Trajectories and stability of self-reported short sleep duration from adolescence to adulthood

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SUMMARY

The trajectories and stability of self-reported sleep duration recorded at ages 13, 15, and 23 years on reported sleep duration at age 30 years among 1105 students (55% male) who participated in the Norwegian Longitudinal Health and Behaviour Study were examined. Questionnaire data were used to obtain demographic and sleep variables. Dichotomised short sleep duration was based on normative values and set as ≤8.5 h (age 13 years), ≤8 h (age 15 years) and ≤7 h (ages 23 and 30 years). Results indicated a significant overall reduction in total sleep duration (h per night) across age groups. Sleep duration (continuous) at age 15 and 23 years (whole group) was moderately but positively correlated with sleep duration at age 30 years ($P < 0.01$). When split by sex, at age 15 years, this association was present among females only ($P < 0.01$); however, at age 23 years, this association was present in both male and females (both $P < 0.001$). Categorical short sleep at age 23 years (whole group) was associated with short sleep at age 30 years (unadjusted odds ratio = 3.67, 95% confidence interval 2.36–5.69). Following sex stratification, this effect was significant for both males (unadjusted odds ratio = 3.77, 95% confidence interval: 2.22–6.42) and females (unadjusted odds ratio = 2.71, 95% confidence interval: 1.46–5.04). No associations were noted for categorical short sleep at ages 13 or 15 years, and subsequent short sleep at 30 years. Habitual short sleep duration during middle adulthood is not sustained from the time of early adolescence. Rather, these trends appear to be formed during early adulthood.

INTRODUCTION

Effective and regular regulation of the sleep/wake cycle is fundamental in order to maintain optimal biological, metabolic and physical functioning; however, it is often exogenously mediated by aspects of socio-cultural, psychosocial, occupational and familial demands (Iglowstein *et al.*, 2003). A number of cross-sectional and longitudinal studies have demonstrated that both long and short habitual sleep periods present as independent risk factors for impaired cardiovascular functioning and subsequent increased rates of cardiovascular disease (Ayas *et al.*, 2003; Qureshi *et al.*, 1997), increased weight (Patel and Hu, 2008) and higher rates of obesity (Buxton and Marcelli, 2010), reduced immune function (Cohen *et al.*, 2009), and an increased risk for all-cause mortality (Cappuccio *et al.*, 2010; Ferrie *et al.*, 2007).

Sleep problems are common among children and adolescents, with as many as 76% of 11–15 year olds surveyed reporting some degree of sleep difficulties (Ipsiroglu *et al.*, 2002). Complaints of difficulty initiating or maintaining sleep

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constitute some of the most common issues (Kecklund and Åkerstedt, 1992; Morphy *et al.*, 2007); however, these symptoms appear to decrease somewhat with age (Laberge *et al.*, 2001; Quach *et al.*, 2009). Habitual total sleep duration has been shown to be highly variable, at least among young children and during periods of early adolescence (Iglowstein *et al.*, 2003; Jenni *et al.*, 2007); however, the onset of early maladaptive sleep habits may have implications for the later development of sleep problems during subsequent developmental phases. Evidence from cross-sectional and longitudinal analyses suggests that the natural course of human sleep maturation has important developmental phases during infancy. Sleep patterns formed during infancy are to some extent carried forward to later periods of childhood (Hysing *et al.*, 2014), and may have further implications in the expression of habitual short and long sleep duration and continuity throughout early adolescence to adulthood (Al Mamun *et al.*, 2012; Magee *et al.*, 2014).

Despite the significant clinical implications of assessing sleep duration from periods of adolescence to adulthood, several areas of investigation still remain. Most notably, there is currently a paucity of detailed longitudinal analyses assessing the stability of sleep duration over time, and it is unclear whether critical age ranges exist in the expression and development of these associations. Moreover, little research is available that examines these factors across extended assessment periods. Of the available studies assessing the natural course and stability of sleep duration and periods of short sleep, much of the literature focuses on periods of childhood (Jenni *et al.*, 2007) or restricted periods of adolescence (Jansson and Linton, 2006).

Given that sleep duration is strongly associated with many chronic yet preventable conditions, a more accurate description of these associations may augment available treatment modalities and improve clinical outcomes for these patients. As a result, the aims of the current study are: (i) to assess the natural development and stability of sleep duration from ages 13, 15, and 23 years to 30 years; and (ii) to identify the association between short sleep duration at ages 13, 15, and 23 years on cases of short sleep duration at age 30 years.

MATERIALS AND METHODS

This study utilises data collected as part of the Norwegian Longitudinal Health and Behaviour Study (NLHB). The NLHB is a nine-wave, cluster-sample research study that followed a cohort of adolescents from age 13 years (initial testing period 1990) to 30 years (final follow-up in 2007). As part of the initial wave in 1990, a total of 1195 adolescents aged 13 years and their parents were invited to participate in the study. An additional 47 students were invited to participate during the two subsequent data collection waves 2 and 3 in 1991 and 1992, resulting in a total sample of 1242. Inclusion for the study required consent from both the adolescent and the parent/guardian, which resulted in a total of 1105 (55% male) students (89% of the total invited sample).

The retention rate at age 30 years is 49% (based on the number of persons who had participated at least once during ages 13–21 years), representing 43% of the original sample.

A more detailed description of the sampling procedures and data collection methods used in the NLHB study can be found elsewhere (Birkeland *et al.*, 2009; Jakobsen, 1997).

Study questionnaires were distributed at the participants' school initially (at ages 13–15 years), and were then distributed by mail to the respondents' home addresses for each subsequent follow-up assessment period. Sleep variables were not measured during all data collection waves, and for this reason data were only used from the 1990, 1992, 2000, and 2007 waves, for the age groups of 13, 15, 23, and 30 years, respectively.

Written informed consent was obtained for each study participant, and the study has been approved by the Norwegian Data Inspectorate. The study was approved by The Regional Committee for Medical Research Ethics in Western Norway.

Variables

Demographics

Sex was first reported in the initial data collection wave in 1990, and was noted at the time of each follow-up in order to assess sex distribution for each study wave.

Sleep variables

Information regarding subjective sleep was collected via self-report at the time of each data collection wave, and information regarding self-reported bedtimes and wake times was obtained separately for both weekdays and weekends. For the current study, only information regarding weekday sleep duration was used. Questionnaire items were modified slightly to include age-relevant statements (i.e. refers to school/work). Response options for bedtimes were graded on a five-point scale. Response options for weekday bedtimes included the following: 'about 21:30 hours or earlier'; 'about 22:00 hours'; 'about 22:30 hours'; 'about 23:00 hours'; or 'about 23:00 hours or later'. Questionnaire items 'time getting up on a school/work day' were presented on a four-point scale, and included response options: 'about 06:30 hours or earlier'; 'about 07:00 hours'; 'about 07:30 hours'; or 08:00 hours or later'. Self-reported sleep-onset latency during weekdays was obtained via the questionnaire item: 'how long does it take for you to fall asleep?' Response options were presented in a continuous format (hh : mm). Estimates of weekday sleep-onset latency were used only as they are more stable data.

Total sleep duration was calculated by the self-reported time in bed (calculated from total difference between bedtime and rise time: hh : mm) minus self-reported sleep latency. These methods have also been employed by studies assessing the correlates of sleep duration among similar

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cohorts (Bjorvatn *et al*., 2007; Ursin *et al*., 2005). For this study, 'short' and 'normal' sleep duration were classified differently for each data collection wave, in order to account for age-related differences with regard to normative sleep values frequently reported for each age group (Iglowstein *et al*., 2003; Olds *et al*., 2010). Short sleep duration at age 13 years (wave 1 – 1990) was defined as ≤8.5 h (31.4%), and normal sleep was >8.5 h per night. Short sleep duration at age 15 years (wave 2 – 1993) was defined as ≤8 h (31.9%), and normal sleep duration was >8 h. Sleep duration of ≤7 h was considered 'short' for those aged 23 years (25.5%) and 30 years (29.8%; waves 3 and 4 – 2000 and 2007, respectively), with >7 h considered within the normal range.

Analyses

To illustrate the trajectories of short sleep across the four waves (Figs 1a,b), the dichotomised sleep duration variables (using the age-based cut-offs) were used to create the six most common courses from age 13 to 30 years (Fig. 1a), and 30 to 13 years (Fig. 1b). Assessment of the association between sleep duration in 2007 and previous waves indicated a reasonable number of categories and dispersion, and little indication of a marked non-monotonic association was noted. The number of categories and dispersion were similar when stratified for gender (results not shown). Chi-square analyses were used to assess differences in dichotomised sleep duration (short versus normal) between those who completed all data waves and those who had missing sleep data on any of the four data waves. One-way ANOVA was used to assess differences in average sleep duration between those who completed all data collection waves and those who had missing sleep data on any of the four data waves. ANOVA with repeated measures with Greenhouse–Geisser correction and Bonferroni *post hoc* tests were used to test for differences in sleep duration across the four waves. Spearman rank-order correlation coefficients (Spearman's Rho) were used to assess the correlations between sleep duration (continuous) at ages 13, 15, and 23 years with sleep duration at age 30 years. Binary logistic regression modelling was used to examine short sleep duration (yes/no) at ages 13, 15, and 23 years as a predictor of reporting poor sleep at age 30 years (yes/no). Statistical analyses including Chi-square analyses, one-way ANOVA and Spearman rank-order correlation coefficient (Spearman's Rho) were assessed using the SPSS statistical software package version 21 (SPSS, Chicago, IL, USA), and all tests were two-tailed with conventional

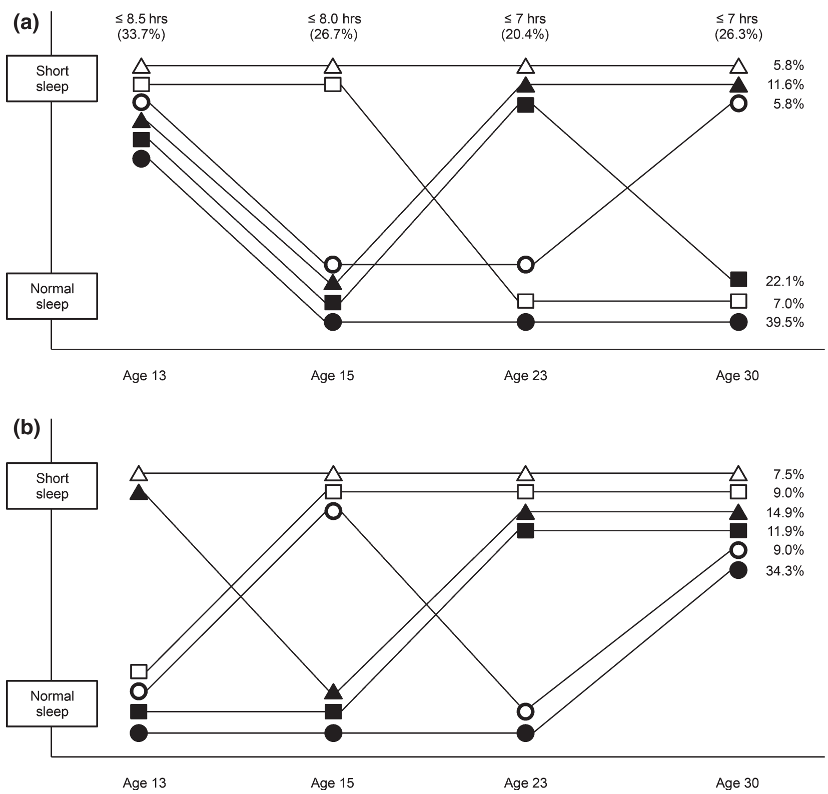

Figure 1. The most common trajectories of short sleep duration across all four time points from age 13 to 30 years. (a) The most common trajectories leading from short sleep duration at age 13 years. For example, among participants with short sleep duration at age 13 years, 5.8% were classified as having short sleep duration throughout all waves (trajectory indicated with white triangles). (b) The most common trajectories leading to short sleep duration at age 30 years. For example, among participants with short sleep duration at age 30 years, 7.5% had short sleep duration also at all previous waves (trajectory indicated with white triangles).

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$P < 0.05$ as significance threshold. Due to missing information about sleep duration across waves, the multiple missing imputation procedure using the multivariate normal approach with five imputations as available in Stata 13.1 for the binary logistic regression models was employed.

RESULTS

Characteristics

Characteristics data and information for sleep variables across all data collection waves for the whole group are presented in Table 1. Sex distribution was comparable for each data collection wave; however, more female participation was noted for the two later waves (waves 3 and 4 – ages 23 and 30 years, respectively) and more males were noted for the first two waves (waves 1 and 2 – ages 13 and 15 years, respectively). Total sleep duration (hh : mm) was noted to decrease significantly as per each data collection wave ($F_{2.7,621.5} = 281.6$, $P < 0.001$). While the average sleep duration at age 13 and 15 years was 9:01 and 8:38, this was reduced to 7:50 and 7:38 at age 23 and 30 years, respectively (all $P < 0.001$). A general reduction was observed for those reporting both ≥10 and 9 to <10 h of sleep per night across age groups, and a general increase was seen among those reporting 7 to <8 h across age groups. A sleep duration of 8 to <9 h was most stable across age groups.

Short sleep versus normal sleep

Fig. 1a describes the developmental trajectory of those individuals who self-reported short sleep duration compared with normal sleep duration at age 13 years through to age 30 years. A large proportion of individuals (39%) who reported short sleep at age 13 years reported a stabilisation of normal sleep duration by age 15 years, of which remained until age 30 years. The second most common developmental trajectory profile (22.1%) was noted for those individuals who reported short sleep at age 13 years and were noted to alternate between short and normal sleep duration over the duration of the assessment waves. Only a small proportion (5.8%) of individuals reported instances of sustained short sleep from early adolescence (age 13 years) through to mid-adulthood (age 30 years). A comparable proportion of individuals (5.8%) was noted to initially report short sleep duration at age 13 years then report normal sleep duration during late adolescence/early adulthood (ages 15 and 23 years), only to again report short sleep at age 30 years. Seven percent of individuals who reported short sleep during both sampling periods of adolescence (ages 13 and 15 years, respectively) reported a stabilisation of normal sleep duration during adulthood (ages 23 and 30 years, respectively).

Fig. 1b displays the reverse developmental trajectory of those individuals who reported short sleep duration compared with normal sleep duration at age 30 years from age 13 years. The most common trajectories leading to short sleep duration at age 30 years were seen among individuals who reported normal sleep duration up until age 23 years (34.3%). A small percentage of individuals who reported short sleep duration at age 30 years were seen to initially report normal sleep at age 13 years until 15 years, or alternate between normal and short sleep between waves (both 9.0%). Only a small proportion of individuals (7.5%) reported consistently short sleep from age 13 years until age 30 years.

Sleep duration

To assess the predictive value of self-reported short sleep duration (dichotomised) at ages 13, 15, and 23 years on short sleep duration at 30 years, binary logistic regression modelling was applied (Fig. 2). For the whole group, short sleep duration at age 23 years was associated with short sleep at age 30 years [unadjusted odds ratio (OR) = 3.67, 95% confidence interval (CI): 2.36–5.69]. Following sex stratification, this association was similarly observed among males (unadjusted OR = 3.77, 95% CI: 2.22–6.42) and females (unadjusted OR = 2.71, 95% CI: 1.46–5.04).

Table 1 Demographics and sleep variables for whole sample

	Age 13 years (n = 653)		*Age 15 years (n = 855)*		*Age 23 years (n = 560)*		*Age 30 years (n = 493)*	
Sex								
Girls, % (*n*)	46.9%	(306)	45.3%	(387)	54.8%	(307)	54.6%	(269)
Boys, % (*n*)	53.1%	(347)	54.7%	(468)	45.5%	(253)	45.4%	(224)
Sleep duration, mean (SD)	8 : 58	(0 : 33)	8 : 31	(0 : 35)	7 : 45	(0 : 50)	7 : 36	(0 : 45)
Sleep duration, % (*n*)								
<7 h	–	–	–	–	11.4%	(64)	11.6%	(57)
7 to <8 h	2.6%	(17)	8.4%	(72)	37.5%	(210)	48.1%	(237)
8 to <9 h	28.8%	(188)	56.4%	(482)	39.5%	(222)	35.1%	(173)
9 to <10 h	62.0%	(405)	33.1%	(283)	9.8%	(55)	4.5%	(22)
≥10 h	6.6%	(43)	2.1%	(18)	1.6%	(9)	0.8%	(4)

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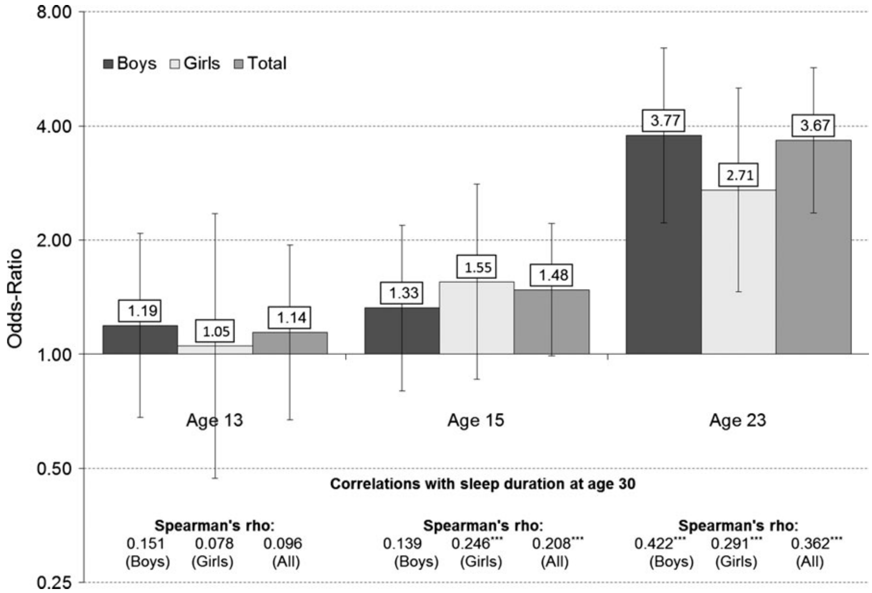

Figure 2. Short sleep duration (dichotomised) at ages 13, 15 and 23 years, and risk factor for short sleep duration at age 30 years, and Spearman's rank-order correlations (Rho) based on the continuous sleep duration variables. Bars represent odds ratios (OR) and error bars represent 95% confidence intervals (CI; *y*-axis has a logarithmic scale). For example, the bar furthermost to the right shows that participants with short sleep duration at age 23 years had 3.67-fold increased odds of having short duration at age 30 years. Similarly, the corresponding correlation between (continuous) sleep duration at age 23 and 30 years was 0.362.
Note: Logistic regression analyses are based on a multiple imputed dataset, whereas correlation analyses are based on the non-imputed dataset. ***$P < 0.001$.

Chi-square analyses assessing differences between completers versus non-completers, and short versus normal sleep duration (data not shown) revealed that the proportion of short sleepers is lower among those who completed all data waves for ages 15, 23, and 30 years (all $P < 0.05$), but not age 13 years.

Associations between self-reported sleep duration (continuous) at ages 13, 15, and 23 years, and at age 30 years, were assessed using Spearman rank-order correlation coefficient (Spearman's Rho). A moderate positive association was noted for self-reported sleep duration at age 15 years and similarly reported sleep habits at age 30 years (Spearman's Rho 0.208, $P < 0.001$; see Fig. S1); however, when split by sex, this association was present among females only (Spearman's Rho 0.246, $P < 0.001$). The corresponding correlation between self-reported sleep duration at ages 23 and 30 years was notably stronger (Spearman's Rho 0.362, $P < 0.001$; see Fig. S2). When split by sex, this association was present among both males (Spearman's Rho 0.422, $P < 0.001$) and females (Spearman's Rho 0.291, $P < 0.001$). No associations were noted for self-reported sleep duration for those aged 13 years on sleep duration at age 30 years (see Fig. S3).

One-way ANOVA revealed that, compared with non-completers, participants who completed all four data (13, 15, 23 and 30 years) waves reported increased sleep duration during the second data collection wave (1992 – 15 years) than those who did not complete data collection ($P = 0.004$). No differences were noted between groups for any other data collection wave.

DISCUSSION

The findings of the current study were in line with previous research, which has demonstrated that a general trend exists for a reduction in self-reported sleep duration with increasing age. We also report that self-reported sleep duration at age 15 and 23 years (whole group) is positively associated with self-reported habitual sleep duration at age 30 years; however, when split by sex, this association is differentially represented between males and females across ages. Assessment of the most common developmental trajectories of poor sleep showed that a large proportion of those who reported short sleep duration during early adolescence (13 years) had stabilised into periods of normal sleep at the time of mid-adolescence to adulthood (ages 15–30 years), and that the development of poor sleep at age 30 years occurs most frequently during periods of early adulthood (23 years).

A gradual reduction in total sleep duration (hh : mm) as a function of increasing age was reported. These findings mirror other longitudinal assessments of sleep duration among population-based cohorts that have used similar age ranges (Hysing *et al*., 2014) and self-report measures (Iglowstein *et al*., 2003). Such changes are thought to primarily reflect changes in biologically driven sleep homeostatic needs as we age (Cajochen *et al*., 2006), however they are similarly recognised to be mediated and influenced by a number of sociocultural, familial and occupational demands characteristic of each life stage. A large portion of the participants in the current study reported obtaining a habitual

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nightly sleep duration, which is considered to fall within the normative limits for each age range (Iglowstein *et al.*, 2003; Riemann *et al.*, 2010); however, approximately 1/10th of those aged both 23 and 30 years reported obtaining less than 7 h of sleep per night. Given the aforementioned health implications of short sleep duration, some vigilance is needed among these individuals in order to maintain optimal associated health outcomes.

Habitual sleep duration has been shown to be highly variable among individuals from periods of childhood and adolescence (Iglowstein *et al.*, 2003; Jansson and Linton, 2006; Wolfson and Carskadon, 1998); however, interpretation of the stability of these factors over time is often impeded by the relatively short assessment duration. It was demonstrated that, for the whole group, self-reported sleep duration at age 15 and 23 years is moderately positively associated with reporting similar sleep duration at age 30 years. Indeed, a trend of late-onset cases of short sleep duration was noted among this cohort, a finding that was somewhat similarly reflected in the assessment of common developmental trajectories leading to short sleep duration at age 30 years (Figs 1a and b). When split by sex, this association is differentially represented between males and females across ages. At age 15 years, this association was present among females only. At age 23 years, this relationship was found in both sexes. The strength of the trajectories of sleep duration through the adolescent to adulthood transition period was weaker than is often asserted for younger age groups (Magee *et al.*, 2014). Thus, it is possible that interplay between occupational and socio-cultural demands during these life stages, particularly during periods of later adolescence, contribute to sleep duration (Jansson and Linton, 2006). Indeed, that there was no association between sleep duration at age 13 years and age 30 years suggests that sleep disturbances experienced early resolve themselves with age and are not persistent, a finding that is concurrent with the limited research describing a general reduction in sleep complaints as a function of increasing age (Quach *et al.*, 2009). Despite these observations, a large degree of intra-individual variation exists with regard to self-reported sleep duration across the lifespan, often as a function of differing occupational, social and health-related factors associated with that particular life stage. As the causative pathways attenuating this relationship remain unconfirmed, there is a need for additional comprehensive longitudinal assessments of the stability of these trends over time.

There is little research assessing the stability of categorical short sleep duration from periods of early adolescence to mid-adulthood. As short sleep duration has been previously linked to deleterious health outcomes (Buxton and Marcelli, 2010; Patel and Hu, 2008), it is therefore surprising that little detailed assessment in this area is currently available. It has been demonstrated that those who reported categorical short sleep duration at age 23 years (whole group) had greater than a 3.6-fold increased odds of similarly reporting short sleep at age 30 years. Following sex stratification, it was demonstrated that men who reported short sleep duration at age 23 years had greater than a 3.7-fold increased odds of similarly reporting short sleep at age 30 years and, among women, these odds were increased approximately 2.7-fold. No such effect was noted for those who reported categorical short sleep at age 13 years or 15 years similarly reporting short sleep at age 30 years. To the authors' knowledge, this is the first research to demonstrate that self-reported short sleep during early adulthood (23 years) predicts instances of short sleep duration in mid-adulthood (30 years). Research investigating the stability and trajectory of sleep duration across the lifespan is typically restricted to periods of childhood or adolescence, or measures different aspects of maladaptive sleeping behaviours (Al Mamun *et al.*, 2012). This may in part be due to the greater perceived necessity of these developmental periods in respect to health outcomes later in life. Whilst assessments during these times are indeed valuable, descriptions of these trends during later developmental periods may have implications for sleep habits later in life. Given the organic changes in sleep architecture as we age, the early development of adaptive sleep habits may foster improved outcomes during these periods.

The current study has several identifiable strengths. Most notably, to the authors' knowledge, this study is the largest assessment of the trajectories and stability of self-reported sleep duration across an extended period of time from early adolescence to mid-adulthood. The use of a longitudinal design and inclusion of a representative cohort of participants allowed to track the stability of these trends over time, and across several critical developmental phases, thus addressing several of the limitations of past research. Moreover, the use of a large, representative, community-based sample combined with the generally high retention rate of participants across data collection waves enables greater generalisability of the reported findings to comparable populations.

The result from this study must be interpreted in light of some methodological limitations. Most notably, the sleep variables used in this study were obtained via self-report questionnaire only, and were not corroborated by additional objective sleep-monitoring devices. However, in-depth analyses and description of objective sleep variables among these participants was not an aim of this study. Secondly, self-reported sleep duration was not assessed to the exact hours and minutes, and was instead defined using predefined categories. Therefore, some of the more subtle changes over time may have been overlooked, and thus no inferences on these trends were able to be made. Further, it is possible that participants under- or overestimated their total sleep time, a factor that may have somewhat attenuated the reported findings. Despite this, a number of longitudinal and cross-sectional studies have utilised similar methods (Jansson-Fröjmark and Lindblom, 2008; Manber and Chambers, 2009), and the use of pre-determined response categories may better assist in describing overall trends in sleep duration at a population level. Lastly, although the overall participant

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retention rate across data waves was high, some attrition was noted between study waves, particularly among males, and thus this may have somewhat influenced the reported findings. Indeed, assessment of sleep characteristics between those who participated in all data collection waves compared with those who missed one or more wave revealed a generally lower proportion of short sleepers among those who completed data collection. Thus, there may be an underestimation of the effect of the reported findings. Despite this, it was noted that the differences were largely negligible with regard to overall sleep duration across waves between completers and non-completers, and thus it is not anticipated that these differences are clinically significant.

In this longitudinal sample of individuals, the first research assessing the stability and trajectory of sleep duration characteristics from early adolescence through periods of mid-adulthood are reported. Instances of self-reported short sleep in mid-adulthood appear to be formed in late adolescence/early adulthood, and these associations are seen to be comparably strong for both men and women. Habitual short sleep duration in early adolescence typically resolves by the end of adolescence and does not predict short sleep during mid-adulthood. Given the natural decline in a number of sleep parameters associated with the natural aging process, proactive maintenance of adaptive sleep habits during these critical periods of early adulthood may assist in associated functional sleep outcomes during periods of mid- to late adulthood and/or older age.

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AUTHOR CONTRIBUTIONS

ACH, JCS, BS and SO were involved in the development and design of the study. BW collected the data, and ACH, JCS, BS, BW and SO constructed variables for this paper and analysed the data. ACH interpreted the data and wrote the manuscript. ACH, JCS, BS, BW, GK, LW and SO were involved in drafting, editing and critical appraisal of the manuscript. All authors have approved the manuscript for submission.

REFERENCES

Al Mamun, A., O'Callaghan, F., Scott, J. *et al.* Continuity and discontinuity of trouble sleeping behaviors from early childhood to young adulthood in a large Australian community-based-birth cohort study. *Sleep Med.*, 2012, 13: 1301–1306.

Ayas, N. T., White, D. P., Manson, J. E. *et al.* A prospective study of sleep duration and coronary heart disease in women. *Arch. Intern. Med.*, 2003, 163: 205–209.

Birkeland, M. S., Torsheim, T. and Wold, B. A longitudinal study of the relationship between leisure-time physical activity and depressed mood among adolescents. *Psychol. Sport Exerc.*, 2009, 10: 25–34.

Bjorvatn, B., Sagen, I., Øyane, N. *et al.* The association between sleep duration, body mass index and metabolic measures in the Hordaland Health Study. *J. Sleep Res.*, 2007, 16: 66–76.

Buxton, O. M. and Marcelli, E. Short and long sleep are positively associated with obesity, diabetes, hypertension, and cardiovascular disease among adults in the United States. *Soc. Sci. Med.*, 2010, 71: 1027–1036.

Cajochen, C., Münch, M., Knoblauch, V., Blatter, K. and Wirz-Justice, A. Age-related changes in the circadian and homeostatic regulation of human sleep. *Chronobiol. Intern.*, 2006, 23: 461–474.

Cappuccio, F. P., D'elia, L., Strazzullo, P., Miller, M. A. Sleep duration and all-cause mortality: a systematic review and meta-analysis of prospective studies. *Sleep*, 2010, 33: 585.

Cohen, S., Doyle, W. J., Alper, C. M., Janicki-Deverts, D. and Turner, R. B. Sleep habits and susceptibility to the common cold. *Arch. Intern. Med.*, 2009, 169: 62–67.

Ferrie, J. E., Shipley, M. J., Cappuccio, F. P. *et al.* A prospective study of change in sleep duration: associations with mortality in the Whitehall II cohort. *Sleep*, 2007, 30: 1659.

Hysing, M., Harvey, A. G., Torgersen, L., Ystrom, E., Reichborn-Kjennerud, T. and Sivertsen, B. Trajectories and predictors of nocturnal awakenings and sleep duration in infants. *J. Dev. Behav. Pediatr.*, 2014, 35: 309–316.

Iglowstein, I., Jenni, O. G., Molinari, L. and Largo, R. H. Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics*, 2003, 111: 302–307.

Ipsiroglu, O. S., Fatemi, A., Werner, I., Paditz, E. and Schwarz, B. Self-reported organic and nonorganic sleep problems in schoolchildren aged 11 to 15 years in Vienna. *J. Adolesc. Health*, 2002, 31: 436–442.

Jakobsen, R. Stages of progression in noncoital sexual interactions among young adolescents: an application of the Mokken scale analysis. *Int. J. Behav. Dev.*, 1997, 21: 537–553.

Jansson, M. and Linton, S. J. The role of anxiety and depression in the development of insomnia: cross-sectional and prospective analyses. *Psychol. Health*, 2006, 21: 383–397.

Jansson-Fröjmark, M. and Lindblom, K. A bidirectional relationship between anxiety and depression, and insomnia? A prospective study in the general population. *J. Psychosom. Res.*, 2008, 64: 443–449.

Jenni, O. G., Molinari, L., Caflisch, J. A. and Largo, R. H. Sleep duration from ages 1 to 10 years: variability and stability in comparison with growth. *Pediatrics*, 2007, 120: e769–e776.

Kecklund, G. and Åkerstedt, T. The psychometric properties of the Karolinska Sleep Questionnaire. *J. Sleep Res.*, 1992, 1: 113.

Laberge, L., Petit, D., Simard, C., Vitaro, F., Tremblay, R. and Montplaisir, J. Development of sleep patterns in early adolescence. *J. Sleep Res.*, 2001, 10: 59–67.

Magee, C. A., Gordon, R. and Caputi, P. Distinct developmental trends in sleep duration during early childhood. *Pediatrics*, 2014, 133: e1561–e1567.

Manber, R. and Chambers, A. S. Insomnia and depression: a multifaceted interplay. *Curr. Psychiatry Rep.*, 2009, 11: 437–442.

Morphy, H., Dunn, K. M., Lewis, M., Boardman, H. F. and Croft, P. R. Epidemiology of insomnia: a longitudinal study in a UK population. *Sleep*, 2007, 30: 274.

Olds, T., Blunden, S., Petkov, J. and Forchino, F. The relationships between sex, age, geography and time in bed in adolescents: a

meta-analysis of data from 23 countries. *Sleep Med. Rev.*, 2010, 14: 371–378.
Patel, S. R. and Hu, F. B. Short sleep duration and weight gain: a systematic review. *Obesity*, 2008, 16: 643–653.
Quach, J., Hiscock, H., Canterford, L. and Wake, M. Outcomes of child sleep problems over the school-transition period: Australian population longitudinal study. *Pediatrics*, 2009, 123: 1287–1292.
Qureshi, A. I., Giles, W. H., Croft, J. B. and Bliwise, D. L. Habitual sleep patterns and risk for stroke and coronary heart disease: a 10-year follow-up from NHANES I. *Neurology*, 1997, 48: 904–910.
Riemann, D., Spiegelhalder, K., Feige, B. *et al.* The hyperarousal model of insomnia: a review of the concept and its evidence. *Sleep Med. Rev.*, 2010, 14: 19–31.
Ursin, R., Bjorvatn, B. and Holsten, F. Sleep duration, subjective sleep need, and sleep habits of 40- to 45-year-olds in the Hordaland Health Study. *Sleep*, 2005, 28: 1260.
Wolfson, A. R. and Carskadon, M. A. Sleep schedules and daytime functioning in adolescents. *Child Dev.*, 1998, 69: 875–887.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Figure S1. Scatterplot of sleep duration 1992 and sleep duration 2007. Size of marker indicates relative number of cases at each intersection. With linear fitline. $N = 401$.

Figure S2. Scatterplot of sleep duration 2000 and sleep duration 2007. Size of marker indicates relative number of cases at each intersection. With linear fitline. $N = 385$.

Figure S3. Scatterplot of sleep duration 1990 and sleep duration 2007. Size of marker indicates relative number of cases at each intersection. With linear fitline. $N = 308$.

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