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Brief report

Poor sleep quality is associated with discordant peer relationships among adolescents with Autism Spectrum Disorder



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ABSTRACT

Background: Individuals with Autism Spectrum Disorder (ASD) experience impairments in social communication, and these deficits often make it difficult to form and maintain friendships with peers. Poor sleep quality and daytime sleepiness are common among adolescents with ASD, and consequences of poor sleep may make social interactions difficult. Connections between sleep quality and social relationships in ASD samples have been understudied; the current study addresses this gap.

Method: Participants were community samples of 19 adolescents with ASD and 10 neurotypical (NT) adolescents. Adolescents completed questionnaires about closeness and discord in relationships with a same-gender peer, and they reported on sleep-wake problems, daytime sleepiness, and internalizing problems. Adolescents also wore an actigraph for 7-nights.

Results: Pearson correlations revealed significant associations between adolescents' reports of sleep problems and discordant peer relationships; more sleep-wake problems and more daytime sleepiness were associated with more discord with peers in the sample with ASD, but not in the NT sample. The closeness aspect of peer relationships was not significantly associated with sleep quality. Internalizing problems did not mediate between sleep quality and discordant relationships.

Conclusions: Adolescents' reports of more sleep problems and daytime sleepiness, but not actigraph indicators of sleep quality, were directly associated with discordant peer relationships. Adolescents who are already challenged in social interactions due to ASD may be especially vulnerable to intense negativity in peer relationships when they also experience poorer nighttime sleep and more daytime sleepiness. NT adolescents may be better able to regulate social interactions despite poor sleep and feeling tired.

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1. Introduction

Impairments in social interaction and social communication and the presence of restricted and repetitive behaviors (RRBs) are core deficits of Autism Spectrum Disorder (ASD). Social deficits span contexts and include difficulties in verbal and nonverbal communication, whereas RRBs refer to patterns of intense, fixated interests or activities ([Centers for Disease](http://www.cdc.gov)

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Control, 2016). These pervasive deficits limit individuals' ability to effectively engage in social exchanges with others, which has consequences for the development and daily maintenance of interpersonal relationships. Children with ASD who have deficient verbal abilities also have fewer social interactions and less satisfying relationships with peers (Hauck, Fein, Waterhouse, & Feinstein, 1995; Sigman et al., 1999). Even children with high functioning ASD appear to lack the social skills and opportunities to engage satisfactorily with peers, despite a reported desire to do so (Bauminger & Kasari, 2000); they report feeling lonelier with poorer quality friendships compared to neurotypical (NT) children. For example, whereas the preferred leisure activities of NT adolescents vary widely (Larson, 2001), adolescents with ASD spend a large amount of their leisure time alone, engaged in solo activities such as using a computer or watching television. The most infrequent activity was having a conversation, with less than 15% of adolescents with ASD choosing to do so during their free time (Orsmond & Kuo, 2011).

1.1. Peer relationships in adolescence

As NT children approach adolescence, the social environment with peers changes qualitatively to one that is more intimate and communicative compared to childhood (Buhrmester, 1990). The period of adolescence for NT individuals includes a quantitative shift to the majority of leisure time being spent with peers (Larson & Richards, 1991; Larson, 2001). For adolescents with ASD, this new social environment may be especially difficult to navigate, and the ability to form close friendships becomes increasingly challenging. Adolescents with ASD spend less time with peers compared to time spent with adults (e.g., parents) (Orsmond & Kuo, 2011). Social deficits associated with ASD may underlie the challenges in forming and maintaining good quality friendships.

1.2. Sleep in children and adolescents with ASD

For individuals with ASD, the consequences of social impairments and compromised relationships may be compounded by other challenges. One common corollary of ASD is poor sleep quality. According to a recent review, between 32% to 71.5% of children and adolescents with ASD experience sleep problems (Deliens, Leproult, Schmitz, Destrebecqz, & Peigneux, 2015). Sleep problems include difficulty falling asleep, inconsistent sleep schedules, insufficient nighttime sleep, as well as daytime sleepiness that impairs daytime functioning (Goldman, Richdale, Clemons, & Malow, 2012). These impairments include increased irritability, greater anxiety, higher sensory sensitivity, and more behavior problems (Katz, Malow, & Reynolds, 2016; Lambert et al., 2016; Malow et al., 2006; Mazurek & Petroski, 2015; Schreck, Mulick, & Smith, 2004; Sikora, Johnson, Clemons, & Katz, 2012). Poorer daytime functioning in turn may be linked to poorer quality social relationships.

In typical adolescent development, pubertal changes that occur during adolescence have been associated with an increase in daytime sleepiness (Colrain & Baker, 2011). The increase of daytime sleepiness seems to co-occur with the onset of puberty, and occurs even when nighttime sleep duration remains unchanged (Carskadon, 1990), suggesting that adolescents with ASD are at risk for even more sleep issues as a result of pubertal changes and ASD status together.

Types of sleep problems change from childhood to adolescence among individuals with ASD (Deliens et al., 2015). For example, children with ASD are reported by parents to have sleep problems such as waking during the night and sleep anxiety, whereas adolescents with ASD are reported by parents to experience difficulty with falling asleep and more daytime sleepiness (Goldman et al., 2012). Young adolescents with ASD tend to spend more time sleeping relative to older adolescents with ASD (i.e., those who have exited high school) (Orsmond & Kuo, 2011). Adolescents with ASD not only take longer to fall asleep than their NT peers, but their sleep latencies are also more variable (Baker, Richdale, Short, & Gradisar, 2013).

Poor sleep and poor social functioning often co-occur in children with ASD. For example, fewer hours of sleep per night predict deficient social skills among children with ASD (Schreck et al., 2004). Children with ASD reported to be poor sleepers by their parents showed poorer social interactions with an examiner during the ADOS, compared to good sleepers (Malow et al., 2006). Sleep issues spill over to affect the daily functioning of children and families, as reported by parents (Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008). To date, little research has been directed toward examination of sleep issues, as reported both by adolescents themselves and through actigraphy, in association with self-reported peer relationship quality among adolescents with ASD. The current study is aimed at addressing this gap.

1.3. Comorbid conditions with ASD

Anxiety and depression are frequent comorbidities among children with ASD (Shtayermman, 2007; van Steensel, Bögels, & Perrin, 2011), and these internalizing conditions could account for problems in both the sleep and social domains. For example, higher levels of anxiety were associated with many types of sleep problems in a study of children with ASD (Mazurek & Petroski, 2015); more symptoms of anxiety also have been linked to social problems such as less assertive social skills among adolescents with ASD (Bellini, 2004). Both higher anxiety and poorer sleep were linked to compromised daytime functioning in a sample of adolescents with ASD (Richdale, Baker, Short, & Gradisar, 2014). In addition, the presence of depressive symptoms that are common to individuals with ASD (e.g., social withdrawal, irritability) has been associated with poorer quality social relationships for adolescents on the ASD spectrum (Whitehouse, Durkin, Jaquet, & Ziatas, 2008).

Thus, symptoms of anxiety and depression could be an underlying mechanism connecting sleep problems with social interactional deficits and will be explored as possible mediators in the current study.

1.4. The current study

Given that social interaction in general and peer relationships in particular are challenging for adolescents with ASD, when sleep problems also exist, there may be more negativity and less positivity in peer interactions. The goal of the present multi-method study was to examine the associations between nocturnal sleep problems and daytime sleepiness in relation to the quality of peer relationships among adolescents with ASD.

Hypothesis 1. As indicated by actigraphy and by self-reported sleep quality, poorer nighttime sleep quality and greater daytime sleepiness were expected for adolescents with ASD compared to NT adolescents.

Hypothesis 2. Adolescents with ASD were expected to report poorer quality peer relationships compared to NT adolescents.

Hypothesis 3. Poorer sleep quality was expected to be associated with less closeness and greater discord in the quality of peer relationships, as reported by adolescents, especially for adolescents already challenged by ASD.

Exploratory analyses examined whether the association between sleep quality and quality of peer relationships was mediated by internalizing problems (i.e., symptoms of anxiety and depression).

2. Method

2.1. Participants

Nineteen adolescents with ASD and 10 NT adolescents without a family history of ASD participated. Adolescents with ASD were recruited from neurodevelopmental and special educational centers, and ASD-oriented community events. Adolescents in the NT group were recruited from community organizations, schools, and from a departmental database of families who had expressed interest in research. The ages of adolescents with ASD ranged from 11 to 20 years ($M = 16.88$;

Table 1
Demographic characteristics of study participants.

Adolescent characteristics	Autism Spectrum Disorder (ASD) $n = 19$ n (%)	Neurotypical (NT) $n = 10$ n (%)	Group differences (ASD vs. NT)
Gender			
Female	3 (15.8%)	4 (40%)	$p = 0.19$, Fisher's exact test
Male	16 (84.2%)	6 (60%)	
Ethnicity			
Caucasian	7 (36.8%)	10 (100%)	$\chi^2(2) = 14.33^{**}$
Multiracial/other	2 (10.6%)	0 (0%)	
Hispanic, non-Caucasian	10 (52.6%)	0 (0%)	
Age	$M(SD)$ 16.88 (2.50)	$M(SD)$ 15.73 (2.00)	$t(27) = -1.25$
Family characteristics	n (%)	n (%)	
Income			
\$0–49,999	2 (10.5%)	0 (0%)	$\chi^2(5) = 10.01$
\$50,000–74,999	5 (26.3%)	2 (20%)	
\$75,000–99,999	2 (10.5%)	2 (20%)	
\$100,000–149,999	2 (10.5%)	5 (50%)	
\$150,000–199,999	4 (21.1%)	1 (10%)	
\$200,000+	4 (21.1%)	0 (0%)	
Maternal education			
High school	1 (5.3%)	0 (0%)	$\chi^2(4) = 2.13$
Some college	1 (5.3%)	0 (0%)	
Community college (Associate's degree)	5 (26.3%)	2 (20%)	
University/college (Bachelor's degree)	10 (52.6%)	7 (70%)	
Graduate professional training	2 (10.5%)	1 (10%)	
Maternal age	$M(SD)$ 50.59 (6.74)	$M(SD)$ 48.43 (2.74)	$t(21.5) = -1.14$

Notes: $**p < 0.01$.

$SD = 2.50$); the majority of the sample (84.2%, $n = 16$) was boys. The sample with ASD was 36.8% ($n = 7$) Caucasian/White (Non-Hispanic), 52.6% ($n = 10$) Hispanic/Latino, and 10.6% ($n = 2$) multiracial or other. NT adolescents' ages ranged from 13 to 18 years ($M = 15.73$; $SD = 2.00$); 60% ($n = 6$) were boys. The NT sample was all Caucasian/White (Non-Hispanic). Characteristics of the samples are shown in Table 1.

Adolescents with ASD had been clinically diagnosed with ASD as reported by parents. These clinical diagnoses were confirmed using the SCQ screen (Rutter, Bailey, & Lord, 2003) and the Autism Diagnostic Observation Schedule assessment (ADOS-2; Lord et al., 2012); adolescents with clinical reports of ASD all met criteria on the SCQ and on Modules 3 and 4 (Fluent Speech) of the ADOS-2.

2.2. Procedure

The study was approved by the University's IRB. During a home visit, adolescents completed surveys that included questions about sleep experiences and behaviors, daytime sleepiness, and quality of peer relationships. The lead author then instructed adolescents in the use of an actigraph sleep watch. Participants were instructed to wear the actigraph for 7-nights on the non-dominant wrist beginning at bedtime and ending when the participant rose from bed. Adolescents completed a sleep diary reporting on bedtime, wake time, and wearing of the actigraph. During a second home visit, materials were collected and families were compensated for their participation.

2.3. Measures

2.3.1. Actigraphy

Objective sleep patterns were obtained using an actigraph, a small electronic device shaped like a watch. Actigraphs have been used successfully in clinics and research, including studies of individuals with ASD (e.g., Øyane & Bjorvatn, 2005). In the present study, participants wore a Micro Motionlogger Sleep Watch actigraph; Act Millennium Version 3.68 software was used to reduce the data (Ambulatory Monitoring Inc.), and the Sadeh algorithm was used to estimate sleep parameters based on movement during periods of down time. Each of the sleep parameters was averaged across the 7-nights of actigraphy to yield four scores: *total sleep time* (minutes scored as sleep), *sleep efficiency* ($((100 * \text{sleep min}) / (\text{true sleep period}))$), *number of wake episodes* (number of blocks of continuous wake epochs), and *sleep latency* (minutes to fall into continuous sleep, i.e., first 20 min of uninterrupted sleep).

2.3.2. Adolescents' sleep/wake problems and daytime sleepiness

The Sleep Habits Survey (SHS; Wolfson & Carskadon, 1998) is an adolescent self-report measure that asks about sleep-wake schedules, sleep and wake behavior problems, general feelings about sleep, and daytime sleepiness. The SHS has demonstrated good reliability and validity when compared to diary and actigraph accounts of sleep patterns among NT high-school students on school nights (Wolfson et al., 2003; see also Lewandowski, Toliver-Sokol, & Palermo, 2011 and Spruyt and Gozal, 2011 for reviews that include the SHS) The SHS also has been used in prior studies of adolescents with high-functioning ASD (Baker et al., 2013; Richdale et al., 2014). Items from the SHS yielded two sleep-related scales. The *sleep-wake problems* subscale had 10-items, each with a 5-point response scale (1 = never to 5 = every day/night) that indicated the frequency of such problems. Items were summed to obtain a total scale score and higher scores represented greater frequency of sleep-wake problem behaviors (Cronbach's $\alpha = 0.65$). The *daytime sleepiness* subscale had 10-items that assessed sleepiness during the past two weeks. We omitted the item "struggled to stay awake, or fallen asleep while driving a car," because only 8 (28%) of the adolescents in our sample drove a car. Each of the remaining 9 items had a 4-point response scale (1 = no, 2 = struggled to stay awake, 3 = fallen asleep, 4 = both struggled to stay awake and fallen asleep). Items were summed and higher scores represented greater daytime sleepiness (Cronbach's $\alpha = 0.87$).

2.3.3. Quality of peer relationships

The Network of Relationships Inventory-Relationship Qualities Version (NRI-RQV; Buhrmester & Furman, 2008) is a measure that was initially developed to assess reports of closeness and discord in family and social relationships. In the current study, only questions about same-sex best/close friends were included. The NRI-RQV has demonstrated acceptable internal reliability and validity in prior studies (Furman and Buhrmester, 2010; Hibbard & Buhrmester, 2010). Although it has not previously been used with individuals with ASD, the NRI-RQV was selected because it has been used widely in studies with adolescents (e.g., Kenny, Dooley, & Fitzgerald, 2013), and because it taps both positive and negative aspects of relationship quality. Thirty items, each with a 5-point response scale (1 = never or hardly at all, 5 = always or extremely much), were grouped into either a 5-feature *closeness* subscale (e.g., companionship, emotional support; Cronbach's $\alpha = 0.84$) or a 5-feature *discord* subscale (e.g., conflict, exclusion; Cronbach's $\alpha = 0.81$) following authors' instructions (Furman & Buhrmester, 2010). Higher scores corresponded to greater closeness and greater discord, respectively.

2.3.4. Internalizing problems

The State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was developed to assess state and trait anxiety. The 20-item state anxiety subscale on the STAI is appropriate for individuals 15 years of age and older and was used in the current study. Adolescents reported on anxious feelings (e.g., "I am worried", "I feel tense,") using a 4-

point scale ranging from “Almost never (1)” to “Almost always (4)”. Higher scores indicated greater anxiety. In the current study, the scale showed high internal consistency (Cronbach’s $\alpha = 0.90$). The STAI was selected because it is a reliable measure of anxiety and has been used successfully in prior studies of adolescents and young adults with ASD (Hillier, Fish, Siegel, & Beversdorf, 2011; Hillier, Greher, Poto, & Dougherty, 2011).

The Center for Epidemiological Studies Depression scale (CES-D; Radloff, 1977) is a 20-item measure on which respondents used a 4-point response scale to rate the frequency of depressive symptoms over the past week. To avoid redundancy and inflated correlations with the sleep measures, the single item on restless sleep was omitted in the calculation of the total score, which was obtained by summing the remaining 19 items. Higher scores indicated more frequent depressive symptoms. The CES-D was selected because it is a reliable measure of depressive affect (Radloff, 1991) and has been used frequently with adolescents (Dierker et al., 2001). The scale demonstrated good reliability with our sample (Cronbach’s $\alpha = 0.82$).

2.4. Plan of analysis

Following data screening, chi-square tests and analyses of covariance were conducted to assess diagnostic group differences on demographic and major study variables. Pearson correlational analyses then were used to examine associations between sleep quality (as measured by adolescent self-report on the sleep questionnaire and by actigraphy) in relation to adolescents’ reports of the quality of peer relationships. Regression analyses were used to explore whether the association between sleep quality and quality of peer relationships was mediated by internalizing problems (i.e. self-reported anxiety and depression symptoms) within the sample with ASD. Using Hayes’ PROCESS macro (Hayes, 2013), sleep quality was posited as the predictor of relationship discord, and internalizing problems (i.e., symptoms of anxiety and depression) were examined as potential mediators. Mediation analyses were tested using the bootstrapping method with bias-corrected confidence estimates (Preacher & Hayes, 2004).

3. Results

3.1. Diagnostic group differences in sleep, peer relationship quality, and internalizing symptoms

ANCOVAs controlling for adolescent gender were conducted to examine group differences in sleep quality and quality of peer relationships (see Table 2). The ASD and NT groups did not significantly differ in self-reported questionnaires of sleep quality. On the actigraph, sleep latency significantly differed by group: Adolescents with ASD took significantly longer to fall asleep than adolescents in the NT group. Also, the group with ASD spent marginally more time asleep than the NT group. In terms of peer relationship quality, there were no significant group differences in self-reports of closeness and discord in peer relationships.

In our sample, 42% ($n = 8$) of the adolescents with ASD scored above the CES-D cutoff for clinical depression compared to only 10% ($n = 1$) of the adolescents in the NT group. However, as a group, the adolescents with ASD were not statistically different from the NT adolescents in their mean level of depressive symptoms (see Table 2). The STAI does not currently provide a cutoff score for clinical anxiety, but the means for anxiety symptoms also did not differ between the ASD and NT groups (see Table 2).

Table 2
Means, standard deviations, and diagnostic group differences of major study variables.

Major study variables	ASD ($n = 19$)		NT ($n = 10$)		Group differences (ANCOVA) <i>F</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Sleep quality					
Adolescent report of sleep-wake problems (SHS) ^a	19.63	6.03	18.50	3.24	0.35
Adolescent report of daytime sleepiness (SHS) ^a	10.95	3.60	12.30	3.13	0.55
Total sleep time (minutes)	419.35	84.61	378.61	70.77	3.46†
Sleep Efficiency (%)	91.92	6.63	88.49	8.93	2.55
Number of Wake Episodes	11.20	5.07	12.28	5.88	1.10
Sleep latency (minutes)	42.48	27.40	22.46	11.56	4.41*
Peer relationship quality					
Closeness	3.24	0.90	3.57	0.43	0.32
Discord	1.65	0.50	2.05	0.47	2.71
Internalizing problems					
Anxiety symptoms (STAI) ^b	33.79	8.89	33.30	9.87	0.17
Depressive symptoms (CES-D) ^c	13.00	6.79	12.40	8.98	0.45

Notes: ^aHigher scores denote poorer sleep quality. ^bHigher scores denote greater anxiety. ^cHigher scores denote more depressive symptoms. † $p < 0.10$. * $p < 0.05$.

Table 3Pearson correlation analyses of major study variables in adolescents with ASD ($n = 19$) and NT ($n = 10$).

Sleep quality	Closeness		Discord	
	ASD	NT	ASD	NT
Adolescent report of sleep-wake problems (SHS) ^a	0.16	−0.08	0.59 ^{**}	0.07
Adolescent report of daytime sleepiness (SHS) ^a	0.18	−0.07	0.54 [†]	−0.14
Total sleep time (minutes)	0.17	−0.47	−0.24	0.21
Sleep efficiency (%)	0.19	−0.35	−0.00	0.02
Number of wake episodes	−0.14	−0.27	−0.03	−0.38
Sleep latency (minutes)	0.12	0.04	−0.18	0.11

Notes: ^aHigher scores denote poorer sleep quality.[†] $p < 0.05$.^{**} $p < 0.01$.

3.2. Within-group associations for sleep quality in relation to adolescents' peer relationship quality

3.2.1. ASD

Pearson correlations were conducted to examine associations between sleep quality, as measured by adolescent self-reports of sleep questionnaires and actigraphy, and quality of peer relationships. No significant associations were observed between any of the sleep measures and adolescent reports of closeness in peer relationships. However, adolescent self-reports of nighttime and daytime sleep-wake problems on questionnaires were significantly associated with reports of discordant relationships. More sleep-wake problems and more daytime sleepiness on the questionnaires were associated with more discordant peer relationships (see Table 3). Significant associations were not found between actigraphy-based measures of sleep and quality of relationships.

3.2.2. NT

As shown in Table 3, only non-significant associations were found between all of the sleep measures and quality of peer relationships in the NT sample.

3.3. Internalizing problems as a potential mediator

Within the group with ASD, regression analyses examined whether the association between sleep quality and quality of peer relationships was mediated by internalizing problems. Selection of the sleep and peer relationship variables was informed by the correlation matrix. Symptoms of anxiety and depression were tested as potential mediators of the association between the quality of self-reported sleep and the level of discord in peer relationships.

The two models that tested anxiety as a potential mediator between sleep quality and relationship discord did not support mediation. In the first model, sleep-wake problems were posited as the predictor of relationship discord with anxiety symptoms as the mediator; in the next model, daytime sleepiness was the predictor. Empirical support for mediation was lacking since the bias-corrected bootstrap confidence interval of the indirect effect included zero (sleep-wake problems: CI = −0.01 to 0.02; daytime sleepiness: CI = −0.01 to 0.03). Similarly, the two models (sleep-wake problems and daytime sleepiness) that tested depressive symptoms as a potential mediator between sleep quality and relationship discord also did not support mediation. The bias-corrected bootstrap confidence interval of the indirect effect included zero (sleep-wake problems: CI = −0.03 to 0.01; daytime sleepiness: CI = −0.07 to 0.02).¹

4. Discussion

Adolescents with ASD often experience greater difficulty in social interactions compared to NT adolescents; poor sleep quality also has been associated with difficulties in social interactions. The current study examined both sleep quality and

¹ In both models that tested anxiety as a mediator in the sample with ASD, sleep quality was significantly associated with relationship discord (path c—sleep-wake problems: $b = 0.05$, $t(17) = 3.02$, $p < 0.01$; daytime sleepiness: $b = 0.08$, $t(17) = 2.64$, $p < 0.05$). However, in both models, sleep quality was not significantly associated with the mediator, anxiety symptoms (path a—sleep-wake problems: $b = 0.28$, $t(17) = 0.79$, $p = 0.44$; daytime sleepiness: $b = 0.33$, $t(17) = 0.56$, $p = 0.59$). The mediator, anxiety symptoms, was not significantly associated with relationship discord (path b—sleep-wake problems: $b = 0.02$, $t(16) = 1.62$, $p = 0.13$; daytime sleepiness: $b = 0.02$, $t(16) = 1.76$, $p = 0.10$). With the inclusion of anxiety symptoms as the mediator, the association between sleep quality and relationship discord remained significant (path c'—sleep-wake problems: $b = 0.05$, $t(16) = 2.80$, $p < 0.05$; daytime sleepiness: $b = 0.07$, $t(16) = 2.54$, $p < 0.05$). In both models that tested depression as a mediator in the sample with ASD, sleep quality was significantly associated with relationship discord (path c—sleep-wake problems: $b = 0.05$, $t(17) = 3.02$, $p < 0.01$; daytime sleepiness: $b = 0.08$, $t(17) = 2.64$, $p < 0.05$). However, in both models, sleep quality was not significantly associated with the mediator, depressive symptoms (path a—sleep-wake problems: $b = 0.38$, $t(17) = 1.47$, $p = 0.16$; daytime sleepiness: $b = 0.73$, $t(17) = 1.73$, $p = 0.10$). Depressive symptoms were not significantly associated with relationship discord (path b—sleep-wake problems: $b = -0.01$, $t(16) = -0.60$, $p = 0.56$; daytime sleepiness: $b = -0.02$, $t(16) = -0.64$, $p = 0.53$). With the inclusion of depressive symptoms as the mediator, the association between sleep quality and relationship discord was still significant (path c'—sleep-wake problems: $b = 0.05$, $t(16) = 2.99$, $p < 0.01$; daytime sleepiness: $b = 0.08$, $t(16) = 2.64$, $p < 0.05$).

social interactions during adolescence. Hypothesis 1, that poorer nighttime sleep quality and greater daytime sleepiness were expected for adolescents with ASD compared to NT adolescents, was partially supported. As indicated by actigraphy, adolescents with ASD took significantly longer to fall asleep than adolescents in the NT group. Unexpectedly, adolescents with ASD spent marginally more time asleep than the NT adolescents. Hypothesis 2 was not supported, as there were no significant group differences in adolescents' reports of the quality of peer relationships. Hypothesis 3 was partially supported: subjective reports, but not the objective measure, of sleep quality were associated with perceived quality of peer relationships among adolescents with ASD. More sleep-wake problems and more daytime sleepiness were associated with more discordant relationships. No significant associations were observed with the positive aspect of peer relationships (i.e., closeness), or within the NT sample. Exploratory analyses did not support internalizing problems as a mediator between quality of sleep and quality of peer relationships.

Findings extend previous studies that reported that adolescents with ASD who experienced greater daytime sleepiness also had greater social deficits (Malow et al., 2006; Schreck et al., 2004). As shown in the current study, adolescent-reported sleep issues are associated with negative aspects of relationships with a same-gender peer. When adolescents with ASD experience poor sleep at night and sleepiness during the day, they may perceive more conflict with their peers, though whether or not this perception is a result of the adolescents' own social deficits is unclear. Likely, social deficits contribute to poor social overtures with peers, which may lead to a negative social response from peers, resulting in more discord in the relationship. Social deficits may also contribute to poor perspective-taking, and adolescents with ASD may misinterpret peer behaviors as negative or hostile when they were neutral or ambiguous. We propose that adolescents with ASD perceive more negativity in their relationships with peers when they are compromised by sleep issues, whereas NT adolescents may be better able to regulate their peer interactions despite feeling tired. Although bidirectional associations are likely (i.e., it is also possible that daytime problems with peers contribute to poorer sleep at night), current findings are consistent with the perspective that poor sleep quality and daytime sleepiness spillover to social relationships.

The finding from actigraphy that adolescents with ASD slept about 40 min longer on average than their NT peers could be seen as positive or negative for adolescent functioning. Obtaining more sleep has been shown to benefit daytime functioning in adolescents and positively influence mood, whereas sleep deprivation worsens mood (Baum et al., 2014; Short & Louca, 2015; Short et al., 2011). Perhaps our sample of adolescents with ASD did not differ from the NT sample in the level of their self-reported symptoms of anxiety and depression in part because they benefitted from extra sleep. On the negative side, more total sleep time and taking longer to fall asleep (adolescents with ASD took about 20 min longer to fall asleep compared to NT adolescents) could be indicative of disturbances in other respects.

Comorbidity of ASD and sleep problems increases the risk of mood disorders, such as anxiety and depression (Tani et al., 2003). We tested the possibility of a mediating effect of anxiety and depressive symptoms on the association between sleep quality and discordant peer relationships but we did not find evidence of mediation in any of the tested models. Past research has linked internalizing problems to both poorer sleep quality (Mazurek & Petroski, 2015) and more discordant social relationships (Whitehouse et al., 2008), although internalizing problems have not been tested previously as a potential mediator between sleep quality and quality of peer relationships. Possibly, the levels of anxiety and depressive symptoms experienced on average by our sample with ASD were not severe enough to mediate the association between sleep quality and peer relationship quality. The sample of adolescents with ASD who exceeded the cutoff for clinical depression on the CES-D was not large enough to test the mediation model. The lack of support for a mediated model and empirical support for the direct path could suggest that deficits associated with poor sleep act directly to compromise social relationships with peers. Future research should test bi-directional paths and include a large sample of adolescents with ASD that has been clinically diagnosed with mood disorders to further examine whether the comorbidity of ASD and serious mood disorders might mediate the associations between sleep quality and quality of peer relationships.

Limitations of our study include the facts that adolescents with ASD who participated in the current study had fluent language, were able to complete questionnaires presented to them, and did not differ significantly from the NT sample in their levels of anxiety and depression symptoms; findings may not generalize to less well-functioning adolescents with ASD. Our study should be replicated with a less cognitively-able sample of adolescents with ASD and comorbid conditions. The NT sample was particularly small and underpowered, which may have contributed to the null findings for that group. Another limitation was the significant difference in race/ethnicity between the two diagnostic groups. Whereas the NT sample was 100% Caucasian/White, more than half of the adolescents in the sample with ASD identified as Hispanic/Latino. Future studies should include diagnostic groups that are more similar in ethnicity. Finally, the correlational study design means that causality and directionality cannot be established.

5. Implications

Strengths of the current study are that both subjective and objective measures of sleep were included and adolescent, rather than parent, perspectives on quality of sleep and peer relationships were collected. Study findings confirm the importance of measuring friendship based on the adolescents' understanding of it (Kuo, Orsmond, Cohn, & Coster, 2013). Adolescents' perspectives about nocturnal sleep and daytime sleepiness are also important to gather because parents are not always cognizant of their adolescent's nighttime sleep/wake behaviors and sleepiness at school or elsewhere.

As adolescents transition into adulthood, they often turn to peers for social support. Based on the current study, adolescents with ASD who suffer poor sleep quality may be at risk for more intense negative interactions with same-gender

peers. Closeness seems to be protected. Therefore, conflicts with peers and daytime sleepiness in addition to nighttime sleep quality are important issues for clinicians to address. Interventions that target sleep may improve social interactions and interventions that teach how to cope with conflict in relationships may ease sleep problems.

Conflict of interest

We do not possess any actual or potential conflicts of interest that could inappropriately influence the work.

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