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SCIENTIFIC INVESTIGATIONS

Sleep in New Zealand children aged 7–9: associations with ethnicity, socioeconomic status, and achievement in reading and mathematics

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Study Objectives: The aims were (1) to investigate differences by ethnicity and socioeconomic status (SES) in objective measures of sleep in children aged 7–9 years and (2) determine whether measures of sleep predict child achievement in reading or mathematics after controlling for ethnicity and SES.
Methods: Four groups of parent–child dyads were recruited: Māori, low-SES schools (n = 18); Māori, high-SES schools (n = 17); New Zealand European, low-SES schools (n = 18); New Zealand European, high-SES schools (n = 17). Child sleep was measured by actigraphy. Parents and teachers reported child daytime sleepiness and behavior, and children completed a self-report of anxiety symptoms. Teachers also reported on child achievement in reading and mathematics.
Results: Children from low-SES schools went to bed later on school nights (F[1,68] = 12.150, P = .001) and woke later (F[1,68] = 15.978, P < .001) than children from high-SES schools but had similar sleep duration. There were no differences related to ethnicity. Children from low-SES schools were almost 3 times more likely to be below national standards for mathematics. Children not meeting academic standards in mathematics had a later sleep start time, lower sleep period efficiency, and a decreased total sleep time. However, when SES and sleep period efficiency were modeled together neither were found to significantly influence achievement in mathematics.
Conclusions: In this study, SES influenced sleep timing but not the quality and quantity of sleep in 7- to 9-year-old children, and a significant independent effect of sleep efficiency on learning could not be demonstrated.
Keywords: sleep, child, actigraphy, ethnicity, socioeconomic status
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BRIEF SUMMARY
Current Knowledge/Study Rationale: Child sleep and sleep outcomes are influenced differently by socioeconomic status and ethnicity in different cultures. This study aimed to assess sleep and sleep outcomes for New Zealand European and Māori children.
Study Impact: In New Zealand, socioeconomic status has more influence on sleep timing than ethnicity. Socioeconomic status also affects learning. Socioeconomic status and sleep problems may interact to affect learning, but this could not be convincingly demonstrated in this small study.

INTRODUCTION

Recent meta-analyses document links between children's school performance and sleep-disordered breathing,[1] sleep quality, sleep duration, and daytime sleepiness.[2]

Two previous studies have documented sleep patterns in New Zealand children.[3,4] Nixon et al[3] documented actigraphy data from 519 7-year-old children. Mean sleep duration was 10.1 hours and longer on weekday compared with weekend nights. This cohort was followed from birth to investigate the long-term effects of growth restriction at birth and at the 7-year data collection; mothers who were non-New Zealand European (non-NZE) were excluded because of a previous poor response rate.

Muller et al[4] reported actigraphy data for 52 New Zealand children aged 6 to 8 years. Average sleep periods were 10 hours on school nights and 9.5 hours on nonschool nights, and parents overestimated children's sleep compared with the objective measure. The majority of participants were non-Māori, attended schools in high socioeconomic status (SES) areas, and lived in 2-adult–2-child households with at least 1 parent in fulltime employment. These cohorts therefore do not reflect the full range of New Zealand children so effects of race and SES on sleep could not be addressed.

These limitations are important because overseas studies measuring sleep in children have documented significant associations between both SES and ethnicity with regard to sleep practices and problems. A review by Gellis[5] concluded that children from low-SES communities appear to be more vulnerable to insufficient sleep and sleep problems, potentially due to correlates of poverty, such as a chaotic or unstable home and neighborhood environments, family disruption, poorer physical health or illness, and housing conditions. Buckhalt and colleagues[6] demonstrated that sleep quality mediated the relationship between SES and cognitive functioning, with similar cognitive functioning for American children from high- and low-SES homes who are good sleepers and disproportionately worse cognitive functioning among poor sleepers from low-SES homes.

Differences have also been reported with regard to ethnicity, with studies reporting poorer sleep patterns in African-American children including less sleep activity, shorter sleep duration, delayed sleep onset during the week, more variable sleep onset, more sleepiness, and more sleep/wake problems.[6] In contrast, in some Asian cultures (Korea, Hong Kong, and China) high SES is associated with shorter sleep duration in prepubertal children.[7,8] Associated factors include television and computer use, poor sleep hygiene, short sleep duration of parent sleep, and the child's homework burden.[9–11] While many sleep issues for children are ubiquitous, factors related to sleep cannot be presumed to be the same in different cultures and socioeconomic environments.[12] These previous studies have not prospectively recruited participants by defining both ethnicity and SES, an approach that would enable more direct comparison between the extremes of SES examined within each ethnic group.

In New Zealand, children from schools with a greater proportion of children living in low-SES neighborhoods are disproportionately represented in poor academic performance.[13] Children of Māori ethnicity, who are overrepresented in low-SES schools, are also overrepresented among low-achieving students. The first aim of the present study was to investigate differences in objective measures of sleep in children aged 7–9 years by ethnicity (Māori and NZE) and by SES through distinguishing low and high SES for each ethnic group. The second aim was to determine whether measures of sleep, after controlling for ethnicity and SES, were predictive of whether children were achieving below academic expectations in reading or mathematics. We hypothesized that children from low-SES schools would have later bedtimes, shorter sleep duration, and poorer sleep efficiency than children from high-SES schools and that these factors would be associated with poorer learning outcomes at school. We further hypothesized that any effects of ethnicity on sleep would be mediated by SES.

METHODS

Participants and procedure

Caregivers provided written informed consent and children informed assent. Participants were recruited from 4 primary schools in Wellington, New Zealand, and participated within 7 weeks during the winter school term. Schools had a start time of 9 AM. Classroom recruitment was dependent on teacher consent to their role in the study. Children aged 7–9 years were sampled from classroom lists based on ethnicity (Māori or NZE), school decile, sex, and age. In New Zealand, decile 1 schools are the 10% of schools with the highest proportion of students from low socioeconomic communities, whereas decile 10 schools are the 10% of schools with the lowest proportion of these students. Two schools served communities with a high proportion of students from low socioeconomic neighborhoods (decile 1 and 2 schools) while the other 2 schools served communities with a high proportion of students from high socioeconomic neighborhoods (decile 9 and 10 schools). These schools will be referred to as "low-SES" and "high-SES" schools throughout this report. Consenting teachers provided class lists with children's sex, age, and ethnicity. Children were matched by age and sex into pairs, 1 Māori, 1 NZE, and these children were invited to participate. If parents did not consent, the next available matching child on the list was used. These children were then paired as closely as possible with another pair from the opposite decile school to make groups of 4 (high-decile Māori, high-decile NZE, low-decile Māori, low-decile NZE) with 2 groups of 4 participating each week. All children who could be matched and who also consented were included. The University of Otago Human Ethics Committee approved the study.

Actigraphy

Over 7 consecutive nights in their own home, each child was monitored with an Actiwatch worn on their nondominant wrist (Actigraph GT9x; Respironics, Inc, Murrysville, PA). Parents recorded child bedtime and wake times on a sleep diary over this period. Manual screening identified rest period start and finish times. Following Werner et al[14], sleep start time was manually set as the first of 5 consecutive epochs scored as immobile near to the "bedtime" identified in sleep diaries. If the sleep diary indicated bedtime was 19:30, epochs were examined from 19:00 onward and the first of 5 epochs that indicated immobility was manually coded as sleep onset. Sleep end time was set as the last epoch that indicated immobility before 5 consecutive epochs that indicated light, moderate, or vigorous physical activity, within a 60-minute window of sleep diary wake time. To establish coding reliability, 2 authors manually set sleep onset and wake time for 5 participants. Following this, each coded these 5 participants separately, and absolute agreement interrater reliability was high (97% for sleep onset, 94% for wake time). The remaining data were coded by 1 author. Sleep data were analyzed with ActiLife software (version 6.5.4; ActiGraph, Pensacola, FL), which identified each 1-minute epoch as sleep or wake using the mathematical model validated by Sadeh et al.[15] The following objective sleep measures were collected:

1. Sleep start time: start time of the first epoch scored as sleep
2. Sleep end time: time at the end of the last epoch scored as sleep
3. Sleep period: time elapsed between sleep start and end times
4. Sleep period efficiency: percentage of scored total sleep time (TST) within the sleep period
5. Waking after sleep onset (WASO): the time in the sleep period scored as awake
6. TST: the time in the sleep period scored as sleep

Sleep-onset latency was not measured as sleep diary information regarding "lights out" was considered too variable and unreliable. Actigraphy data were averaged over 5 "school nights" (Sunday–Thursday night) and 2 "weekend nights" (Friday and Saturday night).

Demographic measures

The parent questionnaire documented annual household income and highest educational achievement. Annual household income was reported in 10 income bands according to the 2013 New Zealand census data (1, <$NZD 22,800; 10, >$164,900). Highest educational achievement was rated on a 6-point scale (1 = no formal qualification, 6 = postgraduate university qualification).

Child sleep environment

Parents reported whether their child shared their bedroom or their bed. Household crowding was assessed using the Equivalized Crowding Index (ECI) developed by Statistics New Zealand.[16] ECI = [(1/2 number of children under 10 years) + (number of couples) + (all other people aged 10 years and over)]/number of bedrooms. A score of 1 reflects that, in 1 bedroom, there was either (1) 1 adult, (2) 2 children younger than 10 years, or (3) 1 couple; and numbers above 1 are interpreted as a "crowded" home.

Parent questionnaire

Parents completed the Children's Sleep Habits Questionnaire (CSHQ), a scale designed by Acebo and colleagues[17] for documenting sleep difficulties in children aged 4 to 10. Items in this measure pertain to children's bedtime and bedtime routine, sleep behavior, waking during the night, morning waking, and daytime sleepiness. The CSHQ has been used to describe parent reports of child sleep in samples from New Zealand[3,4] and was used with additional items as modified by Muller and colleagues[4] for the New Zealand setting.

A parent knowledge of child sleep measure was modified from a scale developed by Owens et al.[18] This measure included 10 statements about children's sleep, and parents indicated if each statement was true, false, or if they don't know. Following Owens et al[18] we also asked parents to indicate whether they believe their child has enough sleep, and if they believe their child has healthy sleeping habits. Parents reported if their child had any ongoing diagnosed health problems or a serious disability. Parents were also asked whether their child had "no difficulty," "moderate difficulty," or "serious difficulty" with their weight.

Child questionnaire

Children completed the child self-report sleep questionnaire as per Owens et al.[19] Those data are not reported here. Child anxiety (physiological anxiety, worry, social anxiety) were measured using the Revised Children's Manifest Anxiety Scale, Second Edition, a self-report measure for children and adolescents age 6–18.

Achievement in reading and mathematics

The New Zealand national standards were the current reference points for academic learning that each child was compared with at each year level at the time of the study (http://nzcurriculum.tki.org.nz/National-Standards). The guidelines specifically state that teachers are to use several sources of evidence to make a judgment as to whether students meet the standard. Teachers were asked whether each participating child was considered "below," "at," or "above" national standards for reading and mathematics at their most recent assessment. Teacher assessments of child performance relative to national standards have been previously reported in the New Zealand literature.[20]

Data analysis

No formal sample size calculation was undertaken. The study design addressed the key variables of ethnicity and SES status by matching. Differences in means of continuous outcome variables (eg, sleep efficiency) were tested using paired *t* tests for within-participant comparisons, independent-samples *t* tests for between-group comparisons, and 2-way analysis of variance with post hoc Bonferroni comparisons when comparing within-school SES by ethnicity groups. Chi-square analyses with Pearson's chi-square statistic (χ^2) were used for categorical data to determine whether 2 categorical variables were related to each other. Binary logistic regression models were used to predict the likelihood of being "below" national standards in reading or mathematics based on multiple predictors. Both continuous (eg, sleep) variables and categorical variables can be used in this model. A P value < .05 was considered significant. Analyses were done using SPSS software (release 2016; IBM SPSS Statistics for Windows, version 24.0; Armonk, NY)

RESULTS

Sample

We recruited 4 groups of parent–child dyads: (1) Māori from low-SES schools (n = 18), (2) Māori from high-SES schools (n = 17), (3) NZEs from low-SES schools (n = 18), (4) NZEs from high-SES schools (n = 17). Seventy-two caregivers (90% of those invited) consented, and questionnaire data were complete for 70 parent-child dyads, with school night actigraphy available for 69, weekend night actigraphy for 66 and both school night and weekend actigraphy available for 66. No child was reported to have a significant disability. There were no differences in mean age, percentage of females, or in which of the 7 weeks families participated in the study (**Table 1**). There were significant differences between the 4 groups in household income, parent education, and percentage of homes categorized as "crowded." Post hoc analyses showed that there were differences between the low-SES and high-SES groups but not between the Māori and NZE children.

Actigraphy sleep measures on school nights and weekend nights

Data from actigraphy and diaries are shown in **Table 2**. On school nights, average sleep start time was 51 minutes earlier (paired $t[63] = -9.219$, $P < .001$), sleep end time was 18 minutes earlier (paired $t[63] = -3.870$, $P < .001$), and the sleep period was 35 minutes longer (paired $t[63] = 6.019$, $P < .001$) in comparison with weekend nights. The mean sleep period efficiencies were statistically different (paired $t[62] = -2.281$, $P = .026$), with sleep efficiency slightly higher in the weekend, but the mean difference was only 1.43%. The mean WASO was increased

Table 1—Descriptive differences by SES and ethnicity.

	Low-SES Schools		High-SES Schools		Statistical Test Results
	Māori (n = 18)	NZE (n = 17)	Māori (n = 18)	NZE (n = 17)	
Age, mean ± SD, years	8.84 ± 0.87	8.63 ± 0.85	8.49 ± 0.74	8.56 ± 0.65	NS, *F*(3,66) = 0.653, *P* = .584
Sex, % female	55.6	41.2	50.0	35.3	NS, χ^2 = 1.721, *P* = .632
Week of data collection (3–9)	5.94 ± 1.83	5.53 ± 2.04	5.72 ± 1.78	5.94 ± 2.36	NS, *F*(3,66) = 0.170, *P* = .916
Household income NZ dollars (median range)	\$22,800–\$32,099	\$22,800–\$32,099	\$100,000–\$123,299	\$82,500–\$99,999	*F*(3,66) = 17.220, *P* < .0005 Bonferroni, differences by low and high SES, not by ethnic group
Parent education, % completed high school	38.9	41.2	77.8	82.8	High vs low SES, χ^2 = 13.566, *P* < .0005; Māori vs NZE, χ^2 = 0.30, *P* = .584
Crowding index, % crowded	55.6	47.1	5.6	5.9	High vs low SES, χ^2 = 17.920, *P* < .0005; Māori vs NZE, χ^2 = 0.143, *P* = .705

NZE = New Zealand European; SES = socioeconomic status.

Table 2—Sleep diary and actigraphy data for weekend and school nights.

	School Nights (n = 69)				Weekend Nights (n = 66)				Weekend – School Nights (n = 66)					
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	*t*	*P*
Sleep diary														
Bedtime, 24-hour clock	19:03	22:39	20:15	0:40	19:00	23:45	21:03	0:57	−1:12	3:07	0:47	0:47	8.163	<.001
Wake time, 24-hour clock	6:06	8:15	7:06	0:33	6:03	10:30	7:33	0:53	−0:53	2:38	0:26	0:39	5.515	<.001
Sleep period, hours:minutes	8:53	12:27	10:50	0:32	7:41	13:10	10:30	1:00	−2:28	1:48	−0:19	0:53	−2.990	.004
Actigraphy														
Sleep start time, 24-hour clock	19:28	23:02	20:47	0:42	19:35	23:35	21:38	0:54	−0:37	2:28	0:52	0:45	9.219	<.001
Sleep end time, 24-hour clock	5:36	8:13	6:50	0:34	5:18	10:02	7:08	0:52	−0:54	2:19	0:18	0:38	3.870	<.001
Sleep period, hours:minutes	8:41	10:58	9:58	0:29	7:18	11:46	9:23	0:46	−3:31	1:12	−0:36	0:48	−6.019	<.001
Sleep period efficiency, %	63	90	79.61	5.30	67	93	81.14	6.02	−8	14	1.43	4.98	2.281	.026

Paired-samples *t* tests were used to examine differences between school-night and weekend sleep data. Max = maximum; Min = minimum.

Table 3—School-night and weekend-night actigraphy data, by school SES and child ethnicity.

Actigraphy	School Nights				Weekend Nights			
	Low-SES Schools		High-SES Schools		Low-SES Schools		High-SES Schools	
	Māori (n = 18)	NZE (n = 17)	Māori (n = 18)	NZE (n = 17)	Māori (n = 15)	NZE (n = 15)	Māori (n = 17)	NZE (n = 17)
Sleep onset, 24-hour clock	21:16 ± 0:45	20:51 ± 0:37	20:31 ± 0:34	20:30 ± 0:38	21:57 ± 0:48	21:52 ± 0:48	21:29 ± 0:58	21:17 ± 0:54
Sleep end time, 24-hour clock	7:15 ± 0:33	6:54 ± 0:30	6:40 ± 0:27	6:30 ± 0:38	7:26 ± 0:52	7:14 ± 0:58	7:07 ± 0:55	6:49 ± 0:40
Sleep period, hours:minutes	9:58 ± 0:30	9:57 ± 0:31	10:04 ± 0:25	9:55 ± 0:30	9:14 ± 0:46	9:18 ± 0:33	9:37 ± 0:55	9:23 ± 0:46
Sleep period efficiency, %	76.42 ± 5.65	78.34 ± 4.67	80.87 ± 5.86	80.38 ± 6.21	76.30 ± 3.85	81.40 ± 6.07	81.84 ± 5.16	82.64 ± 6.16

Values are means ± SDs. NZE = New Zealand European; SES = socioeconomic status.

on school nights by 14 minutes (paired $t[63] = 4.128$, $P = .002$). Despite this, the mean TST was still increased by 19 minutes (paired $t[63] = 3.200$, $P < .001$) on school nights.

Actigraphy measures of sleep by school, SES, and child ethnicity

On average, across school nights, children from low-SES schools went to bed later ($F[1,68] = 12.150$, $P = .001$, $\eta^2 = 0.152$) and woke later ($F[1,68] = 15.978$, $P < .001$, $\eta^2 = 0.190$) than children from high-SES schools (**Table 3**). There were no significant differences found for sleep period duration, TST, sleep period efficiency, or WASO, indicating these differences related to sleep timing rather than sleep duration or sleep quality. On weekend nights, children from low-SES schools also went to bed later ($F[1,62] = 5.940$, $P = .018$, $\eta^2 = 0.087$), but significant differences were not found for other weekend sleep variables. There were no significant differences in school night actigraphy variables by ethnicity.

Sleep and environment

Bedroom sharing

Thirty-seven children (53%) shared bedrooms with at least 1 other person. No statistically significant differences were found in actigraphy measures for school and weekend nights between children who shared and children who slept alone. Children from low-SES schools were more likely to share their bedroom (Pearson $\chi^2 = 4.644$, $P = .031$; n = 23, 66%) than children from high-SES schools (n = 14, 40%). Differences by ethnicity were not found (Pearson $\chi^2 = 0.892$, $P = .345$). Four children (6%), all from low-SES schools, shared their bed with another person.

Household crowding

The ECI household crowding index ranged from 0.50 to 2.75, with 20 (29%) of the parent–child dyads categorized as living in a "crowded" household. For children in crowded homes, on school nights sleep start time was 33 minutes later, on average (t[68] = −3.069, $P = .003$) and sleep end time was 28 minutes later (t[68] = −3.236, $P = .002$). Differences were not found in sleep period duration and there was no significant difference in school night sleep period efficiency between children living in crowded houses and those who were not (t[67] = 0.839, $P = .41$). Weekend night sleep period efficiency was significantly lower (3.5%) in those children living in crowded homes (t[62] = 2.056, $P = .044$), as was weekend TST (t[62] = 2.088, $P = .041$). Children from low-SES schools were more likely to live in crowded housing (Pearson χ^2 [1] = 17.920, $P < .001$; n = 18, 51%) than children from high-SES schools (n = 2, 6%). but there were no differences by ethnicity (Pearson χ^2 [1] = 0.143, $P = .794$).

Sleep and school achievement

Achievement in reading

Significant differences were found between children identified by their teacher as "below" (n = 25), "at" (n = 24), and "above" (n = 20) national standards in reading for school night sleep start time (F[2,67] = 4.428, $P = .016$) but not for school night sleep period efficiency (F[2,66] = 0.396, $P = .675$) or weekend sleep period efficiency (F[2,61] = 0.431, $P = .652$). Post hoc analysis indicated that children "below" national standards in reading had significantly later sleep start time (35 minutes on average; Bonferroni adjusted $P = .018$) in comparison with children "above" national standards. There were no differences with respect to other sleep variables. Children from low-SES schools were more likely to be "below" national standards in reading (Pearson χ^2 [1] = 7.529, $P = .006$; n = 18/35, 51%) than children from high-SES schools (n = 7/35, 20%). Differences were not found by ethnicity (Pearson χ^2 [1] = 2.460, $P = .117$).

Achievement in mathematics

A different pattern was found for children identified by their teacher as "below" (n = 29), "at" (n = 24), and "above" (n = 17) national standards in mathematics. There was considerable overlap between reading and mathematics achievement groups, with 44 of 70 (63%) children being in the same assessment group for both reading and mathematics. Children who were "below," "at," and "above" expected standards differed in school night sleep start time (F[2,67] = 4.905, $P = .010$), school night sleep period efficiency (F[2,66] = 3.125, $P = .050$), and TST (F[2,67] = 3.904, $P = .025$). Post hoc analysis indicated that children "below" or "at" national standards in mathematics had significantly later sleep start time (35 minutes on average) in comparison with children "above" national standards. Children "below" national standards in mathematics had poorer sleep period efficiency (by 2.6% on average) in comparison with children "at" or "above" national standards (F[1,67] = 4.313, $P = .042$). Children achieving "below" national standards in mathematics had significantly lower TST (23 minutes on average) than those who achieved "at" or "above" national standards in mathematics.

Influences on learning achievement in mathematics

Multivariable logistic regression was used to investigate the relationships between SES variables (ethnicity, decile, household crowding, and household income), actigraphy variables (weekday sleep start time and sleep period efficiency), and school performance (mathematics below national standards versus at or above national standards). We asked whether sleep quality was mediating the effect of SES variables on mathematics performance. Of the SES variables measured, only school decile significantly predicted mathematics performance. With school decile in the model, all other SES variables were not significant. Decile had a P value of .031, and an odds ratio of 2.969 (95% confidence interval [CI]: 1.103, 7.990), indicating that children from low-SES schools had almost 3 times the odds of being "below" national standards for mathematics than did those from high-SES schools.

Both mean weekday sleep start time and mean weekday sleep period efficiency significantly predicted mathematics performance, but when both were in the model, only sleep period efficiency was significant. Alone, sleep period efficiency had a P value of .040, and an odds ratio of 0.895 (95% CI: 0.806, 0.995), indicating that, as sleep efficiency increased, the likelihood of performing "below" national standards decreased. When both school decile and mean weekday sleep period efficiency were in the model to predict mathematics performance, sleep period efficiency had a P value of .076 and an odds ratio of 0.913 (95% CI: 0.826, 1.010), similar to the results when it was the only predictor in the model. School decile had a P value of .062 and an odds ratio of 2.637 (95% CI: 0.951, 7.311). Thus, when both decile and sleep period efficiency were in the model, neither met the .05 criterion for significance; however, both had a P value < .10. This suggests that, while neither decile nor sleep period efficiency were statistically significant, there is some evidence that each is moderating the effect of the other. The pattern with income and sleep period efficiency was similar to that with school decile.

Factors affecting school night sleep period efficiency

The effect of house crowding on sleep period efficiency on weekend nights has been discussed. Of 11 (15.7%) children reported as having a health problem, 8 had asthma or eczema or both, 2 had hayfever, and 1 had recurrent ear infections. These children had a shorter TST ($F[1,68] = 4.112$, $P = .047$) than their peers but the difference in mean weekday sleep period efficiency did not reach a level of significance (ie, $P > .05$) ($F[1,67] = 3.790$, $P = .056$) and no difference was found for weekend sleep. The presence or absence of health problems was not related to SES (χ^2 [1] = 0.971, $P = .324$). Parents were asked if their child had no difficulty or a moderate or serious difficulty with their weight. The mean weekday sleep period efficiencies for each category, respectively, were 80.1% (n = 57), 79.6% (n = 8), and 70.7% (n = 2). Post hoc comparisons determined that the difference between the "no difficulty" and "serious difficulty" groups was significant ($P = .029$). Snoring was reported as usual for 1 child (1.4%) and 4 children (5.7%) were reported to sometimes snort or gasp during sleep. No significant relationships were found between sleep period efficiency and parental report of nighttime sleep problems, such as snoring, pauses in breathing, snorting or gasping, awakening with sweating and inconsolable (night terrors), or awakening with a frightening dream. There were also no associations found between self-reported symptoms of child anxiety or parental knowledge of child sleep.

DISCUSSION

These data indicate that, in New Zealand children, SES influences sleep timing but ethnicity does not when Māori and NZE ethnicities are compared. However, despite differences in the timing of child sleep between children living in high- and low-SES neighborhoods, there were no differences in sleep duration, which, for most children, was between 9.5 to 10 hours, consistent with previous New Zealand data.[3,4] Children living in low-SES neighborhoods went to bed later and woke up later but were still up in time to get to school at 9 AM. This is consistent with our primary hypothesis about expected differences in child bedtimes, but the finding that sleep duration was not significantly different between the 2 groups was not expected. It is, however, reassuring.

These data differ from reports suggesting that SES influences sleep duration, with findings reported in both directions. In reported data from the United States decreased sleep duration in mid-childhood is associated with low SES, whereas in studies from Asia high SES has been associated with short sleep duration.[5,9,21,22] Findings from the United Kingdom are more in line with the current study findings.[23] In the Avon study a cohort of over 7,000 children were assessed by parent questionnaire, with sleep times ranging from 8.5 to 11 hours at age 11. Children from low-income families went to bed later and woke later but, as in the current study, there was no significant difference in sleep duration by SES. Clinical experience indicates that some children need to get up early to leave home when both their parents have an early start at work. This could be more likely for parents with higher education and income. In New Zealand, if children attend a private school outside of their local area this is usually only for secondary school education. We therefore do not think an earlier rise time for the high-SES children related to the need to travel farther to a private school. Although we do not have specific data about these variations, our data do suggest that earlier rising was balanced by an earlier bedtime.

Another difference between the current study and other international research was that school-night sleep times were longer than weekend-night sleep times so there was no effect of catch-up sleep on the weekends. This is similar to findings in the 2 previous New Zealand studies[3,4] and an Australian study.[24] This may be because sleep times during the weekdays were of a reasonable duration and consistent with published norms for this age group.[25] Other studies have documented shorter sleep times despite excluding children with known sleep disorders.[26] Studies that have shown longer weekend sleep times for children in this age group have included those reporting shorter sleep times associated with higher SES.[8] The winter timing of the current study may have been an influence on the earlier weekend nights. Also, the New Zealand primary school start time of 9 AM is later than is seen in many elementary schools in the United States.[27] The 9 AM school start time for students in the current study meant that those with a later bedtime and wake time were not further disadvantaged. However, the opportunity for a later rise time because of a later school start time is not an advantage to students if their rise time is set earlier to facilitate an early work start time for their parents.

As well as sleep duration we were also interested in sleep efficiency as a measure of quality of sleep. There were no differences in sleep efficiency related to SES or ethnicity. Overall, sleep efficiency was significantly higher in the weekend but, as the difference was very small, it is unlikely that this was of clinical significance. However, those children living in crowded houses in the weekend had lower sleep efficiency than their peers. It is possible that may relate to extra people being in the house during the weekend or other household activities that were occurring only in the weekend, but we did not have data available to determine that. Sleep efficiency was also lower in children described by their parent as having a serious problem with weight when compared with those with no difficulty. Although this difference was statistically significant, and also likely clinically significant (80.1% versus 70.7% efficiency), there were only 2 children regarded as having a serious weight problem in this sample. Parent-reported symptoms suggestive of obstructive sleep apnea were not more common in children with lower sleep efficiency. It is likely that the sample size was too small to assess the effect of sleep-disordered breathing in this group.

In the current study, sleep period efficiency values were low overall, with a range of 63–90% for school-night values and a range of 67–96% for weekend values. Sadeh et al,[28] assessing children with actigraphy aged between 7 and 12 years of age, defined poor sleepers as those with either a sleep period efficiency of less than 90% or waking 3 times or more per night for at least 5 minutes. While Sadeh et al would classify many of the children in the current study as poor sleepers, a recent meta-analysis of actigraphy-derived sleep variables in children reported the range of mean sleep efficiencies in normal children to be 79–97%, so the majority of children in the current sample fall into this range.[29] Actigraphy has previously been shown to overestimate waking after sleep onset.[30] Despite this limitation that the reported sleep period efficiency values may represent an overestimation of wakefulness, the methodology was consistent for all participants, supporting the validity of the conclusions drawn. For the purposes of the current study sleep efficiency was measured only after sleep onset so did not include sleep-onset latency. This is likely why no association was found between childhood anxiety and sleep efficiency. Despite increasing use of actigraphy for assessing sleep in infants and children there are no published guidelines for sleep–wake identification in pediatric age groups.[31] In a recent meta-analysis of data published using a variety of actigraphy devices, study means for WASO ranged between 7 and 109 minutes and means for sleep period efficiency between 79% and 97%, indicating the wide range documented within sleep estimates by actigraphy when various types of devices are used.[29] This makes it difficult to determine what a normal range for sleep efficiency might be for children as measured by actigraphy.

We found some effects of sleep on learning, but this effect was only present for progress in mathematics. Children who were "below" the national standard in mathematics had lower sleep efficiency and a lower TST. There was also a very strong effect of SES on performance in mathematics. When both SES and the sleep variables were modeled there was some indication that one was moderating the other, although in this relatively small sample we could not demonstrate that a potentially modifiable sleep factor was significantly influencing learning in mathematics. It is possible that in a larger sample an effect might be able to be demonstrated.

This study design had some important limitations. SES can be conceptualized as both status and resources and can be measured at the individual or community level. El-Sheikh et al[32] demonstrated that relations between SES and child sleep differed by SES measure, and that the associations between some indicators of SES and sleep were moderated by child ethnicity. Our measure was based on a neighborhood measure of SES using school decile. Although this measure correlated well with other demographic variables, such as parental income and parental education, there may have been some outlier families in both the low-and high-SES groups. Low SES based on neighborhood criteria is associated with increased risk of obstructive sleep apnea in children.[33,34] With regard to other sleep problems, findings can vary with different socioeconomic measures. For example, maternal education has been shown to be associated with decreased sleep efficiency and less time in bed[32,35] and parental education can moderate the effect of sleep problems on adverse cognitive outcomes.[26]

Another limitation in the current study is the small sample size. Because of this, the analyses had low power to detect differences between groups. Some of this disadvantage was overcome as groups were well matched. The prevalence of symptoms suggesting sleep-disordered breathing was not high in this cohort, so the effect of possible obstructive sleep apnea could not be assessed. However, this also meant we had a relatively healthy group without significant sleep problems, although sleep disorders were not specifically excluded. It would also have been useful to have more information about the quality of the sleep environment, particularly overnight temperature and measures of humidity. This will be explored in further studies. Also, we did not assess the child's chronotype. It is possible that individual differences in chronotype may have influenced bedtimes and rise times.

A further limitation of the study is that we were unable to determine whether there was systemic bias in the assessment of student performance by teachers. We did not measure the ethnicity of the teachers undertaking the assessment, but also we did not find that ethnicity was a risk factor for poor education outcomes in this group of children. If there was bias with regard to ethnicity it would be expected that this would be similar for Māori children at high-decile schools. We chose as our measure of educational outcome how children were assessed to be performing against national standards because it was the best objective assessment readily available. If there was bias with regard to the teachers' assessments it is more likely to have been related to perception of the child's SES rather than ethnicity.

This study provides, for the first time, data regarding the influence of ethnicity and SES on sleep in New Zealand children. These data indicate that SES influences sleep patterns but not the quality and quantity of sleep. We could not demonstrate a clear association between sleep variables, as recorded by actigraphy, and learning in this sample. This needs to be explored further in a larger study group. In this study, ethnicity (Māori versus NZE) was not an independent predictor of differences in the sleep measures tested.

ABBREVIATIONS

CI, confidence interval
CSHQ, Children's Sleep Habits Questionnaire
ECI, Equivalized Crowding Index
NZE, New Zealand European
SES, socioeconomic status
TST, total sleep time
WASO, waking after sleep onset

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