Sleepy and Secluded: Sleep Disturbances are Associated with Connectedness in Early
Adolescent Social Networks

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Abstract

Studies in adults suggest that sleep disturbances predict poorer socioemotional skills and impaired social interactions. However, little is known regarding how sleep problems are associated with social processes during adolescence, a period when both sleep neurobiology and social relationships are undergoing dramatic developmental changes. The current study examined associations among sleep disturbances and peer connectedness among a sample of middle-school students ($N = 213$, 11-15 years old, 57% female) using a social network approach. Findings suggested that youth with greater sleep disturbances reported having fewer friends, fewer peers rated them as friends, and were less likely to have reciprocated friendships, even after controlling for sociodemographic characteristics and mental health symptoms.

Keywords: insomnia; peer relationships; popularity; early adolescence; social network analysis

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Sleep is ubiquitous health behavior that is essential for maintaining daytime functioning, and sleep disturbances result in a number of downstream physical, cognitive, and socioemotional impairments (García-Perdomo et al., 2019; Lim & Dinges, 2010; Palmer & Alfano, 2017a). Despite the importance of sleep for nearly every domain of functioning, insufficient sleep in adolescence is common and increasing in prevalence, with as many as 70-80% of teens receiving less than the recommended 8-10 hours of sleep a night (Keyes et al., 2015; Owens et al., 2014; Palmer et al., in press). With the onset of puberty, adolescents experience a delay in the onset of the hormone melatonin and a slowed accumulation of homeostatic sleep pressure, which produces later bedtimes (Crowley et al., 2018; Jenni et al., 2005). This sleep delay during this developmental period, in combination with increased societal pressure for early rise times (e.g., early school start times), truncates sleep opportunities and results in insufficient sleep for many teens (Crowley et al., 2018). Early adolescence in particular is a time of unique neurodevelopmental changes that can be directly impacted by poor sleep, including the development of a number of critical socioemotional skills necessary for positive social interactions (Beattie et al. 2015; Blakemore & Mills, 2014). Despite high rates of inadequate sleep and rapid social development during this period of the life-span, along with an increased importance of peers for social support, little is known regarding how early adolescent sleep patterns are connected with social outcomes. The current study examines relations between sleep disturbances and social connectedness with peers using a social network approach in a sample of early adolescents.

Early Adolescent Peer Relationships

In addition to the dramatic changes in sleep patterns and disturbances that occur during the transition to adolescence, the early adolescent period is marked by considerable social changes which result in the increased importance and frequency of peer relationships and interactions (Furman & Buhrmester, 1992; Hunter & Youniss, 1982). Compared to earlier ages, adolescents generally experience greater personal autonomy, increased interactions with same-aged individuals, and preferences for peer interaction compared to interactions with parents (Smetana et al., 2006), and the importance of peers may be especially critical during the early adolescent period (Berndt, 1979; Gardner & Steinberg, 2005; Steinberg & Silverberg, 1986). Neurobiological changes during early adolescence result in a heightened sense of self-awareness, making youth more susceptible to the influence of peers during early adolescence, but these effects dissipate later in adolescence (Blakemore & Choudhury, 2006).

Importantly, feelings of peer connectedness and perceived peer acceptance during adolescence are associated with a number of positive outcomes, including less internalizing symptoms and physiological experiences of stress (McGraw et al., 2008; Miller et al., 2017; Murray-Close, 2012), lower substance use (Diego, Field, & Sanders, 2003), and better academic performance (Diego et al., 2003). Adolescence is also a time of increased risk for psychopathology and the onset of many psychiatric disorders (Lee et al., 2014), which can be exacerbated by impaired social interactions and isolation (Fett et al., 2015; Meyer-Lindenberg & Tost, 2012). Thus, understanding factors that may impact social relationships and functioning during the early adolescent period is critical.

Sleep and Social Functioning

Sleep is one health behavior that may have implications for social development in adolescents. To date, research on the impact of sleep disruption on social processes has primarily been documented in adults. These findings suggest that sleep loss impairs a number of socioemotional skills, including emotion perception, empathy, emotional expressivity, stress reactivity, and emotion regulation, all of which are important for successful interpersonal interactions (Beattie et al., 2015; Palmer & Alfano, 2017a). Poor sleep in adults also results in greater sensitivity to social stressors and relationship conflict (Gordon et al., 2017) and greater social withdrawal (Ben-Simon & Walker, 2018). For example, Ben-Simon and Walker (2018) found that experimentally depriving adults of sleep resulted in more socially avoidant behaviors and greater feelings of loneliness. Additionally, this study found that sleep deprived participants, compared to well-rested participants, were rated by others as being lonelier and as less desirable social partners after interpersonal interactions. In sum, research in adults suggests that sleep disruption may result in a behavioral profile of social withdrawal and impaired social skills that may exaggerate poor interpersonal interactions. When sleep problems are persistent or chronic, the resulting social impairment may disrupt long-term connections with others and overall social embeddedness may decrease.

Despite compelling findings in adults related to sleep and daytime social functioning, research on the association between sleep and social processes is nascent in youth samples. Understanding these processes at younger ages is critical in light of the increased risk for poor sleep with the onset of puberty (Crowley et al., 2018), along with the importance of positive social relationships for overall development and emotional risk (Fett et al., 2015; Meyer-Lindenberg & Tost, 2012). Additionally, preliminary evidence suggests that the effects of poor sleep on daytime functioning may be stronger for youth compared to adults (Talbot et al., 2010),

and adolescents may be more sensitive to the social environment compared to other ages (Blakemore & Mills, 2014). As a result, understanding associations between sleep and social outcomes is a critical next step for understanding factors that may influence social development during the early adolescent period.

Current understanding of sleep and social functioning in youth has primarily been limited to studies on family dynamics or general anti-social behaviors, and less is known regarding sleep disturbances and peer relationships during the early adolescent age period. Preliminary studies suggest that similar to adults, poor sleep during the adolescent years is associated with impaired socioemotional skills, including poor emotion regulation (Palmer et al., 2018), increased irritability, hostility, and oppositionality (Baum et al., 2014), more negative affective behavior during a peer conflict (McMakin et al., 2016), less accurate processing of emotional faces (Soffer-Dudek et al., 2011), and less empathy (Brand et al., 2016). How these impaired socioemotional skills translate to social connections with peers remains unclear, but adolescents experiencing disrupted sleep also report feeling less social support (Roberts et al., 2002) and are more likely to be bullies or victims of bullying (Donoghue & Meltzer, 2018).

To date, one study has examined social networks in relation to sleep in a youth sample. Among middle to late adolescents (ages 13-21 years), Li and colleagues (2019) found that boys who were more isolated and who did not have any social ties reported more insomnia symptoms, whereas girls who received more friendship nominations from others and who served as liaisons between social groups reported receiving insufficient sleep. These data are consistent with other research suggesting that adolescent boys with poor sleep patterns—but not girls—are less likely to engage in approach behavior (Palmer et al., in press), which may result in fewer positive

interpersonal interactions. Nonetheless, understanding of sleep in early adolescence and how sleep disturbances correspond with peer outcomes and social connectedness is still unknown.

Current Study

To date, the majority of research on sleep and social experiences has been in adult samples. Examining these processes may be especially important in early adolescence, when youth are undergoing rapid developmental changes in sleep neurobiology and when the importance of peer relationships dramatically increases. The current study examined associations between sleep disturbances and social connectedness among early adolescents using a social network methodological approach. Social network methodology is especially well-suited to examine connections between sleep disturbances and social connectedness among early adolescents because it can directly model youths' positions within a peer network. We expected that youth reporting greater sleep disturbances would also experience less social connectedness within their social network, including reports of having fewer friends, fewer friend nominations from peers, less reciprocated friendships, less connections with popular peers, and less connections between distinct groups of peers. Building on prior preliminary research (Li et al., 2019; Palmer et al., in press), we also explored how associations between sleep disturbances and social connectedness might vary by gender.

Method

Participants and Procedure

Participants included 213 middle school students in 6th-8th grade recruited from a rural county in the Northwestern United States. At the time of data collection, participants were between the ages of 11 to 15 years ($M = 12.50$, $SD = .93$) and were about half female (57%) and primarily non-Hispanic White (85.3%, 7.1% Native American, 2.6% Asian or Pacific Islander;

9.8% Hispanic/Latino). The participating middle school served 250 students at the time of data collection, so the sample size of 213 represents 85.2% of all eligible participants. The participating school is centrally located within the >5,000 square mile county, and is the primary public middle school within the county, increasing confidence that we captured a majority of the same-aged local peer network among participants.

Consistent with past research collecting social network data with middle school students in the United States (Andrews et al., 2016; Birkett, & Espelage, 2015; Kornienko et al., 2016), an opt-out consent procedure with active student assent was used for this study. This strategy was chosen because large amounts of missing data on friendship ties renders social network data unusable (Burt, 1987). Consent letters were sent to parents who were given the option of opting their child out of participation in the study, and students provided active assent. During data collection, students were reminded that they could skip any questions they did not want to answer and refuse to participate at any time without penalty. The study protocol, procedure, and questionnaire were approved by the Institutional Review Board at (removed for masked review), and prior to data collection all study procedures and materials were reviewed and approved by a community advisory board composed of community members, parents, and school administrators from the local area including the superintendent and the principal of the middle school.

Questionnaires

Social Connectedness. Participants were provided with the option to identify up to 7 people within the school that they spend the most time with by selecting names from an electronic pre-populated list. Students were allowed to nominate any student within the middle school regardless of classroom or age to capture school-level networks. If students did not spend time with up to 7 other students, they were instructed to leave remaining spaces blank. Any

nominations made of non-participating students were converted to a missing code and these data were not used. After selecting each person, participants were asked to rate how much they like spending time with that person on a 5-point scale from (1 = *not at all*, 2 = *a little*, 3 = *somewhat*, 4 = *a good amount*, 5 = *a lot*). For the purpose of this study, friendship was defined as liking the time spent with a nominated peer at least somewhat. This definition captures both the personal contact and relational affinity of friendships without relying on semantic evaluations (e.g., I like and spend time with person but don't consider them a friend) and is consistent with best-practice recommendations for social network methodology (Neal, 2020).

Using these peer nominations, five indicators of social connectedness were calculated based on the peer network. *Popularity* was measured by a participant's in-degree which represents the total number of other people who nominated a particular child. *Activity* was measured by a participant's out-degree which represents the total number of people nominated by a child. *Reciprocity* is represented by the number of peer nominations that are reciprocated by a child. *Betweenness* indicates the extent to which a child's social position falls between two distinct groups of other children. Participants' *eigenvector* represents connection with highly connected peers. These metrics represent commonly used indicators of social connectedness by developmental scientists who study social networks (Neal, 2020).

Sleep Disturbances. Participants reported on their overall sleep disturbances using the 8-item National Institutes of Health Patient-Reported Outcomes Measurement Information System (PROMIS) Pediatric Sleep Disturbance scale (Forrest et al., 2018). This measure has been validated in both non-clinical samples and clinical pediatric sleep patients and has shown excellent validity and precision for children and adolescents ages 8-17 years (Forrest et al., 2018). This measure primarily captures overall sleep difficulties over the last 7 days (e.g., "I had

trouble sleeping”) on a scale from 1 (*never*) to 5 (*always*). In the current sample, reliability of the scale was excellent ($\omega = .90$).

Anxiety and Depressive Symptoms. Participants also reported on their depressive symptoms and anxiety symptoms using fixed-item National Institutes of Health Patient-Reported Outcomes Measurement Information System (PROMIS) questionnaires (Quinn et al., 2014). The depression scale included 8 items regarding symptoms over the last 7 days (e.g., “It was hard for me to have fun”) on a scale from 1 (*never*) to 5 (*almost always*). Likewise, the anxiety scale included 8 items assessing symptoms over the last 7 days (e.g., “I felt like something awful might happen”) on a scale from 1 (*never*) to 5 (*almost always*). Reliability for both anxiety ($\omega = .94$) and depression ($\omega = .95$) were excellent.

Sociodemographics. Participants reported on their grade, gender, parental education, and race/ethnicity. Youth also reported on whether their families had difficulty buying things they wanted or needed, as a proxy for family financial strain (Galinsky, 1999).

Analytic Technique

All network analyses were conducted in the R using the statnet package suite. The statnet package suite was first used to quantify a directed adjacency matrix that represented whether a given node (child) was connected with a peer and if this connection was characterized by enjoying that time at least somewhat. The *idegree* function was then used to extract the popularity metric for each node and the *odegree* function was used to extract the activity metric for each node. *Reciprocity* was calculated by converting the directed adjacency matrix to an undirected matrix using the “strong” rule and extracting the degrees (Luke, 2015). The *betweenness* function was used to extract the extent to which a node served as a broker between disparate groups and the *evcent* function was used to quantify the eigenvector characterized by

the extent to which a node was connected with popular others. Multiple regression models were used to predict each of the social connectedness indicators extracted from the peer network. Sleep disturbances was entered as the primary predictor for each model, with adolescent grade, gender, parent education, financial strain, race/ethnicity, depressive symptoms, and anxiety symptoms entered as covariates. Additional models were run to examine gender as a moderator of the associations between sleep and social connectedness variables. R script for analyses are available in the supplemental file. Given the sensitive nature of network data, raw data will be made available upon request and with ethics board approval.

Missing Data. Low levels of missing data (<5%) were estimated using multiple imputation and the MICE package. Sensitivity analyses demonstrated that findings were similar in terms of effect size and pattern of significance when using multiple imputation and listwise deletion.

Results

The peer network was characterized by 213 nodes (children) and 1,093 edges or ties between nodes (see Figure 1). The average density of the network was .03 indicating that roughly 3% of all possible ties were selected. Table 1 displays the descriptive statistics and bivariate correlations among the social connectedness network indicators, covariates, and sleep disturbances. On average, youth nominated about 5 (out of a possible 7) friends and were nominated by an average of 5 others. Youth had an average of about 3 reciprocated ties. Bivariate correlations demonstrate that the indicators of social connectedness were positively correlated with one another (r 's range from .08 to .74). Sleep disturbances were moderately correlated with anxiety and depression (r 's were .62 and .59, respectively). Sleep disturbances were also significantly and negatively correlated with popularity, activity, and reciprocity.

Multiple regressions were used to examine associations between early adolescent sleep disturbances and social connectedness after accounting for adolescent grade, gender, parent education, financial strain, race/ethnicity, depressive symptoms, and anxiety symptoms. Table 2 displays the model estimates for popularity, activity, and reciprocity and Table 3 displays the model estimates for betweenness and eigenvector. Adolescent girls demonstrated higher activity, reciprocity, betweenness, and eigenvector relative to boys. Youth with less financial strain had less eigenvector relative to those with more financial strain. Youth with more educated parents were more popular, active, had more reciprocated friendships, and had higher betweenness. Youth who endorsed greater depressive symptoms had lower betweenness. Youth who reported greater sleep problems were less popular, had lower activity, and fewer reciprocated friendships.

Figure 2 displays plots of the associations between sleep and social connectedness. Relative to those who reported that they “never” experienced sleep problems, early adolescents who reported “almost never” experiencing sleep problems had on average .5 fewer peers who nominate them as a friend and early adolescents who reported “always” experiencing sleep problems had 1 fewer peers nominate them as a friend (Figure 2a). Regarding peer activity, early adolescents who reported “almost never” experiencing sleep problems nominated on average 1 fewer peers as a friend and early adolescents who reported “always” experiencing sleep problems nominated on average 1.5 fewer peers as a friend relative to those who “never” experienced sleep problems (Figure 2b). For reciprocated friendships, early adolescents who reported “almost never” experiencing sleep problems had similar levels of reciprocated friendships as those who reported “never” having sleep problems. However, early adolescents who reported “always” experiencing sleep problems had approximately half as many reciprocated friendships relative to those who never experienced sleep problems (Figure 2c).

Results from the moderation analyses did not indicate that any association between sleep and social connectedness were significantly moderated by gender.

Discussion

Early adolescence is a developmental period characterized by a heightened sensitivity to sleep disturbances and greater prioritization of peer relationships. Building on evidence in adults suggesting that poor or insufficient sleep results in more negative social interactions (Beattie et al., 2015; Gordon et al., 2017), findings from this study suggest that sleep disturbances in early adolescence are associated with lower social connectedness across a range of indicators. These results provide support that sleep may be one factor that could foster or hinder social connections during the early adolescent period, when social development is undergoing rapid changes. These findings are especially important in light of the high and increasing rates of insufficient sleep among youth (Keyes et al., 2015; Owens et al., 2014; Palmer et al., in press) combined with the increased neurobiological sensitivity to social interactions and development of key social skills during the adolescent period (Blakemore & Mills, 2014).

Results from this study indicate that youth who reported greater sleep disturbances nominated fewer friends, had fewer peers nominate them as a friend, and had fewer reciprocated friendships. Notably, youth who reported high levels of sleep problems had less than half as many reciprocated friendships compared to youth not reporting any sleep problems. The magnitude of effects are not surprising in light of adult studies suggesting impaired social functioning as a result of sleep disruption (Beattie et al., 2015) and preliminary research in youth suggesting that the daytime functioning of poor sleepers may be impaired in ways that can directly impact social interactions. For example, poor sleep is associated with poorer emotion regulation, increased hostility, and impaired empathy (Baum et al., 2014; Brand et al., 2016; Palmer et al., 2018; Soffer-Dudek et al., 2011). It is possible that youth who reported greater

sleep disturbances also had more difficulty fostering positive social interactions due to these socioemotional impairments, thus contributing to less social connectedness and friendships. These findings are consistent with Li and colleagues (2019) who found that more socially isolated adolescent boys also experienced greater insomnia symptoms.

In contrast to the negative associations between sleep disturbances and connectedness in the current study, Li and colleagues (2019) found that popular adolescent girls were more likely to report insufficient or shorter sleep. It is possible that the discrepancy in these results may be due to age differences in these samples, as Li and colleagues included adolescents 13-21 years old. Indeed, total sleep time significantly decreases with age throughout adolescence, as circadian phase delays and lower homeostatic sleep pressure shift bedtimes later, which results in greater sleep loss when combined with early school start times (Crowley et al., 2018; Galland et al., 2018). It is possible that poor sleep in older adolescents has different underlying mechanisms than insufficient sleep in our younger adolescents (i.e., due to earlier high school schedules as opposed to more endogenous sleep problems), or may be more problematic socially if sleep problems or daytime sleepiness is less common among peers. It is also possible that older adolescents who are popular are more likely to engage in substance use behaviors that can directly impact sleep (Mathys et al., 2013; Mayeux et al., 2008; Pasch et al., 2012) or spend more time interacting with peers using electronic media, which can displace opportunities for sleep (Cain & Gradisar, 2010; Fobian et al., 2016; Hysing et al., 2015). The added time burdens that arise with being popular can interfere with sleep opportunities, but these time burdens may not manifest until later in adolescence when personal autonomy over schedules and peer interactions increase, and parental control and oversight regarding bedtimes and sleep schedules decrease (Crowley et al., 2018). Instead, the emotional benefits of positive peer relationships, such as

increased belongingness and support, may outweigh any increased time demands from having more friends during the early adolescent years.

Results from the current study did not suggest associations between sleep disturbances and measures of betweenness or participants' eigenvector values, which represent connections among distinct peer groups or with highly connected peers. This suggests that associations between sleep disturbances and social connectedness primarily emerged for the quantity of friendships, rather than the position that youth hold within the social network. We also did not find any evidence that associations varied for participants based on gender, despite research suggesting that sleep disturbances may differentially impact daytime functioning in adolescent girls compared to boys (Li et al., 2019; Short & Louca, 2015; van Zundert et al., 2015).

Emerging evidence also suggests that pre-existing emotional risk (i.e., anxiety or depression) can amplify or alter the effects of sleep loss on daytime functioning (e.g., Giedke & Schwärzler, 2002; Palmer & Alfano, 2020). Thus, it is possible that gender differences in sensitivity to sleep problems do not emerge until later in adolescence, when girls begin to experience affective disorders at higher rates compared to boys (Altemus et al., 2014).

Limitations and Future Directions

The current study had a number of strengths. Notably, this sample included the majority of the school peer network (85%), and captured students at the only public school available in a large, rural county, which increases confidence that the majority of same-aged peers were included in the network. We also obtained both self- and peer-report of friendships, which provides a more comprehensive view of social connections as reports of social competence can be discrepant across reporters (e.g., Topalli et al., 2019). We also adjusted for anxiety and depressive symptoms in our analyses, given a number of studies suggesting high rates of comorbidity between sleep problems and affective symptoms (e.g., Gregory & Sadeh, 2016;

Palmer, 2020), and associations between depressive symptoms, anxiety, and social interactions (Kochel et al., 2012; La Greca & Harrison, 2005), which increases confidence that associations between sleep and social connectedness are not due to broader emotional difficulties that may emerge as a result of poor sleep.

Despite these strengths, findings should still be interpreted in light of several limitations. Most importantly, these data are based on cross-sectional analyses and it is not possible to determine causality or directionality. We posited that poor sleep may result in negative downstream social outcomes based on experimental and longitudinal data suggesting that sleep reduction or disturbances result in next day social impairments, and that sleep more strongly predicts daytime emotional outcomes rather than daytime difficulties predicting later sleep problems (e.g., Beattie et al., 2015; Ben-Simon & Walker, 2018; McMakin & Alfano, 2015). However, these associations are likely bidirectional, and poor social relationships could also impact nighttime sleep quality. Future studies should examine these processes longitudinally to better determine these temporal associations. Additionally, while the sample demographics are similar to the population of the surrounding community, our sample was primarily White. Given higher rates of sleep disturbances among Black and Hispanic/Latino youth (e.g., Goldstone et al., 2020; Yip et al., 2020), the relative homogeneity of our sample limits the generalizability of our findings. We also relied on self-reports of sleep disturbances. While self-reported sleep quality is an important, independent indicator of sleep health (Buysse, 2014), future studies would benefit from the inclusion of objective assessments of sleep such as actigraphy, or from capturing a more diverse array of sleep problems such as sleep efficiency or duration, which may differentially predict daytime outcomes (Goldstone et al., 2020; Palmer & Alfano, 2017b; Reynolds & Alfano, 2017).

Conclusions

The current study builds on emerging evidence that poor sleep has implications for daytime social interactions and suggest that among a sample of early adolescents, sleep disturbances are associated with overall poorer connectedness among peers using a social network approach. Youth experiencing more sleep disturbances had fewer friend nominations, fewer nominations as a friend by peers, and fewer reciprocated friendships. These findings emerged even after adjusting for sociodemographic characteristics and mental health symptoms. These results have important implications for the social development of teenagers, as the early adolescent years are a time of dramatic changes in sleep neurobiology, the development of socioemotional skills, and the importance of peer relationships. Findings suggest that sleep disturbances during early adolescence may be a possible intervention or prevention target for youth in regards to their social competency, and has broader significance for theories of social development, adolescent mental health, and behavioral sleep medicine.

References

- Altemus, M., Sarvaiya, N., Epperson, C. N. (2014). Sex differences in anxiety and depression clinical perspectives. *Frontiers in Neuroendocrinology*, 35, 320-330.
- Andrews, N. C., Hanish, L. D., Updegraff, K. A., Martin, C. L., & Santos, C. E. (2016). Targeted victimization: Exploring linear and curvilinear associations between social network prestige and victimization. *Journal of Youth and Adolescence*, 45(9), 1772-1785.
<https://doi.org/10.1007/s10964-016-0450-1>
- Baum, K. T., Desai, A., Field, J., Miller, L. E., Rausch, J., Beebe, D. (2014). Sleep restriction worsens mood and emotion regulation in adolescents. *Journal of Child Psychology and Psychiatry*, 55, 180-190.
- Beattie, L., Kyle, S. D., Espie, C. A., & Biello, S. M. (2015). Social interactions, emotion and sleep: A systematic review and research agenda. *Sleep Medicine Reviews*, 24, 83-100.
<https://doi.org/10.1016/j.smr.2014.12.005>
- Ben-Simon, E., & Walker, M. P. (2018). Sleep loss causes social withdrawal and loneliness. *Nature Communications*, 9, 3146. <https://doi.org/10.1038/s41467-018-05377-0>
- Berndt, T. J. (1979). Developmental changes in conformity to peers and parents. *Developmental Psychology*, 15(6), 608–616. <https://doi.org/10.1037/0012-1649.15.6.608>
- Birkett, M., & Espelage, D. L. (2015). Homophobic name-calling, peer-groups, and masculinity: The socialization of homophobic behavior in adolescents. *Social Development*, 24(1), 184-205. <https://doi.org/10.1111/sode.12085>
- Blakemore, S., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*, 47, 296-312. <https://doi.org/10.1111/j.1469-7610.2006.01611.x>

- Blakemore, S., & Mills, K. L. (2014). Is adolescence a sensitive period for sociocultural processing? *Annual Review of Psychology*, 65, 187-207. <https://doi.org/10.1146/annurev-psych-010213-115202>
- Brand, S., Kirov, R., Kalak, N., Geber, M., Schmidt, N. B., Lemola, S., Correll, C. U., Holsboer-Trachsler, E. (2016). Poor sleep is related to lower emotional competence among adolescents. *Behavioral Sleep Medicine*, 14, 602-614. <https://doi.org/10.1080/15402002.2015.1048450>
- Burt, R. S. (1987). A note on missing network data in the general social survey. *Social Networks*, 9, 63-73.
- Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep*, 37, 9-17. <https://doi.org/10.5665/sleep.3298>
- Cain, N., & Gradisar, M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine*, 11, 735-742. <https://doi.org/10.1016/j.sleep.2010.02.006>
- Crowley, S. J., Wolfson, A. R., Tarokh, L., & Carskadon, M. A. (2018). An update on adolescent sleep: New evidence informing the perfect storm model. *Journal of Adolescence*, 67, 55-65. <https://doi.org/10.1016/j.adolescence.2018.06.001>
- Diego, M. A., Field, T. M., & Sanders, C. E. (2003). Academic performance, popularity, and depression predict adolescent substance use. *Adolescence*, 38, 35-42.
- Donoghue, C., & Meltzer, L. J. (2018). Sleep it off: Bullying and sleep disturbances and adolescents. *Journal of Adolescence*, 68, 87-93.

- Fett, A. K., Shergill, S. S., Krabbendam, L. (2015). Social neuroscience in psychiatry: Unraveling the neural mechanisms of social dysfunction. *Psychological Medicine*, 45, 1145-1165. <https://doi.org/10.1017/S0033291714002487>
- Fobian, A. D., Avis, K., & Schwebel, D. C. (2016). The impact of media use on adolescent sleep efficiency. *Journal of Developmental and Behavioral Pediatrics*, 37, 9-14. <https://doi.org/10.1097/DBP.0000000000000239>
- Forrest, C. B., Meltzer, L. J., Marcus, C. L., de la Motte, A., Kratchman, A., Buysse, D. J., Pilkonis, P. A., Becker, B. D., Bevans, K. B. (2018). Development and validation of the PROMIS Pediatric Sleep Disturbance and Sleep-Related Impairment item banks. *Sleep*, 41, zsy054. <https://doi.org/10.1093/sleep/zsy054>
- Furman, W., & Buhrmester, D. (1992). Age and sex differences in perceptions of networks of personal relationships. *Child Development*, 63, 103–115. <https://doi.org/10.2307/1130905>
- Galinsky, E. (1999). *Ask the children: What America's children really think about working parents*. New York: Morrow.
- Galland, B. C., Short, M. A., Terrill, P., Rigney, G., Haszard, J. J., Coussens, S., Foster-Owens, M., Biggs, S. N. (2018). Establishing normal values for pediatric nighttime sleep measured by actigraphy: A systematic review and meta-analysis. *Sleep*, 41, zsy017. <https://doi.org/10.1093/sleep/zsy017>
- García-Perdomo, H. A., Zapata-Copete, J., & Rojas-Cerón, C. A. (2019). Sleep duration and risk of all-cause mortality: A systematic review and meta-analysis. *Epidemiology and Psychiatric Sciences*, 28(5), 578-588. <https://doi.org/10.1017/S2045796018000379>

- Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology, 41*(4), 625–635. <https://doi.org/10.1037/0012-1649.41.4.625>
- Giedke, H., & Schwärzler, F. (2002). Therapeutic use of sleep deprivation in depression. *Sleep Medicine Reviews, 6*, 361-377. <https://doi.org/10.1053/smr.2002.0235>
- Goldstone, A., Javitz, H. S., Claudatos, S. A., Buysse, D. J., Hasler, B. P., de Zamboti, M., Clark, D. B., Franzen, P. L., Prouty, D. E., Colrain, I. M., & Baker, F. C. (2020). Sleep disturbance predicts depression symptoms in early adolescence: Initial findings from the Adolescent Brain Cognitive Development Study. *Journal of Adolescent Health, 66*, 567-574. <https://doi.org/10.1016/j.jadohealth.2019.12.005>
- Gordon, A. M., Mendes, W. B., & Prather, A. A. (2017). The social side of sleep: Elucidating the links between sleep and social processes. *Current Directions in Psychological Science, 26*, 470-475. <https://doi.org/10.1177/0963721417712269>
- Gregory, A. M., & Sadeh, A. (2016). Annual research review: Sleep problems in child psychiatric disorders – a review of the latest science. *Journal of Child Psychology and Psychiatry, 57*, 296-317. <https://doi.org/10.1111/jcpp.12469>
- Hunter, F. T., & Youniss, J. (1982). Changes in function of three relations during adolescence. *Developmental Psychology, 18*, 806–811. <https://doi.org/10.1037/0012-1649.18.6.806>
- Hysing, M., Pallesen, S., Stormark, K.M., Jakobsen, R., Lundervold, A., & Sivertsen, B. (2015). Sleep and use of electronic devices in adolescence: Results from a large population-based study. *BMJ Open, 5*, e006748. <http://dx.doi.org/10.1136/bmjopen-2014-006748>
- Jenni, O. G., Achermann, P., & Carskadon, M. A. (2005). Homeostatic sleep regulation in adolescents. *Sleep, 28*, 1446-1454. <https://doi.org/10.1093/sleep/28.11.1446>

- Keyes, K. M., Maslowsky, J., Hamilton, A., & Schulenberg, J. (2015). The great sleep recession: Changes in sleep duration in US adolescents, 1991-2012. *Pediatrics*, 135(3), 460-468.
<https://doi.org/10.1542/peds.2014-2707>
- Kochel, K. P., Ladd, G. W., & Rudolph, K. D. (2012). Longitudinal associations among youth depressive symptoms, peer victimization, and low peer acceptance: An interpersonal process perspective. *Child Development*, 83(2), 637-650. <https://doi.org/10.1111/j.1467-8624.2011.01722.x>
- Kornienko, O., Santos, C. E., Martin, C. L., & Granger, K. L. (2016). Peer influence on gender identity development in adolescence. *Developmental Psychology*, 52(10), 1578.
<https://doi.org/10.1037/dev0000200>
- La Greca, A. M., & Harrison, H. M. (2005). Adolescent peer relations, friendships, and romantic relationships: Do they predict social anxiety and depression? *Journal of Clinical Child and Adolescent Psychology*, 34(1), 49-61. https://doi.org/10.1207/s15374424jccp3401_5
- Lee, F. S., Heimer, H., Giedd, J. N., Lein, E. S., Šestan, N., Weinberger, D. R. & Casey, B. J. (2014). Adolescent mental health – opportunity and obligation. *Science*, 346, 547-549.
<https://doi.org/10.1126/science.1260497>
- Li, X., Kawachi, I., Buxton, O. M., Haneuse, S., Onnela, J. (2019). Social network analysis of group position, popularity, and sleep behaviors among U.S. adolescents. *Social Science & Medicine*, 232, 417-426. <https://doi.org/10.1016/j.socscimed.2019.05.026>
- Lim, J., & Dinges, D. F. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychological Bulletin*, 136, 375-389.
<https://doi.org/10.1037/a0018883>

- Luke, D. (2015). *A user's guide to network analysis in R*. Heidelberg, Switzerland: Springer International.
- Mathys, C., Burk, W. J., & Cillessen, A. H. N. (2013). Popularity as a moderator of peer selection and socialization of adolescent alcohol, marijuana, and tobacco use. *Journal of Research on Adolescence*, 23, 513-523.
- Mayeux, L., Sandstrom, M. J., & Cillessen, A. H. N. (2008). Is being popular a risky proposition? *Journal of Research on Adolescence*, 18, 49-74.
- McGraw, K., Moore, S., Fuller, A., & Bates, G. (2008). Family, peer and school connectedness in final year secondary school students. *Australian Psychologist*, 43, 27-37.
- McMakin, D. L., & Alfano, C. A. (2015). Sleep and anxiety in late childhood and early adolescence. *Current Opinion in Psychiatry*, 28, 483-489.
<https://doi.org/10.1097/YCO.0000000000000204>
- McMakin, D. L., Dahl, R. E., Buysse, D. J., Cousins, J. C., Forbes, E. E., Silk, J. S., Siegle, G. J., Franzen, P. L. (2016). The impact of experimental sleep restriction on affective functioning in social and nonsocial contexts among adolescents. *Journal of Child Psychology and Psychiatry*, 57, 1027-1037. <https://doi.org/10.1111/jcpp.12568>
- Meyer-Lindenberg, A., & Tost, H. (2012). Neural mechanisms of social risk for psychiatric disorders. *Nature Neuroscience*, 15, 663-668. <https://doi.org/10.1038/nn.3083>
- Miller, K. F., Margolin, G., Shapiro, L. S., & Timmons, A. C. (2017). Adolescent life stress and the cortisol awakening response: The moderating roles of attachment and sex. *Journal of Research on Adolescence*, 27, 34-48.
- Murray-Close, D. (2012). Psychophysiology of adolescent peer relations I: Theory and research findings. *Journal of Research on Adolescence*, 23, 236-259.

- Neal, J. W. (2020). A systematic review of social network methods in high impact developmental psychology journals. *Social Development*, 1-22.
<https://doi.org/10.1111/sode.12442>
- Owens, J., & Adolescent Sleep Working Group, Committee of Adolescence. (2014). Insufficient sleep in adolescents and young adults: An update on causes and consequences. *Pediatrics*, 134(3), e921-932. <https://doi.org/10.1542/peds.2014-1696>
- Palmer, C. A. (2020). Tired teens: Sleep disturbances and heightened vulnerability for mental health difficulties. *Journal of Adolescent Health*, 66, 520-521.
<https://doi.org/10.1016/j.jadohealth.2020.01.023>
- Palmer, C. A., & Alfano, C. A. (2017a). Sleep and emotion regulation: An organizing, integrative review. *Sleep Medicine Reviews*, 31, 6-16.
<https://doi.org/10.1016/j.smr.2015.12.006>
- Palmer, C. A., & Alfano, C. A. (2017b). Sleep architecture relates to daytime affect and somatic complaints in clinically anxious and healthy children. *Journal of Clinical Child and Adolescent Psychology*, 46, 175-187. <https://doi.org/10.1080/15374416.2016.1188704>
- Palmer, C. A., & Alfano, C. A. (2020). Anxiety modifies the emotional effects of sleep loss. *Current Opinion in Psychology*, 34, 100-104.
<https://doi.org/10.1016/j.copsyc.2019.12.001>
- Palmer, C. A., Alfano, C. A., & Bower, J. L. (in press). Adolescent sleep patterns are associated with the selection of positive and negative emotional situations. *Journal of Sleep Research*, e12917. <https://doi.org/10.1111/jsr.12917>
- Palmer, C. A., Oosterhoff, B., Bower, J. L., Kaplow, J. B., & Alfano, C. A. (2018). Associations among adolescent sleep problems, emotion regulation, and affective disorders: Findings

- from a nationally representative sample. *Journal of Psychiatric Research*, 96, 1-8.
<https://doi.org/10.1016/j.jpsychires.2017.09.015>
- Pasch, K. E., Latimer, L. A., Cance, J. D., Moe, S. G., Lytle, L. A. (2012). Longitudinal and bi-directional relationships between sleep and youth substance use. *Journal of Youth and Adolescence*, 41, 1184-1196.
- Quinn, H., Thissen, D., Liu, Y., Magnus, B., Lai, J., Amtmann, D., Varni, J., Gross, H. E., DeWalt, D. A. (2014). *Health and Quality of Life Outcomes*, 12, 160.
- Reynolds, K. C., & Alfano, C. A. (2016). Childhood bedtime problems predict adolescent internalizing symptoms through emotional reactivity. *Journal of Pediatric Psychology*, 41(9), 971–982. <https://doi.org/10.1093/jpepsy/jsw014>
- Roberts, R. E., Roberts, C. R., Chen, I. G. (2002). Impact of insomnia on future functioning of adolescents. *Journal of Psychosomatic Research*, 53, 561-569.
[https://doi.org/10.1016/S0022-3999\(02\)00446-4](https://doi.org/10.1016/S0022-3999(02)00446-4)
- Short, M. A., & Louca, M. (2015). Sleep deprivation leads to mood deficits in healthy adolescents. *Sleep Medicine*, 16, 987–993. <https://doi.org/10.1016/j.sleep.2015.03.007>
- Smetana, J. G., Campione-Barr, N., Metzger, A. (2006). Adolescent development in interpersonal and societal contexts. *Annual Review of Psychology*, 57, 255-284.
<https://doi.org/10.1146/annurev.psych.57.102904.190124>
- Soffer-Dudek, N., Sadeh, A., Dahl, R. E., & Rosenblat-Stein, S. (2011). Poor sleep quality predicts deficient emotion informational processing over time in early adolescence. *Sleep*, 34, 1499-1508. <https://doi.org/10.5665/sleep.1386>
- Steinberg, L., & Silverberg, S. B. (1986). The vicissitudes of autonomy in early adolescence. *Child Development*, 57, 841-851. <https://doi.org/10.2307/1130361>

- Talbot, L. S., McGlinchey, E. L., Kaplan, K. A., Dahl, R. E., & Harvey, A. G. (2010). Sleep deprivation in adolescents and adults: Changes in affect. *Emotion, 10*, 831–841.
<https://doi.org/10.1037/a0020138>
- Topalli, P., Junttila, N., Acquah, E. O., Veermans, K., Niemi, P. M. (2020). Perceptual discrepancy profiles of social competence and their interrelations with depressive symptoms among early adolescents. *Journal of Research on Adolescence, 30*, 109-125.
- van Zundert, R. M., van Roekel, E., Engels, R. C., & Scholte, R. H. (2015). Reciprocal associations between adolescents' night-time sleep and daytime affect and the role of gender and depressive symptoms. *Journal of Youth and Adolescence, 44*, 556-569.
<https://doi.org/10.1007/s10964-013-0009-3>
- Yip, T., Cheon, Y. M., Wang, Y., Cham, H., Tyron, W., El-Sheikh, M. (2020). Racial disparities in sleep: Associations with discrimination among ethnic/racial minority adolescents. *Child Development, 91*, 914-931. <https://doi.org/10.1111/cdev.13234>

Table 1

Means, Standard Deviations, and Bivariate Correlations among Study Variables

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Gender	1.54	0.50													
2. Grade	2.04	0.81	.08												
3. Race: White	0.86	0.35	.22**	.02											
4. Ethnicity	1.09	0.29	.02	.00	-.20**										
5. Financial Strain	2.77	0.74	.08	-.17*	.04	.03									
6. Parents' Education	2.64	0.66	-.05	-.07	.15*	-.08	.33**								
7. Anxiety Symptoms	1.90	1.03	.21**	.08	-.02	.01	-.29**	-.17*							
8. Depressive Symptoms	1.93	1.08	.19**	.10	-.03	.07	-.41**	-.25**	.83**						
9. Sleep Problems	2.17	0.93	.07	-.00	-.02	.03	-.22**	-.11	.62**	.59**					
10. Popularity	4.91	2.79	.17*	.11	.11	-.02	.19**	.21**	-.04	-.11	-.20**				
11. Activity	4.90	1.99	.30**	.12	.12	-.03	.25**	.31**	-.02	-.12	-.18**	.38**			
12. Betweenness	825.14	922.18	.18**	-.01	.10	-.09	.20**	.23**	-.05	-.15*	-.04	.28**	.41**		
13. Eigenvector	0.03	0.06	.29**	.06	.14*	-.07	.21**	.12	-.05	-.10	-.12	.30**	.43**	.08	
14. Reciprocity	2.77	1.69	.33**	.04	.14*	-.02	.17*	.22**	-.00	-.07	-.22**	.74**	.62**	.23**	.39**

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. * indicates $p < .05$. ** indicates $p < .01$.

Table 2

Regression Coefficients for Associations between Sleep Problems, Popularity, Activity, and Reciprocity

<i>Predictors</i>	Popularity			Activity			Reciprocity		
	<i>Estimates</i>	<i>SE</i>	<i>p</i>	<i>Estimates</i>	<i>SE</i>	<i>p</i>	<i>Estimates</i>	<i>SE</i>	<i>p</i>
(Intercept)	0.35	1.57	0.821	-0.06	1.04	0.957	-0.20	0.90	0.821
Gender	0.74	0.39	0.060	1.15	0.26	<0.001	1.06	0.22	<0.001
Grade	0.42	0.23	0.071	0.32	0.15	0.038	0.06	0.13	0.670
Race: White	0.34	0.55	0.537	-0.00	0.37	0.991	0.16	0.32	0.620
Ethnicity	-0.01	0.65	0.989	-0.02	0.43	0.961	0.05	0.38	0.891
Financial Strain	0.47	0.28	0.102	0.33	0.19	0.080	0.13	0.16	0.444
Parents' Education	0.71	0.30	0.018	0.85	0.20	<0.001	0.53	0.17	0.002
Anxiety Symptoms	0.52	0.34	0.127	0.43	0.22	0.056	0.37	0.19	0.054
Depressive Symptoms	-0.16	0.33	0.622	-0.24	0.22	0.273	-0.11	0.19	0.565
Sleep Problems	-0.72	0.25	0.005	-0.43	0.17	0.012	-0.56	0.15	<0.001
R ² / R ² adjusted	0.147 / 0.109			0.266 / 0.234			0.237 / 0.203		

Note. Bolded values are significant at $p < .05$.

Table 3

Regression Coefficients for Associations between Sleep Problems, Betweenness, and Eigenvector

<i>Predictors</i>	Betweenness			Eigenvector		
	<i>Estimates</i>	<i>SE</i>	<i>p</i>	<i>Estimates</i>	<i>SE</i>	<i>p</i>
(Intercept)	-384.65	523.05	0.463	-0.06	0.03	0.097
Gender	359.95	130.70	0.006	0.03	0.01	<0.001
Grade	18.38	76.42	0.810	0.01	0.00	0.305
Race: White	9.54	184.42	0.959	0.01	0.01	0.465
Ethnicity	-218.54	218.78	0.319	-0.01	0.01	0.388
Financial Strain	94.56	95.19	0.322	0.01	0.01	0.048
Parents' Education	248.53	99.95	0.014	0.01	0.01	0.405
Anxiety Symptoms	142.94	112.68	0.206	0.00	0.01	0.676
Depressive Symptoms	-231.82	110.30	0.037	-0.00	0.01	0.586
Sleep Problems	48.11	84.70	0.571	-0.01	0.01	0.303
R ² / R ² adjusted	0.129 / 0.090			0.150 / 0.112		

Note. Bolded values are significant at $p < .05$.

Figure 1. Early adolescents' peer network.

Figure 2. Significant Associations between Sleep Problems and Social Connectedness. Figure 2a: Associations between Sleep Problems and Popularity (in-degree). Figure 2b: Associations between Sleep Problems and Activity (out-degree). Figure 2c: Associations between Sleep Problems and Reciprocity.