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**Title:** The association between bullying-victimisation and sleep disturbances in adolescence: Evidence from a twin study

**Shortened title:** Bullying-victimisation and sleep disturbances

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**Disclosures:** Alice Gregory is an advisor for a project sponsored by Johnson's Baby. She has written the books *Nodding Off* (Bloomsbury Sigma, 2018) and *The Sleepy Pebble* (Flying Eye Books, 2019). She is a regular contributor to BBC Focus magazine and has contributed to other outlets (such as *The Conversation*, *The Guardian* and *Balance Magazine*). She occasionally receives sample products related to sleep (e.g. blue light blocking glasses) and has given a paid talk to a business. Angelica Ronald has written for the National Childbirth Trust. Sania Shakoor is a trustee for the anti-bullying charity Kidscape.

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## ABSTRACT

Bullying-victimisation has been associated with sleep disturbances. This study investigated the degree to which subtypes of bullying victimisation in adolescence are linked with sleep disturbances. Genetic and environmental contributions underlying bullying-victimisation and sleep disturbances were investigated. Participants (3,242-5,076 pairs) from a longitudinal community twin study reported on their bullying-victimisation at age-14, sleep quality and insomnia symptoms at age-16. Regression analyses were used, accounting for the role of individual and family factors. Structural equation twin model-fitting was conducted. Bullying victimisation was modestly associated with sleep quality and insomnia symptoms ( $r = .22-.23$ ) and a similar strength of associations was found across bullying-victimisation subtypes ( $r=.11-.22$ ). Bullying-victimisation, sleep quality and insomnia symptoms were predominantly influenced by genes (25%-59%) and non-shared environments (40%-62%). The association between bullying-victimisation and sleep-quality was explained by genetic and non-shared environmental influences. For insomnia symptoms and sleep quality, the association with bullying-victimisation was in part explained by a genetic overlap. Associations between bullying-victimisation and sleep disturbances are not limited to specific aspects of bullying-victimisation but appear to exist for all subtypes. These findings stimulate research questions regarding the mechanisms underlying these links. For example, could certain heritable traits, such as temperament, increase vulnerability to experiencing sleep disturbances and being bullied? Research on bullying and sleep should aim to take the role of genetic predisposition into account, while also noting that it is not the only causal influence. Understanding more about these pathways could strengthen the development of techniques to prevent these difficulties from occurring.

**Keywords:** Bullying, sleep quality, insomnia symptoms, twin study, behavioural genetics

### **The association between bullying-victimisation and sleep disturbances in adolescence: Evidence from a twin study**

Bullying-victimisation is characterised by repeated hurtful actions between peers where a power imbalance exists (Shakoor et al., 2011). It is associated with psychological and physical difficulties including emotional and behavioural problems (Arseneault, Bowes & Shakoor, 2010), headaches and sleep disturbances (Gini & Pozzoli, 2013) in childhood and adolescence. Aetiological explorations have found genetic and environmental factors to play pivotal roles (Arseneault, 2018). This has been informative for policy makers and practitioners as it has provided a greater understanding of the risk bullying-victimisation poses on well-being.

An association which still warrants further aetiological exploration is that between bullying-victimisation and sleep. Important for cognitive and emotional functioning (Walker, 2010), disturbances in sleep have been associated with outcomes frequently seen amongst victims of bullying such as physical health (Grandner, 2012) and psychological well-being (Gregory & Sadeh, 2016). It is possible that the fear associated with being bullied and rumination over bullying experiences may interfere with the onset of sleep and contribute towards poor sleep-quality and insomnia (Dahl & Lewin, 2002, Harvey, 2002). Evidence supports a robust association between bullying-victimisation, sleep problems (i.e. difficulties falling or remaining asleep) and insomnia (van Geel, Goemans, & Vedder, 2016), which remains evident after controlling for potential confounders (e.g. emotional and behavioural problems) (Wolke & Lereya, 2014). Bullying-victimisation is thus an independent risk factor for sleep disturbances and warrants deeper investigation; in particular in adolescence, as this is a period marked by changes in sleep timing and patterns (Crowley, Wolfson, Tarokh, & Carskadon, 2018).

Twin studies have implicated both genetic and environmental factors in bullying-victimisation (Shakoor, et al., 2015) and sleep disturbances (Gregory, 2008).

Evidence suggests an overlap in certain correlates, such as socioeconomic deprivation and exposure to violence in the home (Arseneault, et al., 2010; Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001). Individual differences in exposure to such things appear to be due to both genetic and environmental influences (Jaffee & Price,

2007). It is thus possible that bullying-victimisation and sleep disturbances may have shared genetic and environmental influences. Exploring commonalities in environmental and genetic risk factors is important as it can inform strategies applied to dampen the impact of sleep disturbances and promote well-being. With this in mind, using a genetically sensitive design, the current study aimed to (1) explore the strength of the relationship between bullying-victimisation with sleep quality and insomnia symptoms during adolescence (after taking family and individual characteristics into consideration) (2) estimate the extent to which genetic and environmental factors influence these relationships. By using this approach, this study aims to extend the literature on the link between bullying-victimisation and sleep disturbances and provide an insight into possible aetiological mechanisms.

## **METHODS**

### **Sample**

Participants belonged to the Twins Early Development Study (TEDS), a longitudinal, general population sample of monozygotic (MZ) and dizygotic (DZ) twins born in England and Wales between 1994 and 1996 (Haworth, Davis, & Plomin, 2013). TEDS has full ethical approval and written consent was obtained at each point of contact.

Twin reports for 3,527 pairs were obtained at age 14 (M= 14.07 years) using postal questionnaires. After exclusions, at age-14, data was available from 3,242, among whom 55% were male, 36% were MZ twin pairs, and 31% were opposite sex twin pairs. At age-16, 5,076 twin pairs returned data (M=16.37 years) using postal questionnaires. After exclusions (N=610) the sample was 45% male, 38% were MZ twin pairs and 30% were opposite sex twin pairs. Participants had a mean age of 16.37 years. Exclusion criteria included autism spectrum conditions, genetic syndromes (including Fragile X syndrome and cystic fibrosis), chromosomal abnormalities (including Down syndrome and cerebral palsy), extreme perinatal or prenatal complications, and missing first contact or zygosity data. Missing data in twin analyses was dealt with using full information maximum likelihood.

The TEDS sample at ages-14 and 16 has remained largely representative of the main sample and the UK population (further details Haworth, et al., 2013; Ronald et al.,

2014). Zygosity was ascertained through a combination of DNA testing and parent report of twin resemblance, which has been found to be over 90% accurate when compared to DNA testing alone (Price et al., 2000).

## **Measures**

### *Age-14 Bullying-victimisation*

Bullying victimisation was assessed using the Multidimensional Peer Victimization Scale (Mynard & Joseph, 2000). Consisting of 16 self-report items the scale captured 4 subscales of bullying-victimisation - physical abuse, verbal abuse, social manipulation and property damage. Each subscale consisted of 4 items and were created in line with previous research (Mynard & Joseph, 2000). Summing across all items captured a total composite measure of bullying-victimisation. Higher scores indicated higher levels of bullying-victimisation. High internal reliability of scales and total composite measure were evident in our sample (Table 1).

### *Age-16 Sleep*

*Sleep-quality* was assessed using the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The measure consisted of 17 self-report items which assessed sleep-quality in the past month by enquiring about duration of sleep, amount of time spent in bed, daytime disruption, sleep medication use, and whether sleep had been disrupted by factors such as struggling to fall and stay asleep. Higher scores indicating poorer sleep-quality. The PSQI displayed good internal consistency (Table 1) in the current sample.

*Insomnia symptoms* was assessed using the Insomnia Severity Index (ISI; Bastien, Vallieres, & Morin, 2001). Consisting of 7 self-report items, the measure assessed symptoms of insomnia, such as sleep problems interfering with daily functioning. Higher scores represented greater insomnia symptoms. The ISI had good internal consistency (Table 1) in the current sample.

### *Age-12 Covariates*

Covariates were selected based on previous research (Kochel, Ladd, & Rudolph, 2012; Stein, et al., 2001). These included bullying-victimisation, cognitive ability, behavioural problems, emotional problems (including symptoms of anxiety),

depression, home chaos, parental discipline and socioeconomic status. It should be noted that behavioural problems include some items which encompass emotional problems therefore these two scales were not entirely independent of each other. Details and descriptive statistics of these measures are reported in Table S1.

### **Statistical analyses**

Analyses were performed using statistical packages STATA 12 (StataCorp. Stata Statistical Software: Release 14. College Station) and Open Mx (Boker et al., 2011). Open Mx uses the method of maximum likelihood estimation and is widely used for analysing genetically sensitive data. In line with standard behavioural genetics procedure, the effects of sex and age were regressed on the phenotypes. Further analyses were conducted using the remaining residuals for each phenotype. Any skewed data were transformed using square root transformation techniques. Analyses were performed as follows: (1) using linear and multivariate regression models we examined the association between bullying-victimisation and sleep whilst taking into account a series of covariates (listed above); (2) we tested the degree of twin similarity on the measures for monozygotic (MZ) and dizygotic (DZ) males and females and DZ opposite sex (DZOS); (3) we used univariate structural equation models to estimate the contributions of genetic and environmental influences on bullying-victimisation and sleep measures; (4), we ran bivariate correlated factors models to examine the overlap between genetic and environmental influences on bullying-victimisation and sleep.

### **The twin design**

The twin design uses MZ and DZ twin pairs to estimate variation in a phenotype, or covariation between phenotypes, that are attributable to genetic and environmental influences. Within pair similarities for MZ and DZ twin pairs were examined to establish the role of genetic and environmental influences based on the assumption that: (1) MZ twin pairs share 100% of their segregating genes and DZ twin pairs share on average 50%; (2) MZ and DZ twin pairs share environmental factors that make both twins in the same family more alike (“shared environment”); and (3) exposure to environmental factors which are experienced differently or are specific to the individual (“non-shared environment”) contribute towards differences between MZ and DZ twin pairs. This includes measurement error (Rijsdijk & Sham, 2002).

Structural equation modelling was employed to establish the relative importance of additive genetic (A), shared environment (C) and non-shared environmental influences (E) (Rijsdijk & Sham, 2002) (Appendix S1 for more details).

## **Results**

### **Descriptive statistics**

Analyses revealed significant mean sex effects for all scales (*Table 1*). Relative to females, males reported higher levels of bullying-victimisation (with the exception of social manipulation). Females reported poorer sleep-quality and greater insomnia symptoms than did males. A main effect for zygosity was observed, whereby DZs reported higher levels of sleep problems in comparison to MZs. However, the combined effect of sex and zygosity on the means for all phenotypes was small ( $R^2=0.00 - 0.11$ ).

**\*\*INSERT TABLE 1\*\***

### **Phenotypic associations between bullying-victimisation subscales at age-14 and sleep at age-16**

Phenotypic correlations between bullying-victimisation subtypes and sleep were small but significant (range  $r = .12-.24$ ). There were no differences between the magnitude of the associations between the sleep phenotypes and the different bullying-victimisation subtypes (*Table 2*). Associations between bullying-victimisation, sleep quality and insomnia symptoms remained significant after accounting for possible individual and family confounders including emotional and behavioural problems, SES and parental discipline (*Table 3*). The associations were higher amongst females, however the differences were non-significant as compared to males. The associations between bullying-victimisation subtypes, sleep quality and insomnia symptoms became non-significant once confounders were taken into account.

**\*\*INSERT TABLE 2 AND 3\*\***

### **Univariate analysis**

MZ correlations (*Table S2*) were higher than DZ correlations suggesting genetic influences on bullying-victimisation and sleep disturbances. Sex differences in



variance components were indicated by a different pattern of correlations between MZ and DZ pairs in males and females. Structural equation model fitting analysis confirmed these initial observations (Table S3). Equating A, C and E estimates across sexes led to significant deterioration in fit for all variables with the exception of sleep-quality. Parameter estimates for the best fitting univariate models are shown in Table 4. Significant genetic influences were shown for all variables in males (all bullying measures: 25%-59%, insomnia symptoms: 34%) and females (all bullying measures: 11%-39%, insomnia symptoms 42%). Shared environmental influences were evident for some bullying measures including total bullying-victimisation and were greater in females (3%- 31%) than males (2%-19%) except for physical bullying. Shared environmental influences were not significantly evident for insomnia symptoms (3%-4%). Non-shared environmental influences were significant for all bullying measures (40%-61%) and insomnia symptoms (56%-62%) in males and females. No significant sex differences were observed for sleep-quality. 42% of variances in sleep-quality were attributable to genetic factors, 58% to non-shared environmental factors and no significant contribution of shared environmental factors was observed.

**\*\*INSERT TABLE 4\*\***

### **Bivariate twin model-fitting results**

Correlations between bullying-victimisation (composite score) and sleep quality and insomnia symptoms were significant ( $r_{ph} = .19-.24$ , Table 2). Due to the associations between bullying-victimisation subtypes and sleep disturbances not remaining after confounders were taken into consideration, we focus on the relationship between the total bullying-victimisation and sleep disturbances in the bivariate twin model-fitting analyses.

Cross-twin cross-trait (CTCT) correlations are shown in Table 5. Due to the evidence of sex differences on variables of interest we fitted a bivariate heterogeneity (sex differences) model (fit statistics presented in Table S4). CTCT correlations suggested that in addition to genetic influences, shared environmental influences may account for some of the covariance between traits (MZM and DZM CTCT correlations were similar). Equating parameters across sexes (bivariate homogeneity model) led to a significant deterioration in fit (Table S4). However, as patterns of genetic and

environmental factors were similar across sexes (see Figures S1a and S1b), here we focus on the results from the homogeneity model.

**\*\*INSERT TABLE 5\*\***

Figure 1a presents the results of the bivariate analysis between total bullying-victimisation and sleep quality. The relationship between total bullying-victimisation and sleep quality was in part due to overlapping genes ( $r_A=.26$  95%CI: .14-.46). A significant correlation between non-shared environmental influences was also observed ( $r_E=.11$  95%CI: .04-.18). Genetic and non-shared environmental influences both significantly explained the phenotypic correlation (50% and 24% respectively; Table 5). Shared environmental influences were non-significant.

Figure 1b presents the results of the bivariate model between total bullying-victimisation and insomnia symptoms. Covariation between total bullying-victimisation and insomnia symptoms was due to genetic influences ( $r_A=.32$  95%CI: .20-.50). Although non-shared environment accounted for 41-60% of the variance in bullying-victimisation and insomnia symptoms these influences were not significantly correlated ( $r_E=.07$  95%CI: .00-.13). As such, there was not significant overlap in non-shared environmental influences between bullying victimisation and insomnia. Rather non-shared environments which are specific to bullying and specific to insomnia were contributing towards each phenotype. Genetic influences did account for a significant proportion of the phenotypic correlation (Table 5; 62%).

**\*\*INSERT FIGURE 1a and 1b\*\***

## **DISCUSSION**

### *Childhood bullying-victimisation and sleep disturbances*

This study found bullying-victimisation at age-14 to be similarly associated with sleep-quality and insomnia symptoms at age-16. Associations remained significant with the composite score of bullying-victimisation after controlling for individual and family characteristics. Our results are consistent with previous reports from population-based studies in children and adolescents (van Geel, et al., 2016). Our findings extend past work by showing that the association between bullying-

victimisation and troubled sleep is not specific to a particular type of bullying-victimisation. The overall experience of bullying-victimisation associates with poorer sleep quality and insomnia symptoms.

Our findings are consistent with the idea that exposure to threat, assessed here as bullying-victimisation, can contribute to sleep disturbances (Dahl & Lewin, 2002). It is possible that cognitive processes could mediate this association. For example, victims of bullying have been found to ruminate more about their experiences in comparison to their non-bullied peers (Hampel, Manhal, & Hayer, 2009). The process of rumination is observed amongst people with insomnia symptoms who report worrying, intrusive thoughts or a racing mind to contribute towards their difficulties with sleep (Harvey, 2002). The heightened preoccupation with past events amongst victims of bullying could be an underlying mechanism explaining the covariation between bullying-victimisation and insomnia symptoms.

#### *The heritability of bullying-victimisation and sleep disturbances*

In concurrence with previous twin studies, both sleep and bullying-victimisation were heritable suggesting that adolescents have genetic predispositions which increase their vulnerabilities for being bullied and experiencing sleep problems (Gregory, 2008; Shakoor, et al., 2015). Our study also found significant non-shared influences for all phenotypes. This indicates that after taking genetic vulnerabilities into account, it is environments that are specific to the individual, such as individual-specific stressful life events, that contribute towards their risk of being bullied and having sleep disturbances. Shared environmental influences were evident for some bullying measures and tended to be greater in females than males. This suggests that the environmental experiences that make family members more alike, which could potentially include socioeconomic deprivation and exposure to violence in the home, may be influential in shaping vulnerabilities for most types of bullying-victimisation. To our knowledge this is the first study to estimate genetic and environmental influences on the subtypes of bullying-victimisation, and although all subtypes share a commonality in their genetic and non-shared environmental influences, the magnitude of effect in the shared environmental influences were significantly higher in certain types of bullying-victimisation.

*Aetiology underlying the association between bullying-victimisation and sleep disturbances*

The association between bullying-victimisation at age-14 with insomnia symptoms and sleep-quality at age-16 was in part explained by overlapping genetic influences. Furthermore, consistent with the possibility of gene-environment correlation, our finding of genetic overlap indicates individuals may have inherent genetic predispositions that influence vulnerabilities to being bullied and experiencing sleep disturbances. For example, early emotional problems increase the risk of bullying-victimisation (Arseneault, et al., 2010). Anxious and depressed individuals may appear less capable of negotiating conflicts or of defending themselves, and are thus viewed as easy targets for abuse from peers. As emotional problems are in part heritable (Bartels, van de Aa, van Beijsterveldt, Middeldorp, & Boomsma, 2011) and associated with sleep disturbances (Gregory, 2008), it is theoretically possible that genetic influences underlying the relationship between bullying-victimisation and sleep disturbances are explained by co-occurring emotional problems. We explored this in our data and found that the phenotypic association between bullying-victimisation and sleep disturbances remained after controlling for emotional problems, suggesting that other mechanisms may be at play (Table 3).

Our finding of genetic overlap between bullying-victimisation and sleep disturbances should be explored further. For example, genetic variants identified from recent genome-wide association studies as being associated with insomnia (Jansen et al., 2018) and sleep length in children and adults (Jones et al., 2016; Marinelli et al., 2016) could be explored for their potential associations with vulnerability to bullying-victimisation. Furthermore, using polygenic risk score analyses, information from genome-wide data could be collated to see whether there is an overlap between the common risk alleles associated with bullying-victimisation and sleep disturbances.

*Limitations and strengths*

Although we measured bullying-victimisation before sleep-quality and insomnia symptoms, we were unable to control for earlier insomnia symptoms and sleep quality. This study therefore does not show that bullying-victimisation is associated with an increase in disturbed sleep over time. The association between sleep disturbances and bullying-victimisation may be bidirectional with sleep disturbances

increasing the likelihood of bullying-victimisation and vice-versa, or influenced by a third underlying factor. Data on sleep disturbances in adolescents was only available at age 16; as such, we were unable to test for a bidirectional relationship.

We used self-reports of bullying-victimisation. It is possible that adolescents at age-14 may not be comfortable reporting bullying-victimisation, however self-reports of bullying-victimisation at a younger age of 12 have been found to be reliable and comparable to parent reports (Shakoor, et al., 2011). We also relied on questionnaire measures of sleep disturbances. Polysomnography and actigraphy measures would provide additional objective perspectives on aspects of sleep (Gregory & Sadeh, 2016), although this form of measurement is often infeasible in large samples. Furthermore, the PSQI and ISI are well-established and validated instruments (Bastien, Vallieres, & Morin, 2001; Buysse et al. 1989). Our measures of sleep focused on sleep-quality and insomnia symptoms. Other sleep disturbances, such as parasomnias have been found to be associated with bullying-victimisation (Wolke & Lereya, 2014) and the investigation into the aetiology of further associations would be informative. Furthermore, we observed substantial overlap between our measures of sleep quality and insomnia symptoms ( $r=0.69$ ;  $p< 0.01$ ). This was expected, although needs to be considered when interpreting the results of the study. We decided to include both measures in this report because they have distinct properties. Indeed, it is possible to report poor sleep quality without reporting insomnia. By including both measures we are capturing a wider range of sleep behaviours.

All of our measures were self-report, which means it is possible that there was potential shared methods variance bias. We explored this in our data by using the Harman's single factor test. Using factor analyses we checked if one single factor emerged or whether a general factor explained the majority of the covariance amongst the measures. It is argued that this general factor captures common methods variance (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Analyses revealed 9 factors explaining 59.22% of the variance. The primary unrotated factor captured only 21.42% of the variance (Table S5). These results do not support the presence of common methods variance. We therefore consider the potential effects of common method variance to be non-substantial.

Despite these limitations, this study's strengths lie in its genetically informative twin design study, which allowed decomposition of the relationship between bullying victimisation and sleep disturbances into genetic and environmental influences. Moreover, the large sample size and multiple dimensions of bullying-victimisation allowed us to conduct novel analyses on the relationship between sleep disturbances and specific types of bullying-victimisation.

### *Conclusions*

Bullying-victimisation at age-14 is associated with sleep disturbances at age-16. These associations were driven by genetic and non-shared environmental risk factors that are partly common to both. Thus, rather than viewing bullying-victimisation as a purely environmental experience that can trigger later sleep disturbances, practitioners and researchers may benefit from focusing on inherited characteristics (e.g. mental health problems and temperament) that may make individuals jointly vulnerable to being bullied and experiencing sleep disturbances.

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Table 1: Means and standard deviations by sex and zygosity for bullying-victimisation sleep quality and insomnia symptoms

	Total	Male	Female	MZ	DZ	Score				Cronbach		ANOVA		
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	Range	Skew	Kurtosis	A	Sex	Zyg	Sex*Zyg	R <sup>2</sup>	N
<b>Bullying-victimisation</b>														
Total	7.61 (7.18)	8.47 (7.73)	6.92 (6.61)	7.48 (7.15)	7.69 (7.19)	0-32	-0.01	2.20	0.90	0.00	0.48	0.51	0.01	3208
Physical	1.02 (1.85)	1.68 (2.23)	0.49 (1.25)	1.00 (1.89)	1.04 (1.83)	0-8	1.17	2.91	0.80	0.00	0.75	0.21	0.11	3208
Verbal	3.31 (2.84)	3.62 (2.82)	3.07 (2.83)	3.20 (2.82)	3.38 (2.85)	0-8	0.35	1.72	0.84	0.00	0.13	0.74	0.01	3208
Social manipulation	1.90 (2.29)	1.53 (2.08)	2.20 (2.40)	1.91 (2.27)	1.90 (2.30)	0-8	0.30	1.70	0.80	0.00	0.78	0.10	0.02	3208
Property damage	1.37 (1.98)	1.65 (2.19)	1.15 (1.76)	1.37 (1.98)	1.38 (1.98)	0-8	0.65	2.13	0.79	0.00	0.80	0.66	0.01	3208
Sleep quality	5.52 (2.74)	5.18 (2.57)	5.81 (2.85)	5.40 (2.70)	5.58 (2.76)	0-21	0.13	3.07	0.76	0.00	0.02	0.70	0.01	3732
Insomnia symptoms	3.81 (4.26)	3.27 (3.88)	4.27 (4.52)	3.61 (4.17)	3.92 (4.31)	0-28	0.35	2.67	0.89	0.00	0.01	0.85	0.02	3721

Note: Means and standard deviation reported prior to transformation. MZ=monozygotic, DZ=dizygotic twins. Analyses of variances were performed using one random member of each twin pair. Sex= p-value associated with the effect of sex on the means; Zyg. = p-value associated with the effect of zygosity on the means; Sex\*Zyg = p-value associated with the effects of the interaction between sex and zygosity on the means; R<sup>2</sup> = proportion of the total variance explained by sex and zygosity; N= number of 1 randomly selected individuals from each twin pair. For Sleep quality, higher scores indicate greater problems.

Table 2: Phenotypic correlations between bullying-victimisation subscales, sleep quality and insomnia symptoms

	Total		Male		Female	
	Sleep quality r (95%CI)	Insomnia symptoms r (95%CI)	Sleep quality r (95%CI)	Insomnia symptoms r (95%CI)	Sleep quality r (95%CI)	Insomnia symptoms r (95%CI)
<b>Bullying-victimisation</b>						
Total bullying-victimisation	.22 (.18/.25)	.22 (.18/.25)	.19 (.14-.24)	.19 (.14-.24)	.24 (.20-.29)	.23 (.19-.27)
Physical	.13 (.09/.16)	.14 (.11/.18)	.12 (.07-.17)	.12 (.07-.18)	.15 (.10-.19)	.17 (.12-.22)
Verbal	.21 (.17/.24)	.19 (.16/.23)	.16 (.11-.21)	.17 (.11-.22)	.24 (.20-.29)	.21 (.17-.26)
Social manipulation	.17 (.14/.21)	.16 (.13/.20)	.17 (.11-.21)	.17 (.12-.23)	.18 (.13-.22)	.16 (.11-.20)
Property damage	.16 (.13/.20)	.16 (.13/.19)	.16 (.11-.21)	.15 (.10-.21)	.17 (.12-.22)	.17 (.12-.21)

Note: Correlations taken from the constrained saturated bivariate model where phenotypic correlations and twin correlations within and across measures were estimated. r = Pearson's correlation; CI= confidence interval. Bullying-victimisation measured at age-14. Sleep quality and insomnia symptoms measured at age-16.

Table 3: Associations between bullying-victimisation, sleep quality and insomnia symptoms

	Total		Males		Female	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
	$\beta$ (95%CI)	$\beta$ (95%CI)	$\beta$ (95%CI)	$\beta$ (95%CI)	$\beta$ (95%CI)	$\beta$ (95%CI)
<b>Dependent variable: Sleep quality</b>						
Total bullying-victimisation	0.21 (0.16, 0.26)	0.19 (0.13, 0.25)	0.19 (0.12, 0.26)	0.18 (0.09, 0.27)	0.26 (0.20, 0.33)	0.20 (0.12, 0.28)
Bullying-victimisation subtypes						
Physical	0.06 (0.01, 0.11)	-0.07 (-0.13, 0.01)	0.10 (0.04, 0.16)	-0.04 (-0.13, 0.06)	0.14 (0.04, 0.23)	-0.07 (-0.19, 0.05)
Verbal	0.20 (0.15, 0.25)	0.15 (0.08, 0.22)	0.18 (0.11, 0.25)	0.09 (-0.02, 0.20)	0.25 (0.19, 0.32)	0.18 (0.08, 0.28)
Social manipulation	0.21 (0.16, 0.26)	0.08 (0.02, 0.15)	0.19 (0.11, 0.26)	0.12 (0.02, 0.23)	0.20 (0.14, 0.27)	0.05 (-0.04, 0.14)
Property damage	0.14 (0.09, 0.19)	0.06 (-0.01, 0.13)	0.15 (0.08, 0.21)	0.06 (-0.04, 0.13)	0.17 (0.10, 0.24)	0.05 (-0.02, 0.14)
<b>Dependent variable: Insomnia symptoms</b>						
Total bullying-victimisation	0.21 (0.16, 0.25)	0.16 (0.10, 0.22)	0.17 (0.10, 0.23)	0.12 (0.03, 0.20)	0.27 (0.21, 0.34)	0.20 (0.12, 0.29)
Bullying-victimisation subtypes						
Physical	0.06 (0.01, 0.11)	-0.04 (-0.12, 0.03)	0.09 (0.03, 0.15)	-0.02 (-0.12, 0.07)	0.18 (0.08, 0.27)	-0.04 (-0.17, 0.09)
Verbal	0.18 (0.13, 0.22)	0.10 (0.02, 0.17)	0.16 (0.09, 0.23)	0.07 (-0.04, 0.18)	0.23 (0.16, 0.29)	0.11 (0.01, 0.21)
Social manipulation	0.22 (0.17, 0.26)	0.09 (0.02, 0.16)	0.18 (0.11, 0.25)	0.09 (-0.02, 0.20)	0.21 (0.14, 0.28)	0.09 (-0.01, 0.18)
Property damage	0.14 (0.09, 0.19)	0.05 (-0.02, 0.11)	0.13 (0.07, 0.19)	0.04 (-0.05, 0.14)	0.18 (0.11, 0.26)	0.05 (-0.05, 0.15)

Note:  $\beta$  = Standardised beta coefficient; CI = confidence interval. Each model adjusts for all individual and family factors simultaneously in one model. Individual and family factors measured at age-12 include bullying victimisation, behavioural problems, emotional problems, depression, general cognition, home chaos, parental discipline, and socioeconomic status. Analyses within each subtype of bullying victimisation adjusts for the remaining subtypes of bullying-victimization in addition to the individual and family factors. Bullying-victimisation measured at age-14. Sleep quality and insomnia symptoms measured at age-16.

Table 4: Parameter estimates for best fitting univariate models

Parameter estimates of best fitting model									
Measure	Total sample			Males			Females		
	A (95%CI)	C (95%CI)	E (95%CI)	A (95%CI)	C (95%CI)	E (95%CI)	A (95%CI)	C (95%CI)	E (95%CI)
Total bullying	-	-	-	.59 (.54, .65)	.00 (.00, .03)	.40 (.35, .45)	.37 (.22, .52)	.23 (.08, .36)	.40 (.36, .45)
Physical	-	-	-	.32 (.15, .46)	.18 (.05, .32)	.51 (.45, .57)	.39 (.29, .46)	.03 (.01, .10)	.59 (.53, .65)
Verbal	-	-	-	.59 (.50-.64)	.00 (.00-.09)	.41 (.36-.46)	.36 (.20-.54)	.18 (.02-.32)	.45 (.41-.51)
Soc manipulation			-	.25 (.11, .53)	.19 (.01, .30)	.56 (.50, .63)	.16 (.02, .30)	.31 (.07, .43)	.53 (.47, .58)
Property damage				.41 (.24, .49)	.02 (.01, .16)	.57 (.01, .63)	.11 (.01, .30)	.28 (.12, .40)	.61 (.55, .66)
Sleep quality	.42 (.37, .46)	.00 (.00, .04)	.58 (.54, .61)	-	-	-	-	-	-
Insomnia symptoms	-	-	-	.34 (.17-.43)	.04 (.00-.18)	.62 (.56-.68)	.42 (.28-.49)	.03 (.00-.14)	.56 (.50-.61)

Note: Total bullying= Total bullying-victimisation; Soc manipulation = Social manipulation; A=additive genetic influences; C=shared environmental influences; E=non-shared environmental influences; CI=confidence intervals

Table 5: Cross-twin cross-trait correlations and proportion of phenotypic correlation due to genetic and environmental factors for relationship between total bullying victimisation, sleep quality and insomnia

	Total Bullying-Sleep Quality (95% CI)	Total Bullying-Insomnia symptoms (95% CI)
<b>Cross-Twin Cross-Trait Correlations</b>		
MZ	.17 (.12-.21)	.18 (.14-.22)
DZ	.11 (.07-.16)	.13 (.09-.17)
MZM	.10 (.03-.17)	.14 (.07-.21)
DZM	.11 (.02-.19)	.13 (.05-.22)
MZF	.22 (.16-.27)	.21 (.15-.27)
DZF	.15 (.08-.22)	.16 (.09-.23)
DZOS	.10 (.04-.16)	.11 (.05-.17)
<b>Proportion of phenotypic correlation due to genetic and environmental factors: Total sample</b>		
A	.50 (.27/.87)	.62 (.39/.98)
C	.26 (-.05/.41)	.24 (-.06/.39)
E	.24 (.09/.40)	.14 (-.02/.30)
<b>Proportion of phenotypic correlation due to genetic and environmental factors: Males</b>		
A	.52 (.17/.90)	.67 (.63/.92)
C	.05 (-.06/.19)	.13 (-.04/.61)
E	.43 (.14/.74)	.21 (.08/.51)
<b>Proportion of phenotypic correlation due to genetic and environmental factors: Females</b>		
A	.39 (-.12/1.00)	.47 (-.03/.58)
C	.48 (-.05/.90)	.45 (-.18/.87)
E	.13 (.02/.25)	.09 (-.11/.28)

Note: Correlations taken from the constrained saturated bivariate model where phenotypic correlations and twin correlations within and across measures were estimated. MZ = Monozygotic; DZ=dizygotic; MZM=monozygotic male; DZM=dizygotic male; MZF= Monozygotic female; DZF=dizygotic female; DZOS=dizygotic opposite sex; A=additive genetic; C=shared environment; E=non-shared environment

Figure 1a and 1b: Correlated factors solution of relationship between bullying-victimisation, insomnia symptoms and sleep quality

Figure: 1a

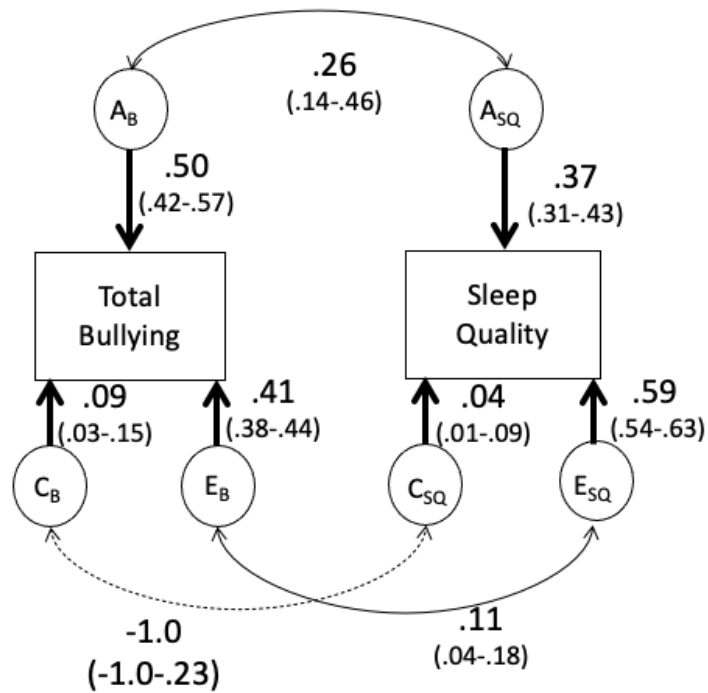


Figure: 1b

