Association between sleep duration and haemoglobin A1c in young adults

Robert J Hancox,1 C Erik Landhuis2

ABSTRACT

Background Epidemiological and experimental evidence suggests that inadequate sleep can cause both obesity and impaired glucose tolerance. Short sleep duration in childhood appears to have a greater impact on the risk for adult obesity than adult sleep duration. The long-term effects of childhood sleep on glucose metabolism have not been investigated. The authors assessed the associations between childhood and adult sleep duration and adult glycosylated haemoglobin (HbA1c) levels.

Methods An unselected cohort of 1037 individuals, born in Dunedin, New Zealand, between 1972 and 1973. Parent reports of times in bed at ages 5, 7, 9 and 11 were used to estimate childhood sleep duration. Adult sleep duration was estimated from self-reported times in bed at age 32. HbA1c levels were measured at age 32. Pregnant women and participants with diabetes were excluded from the analyses.

Results Childhood sleep duration did not predict adult HbA1c. However, less time spent in bed at age 32 was associated with higher levels of HbA1c (p=0.002) and an increased risk of prediabetes (p=0.015). The inverse association between adult sleep times and HbA1c was independent of body mass index, smoking, socioeconomic status, shift work and symptoms of obstructive sleep apnoea.

Conclusions Short sleep duration is associated with higher levels of HbA1c and an increased risk of prediabetes in young adults. The findings suggest that inadequate sleep impairs glucose control in the short term and may increase the risk for long-term health problems.

INTRODUCTION

Chronic sleep deprivation is a common feature of modern life.1 Among the health concerns about inadequate sleep is the potential impact on metabolic function.2 Epidemiological studies have found short sleep duration to be associated with obesity,3 the metabolic syndrome,5 the development of diabetes5–11 and poor diabetic control.12 These epidemiological observations are supported by short-term studies of experimental sleep restriction, which have shown to alter glucose metabolism and increase insulin resistance.2 13–15 However, there is little information on the influence of differences in sleep duration on blood glucose levels in healthy non-diabetic adults in real life.

In a previous analysis of a birth cohort followed to adulthood, we found that less time in bed (as a measure of the time available for sleep) during childhood was a stronger predictor of risk for overweight and obesity in adulthood than concurrent adult estimates of sleep duration.16 This suggests that the metabolic consequences of sleep deprivation in childhood may be long lasting and of greater importance than recent sleep habits. Moreover, whereas there may have been little change in adult sleep habits over recent decades,17 there is evidence that children and adolescents are sleeping less than in previous generations.18 We are not aware of any studies of the long-term effects of childhood sleep duration on glucose metabolism. We therefore sought to assess the long-term and cross-sectional associations between time available for sleep during childhood and adulthood and glycosylated haemoglobin (HbA1c) levels at age 32 in the same birth cohort.

METHODS

The Dunedin Multidisciplinary Health and Development Study is a longitudinal study of the health and behaviour of an unselected birth cohort.19 Study members were born in Dunedin, New Zealand, between April 1972 and March 1973. All children still living in the Otago province were invited to participate in the first follow-up assessment at age 3. One thousand and thirty-seven children (91% of eligible births, 52% male) participated in this first assessment, forming the base sample for the longitudinal study. Study members were assessed every 2 years up to age 15 and again at ages 18, 21, 26 and most recently at age 32, when we assessed 96% (n=972) of the living study members. Study members represent the full range of socioeconomic status in the general population of New Zealand’s South Island and are primarily of New Zealand European ethnicity. Written informed consent was obtained for each assessment. The study is approved by the Otago Ethics Committee.

Sleep duration

The times spent in bed during childhood and adulthood are used as estimates of sleep duration. Information on time spent in bed during childhood was obtained from parental reports. At ages 5, 7 and 9, the parent attending with the study member reported what time the study member went to bed and what time they woke up the morning of the assessment day. At age 11, they reported what time the study member usually went to bed the night before and what time they woke up on the morning of the assessment day. At age 32, they reported what time the study members usually went to bed and what time they usually get up the morning. Parental reports of time in bed for all four ages were available for 84% of study members. The mean time in bed across these ages (based on a mean of 5.8 parental reports) was calculated as an estimate of childhood sleep duration between the ages 5 and 11.16

Time in bed was assessed at age 32, when the study members reported what time they usually go to bed and what time they usually get up. These
were used to estimate adult sleep duration. Study members were asked how often they did shift work. Shift workers were defined as those who reported that they worked more than occasional shifts. Those who worked varying shifts were asked to report their usual going to bed and getting up times for days when they worked day shifts.

**HbA1c**

Non-fasting blood samples were obtained at the same time of day for each study member approximately 4 h after lunch. HbA1c (expressed as a % of total haemoglobin) was measured on a Bio-Rad Variant II (Bio-Rad, Hercules, California, USA) using ion-exchange high-performance liquid chromatography, a method certified by the National Glycohemoglobin Standardization Programme (http:\www.missouri.edu/~diabetes/ngsp.html). The between-day coefficient of variation was 1.9%. Within-day coefficient of variation (based on paired duplicates, n=66) was 1.6%.

**Covariates**

At age 32, body weight was recorded using calibrated scales (Tanita BC-418, Tokyo, Japan) in light clothing to the nearest 0.1 of a kilogram. Height was measured to the nearest millimetre on a stadiometer, without shoes and with feet together and standing as tall as possible. Body mass index (BMI) was calculated in kilograms per square metre. Body fat percentage was measured via body impedance using the Tanita BC-418 Body Composition Analyser. Waist circumference was measured at the skin, using a steel tape, calibrated in centimetres with millimetre gradations at the level of the noticeable waist narrowing located approximately half way between the costal border and the iliac crest; it was measured at the time of greatest expiration and with instructions to relax the diaphragm. Measurements were taken twice, and the mean of the two readings was calculated. Current smoking at age 32 was defined as smoking at least one cigarette a day for a month during the last 12 months. Socioeconomic status during childhood was based on parental occupation according to the Elley–Irving score (1=high, 6=low) and recorded as the average of the highest socioeconomic status of either parent assessed on multiple occasions between birth and age 15 as previously reported.16 Adult socioeconomic status at age 32 was assessed from the skin, using a steel tape, calibrated in centimetres with millimetre gradations at the level of the noticeable waist narrowing located approximately half way between the costal border and the iliac crest; it was measured at the time of greatest expiration and with instructions to relax the diaphragm. Measurements were taken twice, and the mean of the two readings was calculated. Current smoking at age 32 was defined as smoking at least one cigarette a day for a month during the last 12 months. Socioeconomic status during childhood was based on parental occupation according to the Elley–Irving score (1=high, 6=low) and recorded as the average of the highest socioeconomic status of either parent assessed on multiple occasions between birth and age 15 as previously reported.16

Adult socioeconomic status at age 32 was assessed from the participants’ own occupation using the same index at age 32. Homemakers and those not in paid employment were assigned an equivalent score based on their qualifications and previous employment. At age 32, participants also completed the Berlin Sleep Questionnaire to identify risk for sleep apnoea syndrome.19 This assesses the risk for obstructive sleep apnoea based on three categories: (1) reported snoring and witnessed sleep apnoeas; (2) daytime sleepiness and (3) high blood pressure or obesity. A positive score for two or more of these categories indicates a high risk for obstructive sleep apnoea. We did not include obesity in our Berlin risk assessment because BMI was included as a separate covariate in the analyses.

**Statistical analyses**

Associations between childhood and adult sleep duration and HbA1c at age 32 were initially tested separately using linear regressions with adjustment for sex. Further analyses included both childhood and adult sleep times, sex, childhood and adult socioeconomic status, night shift work, adult smoking and BMI, per cent body fat or waist circumference. To test whether any association was explained by obstructive sleep apnoea syndrome, further analyses included risk of sleep apnoea syndrome assessed by the number of positive symptom categories and reported high blood pressure according to the Berlin Questionnaire. To take into account the changing sleep times across childhood and fact that some study members did not provide bedtimes data for all four ages in childhood, the analyses were repeated using the mean of standardised (z scores) sleep times from each age.

Pregnant women (n=31) and study members with diabetes (n=7) were excluded from all analyses. Another individual with an HbA1c level of 8.6% was also excluded on the basis that they probably had undiagnosed diabetes.20 All other study members had levels ≤6.5%. HbA1c levels within the range 5.7%–6.5% were classified as prediabetic.20 Associations between prediabetes and child and adult sleep times were analysed by logistic regression with and without adjustment for the above covariates.

Further analyses tested for sex × sleep interactions and assessed male and female study members separately. Analyses also tested for non-linear associations using quadratic terms for child and adult bedtime. We checked linear regression models by visual inspection of the residuals to ensure that they were normal in distribution and that they were randomly scattered versus the fitted values.

All analyses were conducted using Stata V.10 (StataCorp.).

**RESULTS**

Summary information on reported times in bed during childhood and adulthood, HbA1c levels, smoking status and BMI are shown in table 1. HbA1c levels were lower in women than in men. Twenty-five women (6.2%) and 38 men (8.4%) had HbA1c levels in the prediabetic range of 5.7%–6.5%. Women spent more time in bed than men in both childhood and adulthood.

| Table 1 Summary statistics for childhood and adult sleep times, HbA1c levels and covariates |
|---------------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Women                                      | Men                 |                      |                      |                      |
|                                             | n     | Mean (SD) | 95% CI    | n     | Mean (SD) | 95% CI    | p Value   |
| Childhood sleep (h)                        | 399   | 11.20 (0.52) | 11.14 to 11.25 | 444   | 11.10 (0.55) | 11.05 to 11.15 | 0.0125   |
| Adult sleep (h)                            | 402   | 8.38 (1.06)  | 8.27 to 8.48   | 443   | 7.91 (1.04)  | 7.81 to 8.01  | <0.0001  |
| HbA1c levels (%)                           | 403   | 5.23 (0.29)  | 5.20 to 5.26   | 450   | 5.28 (0.31)  | 5.25 to 5.30  | 0.030    |
| BMI (kg/m²)                                | 402   | 25.8 (5.5)   | 25.3 to 26.3   | 450   | 26.3 (4.2)   | 25.9 to 26.7  | 0.111    |
| Smokers                                    | 403   | 137         | 34.0         | 450   | 166         | 36.9       | 0.378    |
| Night shift workers                        | 402   | 17          | 4.2          | 446   | 41          | 9.2        | 0.004    |
| Berlin score ≥2                            | 401   | 46          | 11.5         | 446   | 46          | 10.3       | 0.589    |
| Obese (BMI ≥30)                            | 402   | 76          | 18.9         | 450   | 68          | 15.1       | 0.140    |

*Values indicate differences between men and women using t tests or χ² tests.

BMI, body mass index.
The sex-adjusted partial correlation between sleep time in childhood and adulthood was 0.02 (p=0.654).

**Childhood sleep duration**

There were no statistically significant associations between average childhood sleep time and adult levels of HbA1c in either sex-adjusted or multiply adjusted regression analyses (tables 2 and 3). There was no statistical evidence of an interaction between sex and childhood sleep duration and there were no associations between childhood sleep time and HbA1c when the sexes were analysed separately. There was also no evidence of a non-linear effect when tested using a quadratic term for sex-adjusted or multiply adjusted regression analyses (tables 2 and 3). There was no statistical evidence that the association between childhood sleep time and HbA1c was different for men and women (sex-by-sleep interaction term p=0.47), although the association achieved statistical significance only in women when the sexes were tested separately. Visual inspection of the residuals from the regression analyses suggested the possibility that the analyses may have been influenced by a small number of extreme sleep values at age 52. We therefore divided the cohort into sex-specific half-hour categories of sleep time. For both men and women, those who spent the least time in bed had the highest HbA1c levels (figure 1). There was little difference between HbA1c levels among the other categories of sleep time suggesting that there might be a threshold effect. However, there was no statistical evidence of a non-linear association when using a quadratic term for sleep duration in a sex-adjusted linear regression analysis (p=0.52).

**Adult sleep duration**

Table 2  Sex-adjusted associations between childhood and adult sleep times and adult HbA1c levels

<table>
<thead>
<tr>
<th>HbA1c</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>Standard coefficient</th>
<th>p Value</th>
<th>OR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Childhood sleep (n=843)</td>
<td>-0.01</td>
<td>-0.05 to 0.03</td>
<td>-0.02</td>
<td>0.568</td>
<td>1.03 (0.63 to 1.66)</td>
<td>0.914</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.046</td>
<td>0.005 to 0.087</td>
<td>0.075</td>
<td>0.029</td>
<td>1.40 (0.83 to 2.37)</td>
<td>0.206</td>
</tr>
<tr>
<td>Adult sleep (n=845)</td>
<td>-0.031</td>
<td>-0.050 to -0.011</td>
<td>-0.109</td>
<td>0.002</td>
<td>0.75 (0.59 to 0.94)</td>
<td>0.015</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.031</td>
<td>-0.010 to 0.073</td>
<td>0.052</td>
<td>0.141</td>
<td>1.24 (0.73 to 2.12)</td>
<td>0.426</td>
</tr>
</tbody>
</table>

Coefficients represent unstandardised regression coefficients from linear regression; these values represent the unit change in HbA1c (%) associated with an hour increase in sleep time or a unit change in the covariates. Standardised coefficients represent the SD change in HbA1c associated with each SD change in sleep time or the covariates. ORs are from logistic regression analyses and represent the change in the odds of prediabetes associated with each 1 h increase in sleep time or unit change in the covariates.

In this cohort of young adults, less time spent in bed was associated with higher levels of HbA1c and a higher prevalence of prediabetes. This association was independent of sex, BMI, smoking, socioeconomic status, childhood sleep times, symptoms of obstructive sleep apnoea and whether the individual worked night shifts. The findings suggest that lack of sleep adversely affects glucose metabolism even among people without diabetes and that these effects are independent of the influence of sleep on overweight and obesity.

We did not find an association between time spent in bed during childhood and adult HbA1c levels. This finding contrasts with our earlier analysis that found that less time in bed during childhood was associated with adult overweight and was a stronger predictor of adult obesity than adult sleep time. Along with several other epidemiological studies, we found that the association between sleep duration and glucose metabolism/diabetes risk is not mediated by obesity.6 9 10 These observations may indicate that there are different mechanisms for the

**CONCLUSIONS**

reported in table 2. This association was of borderline significance after further adjustment for BMI, smoking, child and adult socioeconomic status, and night shift work (table 3).

<table>
<thead>
<tr>
<th>HbA1c</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>Standard coefficient</th>
<th>p Value</th>
<th>OR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Childhood sleep time</td>
<td>-0.008</td>
<td>-0.047 to 0.031</td>
<td>-0.014</td>
<td>0.687</td>
<td>1.10 (0.69 to 1.77)</td>
<td>0.692</td>
</tr>
<tr>
<td>Adult sleep time</td>
<td>-0.028</td>
<td>-0.048 to -0.008</td>
<td>-0.099</td>
<td>0.006</td>
<td>0.79 (0.63 to 1.00)</td>
<td>0.052</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.029</td>
<td>-0.013 to 0.072</td>
<td>0.048</td>
<td>0.179</td>
<td>1.21 (0.70 to 2.09)</td>
<td>0.485</td>
</tr>
<tr>
<td>Adult BMI</td>
<td>0.006</td>
<td>0.002 to 0.010</td>
<td>0.093</td>
<td>0.008</td>
<td>1.06 (1.02 to 1.12)</td>
<td>0.010</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.062</td>
<td>0.017 to 0.107</td>
<td>0.097</td>
<td>0.008</td>
<td>1.31 (0.75 to 2.29)</td>
<td>0.338</td>
</tr>
<tr>
<td>Childhood SES</td>
<td>0.014</td>
<td>-0.005 to 0.033</td>
<td>0.053</td>
<td>0.144</td>
<td>0.97 (0.76 to 1.23)</td>
<td>0.788</td>
</tr>
<tr>
<td>Adult SES</td>
<td>0.000</td>
<td>-0.015 to 0.015</td>
<td>0.000</td>
<td>0.992</td>
<td>0.93 (0.77 to 1.13)</td>
<td>0.457</td>
</tr>
<tr>
<td>Night shift worker</td>
<td>-0.028</td>
<td>-0.111 to 0.056</td>
<td>-0.023</td>
<td>0.512</td>
<td>1.93 (0.86 to 4.35)</td>
<td>0.110</td>
</tr>
</tbody>
</table>

Coefficients represent unstandardised regression coefficients from linear regression; these values represent the unit change in HbA1c (%) associated with an hour increase in sleep time or a unit change in the covariates. Standardised coefficients represent the SD change in HbA1c associated with each SD change in sleep time or the covariates. ORs are from logistic regression analyses and represent the change in the odds of prediabetes associated with each 1 h increase in sleep time or unit change in the covariates.

Inadequate sleep may also influence glucose homeostasis by disruption of circadian rhythms and clock gene function and by altering autonomic nervous system activity. Sleep disruption caused by obstructive sleep apnoea is also associated with abnormal glucose metabolism. Although we did not observe an association between symptoms of obstructive sleep apnoea and HbA1c levels in this cohort, it is possible that sleep disruption due to asymptomatic apnoeas led some participants to spend less time in bed. These effects may become more important as the cohort ages and the prevalence of obstructive sleep apnoea increases.

The consequences of these findings for health are not yet clear. The inverse association that we have observed between time spent in bed in adulthood and HbA1c levels is cross-sectional in nature and we are unable to prove a causal association. Nor can we show that inadequate sleep will lead to long-term adverse effects. However, we found that those who spent less time in bed had a higher risk for prediabetes, which is associated with a greatly increased risk of developing diabetes. Moreover, even within the non-diabetic range, higher levels of HbA1c are associated with increased risk of cardiovascular disease. Based on the standardised regression coefficients, the strength of the association between sleep time and HbA1c levels was of a similar magnitude to the association between BMI and HbA1c levels (table 5). Hence, it seems likely that sustained sleep restriction will have important adverse effects of health due to impaired glucose metabolism, although we cannot quantify these effects at present.

This study has a number of strengths. It is a population-based cohort with a high rate of participation. All participants were aged 32, so we can exclude age-related effects on glucose metabolism or sleep duration. We have also been able to adjust for a number of potential confounding factors such as shift work and BMI. The main weakness is the fact that bedtimes were parent reported or self-reported and are likely to contain errors. The validity of parental reports of children’s bedtimes is uncertain and it is possible that errors in these reports resulted in the lack of association between children’s time in bed and adult HbA1c levels, although we have previously found that parents’ reports of childhood time in bed did predict the risk for adult obesity. We also do not know how much of the time in bed

What is already known on this subject

Inadequate sleep impairs insulin sensitivity and is associated with an increased risk of diabetes and obesity in adults. The effects of sleep duration on glucose levels in non-diabetic adults are unknown. Short sleep duration in childhood is associated with an increased long-term risk for adult obesity, but there are no data on the long-term effects on blood glucose levels.

What this study adds

Shorter sleep times are associated with higher levels of glycosylated haemoglobin in adults, but childhood sleep time does not predict adult glucose control. Increasing sleep time in childhood may help to reduce the risk for adult obesity but is unlikely to have an independent long-term influence on blood glucose levels.
was spent sleeping nor the quality of the sleep obtained. It seems unlikely that these problems would introduce a systematic bias to the findings since neither the participants nor the interviewers would have been aware of their HbA1c levels. Such measurement errors would be more likely to reduce the strength of the association between time in bed and HbA1c levels.

In summary, we have found a cross-sectional association between HbA1c levels and reported time in bed among a general population sample of young adults. This association was independent of BMI and a number of potential confounding factors. This suggests that a short sleep duration has adverse effects on glucose metabolism in young adults.

Acknowledgements We are grateful to the study members and their families and friends for their continued support. We thank Dr Phil A Silva, the study founder, and Professor Richie Poulton, the current director.

Funding The Dunedin Multidisciplinary Health and Development Research Unit is funded by the Health Research Council of New Zealand. This research was also supported by UK MRC grants G0100527, G0601483, US-NIMH grants MH45070 and MH94914, and the William T. Grant Foundation.

Competing interests None declared.

Ethics approval Otago Ethics Committee.

Contributors RJH developed the concept, reviewed the literature, collected and analysed data, and wrote the manuscript. CÉL also developed the concept, reviewed the literature, analysed data and edited the manuscript.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES