight	Baseline			Baseline		
Obese	0.04 (0.10)	-0.15 – 0.23	Non-significant	0.84 (0.10)	-0.37 – 0.02	Non-significant
Overweight	-0.17 (0.07)	-0.30 – -0.04	Significant	0.96 (0.06)	-0.16 – 0.08	Non-significant
Thin	-0.21 (0.13)	-0.48 – 0.06	Non-significant	1.04 (0.12)	-0.20 – 0.26	Non-significant

Note: SD = standard deviation; HDI = highest density interval

Prevalence estimates of children in NZ meeting, or not meeting, sleep duration guidelines, after controlling for all sociodemographic characteristics included in the Bayesian multivariate linear regression model (Table 10) were modelled by gender, ethnicity, area-level socioeconomic deprivation and all significant predictors from the multivariate model i.e. heavy traffic and body size (Table 11). In the absence of repeated measures at each time point, we assumed a common within-individual standard deviation for all children. Therefore, the dispersion around mean TST is similar but the mean differs, depending on each child's sociodemographic characteristics.

Results indicate that in the NZ population, estimated average TST at 24 months of age is 12.46 hours, 15.6% of children have a high probability of short sleep, 70.2% of children have a high probability of appropriate sleep durations and 14.2% of children have a high probability of long sleep (Table 11). At 24 months of age, a larger proportion of girls have a high probability of short sleep (16.5%) compared to boys (14.7%), whereas a larger proportion of boys have a high probability of long sleep (15.1%) compared to girls (13.3%). An estimated 17.5% of Māori children, 27.5% of Pacific children and 22.9% of Asian children have a high probability of short sleep, compared to 10.2% of children in the European/Other ethnicity grouping. Whereas, 18.8% of European/Other children have a high probability of long TST compared to 11.4% of Māori children, 6.1% of Pacific children and 8.0% of Asian children. Nearly one quarter (23.4%) of children living in most deprived areas (NZDep2006 quintile 5) have a high probability of short sleep and 8.5% have a high probability of long sleep, whereas 12.0% of children living in least deprived areas (NZDep2006 quintile 1) have a high probability of short sleep and 17.2% have a high probability of long sleep.

Approximately one fifth (18.7%) of children living in areas with heavy traffic have a high probability of short sleep and 11.7% have a high probability of long sleep, compared with 14.0% and 15.5% respectively of children not living near heavy traffic (Table 11). Approximately 17.8% of children who are overweight are estimated to have a high probability of short TST and 12.3% of children who are overweight are estimated to have long TST. Whereas, 14.3% of healthy weight children are predicted to have short sleep and 15.2% of children with a healthy weight have a high probability of long sleep at 24 months of age.

Table 11: Estimated prevalence of children in NZ meeting sleep duration guidelines at 24 months of age, reported by sociodemographic factors

Sociodemographic Variable	TST Mean (95% CI)[b]	Short % (95% CI)[b]	Appropriate % (95% CI)[b]	Long % (95% CI)[b]
All predictors[a]	12.46 (9.77-15.15)	15.57% (14.90-16.27)	70.20% (69.29-71.09)	14.23% (13.58-14.91)
Gender:				
Boy	12.51 (9.83-15.20)	14.68% (14.02-15.35)	70.21% (69.31-71.11)	15.11% (14.44-15.80)
Girl*	12.40 (9.71-15.09)	16.54% (15.85-17.25)	70.17% (69.27-71.07)	13.29% (12.65-13.94)
Ethnicity:				
European/Other	12.77 (10.08-15.45)	10.22% (9.64-10.82)	70.95% (70.05-71.84)	18.83% (18.08-19.60)
Māori*	12.31 (9.62-15.00)	17.50% (16.77-18.25)	71.11% (70.21-72.00)	11.39% (10.79-12.02)
Pacific*	11.83 (9.14-14.53)	27.54% (26.68-28.41)	66.37% (65.44-67.29)	6.09% (5.64-6.57)
Asian*	12.03 (9.35-14.72)	22.91% (22.10-23.74)	69.14% (68.23-70.04)	7.95% (7.43-8.49)
NZDep2006 quintiles:				
1	12.66 (9.97-15.35)	11.98% (11.36-12.61)	70.84% (69.94-71.73)	17.18% (16.46-17.92)
2	12.68 (9.99-15.36)	11.87% (11.27-12.50)	70.59% (69.69-71.48)	17.53% (16.81-18.28)
3	12.55 (9.86-15.24)	13.72% (13.07-14.39)	70.79% (69.89-71.68)	15.49% (14.81-16.20)
4	12.36 (9.67-15.04)	17.00% (16.29-17.73)	70.64% (69.74-71.53)	12.36% (11.74-13.00)
5*	12.04 (9.35-14.73)	23.38% (22.58-24.20)	68.13% (67.21-69.04)	8.49% (7.98-9.04)
Neighbourhood traffic:				
Disagree	12.55 (9.86-15.23)	13.97% (13.32-14.64)	70.49% (69.59-71.38)	15.54% (14.86-16.24)
Agree (traffic)*	12.28 (9.59-14.97)	18.70% (17.97-19.45)	69.61% (68.70-70.51)	11.69% (11.09-12.31)
Body size:				
Healthy weight	12.53 (9.84-15.21)	14.34% (13.68-15.01)	70.50% (69.60-71.39)	15.16% (14.49-15.86)
Obese	12.43 (9.74-15.12)	16.26% (15.57-16.96)	69.71% (68.80-70.61)	14.03% (13.39-14.70)
Overweight*	12.33 (9.64-15.02)	17.80% (17.09-18.54)	69.86% (68.96-70.76)	12.33% (11.72-12.97)
Thin	12.13 (9.43-14.83)	21.93% (21.15-22.72)	68.07% (67.15-68.98)	10.00% (9.45-10.57)

Note: CI = confidence interval; *Significant in the multivariate model (Table 10)

[a]Controlling for all sociodemographic predictors in the model described in Table 10; [b]95% CI were computed based on 10,000 iterations and the resulting confidence intervals are narrow and must be interpreted with caution

Prevalence estimates of children in NZ meeting, or not meeting, sleep quality (night waking) guidelines, after controlling for all sociodemographic characteristics included in the Bayesian negative binomial multiple regression model (Table 10) were modelled by gender, ethnicity, area-level socioeconomic deprivation and all significant predictors from the multivariate model i.e. rurality, material standard of living, neighbourhood traffic and general health (Table 12).

Results indicate that in the NZ population, the estimated average number of wakings at 24 months of age is 0.7 per night (Table 12). Approximately 84.6% of children have a high probability of waking an appropriate number of times at night, 11.6% of children have a high probability of waking twice a night ('uncertain') and 3.8% of children have a high probability of waking three or more times at night ('not appropriate'). Approximately 7.0% of Asian children have a high probability of having a 'not appropriate' number of night wakings compared to 2.7% of European/Other children. Approximately 4.0% of children living in urban areas and 4.9% of children living in areas with heavy traffic have a high probability of waking three or more times at night compared to 1.9% of children living in rural environments and 3.3% of children not living by heavy traffic respectively. Around 89.2% of children living in households with 'more than enough' and 86.1% of children living in households with 'enough' financial resources to meet every day needs have a high probability of meeting night waking guidelines (waking once or less), whereas 79.8% of children living in households with 'not enough' have a high probability of doing so. An estimated 5.8% of children living in households with parent/s plus other adults have a high probability of waking three or more times at night compared to 2.8% of children in sole parent households. Whereas, 2.7% of children with excellent health are estimated to have a high probability of 'not appropriate' night wakings at 24 months of age compared to 10.5% of children with poor health.

Table 12: Estimated prevalence of children in NZ meeting night waking guidelines at 24 months of age, reported by sociodemographic factors

Sociodemographic Variable	Wakings Mean (95% CI)[b]	Appropriate % (95% CI)[b]	Uncertain % (95% CI)[b]	Not Appropriate % (95% CI)[b]
All predictors[a]	0.69 (0.00-2.64)	84.58% (84.30-84.86)	11.61% (11.45-11.78)	3.81% (3.69-3.93)
Gender:				
Boy	0.70 (0.00-2.68)	84.17% (83.77-84.57)	11.86% (11.63-12.09)	3.97% (3.79-4.14)
Girl	0.67 (0.00-2.61)	85.01% (84.63-85.40)	11.35% (11.12-11.58)	3.64% (3.47-3.80)
Ethnicity:				
European/Other	0.60 (0.00-2.42)	87.52% (87.26-87.79)	9.83% (9.66-10.00)	2.65% (2.55-2.75)
Māori	0.74 (0.00-2.80)	82.78% (82.16-83.40)	12.74% (12.40-13.09)	4.48% (4.19-4.76)
Pacific	0.74 (0.00-2.85)	82.69% (82.01-83.38)	12.94% (12.53-13.36)	4.37% (4.09-4.65)
Asian*	0.91 (0.00-3.16)	76.94% (76.14-77.75)	16.05% (15.66-16.45)	7.00% (6.58-7.43)
NZDep2006 quintiles:				
1	0.59 (0.00-2.38)	87.71% (87.23-88.19)	9.63% (9.33-9.93)	2.66% (2.47-2.84)
2	0.68 (0.00-2.64)	84.89% (84.32-85.47)	11.47% (11.13-11.82)	3.63% (3.39-3.88)
3	0.73 (0.00-2.74)	83.03% (82.32-83.73)	12.51% (12.12-12.90)	4.46% (4.13-4.79)
4	0.69 (0.00-2.65)	84.52% (83.91-85.12)	11.68% (11.32-12.04)	3.80% (3.54-4.06)
5	0.76 (0.00-2.84)	82.21% (81.57-82.85)	13.11% (12.75-13.47)	4.68% (4.39-4.97)
Rurality:				
Rural	0.53 (0.00-2.23)	89.86% (89.31-90.42)	8.20% (7.82-8.58)	1.94% (1.75-2.12)
Urban*	0.70 (0.00-2.69)	84.02% (83.72-84.31)	11.98% (11.81-12.15)	4.01% (3.88-4.13)

Note: CI = confidence interval; *Significant in the multivariate model (Table 10)

[a]Controlling for all sociodemographic predictors in the model described in Table 10; [b]95% CI were computed based on 10,000 iterations and the resulting confidence intervals are narrow and must be interpreted with caution

Table 12 (continued): Estimated prevalence of children in NZ meeting night waking guidelines at 24 months of age, reported by sociodemographic factors

Sociodemographic Variable	Wakings Mean (95% CI)[b]	Appropriate % (95% CI)[b]	Uncertain % (95% CI)[b]	Not Appropriate % (95% CI)[b]
Material standard of living:				
Not enough	0.83 (0.00-3.05)	79.84% (78.87-80.80)	14.47% (13.97-14.96)	5.70% (5.21-6.18)
Just enough	0.79 (0.00-2.94)	81.04% (80.53-81.55)	13.79% (13.52-14.07)	5.17% (4.92-5.41)
Enough*	0.64 (0.00-2.52)	86.11% (85.74-86.48)	10.71% (10.48-10.94)	3.18% (3.03-3.33)
More than enough*	0.55 (0.00-2.25)	89.16% (88.82-89.50)	8.75% (8.52-8.98)	2.09% (1.97-2.20)
Neighbourhood traffic:				
Disagree	0.65 (0.00-2.54)	85.96% (85.65-86.26)	10.78% (10.60-10.97)	3.26% (3.14-3.39)
Agree (traffic)*	0.77 (0.00-2.85)	81.81% (81.29-82.33)	13.29% (13.00-13.58)	4.90% (4.66-5.15)
Household structure:				
Parent alone	0.61 (0.00-2.46)	87.08% (86.11-88.06)	10.11% (9.47-10.75)	2.81% (2.45-3.16)
Two parents	0.64 (0.00-2.53)	86.12% (85.84-86.40)	10.70% (10.52-10.87)	3.18% (3.07-3.30)
Parent/s with others*	0.83 (0.00-3.01)	79.57% (78.95-80.19)	14.60% (14.28-14.93)	5.83% (5.52-6.13)
General health:				
Poor	1.08 (0.00-3.53)	70.90% (66.94-74.87)	18.59% (16.94-20.24)	10.50% (8.12-12.89)
Fair	1.07 (0.00-3.51)	71.16% (69.16-73.16)	18.59% (17.73-19.45)	10.25% (9.06-11.44)
Good	0.81 (0.00-2.99)	80.48% (79.62-81.34)	14.14% (13.66-14.61)	5.38% (4.99-5.77)
Very good	0.72 (0.00-2.73)	83.54% (83.12-83.97)	12.37% (12.11-12.62)	4.09% (3.91-4.27)
Excellent*	0.61 (0.00-2.44)	87.24% (86.96-87.52)	10.02% (9.84-10.20)	2.74% (2.64-2.84)

Note: CI = confidence interval; *Significant in the multivariate model (Table 10)

[a]Controlling for all sociodemographic predictors in the model described in Table 10; [b]95% CI were computed based on 10,000 iterations and the resulting confidence intervals are narrow and must be interpreted with caution

Factors associated with children meeting sleep guidelines at 45 months

Univariate relationships between sociodemographic factors and sleep at 45 months

Results of linear regression and Poisson regression models investigating univariate associations between sociodemographic variables and children's continuous sleep duration and number of night wakings at 45 months are summarised in Appendices 3 and 4. At the univariate level, there were significant differences in how long children slept by gender. Boys had an average TST of 11.23 hours at 45 months of age, whereas girls slept slightly less by an average of 4 minutes. However, the number of times children woke at night did not differ by gender. Māori and Asian children slept 9 minutes and 18 minutes less respectively, compared to European/Other children, who had an average TST of 11.23 hours. Māori, Pacific and Asian children woke an average 1.3, 1.2 and 1.3 times respectively more than European/Other children. TST did not differ significantly by area-level socioeconomic deprivation, however children living in most deprived areas (NZDep2013 quintile 5) woke, on average, 1.1 times more than children living in least deprived areas (NZDep2013 quintile 1).

As summarised in Appendices 3 and 4, children who shared a room or shared a bed slept 7 minutes and 11 minutes less respectively, than children who slept in a separate room alone. Children who shared a bed also woke an average 1.5 times more during the night, compared to children who slept separately. Using visual media for 3 or more hours a day was associated with TST being shorter by 13 minutes compared to TST of children who watched less than an hour of visual media. In addition, 2 to <3 hours and ≥3 hours of visual media use was associated with children waking 1.2 times more than children who used visual media for less than an hour. No statistically significant univariate associations were identified between rurality, household structure or maternal paid work and children's TST and night wakings at 45 months of age.

Multivariate relationships between sociodemographic factors and sleep at 45 months

Results of Bayesian multivariate linear regression and Bayesian negative binomial multiple regression models of children's TST and night wakings at 45 months are summarised in Table 13. All of the sociodemographic variables that were included in univariate linear regression and Poisson regression models of sleep at 45 months (Appendices 3 and 4) were simultaneously included in multivariate models. An exception was *child's sleep location* which was identified as an additional variable of interest after multivariate modelling had already been completed.

After controlling for all sociodemographic variables in the model, gender was significantly associated with children's TST, and ethnicity and visual media use were significantly associated with children's night wakings, at 45 months of age

(Table 13). Girls slept an average of 8 minutes less per day than boys. On average, Māori children woke 1.3 times more, Pacific children woke 1.2 times more and Asian children woke 1.3 times more than European/Other children. In addition, children who usually used visual media for 2 to <3 hours or ≥3 hours per day woke an average of 1.2 times more than children who usually used visual media for less than an hour per day.

Prevalence estimates of children in NZ meeting, or not meeting, sleep duration guidelines at 45 months of age, after controlling for all sociodemographic factors included in the Bayesian multivariate linear regression model (Table 13) were modelled by gender, ethnicity and area-level socioeconomic deprivation (Table 14). No other sociodemographic factors were statistically significant in the multivariate model, therefore no additional variables were included. Findings indicate that the estimated TST of 45 month old children in the NZ population is 11.21 hours, that 14.1% of children have a high probability of short sleep, 80.5% of children have a high probability of appropriate sleep durations and 5.4% of children have a high probability of long sleep. Approximately 79.8% of girls will have a high probability of sleeping an appropriate amount and 15.5% of girls will have a high probability of short sleep, whereas 81.2% of boys will have a high probability of sleeping an appropriate amount and 12.8% of boys will have a high probability of short sleep.

Table 13: Associations between sociodemographic factors and child sleep durations and night wakings at 45 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,186)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Intercept	11.35 (0.13)	11.09 – 11.62	Significant	0.37 (0.12)	-1.23 - -0.76	Significant
Gender:						
Boy	Baseline			Baseline		
Girl	-0.14 (0.04)	-0.23 - -0.05	Significant	1.05 (0.04)	-0.03 – 0.13	Non-significant
Ethnicity:						
European/Other	Baseline			Baseline		
Māori	-0.06 (0.06)	-0.18 – 0.07-	Non-significant	1.25 (0.05)	0.12 – 0.33	Significant
Pacific	-0.12 (0.08)	0.29 – 0.04	Non-significant	1.21 (0.07)	0.05 – 0.32	Significant
Asian	-0.21 (0.07)	-0.35 - -0.07	Non-significant	1.28 (0.06)	0.13 – 0.36	Significant
NZDep2013 quintiles:						
1	Baseline			Baseline		
2	0.05 (0.07)	-0.08 – 0.18	Non-significant	0.98 (0.06)	-0.14 – 0.11	Non-significant
3	-0.02 (0.07)	-0.16 – 0.11	Non-significant	0.95 (0.07)	-0.18 – 0.08	Non-significant
4	0.02 (0.07)	-0.13 – 0.17	Non-significant	0.95 (0.07)	-0.18 – 0.08	Non-significant
5	-0.01 (0.08)	-0.17 – 0.14	Non-significant	0.99 (0.07)	-0.14 – 0.12	Non-significant
Rurality:						
Rural	Baseline			Baseline		
Urban	-0.04 (0.07)	-0.19 – 0.11	Non-significant	1.01 (0.07)	-0.13 – 0.14	Non-significant
Household structure:						
Parent alone	Baseline			Baseline		
Two parents	0.07 (0.09)	-0.12 – 0.25	Non-significant	1.07 (0.08)	-0.09 – 0.22	Non-significant
Parent/s with others	0.01 (0.10)	-0.19 – 0.21	Non-significant	1.03 (0.08)	-0.14 – 0.20	Non-significant

Note: SD = standard deviation; HDI = highest density interval

Table 13 (continued): Associations between sociodemographic factors and child sleep durations and night wakings at 45 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,186)

Sociodemographic Variable	Total Sleep Time			Night Wakings		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Maternal paid work:						
Yes	Baseline			Baseline		
No	-0.03 (0.05)	-0.12 – 0.06	Non-significant	0.97 (0.04)	-0.11 – 0.05	Non-significant
Visual media use:						
<1hr	Baseline			Baseline		
1 - <2hr	-0.01 (0.06)	-0.13 – 0.11	Non-significant	1.03 (0.06)	-0.08 – 0.15	Non-significant
2 - <3hr	-0.05 (0.07)	-0.19 – 0.08	Non-significant	1.16 (0.06)	0.03 – 0.28	Significant
≥3hr	-0.08 (0.08)	-0.23 – 0.07	Non-significant	1.15 (0.07)	0.01 – 0.27	Significant

Note: SD = standard deviation; HDI = highest density interval

Table 14: Estimated prevalence of children in NZ meeting sleep duration guidelines at 45 months of age, reported by sociodemographic factors

Sociodemographic Variable	TST Mean (95% CI)[b]	Short % (95% CI)[b]	Appropriate % (95% CI)[b]	Long % (95% CI)[b]
All predictors[a]	11.21 (9.03-13.39)	14.06% (13.39-14.76)	80.49% (79.70-81.26)	5.44% (5.01-5.90)
Gender:				
Boy	11.27 (9.09-13.45)	12.75% (12.10-13.41)	81.16% (80.38-81.92)	6.09% (5.63-6.58)
Girl*	11.14 (8.96-13.32)	15.47% (14.76-16.19)	79.78% (78.98-80.56)	4.75% (4.35-5.19)
Ethnicity:				
European/Other	11.27 9.10-13.45)	12.66% (12.01-13.32)	81.26% (80.48-82.02)	6.09% (5.63-6.57)
Māori	11.19 (9.01-13.37)	14.37% (13.69-15.07)	80.41% (79.61-81.18)	5.23% (4.80-5.68)
Pacific	11.11 (8.93-13.30)	15.95% (15.24-16.68)	79.49% (78.69-80.28)	4.56% (4.16-4.99)
Asian	11.03 (8.85-13.21)	17.78% (17.03-18.54)	78.35% (77.53-79.15)	3.88% (3.51-4.27)
NZDep2013 quintiles:				
1	11.23 (9.05-13.41)	13.58% (12.92-14.26)	80.77% (79.98-81.54)	5.65% (5.21-6.12)
2	11.27 (9.09-13.45)	12.87% (12.22-13.54)	81.07% (80.28-81.83)	6.06% (5.61-6.55)
3	11.19 (9.01-13.37)	14.41% (13.73-15.11)	80.34% (79.55-81.12)	5.25% (4.82-5.70)
4	11.20 (9.02-13.38)	14.22% (13.54-14.91)	80.41% (79.62-81.18)	5.37% (4.94-5.83)
5	11.13 (8.95-13.31)	15.58% (14.87-16.30)	79.70% (78.90-80.48)	4.72% (4.32-5.16)

Note: CI = confidence interval; *Significant in the multivariate model (Table 13)

[a]Controlling for all sociodemographic predictors in the model described in Table 13; [b]95% CI were computed based on 10,000 iterations and the resulting confidence intervals are narrow and must be interpreted with caution

Prevalence estimates of children in NZ meeting, or not meeting, sleep quality (night waking) guidelines at 45 months of age, after controlling for all sociodemographic factors in the Bayesian negative binomial multiple regression model (Table 13) were also modelled by gender, ethnicity, area-level socioeconomic deprivation and visual media use which was a significant predictor in the multivariate model (Table 15). Results indicate that in the NZ population, 45 month old children wake an average of 0.5 times per night. Approximately 91.7% of children in this age group will have a high probability of waking an appropriate number of times (once or less) at night, 7.0% of children will have a high probability of waking twice a night (i.e. 'uncertain') and 1.3% of children will have a high probability of waking three or more times a night (i.e. 'not appropriate'). An estimated 89.9% of Māori children, 90.4% of Pacific children and 89.6% of Asian children will have a high probability of waking an appropriate number of times per night, compared to 93.4% of European/Other children. Approximately 1.8% Māori, 1.6% Pacific and 1.8% Asian children will have a high probability of waking 3 or more times per night (i.e. 'not appropriate'), whereas less than one percent (0.9%) of European/Other children will. In addition, 1.6% of children who usually use visual media 2 to <3 hours per day and 1.7% of children who usually use visual media for 3 or more hours per day will have a high probability of having 'not appropriate' night wakings versus 1.0% of children who usually use visual media for one hour or less.

Table 15: Estimated prevalence of children in NZ meeting night waking guidelines at 45 months of age, reported by sociodemographic factors

Sociodemographic Variable	Wakings Mean (95% CI)[b]	Appropriate % (95% CI)[b]	Uncertain % (95% CI)[b]	Not Appropriate % (95% CI)[b]
All predictors[a]	0.47 (0.00-2.01)	91.67% (91.62-91.72)	7.01% (6.96-7.05)	1.32% (1.31-1.33)
Gender:				
Boy	0.46 (0.00-2.00)	91.98% (91.91-92.06)	6.77% (6.72-6.83)	1.24% (1.23-1.26)
Girl	0.48 (0.00-2.01)	91.35% (91.27-91.43)	7.25% (7.19-7.31)	1.40% (1.38-1.42)
Ethnicity:				
European/Other	0.42 (0.00-2.00)	93.37% (93.33-93.40)	5.73% (5.70-5.75)	0.91% (0.90-0.92)
Māori*	0.53 (0.00-2.01)	89.88% (89.82-89.95)	8.36% (8.31-8.41)	1.75% (1.73-1.77)
Pacific*	0.52 (0.00-2.00)	90.36% (90.28-90.45)	8.00% (7.94-8.07)	1.63% (1.61-1.66)
Asian*	0.54 (0.00-2.04)	89.60% (89.51-89.69)	8.56% (8.49-8.63)	1.84% (1.81-1.86)
NZDep2013 quintiles:				
1	0.46 (0.00-2.01)	92.21% (92.11-92.32)	6.60% (6.52-6.68)	1.19% (1.16-1.21)
2	0.46 (0.00-2.01)	92.08% (91.97-92.20)	6.69% (6.61-6.78)	1.22% (1.19-1.25)
3	0.45 (0.00-2.00)	92.28% (92.16-92.40)	6.55% (6.46-6.64)	1.17% (1.14-1.20)
4	0.47 (0.00-2.00)	91.73% (91.60-91.85)	6.97% (6.88-7.07)	1.30% (1.27-1.33)
5	0.52 (0.00-2.02)	90.26% (90.17-90.36)	8.07% (7.99-8.14)	1.67% (1.64-1.69)
Visual media use:				
<1hr	0.42 (0.00-2.00)	93.11% (93.02-93.20)	5.91% (5.85-5.98)	0.98% (0.96-1.00)
1 - <2hr	0.44 (0.00-2.00)	92.66% (92.59-92.72)	6.27% (6.22-6.32)	1.07% (1.06-1.09)
2 - <3hr*	0.51 (0.00-2.02)	90.52% (90.42-90.62)	7.88% (7.81-7.95)	1.60% (1.58-1.63)
≥3hr*	0.53 (0.00-2.01)	90.12% (90.02-90.21)	8.18% (8.11-8.25)	1.71% (1.68-1.73)

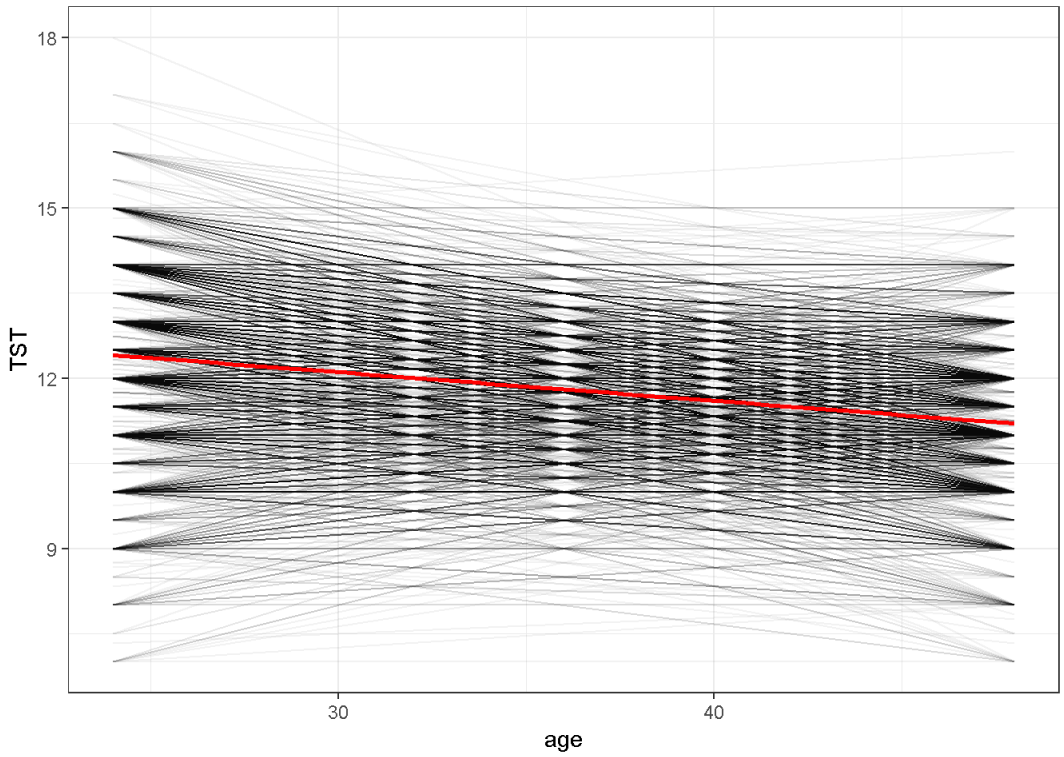
Note: CI = confidence interval; *Significant in the multivariate model (Table 13)

[a]Controlling for all sociodemographic predictors in the model described in Table 13; [b]95% CI were computed based on 10,000 iterations and the resulting confidence intervals are narrow and must be interpreted with caution

Sleep trajectories from 24 months to 45 months

Results of the Bayesian growth curve model for TST trajectories from 24 to 45 months are summarised in Table 16. Modelling sleep in this way means that all children have a common intercept (representing TST at 24 months) and a common slope (representing the rate of change in TST from 24 to 45 months). In addition, each child has their own random effect, which is their individual-specific intercept (TST at 24 months) and slope (change in TST from 24 to 45 months). In this model, both the random effect intercepts and slopes will depend on gender, ethnicity and area-level socioeconomic deprivation, which were included as predictors in the model simultaneously. The red line in Figure 5 represents the mean trajectory of TST across the two time points.

Figure 5: Trajectory of average total sleep time (hours) from 24 months to 45 months of age



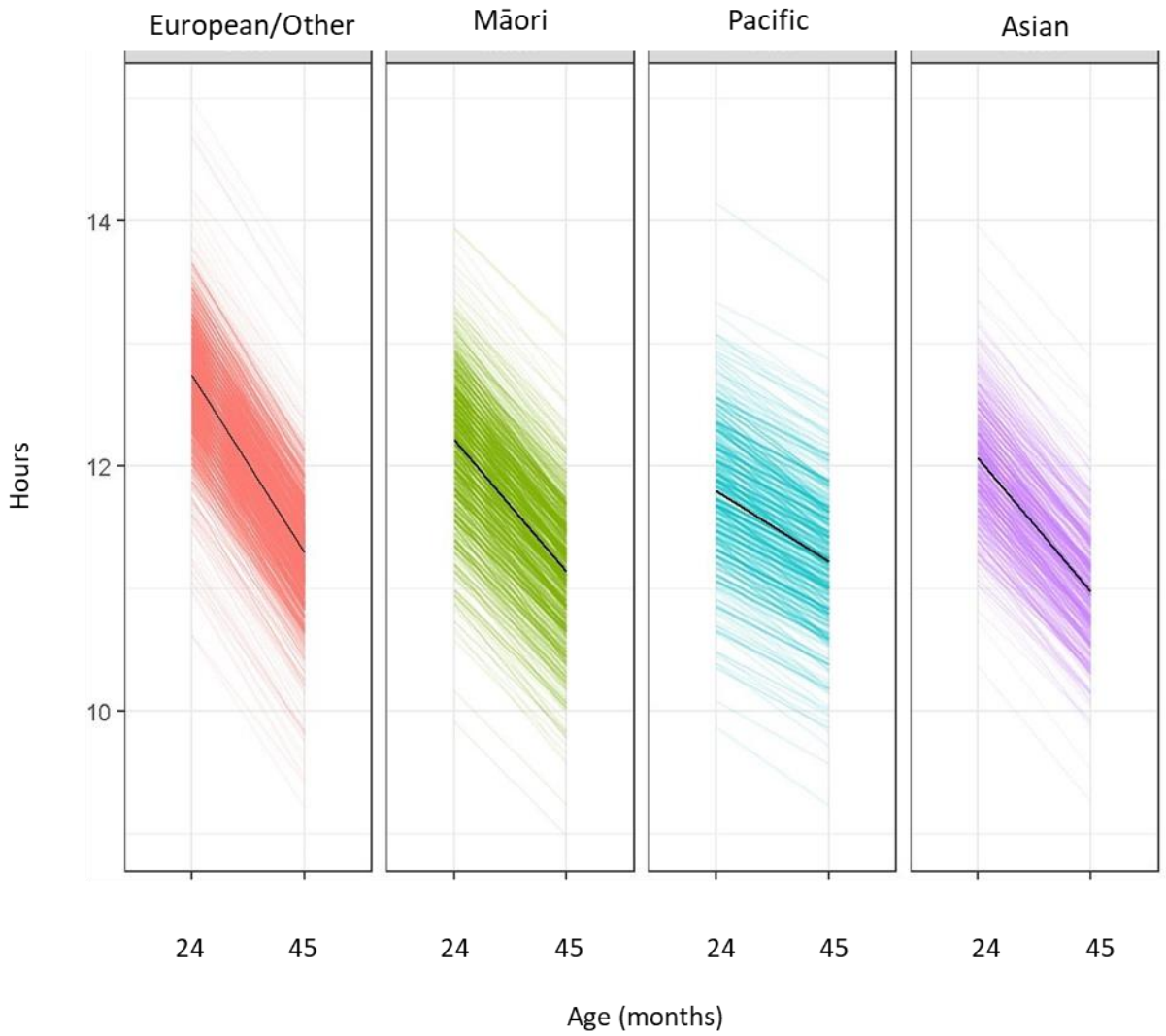
Boys from the European/Other ethnicity grouping, who lived in areas with least socioeconomic deprivation (NZDep quintile 1), had average TST at 24 months of 12.86 hours (global intercept), which decreased across time by 1.54 hours (global slope) from 24 to 45 months of age (Table 16). Girls' average TST was significantly shorter by 5 minutes than boys at 24 months of age, however there was no difference in the rate that TST changed from 24 to 45 months by gender. At 24 months of age, Māori, Pacific and Asian children's TST was significantly shorter by 26 minutes, 46 minutes and 37 minutes respectively compared to European/Other children. TST from 24 to 45 months changed at a significantly slower rate for Māori, Pacific and Asian children compared to European/Other children. In other words, European/Other children tended to sleep more at 24 months of age compared to Māori, Pacific and Asian children, but their TST declined more between the two time points compared to children in the other ethnicity groupings resulting in TST at 45 months of age being more similar (Figure 6). Children living in more socioeconomically deprived areas (NZDep quintiles 4 and 5) had significantly shorter average TST at 24 months and their TST changed at a slower rate from 24 to 45 months compared to children living in least deprived areas (NZDep quintile 1).

Table 16: Trajectories of children's sleep durations from 24 months to 45 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,004)

Sociodemographic Variable	Intercept (24 months)			Slope (change from 24 to 45 months)		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Global intercept	12.86 (0.04)	12.78 – 12.95	Significant	-1.54 (0.05)	-1.65 - -1.45	Significant
Gender:						
Girl	-0.08 (0.03)	-0.15 - -0.02	Significant	0.01 (0.04)	-0.06 – 0.08	Non-significant
Ethnicity:						
Māori	-0.43 (0.05)	-0.52 - -0.34	Significant	0.29 (0.06)	0.16 – 0.42	Significant
Pacific	-0.77 (0.06)	-0.88 - -0.66	Significant	0.72 (0.07)	0.59 – 0.84	Significant
Asian	-0.62 (0.05)	-0.72 - -0.52	Significant	0.30 (0.06)	0.19 – 0.42	Significant
NZDep quintiles:						
2	0.002 (0.06)	-0.11 – 0.11	Non-significant	0.02 (0.07)	-0.10 – 0.15	Non-significant
3	-0.10 (0.06)	-0.21 – 0.03	Non-significant	0.13 (0.08)	-0.06 – 0.26	Non-significant
4	-0.17 (0.06)	-0.29 - -0.07	Significant	0.16 (0.07)	0.07 – 0.32	Significant
5	-0.36 (0.06)	-0.49 - -0.25	Significant	0.34 (0.08)	0.22 – 0.55	Significant

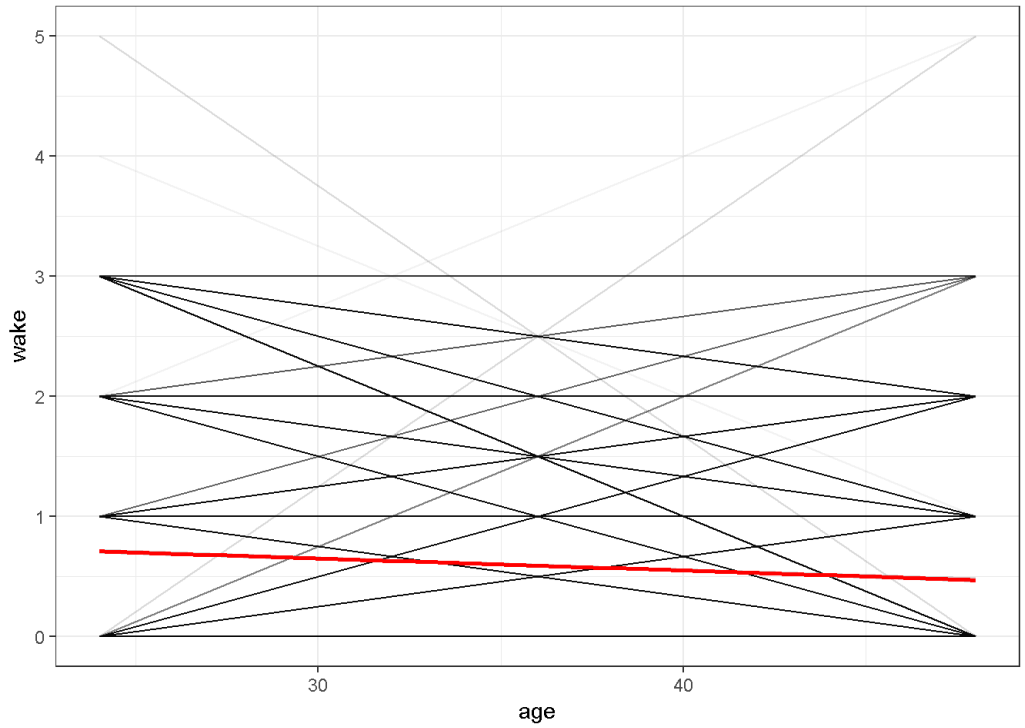
Note: SD = standard deviation; HDI = highest density interval

Figure 6: Trajectory of average total sleep time from 24 months to 45 months of age, by child ethnicity



Results of the Bayesian growth curve model for night waking trajectories from 24 to 45 months are summarised in Table 17. Similar to the TST growth curve model, all children have a common intercept (representing the average number of night wakings of boys in the European/Other ethnicity grouping, living in areas with least deprivation [NZDep quintile 1] at 24 months) and a common slope (representing the rate of change in night wakings from 24 to 45 months). In addition, each child has their own intercept and slope (random effect). Both the random effect intercepts and slopes will depend on gender, ethnicity and area-level socioeconomic deprivation, which were included as predictors in the model simultaneously. The red line in Figure 7 represents the mean trajectory of night wakings from 24 to 45 months of age.

Figure 7: Trajectory of average number of night wakings from 24 months to 45 months of age



The average number of times that children woke during the night at 24 months of age was 0.5 (global intercept), which changed across the two time points at a rate of 0.6 (global slope) resulting in an average number of night wakings at 45 months of age of 0.3 (Table 17). The average number of night wakings at 24 months did not significantly differ by gender, however the rate that this changed over time did. This meant that there was less change in the average number of night wakings from 24 to 45 months for girls compared to boys (mean number of wakes – girls: 24 months = 0.70, 45 months = 0.48; boys: 24 months = 0.73, 45 months = 0.46). Māori and Asian children tended to wake more at night at 24 months compared to European/Asian children. There was no significant difference in the rate of change in night wakings from 24 to 45 months by ethnicity, which meant that Māori and Asian children were likely to wake more than European/Other children at 45 months (mean number of wakes – Māori: 24 months = 0.77, 45 months = 0.54; Pacific: 24 months = 0.70, 45 months = 0.51; Asian: 24 months = 0.93, 45 months = 0.54; European/Other: 24 months = 0.63, 45 months = 0.42). No significant differences in night waking trajectories were found by area-level socioeconomic deprivation.

Table 17: Trajectories of children's night wakings from 24 months to 45 months of age, reported as adjusted mean, standard deviation and 95% highest density intervals (n=6,004)

Sociodemographic Variable	Intercept (24 months)			Slope (change from 24 to 45 months)		
	Mean (SD)	95% HDI	Significance	Mean (SD)	95% HDI	Significance
Global intercept	0.54 (0.05)	-0.70 - -0.51	Significant	0.62 (0.06)	-0.61 - -0.38	Significant
Gender:						
Girl	0.96 (0.03)	-0.11 – 0.02	Non-significant	1.09 (0.04)	0.03 – 0.16	Significant
Ethnicity:						
Māori	1.20 (0.05)	0.07 – 0.28	Significant	1.08 (0.09)	-0.08 – 1.08	Non-significant
Pacific	1.08 (0.07)	-0.06 – 0.21	Non-significant	1.14 (0.13)	-0.12 – 0.39	Non-significant
Asian	1.46 (0.06)	0.26 – 0.49	Significant	0.90 (0.10)	-0.26 – 0.12	Non-significant
NZDep quintiles:						
2	1.01 (0.06)	-0.10 – 0.13	Non-significant	1.08 (0.08)	-0.08 – 0.21	Non-significant
3	1.09 (0.06)	-0.03 – 0.20	Non-significant	1.03 (0.08)	-0.11 – 0.17	Non-significant
4	1.02 (0.06)	-0.09 – 0.13	Non-significant	0.99 (0.08)	-0.16 – 0.15	Non-significant
5	1.11 (0.06)	-0.004 – 0.22	Non-significant	0.93 (0.07)	-0.22 – 0.08	Non-significant

Note: SD = standard deviation; HDI = highest density interval

Discussion

The primary aim of this research was to identify how many children in NZ are meeting Ministry of Health sleep guidelines and to investigate sociodemographic factors associated with meeting, or not meeting, sleep duration and sleep quality guidelines. GUiNZ sleep duration and night waking (an indicator of sleep quality) data collected when children were 24 and 45 months old were analysed, in conjunction with a range of sociodemographic variables from the GUiNZ dataset that were available. Study findings provide a detailed description of how long and how well children in the GUiNZ cohort are sleeping across early childhood.

A novel aspect of this study was the use of complex statistical modelling which enabled day-to-day variation in each child's sleep to be included in analyses. This enabled the prevalence of children in the NZ population meeting, or not meeting, sleep guidelines to be estimated after controlling for a range of sociodemographic factors. It also allowed the identification of sociodemographic factors independently associated with children having a greater or lesser likelihood of having sufficient, good quality sleep at 24 months and 45 months of age. Sophisticated statistical modelling techniques were also used to investigate longitudinal trajectories of children's sleep duration and night wakings from 24 to 45 months, by gender, ethnicity and area-level socioeconomic deprivation. Thus, providing nuanced information on sleep over time of children from different sociodemographic groups in NZ. Study findings will contribute to child wellbeing in NZ by informing health and wellbeing strategy and policy, targeted sleep health interventions and future research.

Prevalence of children in the Growing Up in New Zealand study meeting sleep guidelines

At 24 months of age, children in the GUiNZ cohort slept an average of approximately ten and a half hours at night and two hours during the day. This equated to a mean (SD) total sleep time (TST) of 12.36 (1.15) hours in a 24 hour period. By 45 months of age, children tended to sleep slightly more at night and much less during the day, with mean (SD) TST of 11.21 (1.18) hours in 24 hours. This is consistent with developmental changes in sleep across early childhood previously reported, in which the distribution of sleep across 24 hours changes as napping duration decreases and, for some children, napping stops and sleep is obtained in one sleep period at night (Acebo et al., 2005). TST values also align with published sleep duration reference values based on a systematic review of observational studies, which indicate that 2 to 3 year olds sleep an average of 12.0 (±1.96 SD: 9.7 – 14.2) hours and 4 to 5 year olds sleep an average of 11.5 (±1.96 SD: 9.1 – 13.9) hours, per 24 hours (Galland, Taylor, Elder, & Herbison, 2012). These data from the GUiNZ cohort provide valuable information on how children's sleep patterns change over time in early

childhood in NZ and contribute to international normative data. This information may be useful for child health services, such as guiding information provided to parents and caregivers, and early childhood education services, such as informing napping best practice guidelines.

Average sleep durations at 24 months were within the Ministry of Health recommendations of 11 to 14 hours of sleep for toddlers and average sleep durations at 45 months were within the recommended 10 to 13 hours of sleep for preschoolers (Ministry of Health, 2017b). However, when TST was examined categorically it became clear that not all children in the GUiNZ sample were meeting Ministry of Health sleep duration guidelines. At 24 months of age, descriptive statistics indicated that approximately seventeen percent of children in the sample did not meet guidelines for appropriate sleep duration (11.9% short; 5.3% long) and at 45 months of age, approximately nine percent of children did not meet appropriate sleep duration guidelines (6.2% short; 3.2% long). In comparison, a recent study of preschoolers' sleep in Australia (n = 488) found that 3.7% of 3 to 5 year olds had sleep durations shorter than the NSF recommendation of 10 to 13 hours sleep and no children had longer sleep durations (Grady, Dodds, Jones, Wolfenden, & Yoong, 2019).

Longitudinally, 77.3% of children in the GUiNZ cohort had appropriate TST at both time points indicating a consistent pattern of adequate sleep duration. Approximately fourteen percent (13.5%) of children went from having short or long sleep at 24 months to appropriate TST at 45 months, indicating that for some children sleep duration improves with age. However, a small percentage (3.1%) of children had sleep durations that were consistently outside of the appropriate range at both time points. An additional six percent went from having appropriate TST at 24 months to having short or long TST at 45 months, suggesting a decline in sleep health over time. These findings indicate the importance of understanding factors associated with children being more or less likely to have appropriate TST over time, so that action can be taken early in the lifecourse to address barriers to obtaining sufficient sleep and to potentially change negative sleep trajectories for those children with consistently poor or declining sleep health.

The number of times children usually woke at night also changed over time. At 24 months, half of children in GUiNZ woke at least once at night, which decreased to approximately one third of children at 45 months. This reduction in night waking is consistent with previous reports of developmental changes in sleep from birth to early childhood in which children wake less at night over time (Galland et al., 2012; Mindell, Sadeh, Wiegand, How, & Goh, 2010). At 24 months, over eighty percent (83.1%) of children met NSF guidelines for good quality sleep indicated by usually waking once or less at night (Ohayon et al., 2017). At 45 months, this increased to over ninety percent (92.9%) of the sample.

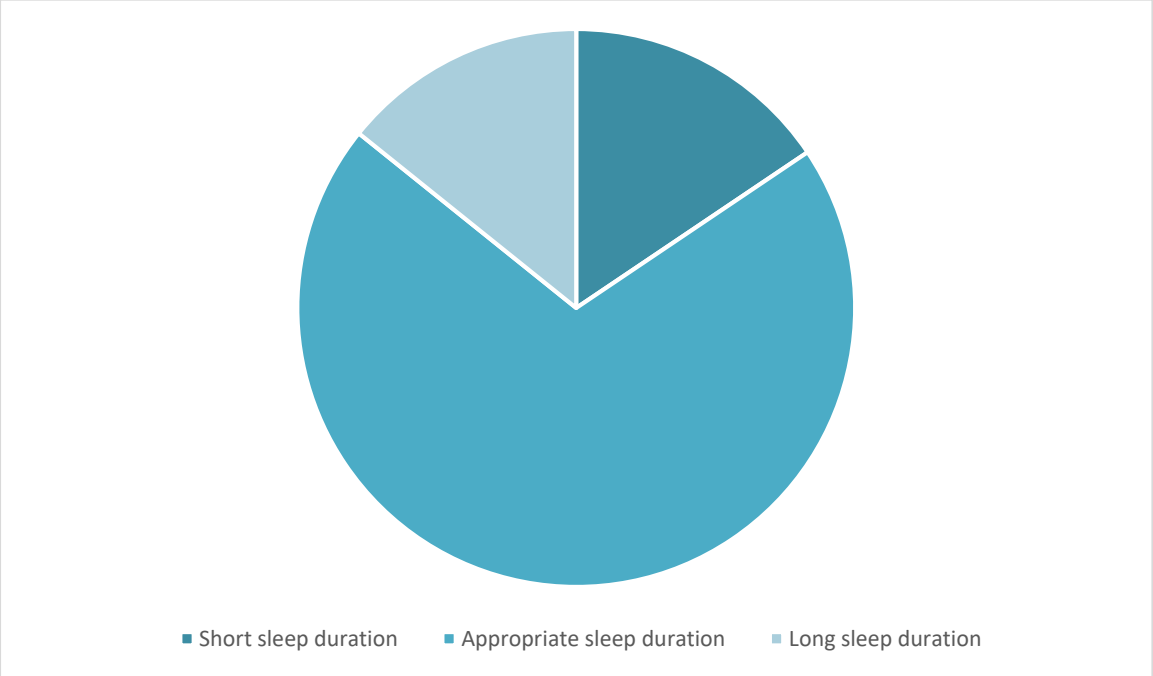
Longitudinally, more than three quarters (79.4%) of children consistently met night waking guidelines at 24 and 45 months of age and an additional 13.4% went from not meeting night waking guidelines at 24 months to meeting them at 45 months. This figure was similar to the 13.5% of children who moved from not meeting, to meeting, sleep duration guidelines. Approximately three percent (3.3%) of children did not meeting night waking guidelines at both 24 and 45 months, which was also consistent with the figure of 3.1% of children not meeting sleep duration guidelines at both time points. However, as we did not investigate sleep duration and night waking in conjunction with each other for each child, it is not known if these were the same children or not. An additional 3.8% of children went from meeting night waking guidelines at 24 months to waking twice or more at 45 months, indicating that their sleep quality had deteriorated over time. We were unable to investigate whether these changes in night wakings, and in TST outlined above, were temporary or part of a continuing trajectory of worsening sleep health, due to night waking and TST data only being available at two time points. Nevertheless, the fact that some children had moved to not meeting sleep guidelines highlights the need to monitor children's sleep over time and supports this study's investigation of factors associated with a greater likelihood of poor sleep health so that interventions can be implemented early to prevent chronic sleep issues developing.

Factors associated with children in Aotearoa/New Zealand meeting sleep guidelines

At 24 months of age, the proportion of children in GUiNZ having appropriate sleep durations and/or night wakings differed significantly at the univariate level by ethnicity, area-level socioeconomic deprivation, rurality, material standard of living, neighbourhood safety, heavy traffic, household structure, maternal paid work, childcare, time spent outside, health and body size. Similar univariate associations were identified when TST and number of night wakings were modelled as continuous and discrete variables respectively.

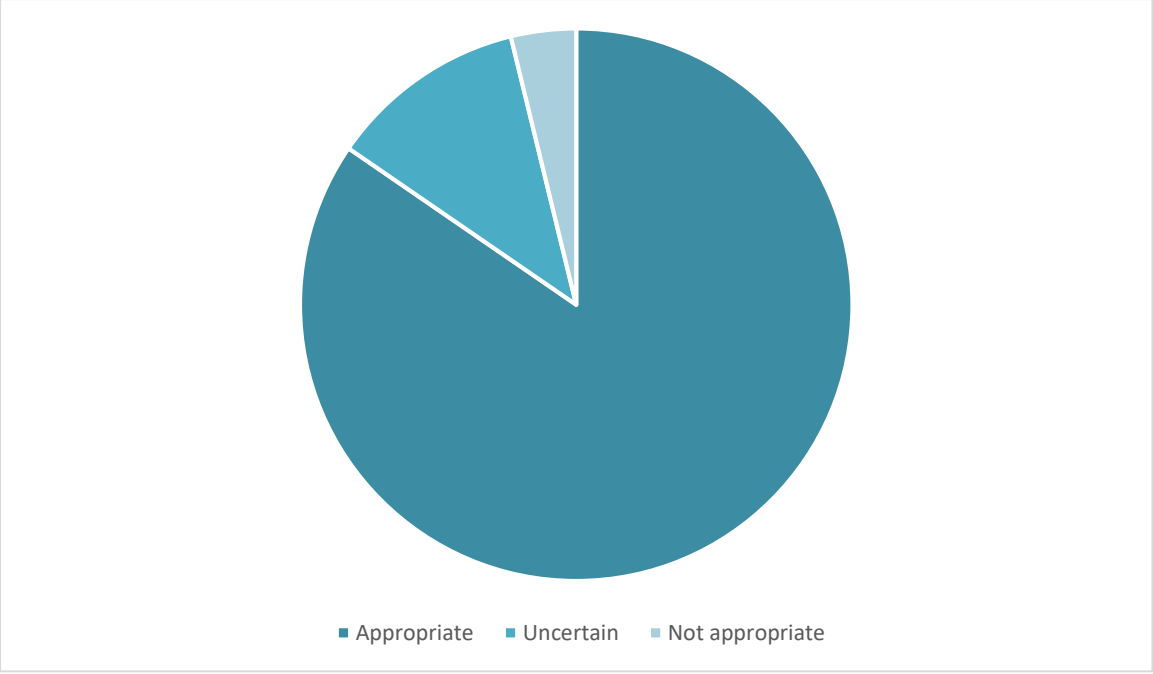
Gender, ethnicity, area-level deprivation, heavy traffic and body size remained significant predictors of TST at 24 months, after controlling for all other sociodemographic factors. Ethnicity, rurality, material standard of living, traffic and health also remained significant predictors of the number of times children usually woke at night at 24 months, after controlling for all other variables. The estimated prevalence of 24 month olds in NZ having a high probability of short, appropriate or long sleep was 15.6%, 70.2% and 14.2% respectively (Figure 8); and the estimated prevalence of two year olds in NZ having a high probability of an appropriate, uncertain or not appropriate number of night wakings was 84.6%, 11.6% and 3.8% respectively (Figure 9), after adjusting for all sociodemographic variables in multivariate models.

Figure 8: Estimated prevalence of children in NZ meeting sleep duration guidelines at 24 months of age[a]



[a]Controlling for all sociodemographic predictors in the model described in Table 10

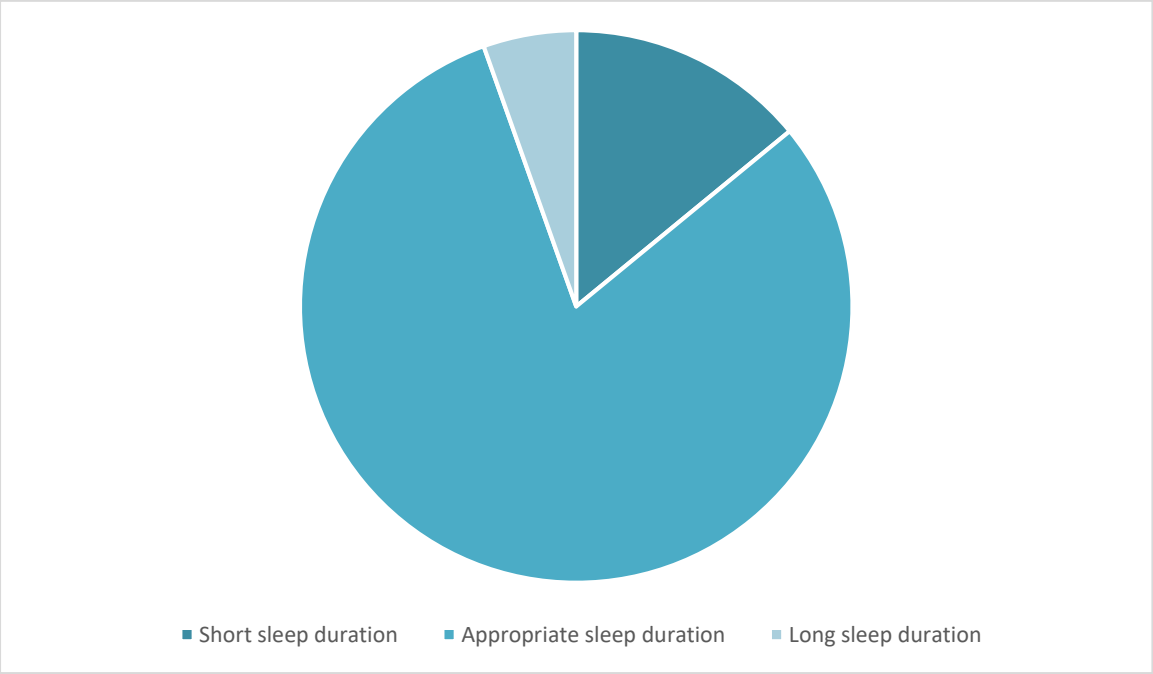
Figure 9: Estimated prevalence of children in NZ meeting night waking guidelines at 24 months of age[a]



[a]Controlling for all sociodemographic predictors in the model described in Table 10

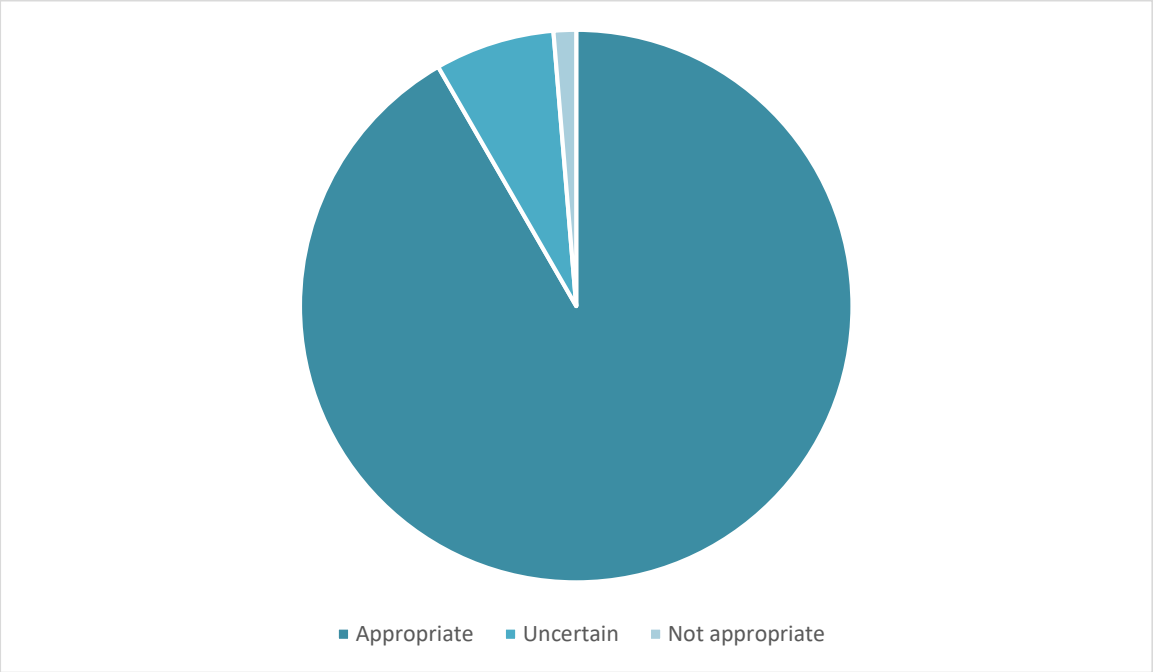
At 45 months of age, fewer sociodemographic variables were available to investigate in relation to sleep. At the univariate level, the proportion of children in GUiNZ having appropriate sleep durations and/or night wakings differed significantly by ethnicity, area-level socioeconomic deprivation, household structure, maternal paid work, child's sleep location and duration of visual media use. Fewer factors were associated at the univariate level when TST and number of night wakings were modelled as continuous and discrete variables respectively. After controlling for other sociodemographic factors, gender was significantly associated with TST and ethnicity and visual media use were significantly associated with the number of times children usually woke at night. The resulting estimated prevalence of 45 month olds in NZ having a high probability of short, appropriate or long sleep was 14.1%, 80.5% and 5.4% respectively (Figure 10); and having a high probability of an appropriate, uncertain or not appropriate number of night wakings was 91.7%, 7.0% and 1.3% respectively (Figure 11), after adjusting for all sociodemographic variables in multivariate models.

Figure 10: Estimated prevalence of children in NZ meeting sleep duration guidelines at 45 months of age[a]



[a]Controlling for all sociodemographic predictors in the model described in Table 13

Figure 11: Estimated prevalence of children in NZ meeting night waking guidelines at 45 months of age[a]



[a]Controlling for all sociodemographic predictors in the model described in Table 13

Growth curve models indicated that trajectories of sleep differed in some instances by gender, ethnicity and area-level socioeconomic deprivation. Girls tended to have shorter sleep durations at 24 months and sleep durations changed at a similar rate for girls and boys, resulting in girls continuing to have shorter sleep durations at 45 months. Girls and boys tended to wake the same number of times at 24 months but the number of wakings decreased at a slower rate for girls, suggesting that boys' night waking improved more with age. Regarding ethnicity, Māori, Pacific and Asian children tended to have shorter sleep than European/Other children at 24 months, but sleep durations declined more for European/Other children over time resulting in more similar sleep durations between groups at 45 months. Māori and Asian children also tended to have more night wakings at 24 months and 45 months than European/Other children, as the rate of change in wakings over time was similar for children from all ethnicity groupings. Children in more socioeconomically deprived areas also tended to sleep less at 24 months, but their sleep duration declined at a slower rate than children in least deprived areas, resulting in less difference across socioeconomic groups at 45 months. In contrast, no difference was found in night waking trajectories by area-level socioeconomic deprivation.

Considered together, the results of this study indicate that not all children in NZ are meeting sleep guidelines in early childhood, and that some children are at a greater risk of sub-optimal sleep durations or more disturbed sleep than others.

At one or both time points, girls, Māori, Pacific and Asian children, and children living in more socioeconomically deprived areas had a high probability of shorter or more disturbed sleep compared to boys, European/Other children and children living in areas with least deprivation. Sleep trajectories differed by these key sociodemographic factors, however as data were only available at two time points it is not yet known how sleep does, or does not, differ between groups as children grow older. However, findings build on recent research which provides evidence that ethnic and socioeconomic inequities exist in preschoolers' sleep durations in NZ (Muller et al., 2019a).

Further research is needed to investigate the mechanisms involved. Whether gender differences in sleep trajectories are due to differential patterns of child development or external environmental factors is not clear. The fact that ethnicity remained a significant predictor of TST and night wakings at 24 months, and of night wakings at 45 months, after controlling for NZDep suggests that something besides socioeconomic deprivation was influencing the sleep of Māori, Pacific and Asian children. One possible explanation is that children's or caregivers' experiences of interpersonal racism (Williams & Mohammed, 2013) negatively influenced children's sleep via increased stress and associated difficulties initiating or maintaining sleep (Shepherd, Li, Cooper, Hopkins, & Farrant, 2017). There may also have been different patterns of sleep locations. Significant associations between greater area-level deprivation and shorter TST at 24 months, and lower material standard of living and more night wakings at 24 months, may have been due to less sleep-conducive environments such household crowding, or bedrooms that are too cold, noisy or light (Wilson, Miller, Lumeng, & Chervin, 2014).

Māori and Pacific peoples are over-represented in areas with greater socioeconomic deprivation and under-represented in areas with least socioeconomic deprivation in NZ (Salmond & Crampton, 2012), which is indicative of structural racism (Williams, 1999; Williams & Mohammed, 2013). Māori and Pacific children may therefore be doubly disadvantaged when it comes to sleep health. This supports action at the political level to address structural racism and to incorporate an equity focus in social, economic and child health policy.

Further research is also required to understand mechanisms involved in relationships between the neighbourhood-, household- and child-level factors that were significantly associated with sleep in this study. For example, children living in urban environments may wake more at night due to disturbance from noise, light, close proximity of housing and less physical activity due to environments that are less conducive to free play than rural environments. Similarly, living in an area with heavy traffic may negatively impact sleep duration and night waking via noise, vibration or light. Greater duration of visual media use was associated with a non-significant trend for shorter sleep and was

significantly associated more night wakings. This suggests that visual media use may not only reduce the opportunity for sleep but may also disrupt sleep quality, perhaps due to the content viewed (LeBourgeois et al., 2017). Being overweight and having poorer health was associated with shorter sleep and more night wakings at 24 months of age. As these relationships were cross-sectional, an understanding of the long term relationship with sleep and direction of causality is needed, which supports the continued collection of body size, health and sleep data over time.

Just why fewer sociodemographic factors are associated with differences in sleep at 45 months, than 24 months is uncertain. Whether or not relationships between sociodemographic characteristics and sleep continue to change over time warrants continued monitoring. Nonetheless, results add to recent NZ research which indicates the importance of child- and family-based sleep information, advice and support being accessible to all families and not using a one-size-fits-all approach to sleep health interventions (Muller, Paine, Wu, & Signal, 2019b).

At a broader level, study findings provide support for the inclusion of sleep as a child wellbeing indicator in the government's first Child and Youth Wellbeing strategy (Department of the Prime Minister and Cabinet, n.d.) and for taking political action to address the drivers of ethnic and socioeconomic inequities in child wellbeing, including sleep, via social and economic policy. This includes tackling structural racism and providing targeted interventions to ensure all families with young children have access to sufficient financial and material resources, living conditions and support to enable all children to achieve good sleep health from an early age and across the lifecourse (Muller et al., 2019b). Results also support tackling obesogenic environments and providing visual media guidelines (Ministry of Health, 2017b).

Limitations and future directions

Limitations

As with any research, there are a number of limitations that need to be taken into account when interpreting these findings. At the time of this study, sleep data were only available for children at 24 and 45 months of age and the questions asked about sleep at these time points were relatively limited. Having only two time points necessarily limits the longitudinal analyses that can be conducted and does not allow detailed exploration of the pattern of change in sleep over time. Investigations of relationships between sleep and other health or developmental outcomes are also limited. It is therefore vital that future data collection waves include measures of sleep.

At both 24 and 45 months, parents reported children's average daytime and nighttime sleep durations and night time awakenings, however no information was collected on the timing of sleep or daytime sleepiness. Sleep is a multi-faceted construct and sleep health is achieved by obtaining sufficient, good quality sleep at appropriate times and without evidence of daytime sleepiness. Collecting more comprehensive sleep data at future time points would provide the opportunity to gain a more detailed understanding of the sleep health of children in NZ.

In any large cohort study, many metrics will be obtained using subjective report. However, parentally-reported sleep does have its limitations, especially as children become more independent over time and parents become less aware of when children fall asleep and wake up. Parents have been shown to over-estimate child sleep duration compared to objectively measured sleep (Iwasaki et al., 2010). That said, as current sleep duration guidelines are predominantly based on parent-report (Hirshkowitz, Whiton, Albert, Alessi, Bruni, DonCarlos, Hazen, Herman, Katz, et al., 2015) subjective sleep duration variables used in this report are considered appropriate. Single "average" estimates of sleep are also limited because sleep in any individual tends to vary greatly from one day to the next and, in particular, between weekdays and the weekend. Future data collection incorporating some objective measures of sleep across both week and weekend days would be of significant value.

This study has demonstrated that there are a wide range of sociodemographic factors associated with sleep durations and night wakings of children in NZ. Other factors that would have been useful to explore include household crowding and housing quality, which could not be accurately determined with the available data; childcare at 45 months, which was not released for external use within the study timeframe; and sleep location, which was investigated at the univariate level but could also have been included in multivariate models. All of these factors are deserving of further investigation in the future.

We acknowledge the limitation of using NZDep2013 measured at 54 months in analyses of sleep at 45 months, due to area-level deprivation not being available at 45 months. This may have resulted in measurement error for children who moved into an area with a differing NZDep quintile between these two time points. We recognise that we also could have analysed children's usual amount of time outside on weekdays and weekends as an average value to capture time outside across the entire week, versus prioritising time on weekdays.

It is also important to note that the NSF guidelines, upon which Ministry of Health guidelines are based, categorise sleep duration in 5 levels, with sub-categories of 'inappropriate' short/long sleep and 'may be' inappropriate short/long sleep, as well as the 'appropriate' sleep duration category. In the present study, 'inappropriate' short or long sleep and 'may be' appropriate short or long sleep were collapsed so that there was a single category of either short

or long sleep. Consequently, a small proportion of children who are naturally and appropriately short or long sleepers may have been categorised as having inappropriate sleep durations.

Strengths

This study has the significant strength of utilising a large, contemporary, demographically diverse dataset, representative of NZ society. Findings are therefore relevant and applicable to children living in NZ. The broad range of measures collected allowed associations between sleep and many different social, environmental and demographic factors to be explored and emphasises how sensitive sleep is to the environments in which children live. Although the number of time points at which sleep data have been collected is limited, the longitudinal study design of GUiNZ allowed changes in sleep over time during early childhood to be investigated and better understood within the NZ context. It also enabled a greater understanding of which sociodemographic factors consistently influence sleep over time and which factors become more or less important at different time points.

Current knowledge of the social and environmental factors associated with changes in adult sleep is reasonably comprehensive, however child-centred research is still limited. Therefore, this study not only adds to our understanding of sleep for NZ children but also contributes to the international knowledge base in this area.

A core component of this research was to describe the sleep of NZ preschoolers, but our sophisticated statistical approach also allowed us to predict the probabilities of children meeting the Ministry of Health sleep guidelines, taking into account variation in each child's sleep.

Future research

The sensitivity of sleep to so many different social and environmental factors at this early life stage points to the need to continue measuring sleep in future data collection waves, using both subjective and objective measures where practicable. This will enable an understanding of the trajectories of sleep as children develop and how various factors influence sleep over a longer period of time and at different critical developmental stages. In addition, it is recommended that the GUiNZ dataset be utilised to investigate the role of short sleep, long sleep and sleep disturbance in child health, wellbeing, learning and behaviour in both the short and longer term, including at critical periods of the lifecourse such as when children transition to school and enter the teenage years. The investigation of inter-relationships between child sleep and wellbeing and the sleep and wellbeing of children's whānau/family is also warranted.

The estimated population prevalence of long sleep in this study was unexpectedly high. Little is known about how sleeping longer than is

recommended may impact children's wellbeing, therefore monitoring the proportion of children in GUiNZ with long sleep over time and how this relates to mental and physical health and wellbeing would provide a valuable opportunity to better understand this aspect of child sleep health and development.

Conclusions

Not all children in NZ are meeting sleep duration and sleep quality guidelines during early childhood. Ethnicity and socioeconomic deprivation are significantly associated with how long and how well preschoolers sleep, indicating that action must be taken to address the root cause of sleep health inequities in young children in NZ to prevent potentially ingrained sleep inequities across the lifecourse. Findings from this research suggest that a multitude of sociodemographic factors at the societal-, neighbourhood-, household- and child-level are associated with how well children sleep. Thus, a comprehensive, multi-pronged approach is needed to ensure all children in NZ are provided with the opportunity to obtain good sleep health. Results indicate value in incorporating child sleep as an indicator in the first Child and Youth Wellbeing Strategy and in continuing to measure sleep in the GUiNZ longitudinal study.

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Appendix 1: Univariate models for TST at 24 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Gender:				
Boy (Baseline)	12.39	0.03	469.76	<.001
Girl	-0.07	0.04	-2.07	.038
Child ethnicity:				
European/Other (Baseline)	12.72	0.03	472.55	<.001
Māori	-0.55	0.05	-11.68	<.001
Pacific	-0.96	0.06	-16.84	<.001
Asian	-0.65	0.06	-11.57	<.001
NZDep2006 quintiles:				
1 (Baseline)	12.65	0.04	286.40	<.001
2	-0.03	0.06	-0.44	.658
3	-0.20	0.06	-3.19	.001
4	-0.39	0.06	-6.37	<.001
5	-0.66	0.06	-11.30	<.001
Rurality:				
Rural (Baseline)	12.62	0.07	189.16	<.001
Urban	-0.27	0.07	-3.91	<.001
Material standard of living:				
Not enough (Baseline)	12.22	0.06	207.80	<.001
Just enough	-0.01	0.07	-0.15	.881
Enough	0.16	0.07	2.44	.015
More than enough	0.39	0.07	5.35	<.001
Neighbourhood safety:				
Disagree (Baseline)	12.19	0.06	190.26	<.001
Agree (safe)	0.19	0.07	2.83	.005
Neighbourhood traffic:				
Disagree (Baseline)	12.43	0.02	531.90	<.001
Agree (heavy traffic)	-0.20	0.04	-5.00	<.001
Household structure:				
Parent alone (Baseline)	12.11	0.08	144.20	<.001
Two parents	0.35	0.09	4.03	<.001
Parent/s with others	0.04	0.09	0.43	.665
Maternal paid work:				
Yes (Baseline)	12.40	0.03	474.51	<.001
No	-0.09	0.04	-2.47	.014

Note: Baseline = baseline category

Appendix 1 (continued): Univariate models for TST at 24 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Childcare:				
No (Baseline)	12.29	0.03	430.17	<.001
Yes	0.13	0.04	3.30	.001
Time outside week:				
0 - <1hr (Baseline)	12.12	0.08	158.18	<.001
1 - <2hr	0.16	0.09	1.80	.072
2 - <3hr	0.33	0.08	3.88	<.001
3 - <4hr	0.27	0.09	3.12	.002
4 - <5hr	0.30	0.09	3.21	.001
≥5hr	0.13	0.09	1.34	.181
Time outside weekend:				
0 - <1hr (Baseline)	12.01	0.10	119.70	<.001
1 - <2hr	0.11	0.12	0.90	.369
2 - <3hr	0.47	0.11	4.31	<.001
3 - <4hr	0.41	0.11	3.79	<.001
4 - <5hr	0.40	0.11	3.66	<.001
≥5hr	0.29	0.11	2.73	.006
General health:				
Poor (Baseline)	11.83	0.27	44.51	<.001
Fair	0.21	0.29	0.75	.452
Good	0.36	0.27	1.32	.187
Very good	0.48	0.27	1.81	.071
Excellent	0.62	0.27	2.32	.020
Body size:				
Healthy weight (baseline)	12.52	0.03	374.63	<.001
Obese	-0.11	0.10	-1.13	.260
Overweight	-0.19	0.07	-2.92	.004
Thin	-0.39	0.14	-2.82	.005

Note: Baseline = baseline category

Appendix 2: Univariate models for night wakings at 24 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Gender:				
Boy (Baseline)	0.72	0.02	-15.66	<.001
Girl	0.96	0.03	-1.31	.190
Child ethnicity:				
European/Other (Baseline)	0.63	0.02	-20.00	<.001
Māori	1.20	0.04	4.89	<.001
Pacific	1.15	0.05	3.08	.002
Asian	1.44	0.04	8.51	<.001
NZDep2006 quintiles:				
1 (Baseline)	0.67	0.04	-11.10	<.001
2	1.04	0.05	0.73	.463
3	1.08	0.05	1.56	.119
4	1.07	0.05	1.37	.171
5	1.13	0.05	2.66	.008
Rurality:				
Rural (Baseline)	0.61	0.06	-8.79	<.001
Urban	1.19	0.06	2.99	.003
Material standard of living:				
Not enough (Baseline)	0.84	0.04	-4.08	<.001
Just enough	0.94	0.05	-1.20	.229
Enough	0.80	0.05	-4.52	<.001
More than enough	0.70	0.06	-6.39	<.001
Neighbourhood safety:				
Disagree (Baseline)	0.79	0.05	-4.89	<.001
Agree (safe)	0.89	0.05	-2.34	.019
Neighbourhood traffic:				
Disagree (Baseline)	0.68	0.02	-20.17	<.001
Agree (heavy traffic)	1.11	0.03	3.38	.001
Household structure:				
Parent alone (Baseline)	0.75	0.06	-4.48	<.001
Two parents	0.90	0.07	-1.56	.112
Parent/s with others	1.07	0.07	0.93	.354
Maternal paid work:				
Yes (Baseline)	0.69	0.02	-17.73	<.001
No	1.06	0.03	2.03	.042

Note: Estimate = exponentiated estimate; Baseline = baseline category

Appendix 2 (continued): Univariate models for night wakings at 24 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Childcare:				
No (Baseline)	0.74	0.02	-13.75	<.001
Yes	0.93	0.03	-2.30	.021
Time outside week:				
0 - <1hr (Baseline)	0.79	0.06	-4.03	<.001
1 - <2hr	0.92	0.07	-1.18	.239
2 - <3hr	0.88	0.06	-1.95	.051
3 - <4hr	0.88	0.07	-1.97	.049
4 - <5hr	0.84	0.07	-2.51	.012
≥5hr	0.93	0.07	-1.04	.300
Time outside weekend:				
0 - <1hr (Baseline)	0.82	0.07	-2.67	.008
1 - <2hr	1.02	0.09	0.17	.861
2 - <3hr	0.83	0.08	-2.29	.022
3 - <4hr	0.87	0.08	-1.74	.081
4 - <5hr	0.84	0.08	-2.21	.027
≥5hr	0.85	0.08	-2.02	.043
General health:				
Poor (Baseline)	1.31	0.15	1.76	.078
Fair	0.86	0.17	-0.92	.359
Good	0.64	0.16	-2.82	.005
Very good	0.56	0.16	-3.53	<.001
Excellent	0.48	0.16	-4.76	<.001
Body size:				
Healthy weight (baseline)	0.69	0.03	-13.07	<.001
Obese	0.91	0.09	-1.09	.275
Overweight	0.99	0.06	-0.20	.844
Thin	1.20	0.11	1.72	.085

Note: Estimate = exponentiated estimate; Baseline = baseline category

Appendix 3: Univariate models for TST at 45 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Gender:				
Boy (Baseline)	11.23	0.02	536.66	<.001
Girl	-0.06	0.03	-2.04	.041
Child ethnicity:				
European/Other (Baseline)	11.29	0.02	521.02	<.001
Māori	-0.15	0.04	-3.84	<.001
Pacific	-0.09	0.05	-1.90	.058
Asian	-0.30	0.05	-6.61	<.001
NZDep2013 quintiles:				
1 (Baseline)	11.23	0.03	334.55	<.001
2	-0.002	0.05	-0.04	.970
3	-0.03	0.05	-0.54	.590
4	-0.05	0.05	-1.07	.283
5	-0.03	0.05	-0.75	.455
Rurality:				
Rural (Baseline)	11.27	0.05	223.67	<.001
Urban	-0.07	0.05	-1.28	.202
Household structure:				
Parent alone (Baseline)	11.19	0.05	210.85	<.001
Two parents	0.03	0.06	0.58	.559
Parent/s with others	-0.04	0.06	-0.64	.522
Maternal paid work:				
No (Baseline)	11.23	0.02	482.85	<.001
Yes	-0.04	0.03	-1.16	.246
Child's sleep location:				
Separate room alone (baseline)	11.29	0.02	502.08	<.001
Shared room	-0.12	0.03	-3.56	<.001
Shared bed	-0.18	0.04	-4.60	<.001
Other	-0.36	0.20	-1.77	.077
Visual media use:				
<1hr (Baseline)	11.30	0.04	317.39	<.001
1 - <2hr	-0.07	0.04	-1.49	.137
2 - <3hr	-0.11	0.05	-2.39	.017
≥3hr	-0.21	0.05	-4.47	<.001

Note: Baseline = baseline category

Appendix 4: Univariate models for night wakings at 45 months

Sociodemographic Variable	Estimate	Standard Error	Statistic	*P* Value
Gender:				
Boy (Baseline)	0.45	0.03	-30.11	<.001
Girl	1.06	0.04	1.64	.102
Child ethnicity:				
European/Other (Baseline)	0.42	0.03	-30.36	<.001
Māori	1.26	0.05	4.90	<.001
Pacific	1.21	0.06	3.26	.001
Asian	1.28	0.06	4.40	<.001
NZDep2013 quintiles:				
1 (Baseline)	0.45	0.04	-18.55	<.001
2	1.02	0.06	0.26	.792
3	0.99	0.06	-0.21	.830
4	1.04	0.06	-0.60	.545
5	1.14	0.06	2.24	.025
Rurality:				
Rural (Baseline)	0.45	0.06	-12.49	<.001
Urban	1.06	0.07	0.87	.387
Household structure:				
Parent alone (Baseline)	0.47	0.07	-11.60	<.001
Two parents	1.00	0.07	-0.06	.956
Parent/s with others	1.02	0.08	0.31	.754
Maternal paid work:				
No (Baseline)	0.48	0.03	-25.68	<.001
Yes	0.94	0.04	-1.68	.093
Child's sleep location:				
Separate room alone (baseline)	0.42	0.03	-29.68	<.001
Shared room	1.05	0.04	1.05	.294
Shared bed	1.47	0.05	8.28	<.001
Other	1.83	0.20	3.05	.002
Visual media use:				
<1hr (Baseline)	0.42	0.05	-18.71	<.001
1 - <2hr	1.05	0.06	0.87	.384
2 - <3hr	1.19	0.06	2.95	.003
≥3hr	1.23	0.07	3.45	.001

Note: Estimate = exponentiated estimate; Baseline = baseline category

Are New Zealand children meeting the Ministry of Health guidelines for sleep?

Muller D

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