



Sleep problems and anxiety from 2 to 8 years and the influence of autistic traits: a longitudinal study

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Abstract

Whether or not childhood sleep problems and anxiety occur simultaneously, or one precedes the other, and any effect of autistic traits on this relationship remains unclear. We investigated longitudinal associations between sleep and anxiety at 2 years and sleep and anxiety at 8 years controlling for demographic variables. We also examined the additional influence of autistic traits at 2 years on sleep problems and anxiety at 8 years. Participants were from the Western Australian Pregnancy Cohort (Raine) Study, where 2900 pregnant women were recruited between 1989 and 1991 and their children assessed every 2–3 years thereafter. Demographic information was provided at 16–18 weeks gestation. Children’s sleep and anxiety at 2 and 8 years and autistic traits at 2 years were measured using the Child Behavior Checklist. Hierarchical multiple regression models tested the prediction of both anxiety and sleep problems at 8 years. Sleep problems at 2 years and 8 years, anxiety at 2 years, and autistic traits at 2 years were significantly associated with anxiety at 8 years. Sleep problems at 2 years and anxiety at 8 years were significantly related to sleep problems at 8 years. Each of these models explained about 20% of variance. Childhood sleep problems, anxiety and autistic traits are interrelated and can occur concurrently in young children, but the best predictor of poor sleep in middle childhood is concurrent anxiety and vice versa. Anxiety and sleep problems may be an early indicator of autism in young children and early autistic traits may also contribute to anxiety problems later in childhood.

Keywords Sleep · Anxiety · Autistic traits · Childhood

Introduction

Sleep problems are defined as difficulties relating to falling asleep, interrupted sleep, sleep maintenance, sleep walking, enuresis, night terrors and other parasomnias [1]. Sleep problems affect 10–40% of typically developing (TD) children between 2- and 6 years of age [2–4] and are mostly transient and outgrown by school age [5, 6]. For some children, sleep problems may be persistent. The negative consequences of poor sleep for the child and their family are far reaching. Children who are poor sleepers have reduced daytime neurobehavioural functioning and display increased emotional and behavioural problems compared to children without sleep difficulties [7, 8]. Poorer health-related quality of life and difficulties with language and learning development have been correlated with sleep problems in children aged 4–5 years [9]. Caregiver sleep is also disturbed, resulting in fatigue, stress and irritability [10–12].

Sleep problems are common in children with anxiety [13]. Approximately, 80–90% of clinically anxious youth have at least one sleep problem [14, 15], but it is unclear whether

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sleep problems precede anxiety or vice versa. A systematic review of longitudinal studies examining sleep, anxiety and depression identified nine longitudinal studies for inclusion [16] only one of which examined sleep and anxiety in children [17]. In a non-clinical study, anxiety at 6 years was strongly associated with sleep problems at 11 years, suggesting that anxiety precedes sleep problems [18]. Conversely, using the Child Behavior Checklist (CBCL), a longitudinal study of sleep problems at 4 years showed that they were related to anxiety/depression at 15 years [17]. Sleep problems in childhood may also relate to anxiety and depression in adulthood [19].

High levels of autistic traits also were reported in 42% of children with anxiety disorders [20] and both elevated sleep problems and anxiety are common in children with autism spectrum disorder (ASD). The frequency of sleep problems reported in children with ASD ranges between 50 and 80% [21–23]. Additionally, about 40% of children with ASD meet criteria for an anxiety disorder [24], compared to 10–20% of TD children [25, 26].

Sleep problems in children with ASD between the ages of 7 and 9 years were associated with sleep problems at 11–13 years with meeting criteria for ASD problems predicting later poor sleep [27]. Verhoeff et al. [28] reported that sleep problems and autistic traits were related at 1.5 and 3 years, and that early autistic traits predicted sleep problems at 3-, 6- and 9 years. Conversely over a 1-year period, sleep problems improved in children with ASD aged 7–12 years [29]. Autistic traits, including sensory over-responsivity, and anxiety are associated with sleep problems in children with ASD aged between 2 and 18 years [30], and in children aged between 5 and 18 years with intellectual disability and ASD, 77% had sleep problems, which were positively correlated with anxiety [31]. In contrast to Alfano et al. [18], sleep disturbances at intake predicted anxiety at one-year follow-up in children with and without ASD aged 7–12 years [29], suggesting that sleep problems may precede anxiety in the middle and late childhood. Further longitudinal research is required to determine the direction of the sleep–anxiety relationship.

Autistic traits are believed to be on a stable continuum in children, with ASD representing the extreme end of the distribution [32, 33]. Anxiety and autistic traits are related, there is an association between sleep and anxiety, and sleep difficulties are common in ASD. Whilst it is apparent that a relationship between poor sleep and anxiety exists, the direction of this relationship and whether one precedes the other remains unclear, and any role of autistic traits in this relationship is unknown. Understanding the contribution of autistic traits to later sleep difficulties and anxiety in the general population may provide important insights into the development and maintenance of clinical conditions such as anxiety and insomnia. Using existing longitudinal data, we

examined sleep and anxiety at 2- and 8 years, and autistic traits at 2 years, to determine their relative contributions to variance in anxiety and sleep problems at 8 years. Thus, the present study comprised three main aims: (1) to determine how well sleep problems and autistic traits at 2- and sleep problems at 8 years predict anxiety at 8-years; (2) to determine how well anxiety and autistic traits at 2 years and anxiety at 8 years predict sleep problems at 8 years; and (3) to determine whether variables at 2 years are more predictive of anxiety at 8 years, or sleep problems at 8 years.

Methods

This study involved secondary data analysis of the Western Australian Pregnancy Cohort (Raine) Study. The original purpose of Raine was to examine how pregnancy ultrasound imaging and events affected children's later health and development [34]. Data were collected on parents at 16–18 weeks into the pregnancy and after childbirth, with follow-ups at 1, 2, 3, 5, 8, 10, 14, 17, 20 and 22 years of age. Information used in this study included parental demographic information collected at 16–18 week gestation, and data from the CBCL [35] collected at 2 and 8 years.

Participants

Pregnant women ($N=2900$) at the King Edward Memorial Hospital and other private clinics in Perth were recruited between May 1989 and November 1991 [34]. Inclusion criteria included sufficient oral and written English skills to answer self- and child-report questionnaires; the intention to remain in Western Australia for follow-up visits; plan to deliver at King Edward Memorial Hospital; and a gestational age between 16 and 18 weeks. Parents provided written informed consent at the 2- and 8-year follow-ups. Permission to use these data was granted by the Raine Executive Committee, and the La Trobe University Human Ethics Committee provided ethics approval.

Materials

Demographics

At 16–18 weeks gestation, mothers completed a 108-item demographic questionnaire relating to parent characteristics. Variables that have previously been associated with children's sleep patterns were included. These were age, level of education beyond high school, household income, language spoken at home (English/language other than English), smoking during pregnancy, father living with mother during

pregnancy, number of people living in the house, number of bedrooms, and gender of the child [36–45].

The Child Behavior Checklist (CBCL)

Sleep difficulties, anxiety and ASD traits were measured using the CBCL, which is a parent-rated questionnaire assessing a child's behavioural, emotional and social functioning. The CBCL/2-3 [46] and the CBCL/4-18 [35] were used at 2 and 8 years, respectively. Parents rated the presence and absence of problems on a 3-point scale: 0 'not true', 1 'somewhat or sometimes true', or 2 'very or often true'.

Sleep problems Sleep problems at 2 years were assessed using the CBCL/2-3 Sleep Problems syndrome scale [46]. The CBCL/4-18 (1991) does not include a sleep problems scale so an 8 year Sleep Problems scale was created using CBCL items related to poor sleep. We used six items that were used previously [17], five of which are similar to CBCL/2-3 (1987) Sleep Problems scale items. As sleep enuresis is listed as a sleep disorder in the International Classification of Sleep Disorders (ICSD-3) [47], it was also included. These seven items were summed for a maximum possible score of 14.

Anxiety The CBCL/1½-5 [48] DSM-oriented Anxiety Problems scale was used to measure Anxiety at 2 years. All items except 'shows panic for no good reason' appeared in the CBCL/2-3 [46], but two items also appeared in the Sleep Problems scale and were removed here to eliminate overlap. The final seven scale items were summed for a maximum Anxiety Problems score of 14.

The CBCL/6-18 [49] DSM-oriented Anxiety Problems scale was used to measure anxiety problems at 8 years as all six items on this scale also appeared in the CBCL/4-18 (1991). Scale items were summed to view a maximum possible score of 12.

Autistic Traits Autistic traits at 2 years were measured using the 13 scale items from the CBCL/1½-5 DSM-oriented Pervasive Developmental Problems (PDP) [48], which also appear on the CBCL/2-3 [46]. The PDP scale measures behaviours associated with the DSM-IV-TR (2000) Pervasive Developmental Disorders [50]. Items on the scale were summed to give a total PDP scale score, with 26 being the maximum score.

The reliability statistics and item-to-total correlations were calculated for each CBCL scale and are reported in Table 1.

Data analyses

Missing data due to not all items of a measure being completed at one or more time points is common in longitudinal studies. For the purpose of this study, participants

Table 1 Characteristics of mothers, fathers, and the household at 16–18 weeks gestation

	N	Descriptive statistic	
Mother's characteristics			
Age	2804	M (SD)	28.07 (5.93)
No further education	2804	% (n)	51.6 (1448)
English spoken at home	2804	% (n)	94.3 (2644)
Smoked while pregnant	2804	% (n)	27 (756)
Father's characteristics			
Age	2743	M (SD)	29.99 (6.69)
English spoken at home	2804	% (n)	93.3 (2616)
Living with mother	2780	% (n)	86.8 (2412)
Household characteristics			
Income under \$24,000	2638	% (n)	43.8 (1155)
Adults	2804	M (SD)	2.24 (0.95)
Babies	2804	M (SD)	0.53 (0.71)
Children	2804	M (SD)	0.3 (0.68)
Bedrooms	2804	M (SD)	2.94 (0.86)

who had 70% or more complete items for each CBCL scale were included. Their missing values were replaced by the mean of their completed data [51]. The mean and standard deviations were calculated for autistic traits at 2 years, and sleep problems and anxiety problems at 2 and 8 years.

Two hierarchical multiple regression models were used to examine variables associated with outcome at 8 years (one model for sleep problems and another for anxiety). The selection of independent variables was driven by previous research. For both models, step 1 controlled for variables relating to the mother including age at 16–18 weeks gestation, smoking, English or another language spoken at home, and education. At step 2, variables relating to the father were entered including age at 16–18 weeks gestation, English or another language spoken at home, and living with the mother or not. At step 3, variables relating to the household were entered and included: household income, the total number of adults, babies and children living in the house, and number of bedrooms. At step 4, gender of the child was entered. As previous research suggests that autistic traits can increase the likelihood of children experiencing sleep and anxiety problems [31], autistic traits were entered at step 5, prior to any sleep or anxiety variables.

To predict anxiety at 8 years, after the addition of demographic information and autistic traits, anxiety at 2 years was controlled for at step 6, and then sleep problems at 2 and 8 years were entered at steps 7 and 8, respectively. The model was repeated for the prediction of sleep problems at 8 years, but sleep problems at 2 years were controlled for at step 6, with anxiety at 2 and 8 years following at steps 7 and 8, respectively.

To examine the combined contributions of the predictors at each step in these models, R , R^2 and change in R^2 (ΔR^2) and F values were screened. For the final model, unstandardized regression coefficients (B), standard errors (SE), standardized regression coefficients (β) and t values as well as the total R^2 and the associated F values were examined. For all analyses, alpha (α) or type I error was fixed at the 0.05 level. Exact p values are reported, with the exception of test statistics with a very low probability where p was reported as <0.001 .

Results

Sample Characteristics

Of the 2900 pregnant women originally recruited, 2868 live births were available, but 16 mothers did not complete the full assessment battery and were excluded from further analyses leaving a total sample of 2852. Forty-eight mothers did not provide any demographic information. Of the 2804 pregnant women who completed the demographics questionnaire at 16–18 weeks gestation, most spoke English at home and mean age at the 16–18 week gestation period was 28 years. About a quarter of mothers were smokers and about half had received some form of education beyond high school. Fathers' mean age was 30 years and majority lived at home with the mother and spoke English at home; around 40% of households earned below \$24,000 per year (Table 2).

As 16 cases had no demographic or CBCL data for both time points they were removed, leaving 2852 children of whom half were male (50.8%, $n=1449$). One-third of participants (33.4%, $n=953$) did not complete the CBCL at 2 years and 26.9% ($n=768$) did not complete the CBCL at 8 years. CBCL data were not available on 16.6% ($n=473$) of children at either of these time points.

Mothers who did not complete the CBCL at one or both time points were younger (2- and 8-year CBCL comparisons both $p < 0.001$), had lower levels of education (both $p < 0.001$), and smoked while pregnant (both $p < 0.001$). Households were more likely to have lower income (both $p < 0.001$), and more adults (2 years, $p = 0.003$) and children (2-year CBCL, $p < 0.001$; 8 years, $p = 0.032$) living in the home. Fathers were more likely to be younger (8-year CBCL, $p = 0.039$), and live separate to the mother (both $p < 0.001$).

Predictors of Anxiety and Sleep at 8 years

Tables 3 and 4 show the R , R^2 and ΔR^2 after entry of variables at each step, as well as the unstandardized regression coefficients (B), standard errors (SE), standardised regression coefficients (β) and t values from the final model.

Multicollinearity between the variables used in the regression was not identified as an issue when using guidelines specified by Tabachnick and Fidell (2013) with all bivariate correlations less than 0.9 and the variance inflation factor < 3.00 .

Prediction of anxiety at 8 years (Table 3)

At Step 1, mothers' demographic variables contributed a non-significant 0.4% of variance, and at Step 2, fathers' demographic variables were also non-significant contributing 0.5% of variance. The addition of family demographic variables at Step 3 was not significant, adding only 0.6% of variance. Gender added 0% of variance at Step 4. At Step five, the addition of autistic traits at 2 years was significant ($p < 0.001$), contributing 5.6% of variance. At Step 6, anxiety at 2 years added a significant ($p < 0.001$) 1.3% of variance. The addition of sleep problems at 2 years in Step 7 significantly added ($p < 0.001$) 0.9% of variance, with the addition of sleep problems at 8 years at Step 8 significantly added a further 12.8% of variance.

For anxiety at 8 years, the final model as a whole accounted for 22.2% of variance in anxiety scores, $F(17, 1560) = 26.16$, $p < 0.001$. Sleep problems at 8 years ($\beta = 0.37$, $p < 0.001$), autistic traits at 2 years ($\beta = 0.15$, $p < 0.001$), anxiety at 2 years ($\beta = 0.09$, $p = 0.001$) made unique statistically significant contributions to the final model predicting sleep problems at 8 years.

Prediction of sleep problems at 8 years (Table 4)

At Step 1, mothers' demographic variables were significant ($p < 0.001$) contributing 1.3% of variance. At Step 2, fathers' demographic variables were significant ($p < 0.001$), contributing 1.1% of variance. The addition of family demographic variables at Step 3 was not significant, adding only 0.7% of variance. Gender added a non-significant 0.2% of variance at Step 4. At Step five, the addition of autistic traits at 2 years was significant ($p < 0.001$), contributing 1.1% of variance. At Step 6, sleep problems at 2 years added a significant ($p < 0.001$) 3.1% of variance. The addition of anxiety at 2 years at Step 7 added a non-significant 0.1% of variance, but the addition of anxiety at 8 years at Step 8 significantly ($p < 0.001$) added 13.1% of variance.

The final model in the prediction of sleep problems at 8 years accounted for 20.7% of variance in sleep problem scores, $F(17, 1560) = 23.90$ $p < 0.001$. Anxiety at 8 years ($\beta = 0.38$, $p < 0.001$), sleep problems at 2 years ($\beta = 0.13$, $p < 0.001$), and mother's language (English spoken at home/English not spoken at home) ($\beta = -0.19$, $p = 0.015$) made unique statistically significant contributions to the final model predicting sleep problems at 8 years.

Table 2 CBCL scale reliability and individual item reliability

Measure	Chronbach's α	Test–rest reliability	Correlation	Chronbach's α if item deleted
Sleep 2-years	0.74	0.92		
Will not sleep alone			0.48	0.70
Trouble getting to sleep			0.60	0.67
Nightmares			0.30	0.74
Resists going to bed			0.51	0.69
Sleeps less than most			0.39	0.72
Talks in sleep			0.36	0.73
Often wakes at night			0.51	0.69
Anxiety 2-years	0.53	0.85		
Clings to adults			0.39	0.43
Wants to stay home			0.14	0.53
Fears animals, situations			0.23	0.53
Too upset separated from parents			0.38	0.43
Nervous, hamstrung, tense			0.25	0.50
Too fearful or anxious			0.36	0.47
Worrying			0.21	0.52
ASD traits 2-years	0.60	0.86		
Afraid to try new things			0.30	0.57
Avoids eye contact			0.33	0.56
Cannot stand things out of place			0.16	0.61
Change in routine			0.29	0.58
Does not answer			0.33	0.57
Does not get along with children			0.25	0.58
Repeatedly rocks head/body			0.14	0.60
Unresponsive to affection			0.24	0.59
Shows little affection			0.32	0.57
Speech problem			0.14	0.60
Strange behaviour			0.12	0.60
Upset new people/situation			0.37	0.55
Withdrawn			0.29	0.58
Sleep 8-years	0.55			
Trouble sleeping			0.43	0.45
Nightmares			0.34	0.49
Overtired			0.33	0.49
Sleeps less than most kids			0.35	0.48
Talks or walks in sleep			0.30	0.50
Sleeps more than most kids			0.11	0.56
Wets the bed			0.06	0.59
Anxiety 8-years	0.69	0.80		
Fears apart from school			0.35	0.68
Clingy/dependent on adults			0.40	0.66
Fears going to school			0.32	0.68
Nervous or highly strung			0.49	0.63
Too fearful or anxious			0.57	0.61
Worries			0.45	0.64

Table 3 Hierarchical multiple regression summary predicting anxiety at 8 years

	<i>R</i>	<i>R</i> ²	ΔR^2	<i>P</i>	<i>B</i>	<i>SE</i>	β	<i>T</i>	<i>P</i>
Step 1	0.066	0.004	0.004	0.148					
Mother's age					0.001	0.010	0.002	0.050	0.960
Mother's lang.					−0.246	0.260	−0.036	−0.946	0.344
Education					0.032	0.087	0.009	0.367	0.714
Smoking					0.065	0.093	0.016	0.696	0.486
Step 2	0.098	0.010	0.005	0.037					
Father's age					0.008	0.009	0.029	0.900	0.368
Father home					−0.035	0.131	−0.007	−0.270	0.787
Father's lang.					0.231	0.245	0.035	0.943	0.346
Step 3	0.125	0.016	0.006	0.098					
Income					0.002	0.093	0.001	0.022	0.982
No. of adults					0.032	0.047	0.017	0.690	0.490
No. of babies					−0.096	0.060	−0.038	−1.618	0.106
No. of bedrooms					−0.021	0.053	−0.010	−0.403	0.687
No. of children					−0.067	0.063	−0.025	−1.052	0.293
Step 4	0.125	0.016	0.000	0.566					
Sex of the child					0.038	0.081	0.011	0.476	0.634
Step 5	0.268	0.072	0.056	<0.001					
Autistic traits 2 years					0.109	0.019	0.150	5.723	<0.001
Step 6	0.291	0.085	0.013	<0.001					
Anxiety 2-years					0.088	0.028	0.086	3.192	0.001
Step 7	0.306	0.093	0.009	<0.001					
Sleep 2-years					0.024	0.016	0.037	1.502	0.133
Step 8	0.471	0.222	0.128	<0.001					
Sleep 8-years					0.409	0.025	0.373	16.049	<0.001

Discussion

This is one of the few studies to longitudinally examine the relationship between sleep problems and anxiety from early childhood to middle childhood, and the additional influence of early autistic traits. Through this study, we are able to examine patterns of homotypic (when one childhood problem predicts itself at later time point) and heterotypic (when one childhood problem relates to another problem at a later time point) continuity [52].

Predicting anxiety at 8 years

Both anxiety and autistic traits at 2 years and sleep problems at 8 years were significantly associated with anxiety at 8 years. Sleep problems at 8 years were the highest contributor, explaining 13% of variance in anxiety at 8 years, suggesting that the two co-occur which is consistent with clinical studies [14, 15].

Autistic traits significantly accounted for variance in anxiety at 8 years, indicating heterotypic continuity between autistic traits and later anxiety [52]; that is higher autistic traits in toddlers put them at risk of later anxiety. It has been previously demonstrated in older children aged 7–16 years

with clinical anxiety that autistic traits and anxiety are linked [20]. Children who also presented with clinically relevant autistic traits were likely to experience more phobias and to have social phobia compared to those with low autistic traits [20]. Such findings may be due to the deficits in social and communication skills common to autistic traits, which may lead to feelings of anxiety when placed in social settings [53]. Autistic traits also include a strong desire to adhere to strict routines or ritualised behaviours; thus, divergence from these routines or exposure to new and different stimuli may evoke distress and fear [54, 55].

Anxiety at 2 years explained a small amount of variance in 8-year-old anxiety, indicating that homotypic continuity was present [52]. However, while early anxiety can be a risk factor for anxiety in middle childhood, behavioural inhibition and parenting, and maternal anxiety are more important contributors [56]. Furthermore, Wichstrom et al. [57] reported that as well as behavioural inhibition, maternal anxiety and peer victimisation, poor social skills at age 4 predicted 6-year-old anxiety. Given that poor social skills and early anxiety are associated with high autistic traits and ASD, the addition of autistic traits may also have accounted for much of the variance in 8-year-old anxiety, which might have been explained by anxiety alone.

Table 4 Hierarchical multiple regression summary predicting sleep problems at 8 years

	<i>R</i>	<i>R</i> ²	ΔR^2	<i>P</i>	<i>B</i>	<i>SE</i>	β	<i>T</i>	<i>P</i>
Step 1	0.113	0.013	0.013	<0.001					
Mother's age					−0.003	0.009	−0.012	−0.363	0.716
Mother's lang.					−0.581	0.239	−0.192	−2.435	0.015
Education					−0.018	0.080	−0.006	−0.226	0.821
Smoking					0.015	0.086	−0.004	0.172	0.864
Step 2	0.154	0.024	0.011	<0.001					
Father's age					−0.009	0.008	−0.045	−1.177	0.239
Father at home					−0.216	0.120	−0.069	−1.795	0.073
Father's lang.					0.212	0.225	0.036	0.940	0.347
Step 3	0.175	0.031	0.007	0.056					
Income					−0.075	0.085	−0.023	−0.877	0.381
No. of adults					−0.015	0.043	−0.009	−0.360	0.719
No. of babies					−0.080	0.055	−0.035	−1.462	0.144
No. of bedrooms					−0.013	0.049	−0.007	−0.259	0.796
No. of children					0.061	0.058	0.025	1.49	0.294
Step 4	0.181	0.033	0.002	0.058					
Gender of child					−0.132	0.074	−0.040	−1.777	0.076
Step 5	0.209	0.044	0.011	<0.001					
Autistic traits 2-years					−0.012	0.018	−0.018	−0.690	0.491
Step 6	0.273	0.074	0.031	<0.001					
Sleep 2-years					0.081	0.015	0.134	5.473	<0.001
Step 7	0.275	0.076	0.001	0.140					
Anxiety 2-years					0.004	0.025	0.005	0.166	0.868
Step 8	0.455	0.207	0.131	<0.001					
Anxiety 8-years					0.347	0.022	0.380	16.049	<0.001

While the model predicting anxiety at 8 years remained significant, and sleep at 2 years explained a similar amount of variance as 2-year anxiety, this was non-significant in the final model. Using the CBCL, previous research [17] found that anxious/depressed symptoms and sleep problems at 4 years, adoptive status and sex, together explained 12% of variance in CBCL anxious/depressed symptoms in children aged 13–15 years, with all variables except sex making a significant contribution. Prior to the addition of sleep at 8 years, demographic data, autistic traits, and anxiety and sleep at 2 years accounted for 9.3% of variance in anxiety at 8 years in our sample, which is of a similar magnitude. Gregory and O'Connor [17] included both anxiety and depressive symptomatology; thus, the additional variance explained by sleep problems may have been due to the inclusion of depressive symptoms in their study.

Sleep problems measured at 2 years may be temporary and thus less likely to predict other problems in middle childhood [5, 6], although in some children sleep problems may be persistent [5]. Diagnostic systems such as the DSM-IV-TR [50] also assume that psychiatric disorders are discrete, but symptom overlap is present; for example, poor sleep is a diagnostic characteristic for generalised anxiety disorder (GAD). Thus, the stronger, contemporaneous association of

sleep and anxiety at 8 years is not surprising, but indicates that longitudinal, heterotypic continuity between sleep and anxiety from early to middle childhood is weak.

However, despite some evidence of homotypic and heterotypic influences on anxiety at 8 years, the amount of variance explained was minimal which indicates that there are a range of other factors not explored here that relate to childhood anxiety.

Predicting sleep problems at 8 years

In the final model, sleep problems at 2 years and anxiety at 8 years were significantly associated with sleep at 8 years. One demographic variable, mother speaking English at home, also contributed significantly to the model.

Anxiety at 8 years was the best predictor of sleep problems at 8 years and explained 13% of variance. This is consistent with results from the first model, providing further evidence that sleep and anxiety problems are interrelated and occur contemporaneously in 8 years old. These findings support Alfano et al. [18] who reported that after controlling for demographic variables and depression, anxiety accounted for 14% of variance in sleep problems in a nonclinical sample of children aged 6 to 11 years. Like anxiety, poor sleep

also demonstrated homotypic continuity from 2 to 8 years. Similarly, an annual examination of children's sleep from age 5 months through to 6 years and their parents' behaviours concluded that early poor sleep was predictive of later poor sleep; associated maladaptive parent behaviours developed in reaction to early poor sleep [58].

The addition of autistic traits did not contribute significantly to the final model and the relationship was unexpectedly negative; this is in contrast to two published population studies [27, 28]. Verhoeff et al. [28] used the CBCL to measure sleep from 1.5 to 9 years and autistic traits at 1.5 and 3 years, and the Social Responsiveness Scale measured autistic traits at 6 and 9 years, reporting that autistic traits predicted sleep problems at 6- and 9 years. Another research group [27] also reported that significant autistic spectrum traits remained a predictor of sleep problems in children from 7–9 to 11–13 years of age, after adjusting for emotional and behavioural problems. Differences may be accounted for by age; that autistic traits were a dichotomous variable with only 0.8% of children in this group; and the use of a single question (3-point Likert scale) for sleep problems [27]. Reasons for differences with the second study [28] are less clear, but their sleep subscale omitted bedwetting and sleeping too much. Nocturnal enuresis (NE) is common in ASD and ASD is common in children with NE [59], but sleeping too much is generally not reported [60]. Thus, differences in sleep measurement may have differentially influenced outcomes. Nevertheless, our sleep scale at 8 years contained questions consistent with the range of sleep disorders reported in ISCD-3 [47].

Adding anxiety at 2 years explained negligible additional variance in 8-year-old sleep. This suggests that anxiety's contribution to poor sleep at 8 years was entirely accounted for by autistic traits and sleep at 2 years and highlights the interrelatedness of sleep problems, anxiety symptoms and autistic traits in young children. Although some studies have suggested anxiety is a precursor to sleep difficulties [16], most have focused on older children and adults. For example, [61] found that anxiety at 7-year predicted insomnia in adolescents with anxiety disorders. The results from the present study suggest that this effect does not translate to young children and that the experience of anxiety in early childhood may be too transient to be associated with sleep problems at 8 years. This is in contrast to older children with anxiety, which appears to be more stable over time, thus more likely to be associated with sleep problems [61].

Strengths and limitations

As far as we are aware this is the first longitudinal examination of relationships between sleep and anxiety and the contribution of early autistic traits to these relationships in young children. Our sample size was large, but a limitation

was the restriction to those data collected by the Western Australian Pregnancy Cohort (Raine) Study, which was not specifically designed to collect the target variables of interest. For example, CBCL sleep items have been found to primarily associate with sleep latency difficulties as measured via sleep diaries and actigraphy [62]. Nevertheless, the CBCL is a widely used measure of children's behaviour and has been used previously to examine sleep, autistic traits, anxiety or behavioural issues, including longitudinal associations [17, 28, 30]. The CBCL scales we used had moderate internal consistency, which can be expected when examining psychological variables [63]. The sleep problems scale created at 8 years had the same internal consistency as [28] who reported an alpha of 0.55 for a CBCL 5-item version at 9 years and was similar to [17] who reported alpha of 0.50 at 4 years and 0.59 at 13–15 years for a CBCL 6-item version. Our 7-item sleep scale also contained questions about bedwetting and sleeping too much.

The CBCL is a parent-report questionnaire, which may lead to under- or over-reporting of symptoms. The CBCL would be less sensitive to identifying sleep disorders such as apnoea and/or restless leg syndrome; therefore, the rates of sleep problems/disorders are likely to be underreported. Additionally, considerable discrepancies in parent and child reporting of sleep problems and anxiety have been found in school-aged children; thus, parent report is not necessarily a reliable measure of sleep in older children [64, 65]. Clinical diagnosis of anxiety and ASD, disorder-specific measures of both anxiety symptoms and autistic traits, and the use of both subjective and objective measures of sleep such as actigraphy would add to reliability. Thus, future longitudinal research using methods and measures specifically designed to address the variables of interest is needed to confirm our findings.

Finally, there was socio-economic bias within the Raine cohort; completer analyses showed that mothers who did not complete the CBCL were more likely to be younger, less educated, have a lower household income, smoke while pregnant and not live with the child's father. As children from lower socio-economic families are more at risk for poor sleep and mental health [6, 36, 37], this suggests that our results may not be generalisable to lower socio-economic families.

Clinical implications

Sleep and anxiety problems during middle childhood occur contemporaneously. Clinicians need to be aware of the associations between these symptoms and should assess for anxiety and other internalising problems in children who present with sleeping difficulties and vice versa. Our findings also highlight the co-occurrence of sleep problems and anxiety in toddlers and the contribution of early

autistic traits to later anxiety. Our findings indicate that children with high autistic traits are at considerable risk of experiencing comorbid anxiety and that the presence of anxiety indicates a contemporary high risk for poor sleep. Thus, when assessing children, clinicians should be conscious of this symptom overlap. Additionally, this symptom overlap suggests that anxiety in toddlers may be an early indicator of high autistic traits. Early interventions targeted for children with significant autistic traits should also take account of the likelihood of comorbid anxiety and development of poor sleep. Improvements in sleep patterns and anxiety reduction may have the added benefit of increasing responsiveness to therapy.

Conclusion

This study is the first to examine the relationship between sleep problems and anxiety and the influence of autistic traits on their development, longitudinally from 2 to 8 years. The current findings provide new insights into whether sleep problems, anxiety symptoms and autistic traits at 2 years directly influence sleep and anxiety problems in middle childhood. The major contributor to anxiety at 8 years was poor sleep and vice versa, which is consistent with earlier reports [15, 18]. Autistic traits at 2 years had a small, but significant impact on 8-year-old anxiety; furthermore, at 2 years, autistic traits, anxiety and sleep problems all overlapped, indicating that these problems are highly interrelated in very young children. While sleep problems and anxiety are common in 2 years old, they are likely to be transient and are not strong predictors of problems later in childhood, but early elevated autistic traits may be a risk indicator for anxiety at 8 years. Further research in this field should aim to design longitudinal studies that help gain a better understanding on the evolution of sleep problems and anxiety across childhood, and the impact of autistic traits. Effective prevention and early intervention are predicted on such understanding. This is of particular importance when considering that poor sleep in late childhood is a significant predictor of anxiety in adolescence [66].

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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