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REGULAR ARTICLE

Developmental trajectories of sleep during childhood and adolescence are related to health in young adulthood

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Abstract

Aim: Sleep behaviour is correlated and causally related to physical and mental health. Limited longitudinal data exist on the associations of poor sleep behaviour in childhood and adolescence with adult health. Parent-reported sleep behaviours from 1993 participants of the Raine Study (at ages 5, 8, 10, 14, 17) were used to determine sleep trajectories (using latent class growth analysis).

Methods: Measures of physical and mental health were compared between sleep trajectories using generalised linear models (at age 20).

Results: Three sleep trajectories were identified as follows: 43% of participants belonged to a trajectory with 'consistently minimal' sleep problems, 49% showed some 'declining' in reporting of sleep problems incidence and 8% had 'persistent' sleep problems. Participants in the 'consistently minimal' trajectory had better physical and mental health outcomes at age 20 compared to those in the 'declining' and 'persistent' trajectories. For example, 'consistently minimal' participants had significantly lower body fat percentage (mean difference: −3.89% (95% CI: −7.41 to −0.38)) and a higher (better) SF-12 mental component score (mean difference: 4.78 (95% CI: 2.35–7.21)) compared to participants in the 'persistent' trajectory.

Conclusion: Poor sleep behaviour across childhood and adolescent years is related to poorer physical and mental health in young adulthood.

KEYWORDS
adult health outcomes, latent class, longitudinal study, sleep behaviour

Abbreviations: AIC, Akanke's information criteria; BIC, bayes information criteria; BMI, body mass index; CBCL, child behaviour check list; DASS-21, depression anxiety stress scales; DXA, dual-energy X-ray; LCGA, latent class growth analysis; MET, metabolic equivalents; SF-12, short form 12—item health survey.

1 | BACKGROUND

Poor sleep has been associated with accidental injuries and death, poorer academic performance, more negative moods and poorer physical health in young people[1] and multiple physical and mental outcomes in adulthood, such as depressive mood and poorer physical health.[2] An understanding of the development of poor sleep behaviours over the life-course is beginning to emerge, with several longitudinal studies showing that poor sleep behaviours can be persistent across childhood.[3–6] For example, Siversten and colleagues have found that approximately one-third of 7–9-year-old children with poor sleep behaviours still have problems at 16–19 years of age.[3] Similarly, Al Mamun et al.[4] reported that 2–4-year-olds with trouble sleeping were 49% more likely to experience sleep trouble at 14 years of age; and those with sleep trouble at 14 were 94% more likely to experience sleep trouble at 21 years. However, it is not clear whether such persistent behavioural problems in childhood and adolescence result in poorer health outcomes in adulthood.

Some evidence suggests poor sleep behaviours during early childhood may have multiple consequences in later life, including attentional difficulties, poor impulse and emotional control, metabolic dysfunction and substance-related problems in young adulthood.[7,8] However, current evidence, which is mostly based on sleep problems being measured at very few time points, does not capture the developmental changes in sleep that occur during childhood and adolescence and their relationship to later health outcomes.[9] One study examined problematic sleep, over childhood and adolescence (ages 2–15 years) and, using structural equation modelling, showed that poor sleep behaviours in the younger years were associated with risk-taking behaviour during adolescence.[10] More recently, trajectories of sleep problems from 5 to 14 years of age have been shown to relate to emotional problems over the same period,[5,6] however, health outcomes in adulthood were not examined.

These studies suggest that the long-term patterns of sleep problems over childhood may have bearing on health outcomes in adulthood. Therefore, this study aimed to investigate whether trajectories of sleep behaviours over the critical developmental periods of childhood and adolescence were associated with physical and mental health outcomes in young adulthood.

Key Notes

- It was unknown whether unique sleep behaviour trajectories over critical periods of childhood-adolescence were associated with physical and mental health outcomes in young adulthood.
- This longitudinal cohort study found that inherent patterns of developmental sleep trajectories exist; poor sleep behaviour across childhood-adolescent years is related to poorer physical and mental health in young adulthood.
- This study reinforces that poor childhood-adolescent sleep behaviours are an important modifiable risk for adult health.

2 | METHOD

2.1 | Participants

Participants were from the Raine Study (www.rainestudy.org.au). The study has been described in detail elsewhere.[11] Briefly, 2,900 pregnant women were recruited from the public antenatal clinic at King Edward Memorial Hospital (KEMH) and surrounding private clinics in Perth, Western Australia between May 1989 and November 1991. Of the 2900 women enrolled (Generation 1), 2,804 delivered live babies (Generation 2). Children have been assessed at birth, and ages 1, 2, 3, 5, 8, 10, 14, 17, 20, 22 and 27 years of age using questionnaires and physical assessments. The study was established with the intent of developing a large cohort of Western Australian children to establish relative contributions of familial and environmental influences to outcome in infancy and to the precursors of adult morbidity.[12] The cohort members participating in data collection at the age 20 follow-up have been compared with contemporaneous Western Australian Census Data of 20-year-old males and females living in Western Australia, and overall, most comparisons showed the Raine cohort to be similar to typical Western Australian community dwelling young adults. Parents initially provided informed, written consent to participate in the study until their children were old enough to provide their consent. The institutional ethics committees of Curtin University (HR 23/2013) and the University of Western Australia (RA/4/20/5722) approved the study.

2.2 | Measures

2.2.1 | Sleep Trajectories

Parents reported on their children's sleep problems at ages 5, 8, 10 and 14 and 17 using the Child Behaviour Checklist (CBCL,[13]). The CBCL was administered at each of the 5 time points, from which six items were used to create a composite score of sleep problems at each time point. The items included 'trouble sleeping', 'nightmares', 'overtired without good reason', 'sleeps less than most kids', 'talks or walks in sleep' and 'sleeps more than most kids during day and/or night'. Each item was rated on a 3-point scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true) and a sum score of the 6-item (range 0–12) was used to represent the level of poor

sleep behaviours, with higher scores indicating poorer sleep behaviours. This CBCL sleep composite score is moderately correlated with clinical diagnoses of sleep disorders,[14] and has been widely used in previous research as a measure of overall sleep functioning.[5,6,15]

2.2.2 | Physical health outcomes at age 20

Broad indicators of physical health were selected from the wide range of phenotypic measures available on the cohort. The physical health component of the Short Form 12-Item Health Survey version 2 (SF-12) was used to assess self-rated health and well-being at age 20.[16] The SF-12 consists of 12 Likert questions that were reverse-coded and transformed into a 100-point scale using standardised guidelines.[17] From these items, individual scores from four items were used to create the Physical Component subscale, with higher scores indicating better health.[17] Percentage body fat (and lean body mass) was obtained from a whole-body Dual-energy X-Ray Absorptiometry (DXA) scan (Norland XR-36 densitometer, Norland Medical Systems, Inc.,) performed according to manufacturer-recommended procedures using built-in software (version 4.3.0). All analyses were checked for consistency and daily calibration was performed on the DXA machine before each scanning session. The densitometer had a variation in the precision of <2.0% for the measured site at standard speed. Body mass and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, by using standardised equipment and procedures, and body mass index (BMI) was derived from these measures. Waist circumference was measured to the nearest 0.1 cm at the level of the iliac crest while the participant was at minimal exhalation.

2.2.3 | Mental health outcomes at age 20

The SF-12 and DASS-21 scores were selected from a wider range of measures available on the cohorts, as general indicators of mental health. The mental component subscale of the Short Form 12-Item Health Survey version 2 (SF-12) was used to assess self-rated mental health and well-being[18] with higher scores indicating better health. Mental health was also assessed with the 21-item self-reported Depression Anxiety Stress Scales (DASS-21).[19] The DASS-21 has been validated in clinical and non-clinical populations.[20] Participants were asked to rate the extent to which they had experienced each state over the past week on a four-point severity/frequency scale with responses ranging from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time). The DASS-21 yields separate depression, anxiety and stress subscale scores (scores range from 0 to 21, based on 7-item), and a composite total score that is the sum of the three subscales (range 0–63, based on all 21-items). Although cut-off scores defining mild/moderate/severe and extremely severe have been developed, the DASS is based on a dimensional concept of psychological disorders, as opposed to a categorical concept.[19] Therefore for this study, continuous scores were used in the analysis.

2.2.4 | Other measures at age 5 and age 20

Selected additional measures from early childhood and young adulthood (known to be associated with poor physical and mental health outcomes i.e., BMI, family income, education, smoking, sleep disturbances, sedentary time and physical activity) were reported and compared between the trajectories (see Table 1). Variables that were significantly different between the trajectories were then used as covariates in subsequent models. At the 5-year follow-up, the participant's height (m) and mass (kg) were measured, and a BMI Z-score was calculated and converted into a percentile (relative to the participant's sex and age). Also, at the 5-year follow-up, parents of the participants completed a questionnaire about their family income category ($1–$8,000/$8,001–16,000/$16,001–$25,000/$25,000–$40,000/$40,000 or more). At the 20-year follow-up, participants completed a questionnaire composed of standard questions drawn from prior studies to gather information on sex, education and smoking history.[21] Participants were asked what their highest level of education was (Primary School/Secondary School/University/Other); if they smoked cigarettes (yes/no); if they had a current diagnosed sleep disturbance (No/Yes in the Past/Yes Now/Yes Now and in the Past); how much television they watched (None/0–7 h/wk/7–14 h/wk/14–21 h/wk/21+h/wk) and about their current physical activity levels (International Physical Activity Questionnaire (IPAQ)). Participants completed the Short Form IPAQ, which is a valid self-report measure of physical activity.[22] Minutes of walking, moderate activity and vigorous activity were translated into MET-minutes per week using MET energy expenditure estimation equations (walking = 3.3, moderate = 4.0, vigorous = 8.0).

2.3 | Data analysis

To determine the trajectories of sleep problems, latent class growth analysis (LCGA)[23] was conducted using parent report data on their child's sleep problems when their children were 5, 8, 10, 14 and 17 years of age. Data were available for 2116 participants at age 5; 2037 participants at age 8; 1994 participants at age 10; 1774 participants at age 14; and 1380 participants at age 17. At age 20, 1565 participants took part in the follow-up at which young adult health outcomes and behaviours were also measured. Parent reports of sleep problems from the five time points (years 5, 8, 10, 14, 17) were used in latent class growth analysis (LCGA) to estimate sleep trajectories, with sex included as an active covariate, such that membership probability to a trajectory could vary as a function of sex.

As there are no definitive criteria for the optimal number of classes, the judgement as to the optimum solution was based on a combination of statistical criteria, model parsimony and interpretability.[24] The following were considered: (i) the minimum values of the goodness of fit measures Bayes Information criteria (BIC), Akaike's information criteria (AIC) as indicators of the optimal

TABLE 1 Descriptive characteristics of participants at age 20 years by sleep behaviour trajectory

	'Consistently minimal'sleep problems (*n* = 863)	'Declining' Sleep Problems (*n* = 974)	'Persistent' Sleep Problems (*n* = 156)	Trajectory differences *p*-value
Female (%)	48	51	43	0.211
BMI (percentile) at age 5	53.3 (29.1)	55.5 (29.2)	55.1 (29.1)	0.295
Family Income at age 5 (%)				**<0.001***
$1–$8000	0.1	0.1	0.0	
$8001–$16 000	7.5	10.2	23.0	
$16 001–$25 000	16.4	18.4	24.5	
$25 000–$40 000	26.0	28.9	19.4	
$40 000 or more	50.1	42.4	33.1	
Highest Year of High School completed (%)				0.100
Year 12 (or equivalent)	85.9	79.2	72.7	
Year 11 (or equivalent)	5.0	8.6	13.6	
Year 10 (or equivalent)	8.0	11.0	13.6	
Year 9 (or equivalent)	0.2	0.0	0.0	
Other/none of the above	0.9	1.2	0.0	
Smoker (%)				**0.037***
No	86.9	81.6	77.1	
Yes	13.1	18.4	22.9	
Current Sleep Disturbance (%)				**<0.001***
No	94.6	91.2	80.5	
Yes (in the past)	2.5	3.2	6.5	
Yes (now)	0.4	1.1	0.0	
Yes (now and in the past)	2.5	4.5	13.0	
TV Time (%)				0.081
None	3.3	4.7	2.7	
0–7 h/week	27.8	27.6	22.7	
7–14 h/week	46.9	40.8	37.3	
14–21 h/week	19.7	22.0	29.3	
21+h/week	2.3	4.9	8.0	
Physical Activity (MET-min/week)	1782 (1413–2133)	1863 (1404–2106)	2319 (924–2892)	0.905

Note: Data are shown as % or median (95% CI).

*Bold *p*-values indicate statistically significant differences among sleep trajectory groups.

number of classes, (ii) the degree to which the trajectory classes identified distinct and potentially meaningful patterns in the data, (iii) the size of the smallest cluster and (iv) the quality of the model in terms of posterior probability diagnostics, namely average posterior probability for each trajectory class, odds of correct classification and classification error. Participants were assigned to the trajectory class for which they had the highest posterior probability of membership. Trajectories of similar size and pattern were identified in all models, thus the model for the combined sex (3+ time points) is presented as the primary model (Table S1), with model fit statistics (for sex-specific (Table S2) and other combinations of time points) presented in supplementary materials. Sensitivity analyses were explored including for participants with one missing time point (Table S3) and for those who had no missing time points (Table S4).

Generalised linear or negative binomial regression models were used to determine the associations between the sleep trajectory classes and physical and mental health outcomes in adulthood. Models were weighted according to the probability of membership of the trajectory class (predictor variable) and adjusted for sex. To consider the early and contemporaneous effect of selected variables associated with physical and mental health, we ran additional models adjusting for the following variables: family income at age 5, smoking and sleep disturbances at age 20. Interactions were explored between sex and trajectory membership with health outcomes and results are presented separately for males and females where the

interaction was significant at $p < 0.10$. All analyses were conducted using Stata v13.1.

3 | RESULTS

3.1 | Sleep problems

The frequency of parent reported CBCL sleep problems classified as 'very true/often true' are shown in Table 2. The frequency of parents reporting that their children 'very often' had sleep problems or that certain sleep problems were 'very true' for their children was higher in the 'declining' sleep problem trajectory and in the 'persistent' sleep problem trajectory compared to the 'consistently minimal' sleep problem trajectory. The prevalence of parents reporting that their children had nightmares decreased as the children got older.

The percentage of participants (with data available at each time point) who reported 'never', 'sometimes' or 'very often' had the 6 sleep problems are shown in Table S5. Typically, over 80% of children were reported to 'never' have sleep problems, with only about 2% of children having any one sleep problem 'very often'. Around 9% of children 'sometimes' had trouble sleeping, slept less than most or slept more than most. Parents reported that over 20% of children were 'sometimes' overtired. The proportion of children 'sometimes' experiencing nightmares declined from 35% at age 5 to 7% at age 17, with a similar decline for sleep walking/talking (from 19% at age 5 to 7% at age 17).

Table S6 compares participants on demographic variables (parent race and participant sex) at birth. Participants included in the latent class analysis had a slightly higher percentage of parents who were both Caucasian and a similar proportion of females to those not included in the final analysis.

3.2 | Sleep problem trajectories

Model fit statistics (Table S1) supported participants (n = 1993) being classified into three classes based on their pattern of parent-reported sleep problems from ages 5 to 17 years (Figure 1). Class 1 (n = 863, 43%) had 'consistently minimal' problems (mean (SD) score: 0.23 (0.53)), participants in Class 2 (n = 974, 49%) had slightly 'declining' problems (mean (SD score: 1.21 (1.21)), and Class 3 (n = 156, 8%) had 'persistent' problems (mean (SD score: 3.77 (1.93)). Females composed 48% of 'consistently minimal' problem trajectory, 51% of 'declining' problem trajectory, and 43% of 'persistent' problem trajectory. Sex-specific model fit statistics (Table S2) confirmed a combined sex model was appropriate, with little differences in fit, prevalence and patterns by sex. Models with 1 (Table S3) and no (Table S4) missing time points confirmed a similar three trajectories model.

Descriptive statistics of the participants at age 5 and age 20, across the three trajectories for the primary model are shown in Table 2. There was no difference for the proportion of females in each trajectory or for BMI percentile at age 5. However, there was a significant difference in the family income at age 5 (Chi-squared = 55.45, $p < 0.001$), with fewer participants in the 'persistent' sleep problem trajectory coming from families in the highest income bracket compared to the other trajectories. There was no difference in the proportion of participants who had completed high school across the trajectories. There were fewer participants in the 'consistently minimal' sleep problem trajectory who did not smoke (Chi-squared = 6.6, $p = 0.037$), or had current sleep disturbances (Chi-squared = 26.17, p <0.001) than participants in the 'declining' and 'persistent' sleep problem trajectories. The time that participants spent watching television and doing physical activity were similar across the sleep problems trajectories.

3.3 | Health outcomes between the trajectories

Because there was no significant sex by trajectory membership interaction, the association between trajectory membership and health outcomes was reported for females and males combined. Patterns of differences across the three trajectories remained similar when adjustments for sex, family income at age 5 and smoking and sleep disturbance (at age 20) were made (Table 3). The differences in physical and mental health outcomes across the three trajectories were similar in magnitude for both sex-only and fully adjusted models for most variables and are described as follows.

3.3.1 | Physical health outcomes

In the sex-only adjusted model, but not in the fully adjusted model, participants in the 'consistently minimal' sleep problem trajectory had a higher (better) SF-12 physical score (mean difference: 1.74 (95% CI: 0.17–3.32)) compared with those in the 'persistent' sleep problem trajectory. In the fully adjusted model, participants in the 'consistently minimal' sleep problem trajectory had a lower body fat percentage (mean difference: −1.81% (95% CI: −3.62 to 0.00)), fat mass (mean difference: −2337 g (95% CI: −4479 to −194)) and BMI (mean difference: −1.06 kg/m^2 (95% CI: −1.96 to −1.67)) compared to participants in the 'declining' sleep problem trajectory. Results were similar in the sex-only adjusted model. Participants in the 'consistently minimal' sleep problem trajectory had a lower body fat percentage (mean difference: −3.89% (95% CI: −7.41 to −0.38)) and fat mass (mean difference: −4423 g (95% CI: −8719 to −126)) for fully adjusted model, compared to participants in the 'persistent' sleep problem trajectory.

3.3.2 | Mental health outcomes

In the fully adjusted model, participants in the 'consistently minimal' sleep problem trajectory had a higher (better) SF-12 mental component scores (mean difference: 3.82 (95% CI: 0.87–6.75)) compared to participants in the 'persistent' sleep problem trajectory, with similar

TABLE 2 Frequency (*n*, %) of parent-reported Child Behaviour Checklist sleep problems to be 'very true/often true' overall and by trajectory

		Age 5	Age 8	Age 10	Age 14	Age 17
N		2116	2037	1994	1774	1380
Total sample	'Overtired'	48 (2.2%)	27 (1.3%)	27 (1.3%)	39 (2.2%)	40 (2.9%)
	'Sleeps less than most kids'	89 (4.1%)	99 (3.8%)	70 (3.5%)	41 (2.3%)	26 (1.9%)
	'Sleeps more than most kids'	27 (1.2%)	17 (0.8%)	15 (0.7%)	16 (0.9%)	11 (0.8%)
	'Trouble sleeping'	52 (2.4%)	65 (3.1%)	51 (2.5%)	34 (1.9%)	30 (2.2%)
	'Nightmares'	42 (2.0%)	42 (2.0%)	34 (1.7%)	10 (0.6%)	7 (0.5%)
	'Talks or walks in sleep'	60 (2.9%)	60 (2.9%)	54 (2.7%)	36 (2.0%)	11 (0.8%)
Consistently minimal sleep problems	'Overtired'	0.2%	0.0%	0.0%	0.0%	0.2%
	'Sleeps less than most kids'	0.00025	0.2%	0.0%	0.0%	0.0%
	'Sleeps more than most kids'	0.4%	0.1%	0.6%	0.1%	0.2%
	'Trouble sleeping'	0.5%	0.1%	0.0%	0.0%	0.3%
	'Nightmares'	0.1%	0.1%	0.0%	0.0%	0.0%
	'Talks or walks in sleep'	0.2%	0.0%	0.2%	0.1%	0.2%
Declining sleep problems	'Overtired'	2.9%	0.9%	1.0%	2.5%	2.8%
	'Sleeps less than most kids'	5.0%	4.9%	3.3%	1.5%	1.3%
	'Sleeps more than most kids'	1.3%	0.9%	1.1%	0.8%	1.3%
	'Trouble sleeping'	1.9%	2.7%	1.8%	1.1%	1.5%
	'Nightmares'	1.8%	1.7%	1.0%	0.5%	0.3%
	'Talks or walks in sleep'	2.9%	3.2%	2.6%	1.8%	0.8%
Persistent sleep problems	'Overtired'	10.1%	11.4%	10.6%	13.6%	18.3%
	'Sleeps less than most kids'	18.8%	30.5%	23.6%	23.5%	17.0%
	'Sleeps more than most kids'	5.9%	4.3%	2.1%	5.0%	16.0%
	'Trouble sleeping'	16.1%	25.9%	22.7%	16.8%	19.1%
	'Nightmares'	15.2%	14.3%	14.2%	5.0%	3.3%
	'Talks or walks in sleep'	7.2%	19.9%	15.0%	15.1%	5.3%

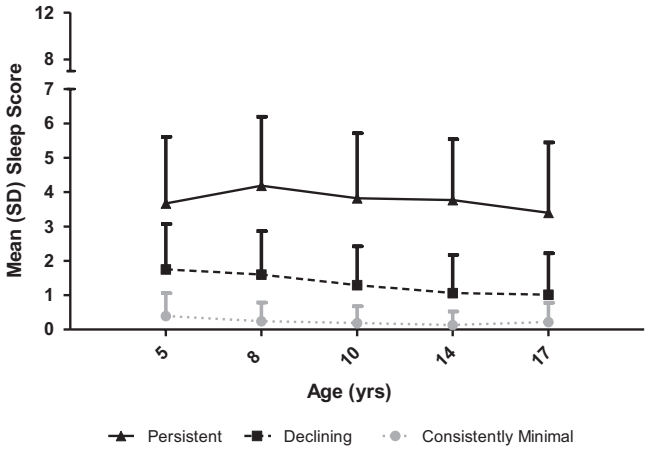

FIGURE 1 Sleep problem trajectories from 5 to 17 years of age (*n* = 1993). 'Consistently Minimal' sleep problems (grey dashed line, *n* = 863, 43%) 'Declining' sleep problem (black dashed line, *n* = 974, 49%) and 'Persistent' sleep problems (solid black line, *n* = 156, 8%)

relationships evident for the sex-only adjusted model. In the fully adjusted model, depression (mean difference: −1.87 (95% CI: −3.24 to −0.49)) scores were lower in the 'consistently minimal' sleep problem trajectory compared to other trajectories.

4 | DISCUSSION

This study used latent class growth analysis to identify three distinct patterns of poor sleep behaviours in a cohort tracked from childhood (5 years) to late adolescence (17 years) and related these trajectories to physical and mental health outcomes in young adulthood (at 20 years). This analytic approach allows the overall time course of poor sleep behaviours during critical developmental periods to be considered, while still accounting for multiplicity with a (latent) categorical variable indicating the number of subgroups.[23] The three sleep trajectories identified in the current study were associated with measures of physical and mental health outcomes at age 20.

Like other studies,[25] in the current study sleep problems tended to be minimal or decrease across the childhood and adolescence period for most of the participants. This finding is also consistent with the work of Wang et al.[5,6] who used a different statistical method (Latent Growth Mixture Model (LGMM) vs. LCGA) in the same

TABLE 3 Mean differences (95% CI for the differences) in health outcomes by sleep behaviour trajectory

			'Consistently Minimal' vs. 'Declining'	'Consistently Minimal' vs. 'Persistent'	'Declining' vs. 'Persistent'
Physical	SF-12 Physical *(n = 1046)*		−0.68 (−1.46 to 0.10)	**1.74 (0.17–3.32)**	1.06 (−0.49 to 2.63)
			0.62 (−0.17 to 1.41)	1.36 (−0.24 to 2.97)	−0.74 (−2.33 to 0.86)
	Adiposity *(n = 724)*	%Fat	**−2.65 (−4.17 to −1.12)**	**−3.43 (−6.29 to −0.57)**	0.78 (−2.04 to 3.62)
			−1.81 (−3.62 to 0.00)	**−3.89 (−7.41 to −0.38)**	−2.08 (−5.55 to 1.399)
		Fat Mass (g)	**−3307 (−4975 to −1640)**	−2775 (−5897 to 346)	−532 (−3617 to 2552)
			−2337 (−4479 to −194)	**−4423 (−8719 to −126)**	−2086 (−6341 to 2168)
		Lean Mass (g)	445 (−986 to 1876)	1960 (−719 to 4640)	1515 (−1133 to −4163)
			36 (−1619 to 1691)	2034 (−1158 to 5227)	2070 (−1084 to 5225)
		BMI (kg/m^2)	**−1.21 (−1.85 to −0.55)**	−0.98 (−2.20 to 0.24)	−0.22 (−1.43 to 0.98)
			−1.06 (−1.96 to −1.67)	−1.59 (−3.39 to 0.21)	−0.53 (−1.26 to 2.31)
		Waist Circum. (cm)	2.61 (−8.24 to 13.47)	−3.58 (−24.45 to 17.28)	−6.20 (−26.97 to 14.56)
			2.28 (−8.56 to 13.13)	−3.29 (−24.13 to 17.55)	−5.57 (−26.32 to 15.18)
Mental	SF-12 Mental *(n = 1046)*		**1.68 (0.47–2.89)**	**4.78 (2.35–7.21)**	3.09 (0.67 to 5.52)
			1.71 (0.33–3.07)	**3.82 (0.87–6.75)**	2.11 (−0.80 to 5.03)
	DASS−21 *(n = 759)*	Total Score*	−1.53 (−4.31 to 1.25)	−5.73 (−12.10 to 0.65)	−4.20 (−1.25 to 4.31)
			−3.50 (−7.40 to 0.40)	−5.79 (−14.72 to 3.14)	−2.29 (−11.27 to 6.70)
		Depression*	−0.86 (−1.83 to 0.10)	−2.08 (−4.27 to 0.11)	−1.22 (−3.42 to 0.99)
			−1.87 (−3.24 to −0.49)	−1.69 (−4.61 to 1.22)	0.17 (−2.79 to 3.13)
		Anxiety*	−0.49 (−1.21 to 0.22)	**−1.64 (−3.30 to 0.03)**	−1.15 (−2.82 to 0.52)
			−0.61 (−1.59 to 0.37)	−1.91 (−4.36 to 0.53)	−1.30 (−3.74 to 1.13)
		Stress*	−0.18 (−1.40 to 1.04)	−2.02 (−4.78 to 0.74)	−1.84 (−4.58 to 0.91)
			−0.42 (−1.80 to 0.95)	−2.07 (−5.11 to 0.97)	−1.65 (−4.68 to 1.38)

Note: Generalised linear models all weighted for probability of membership and adjusted for sex (white rows) or adjusted for sex, family income at age 5; and sleep disturbance and smoking at age 20 (shaded grey rows). Bold font indicates significantly different differences at $p < 0.05$.

Abbreviations: BMI, body mass index; DASS-21, depression, anxiety and stress Scale; SF-12, short form 12.

*Negative binomial regression.

cohort of participants. In the current study, three trajectories of sleep problems were identified, with 8% of participants being classified as having 'persistent' sleep problems, a similar proportion to the 10.6% of 'problem' sleepers identified using a LGMM model (across the same ages i.e., 5–17 years) in Wang et al's.[5,6]study. The persistence/consistency of sleep problems for the participants across

the childhood and adolescent years in the current study supports similar work which has demonstrated a continuation of poor sleep behaviours from adolescence to adulthood.[26]

In the current study, better sleep behaviours across childhood and adolescence were associated with better young adult physical (better SF-12 scores and more favourable body composition) and mental health (better SF-12 scores and lower depression scores). This finding builds on previous work which has found trajectories of reduced sleep duration across childhood to be related to poorer health outcomes in childhood.[8,27] For example, Magee et al.[27] reported that a trajectory of persistent short sleep (from age 0 to 6 years) was associated with poorer physical, emotional and social health than a typical sleep trajectory. Further, other studies have shown that children who were classified as having shorter sleep trajectories (between 2.5 and 6 years of age) were more likely to be hyperactive[8] and in slightly older children (between ages 10 and 13 years), shorter sleep trajectories were associated with being overweight.[28] The current study extends existing evidence and reinforces that poor childhood-adolescent sleep behaviours are an important modifiable health risk for adult health.

Some of the associations noted in the current study are likely to have notable clinical implications. For example, the 3.6% difference in body fat percentage between those in the 'consistently minimal' vs. 'persistent' sleep problem trajectory is in the range of weight loss (i.e., 2–5%) considered to be associated with clinically meaningful health improvements by the American College of Cardiology (ACC)/American Heart Association (AHA)/The Obesity Society (TOS) guidelines.[29] The almost 5 points higher score in the SF-12 mental health questionnaire, for participants in the 'consistently minimal' trajectory compared to those in the 'persistent' sleep problem trajectories is similar to what has been described as a clinically meaningful difference in adults with chronic low back pain (i.e., an improvement in SF-12 mental health score of >3.77).[30] Most health associations with sleep trajectories remained after adjusting for family income at age 5 as well as current sleep problems and smoking (at age 20), suggesting that any effects were related to accumulation of sleep problems over the life-course as indicated by membership of the sleep behaviour trajectories, and not necessarily determined by initial health status nor by current behaviours.

In addition to providing the first examination of the associations between poor childhood-adolescent sleep behaviour trajectories and young adult physical and mental health outcomes, other key strengths of the study include the large longitudinal cohort and repeated measures of sleep behaviour spanning critical periods of development. It is possible that the inherent limitations of parent report of child and adolescent sleep behaviours could have influenced the trajectories. For example, parents may be more aware of sleep issues when their children are younger, compared to when their children are adolescents (when parents may not be as aware of sleep issues as their teenagers). Physiological monitoring of sleep quality would have been preferable but is difficult to use in a community (field)-based longitudinal study due to high burden. Additionally, all items that were included from the CBCL had equal weighting for the current study, but it is possible that the different items in the scale may have different relationships with health outcomes (via different mechanisms). Prior analysis has shown that although the Raine Study cohort is quite comparable to the broader Western Australian community and there are high rates of follow-up for the cohort and evidence of only limited selection bias in those participants who have remained in the Raine Study,[12] the single cohort location should also be considered a potential limitation in terms of generalisability. Additional analysis conducted for this study showed that although more participants who had Caucasian parents had sleep data, these rates were similar across the five assessment points, suggesting limited selective attrition. However, generalisation to children without Caucasian parents should be made with caution. Additionally, whether or not participants in the 'declining' trajectory received any interventions to treat their sleep problems is unknown but would have been useful information in helping to understand this pattern of sleep behaviour. As the participants in this study were from a community sample, it includes children with a range of disorders, including the spectrum of neurodevelopmental disorders. While it would indeed be interesting to explore whether children with specific disorders have greater problems with sleep, the low numbers of children with each specific disorder means a community sample is not be best place to examine this. Rather clinical case cohorts would offer a valuable approach to examine this question. Finally, the pathway of influence on the aetiology of sleep behaviours was beyond the scope of this study, that is mediators and or moderators of sleep behaviour were not considered. Although there are likely to be many confounders in the relationship (e.g., the co-development of dietary and other lifestyle behaviours as well as early childhood health), and the possibility of reverse causality, the consideration of body composition and family income at age 5 in the analysis is an additional strength of this study.

In summary, this study identified three distinct trajectories of sleep behaviour across childhood and adolescence. A small minority of participants had a trajectory indicative of consistently poor sleep behaviour. Children in the trajectory of consistently minimal sleep behaviour problems had better physical and mental health as a young adult. Ideally, future research should aim to replicate these trajectories and examine their predictors and determine mechanisms and timing of interventions to support good sleep behaviours.

5 | AUTHORS'CONTRIBUTIONS

All authors: contributed to the study conception and design. Joanne McVeigh and Anne Smith: performed material preparation and analysis. Joanne McVeigh: drafted the first manuscript. All authors commented on previous versions of the manuscript. All authors: read and approved the final manuscript.

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CONFLICTS OF INTEREST

None.

CONSENT TO PARTICIPATE

Parents initially provided informed, written consent to participate in the study until their children were old enough to provide their consent.

CONSENT FOR PUBLICATION

Parents initially provided informed, written consent to participate in the study until their children were old enough to provide their consent.

DATA AVAILABILITY STATEMENT

Data access is subject to restrictions imposed in order to protect participant privacy. All researchers using Raine Study data must sign a data access agreement stipulating that data may not be released to anyone other than the investigators of the approved project. Additional details regarding data access are available from: http://www.rainestudy.org.au/.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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