Puberty-Dependent Sleep Regulation and Alcohol Use in Early Adolescents

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**Background:** Research has shown a bi-directional relation between alcohol use and sleep regulation in adults. Much less is known about this association in early adolescents, while profound pubertal-dependent transitions regarding sleep patterns take place in early adolescence. Moreover, puberty has been associated with an increase in alcohol use of adolescents.

**Methods:** In this study, we investigated the associations between pubertal development, sleep preference, sleep problems, and alcohol use in 431 early adolescents (mean age: 13.66). Second, it was studied whether the associations changed when controlling for adolescent internalizing and externalizing problems. Furthermore, we included gender as a moderator on all the associations.

**Results:** Results showed that pubertal development was positively associated with sleep problems and more evening-type tendencies (e.g., favoring later bedtimes), which in turn were positively related to alcohol use. Underlying psychopathology, gender and educational level did not change these relationships.

**Conclusions:** From this study, it can be concluded that both puberty and sleep regulation are important factors in explaining alcohol use in early adolescence.

**Key Words:** Early Adolescents, Puberty, Alcohol Use, Sleep Regulation, Sleep Problems, Psychopathology.
preference should also be taken into account in the relation between pubertal maturation, sleep problems, and adolescent alcohol use.

To our knowledge, only 2 studies have addressed the direct relation between circadian phase preference and substance use in adolescence. Tynjälä and colleagues (1997) found that sleep habits, a factor composed of variables such as irregular bedtimes, later bedtimes during school weeks and large differences in sleep duration between school and weekend nights, were positively associated with substance use in 15-year-old boys and girls. In addition, Giannotti and colleagues (2002) found that evening-type mid- and late adolescents were more likely to use substances such as alcohol, tobacco, and beverages containing caffeine (Giannotti et al., 2002). No studies have yet examined the relation between circadian phase preference and alcohol use in early adolescents, while accounting for differences in pubertal status. Given the interrelation between puberty, sleep problems, and alcohol use, one could argue that sleep regulation is one of the missing links in the association between puberty and alcohol use.

Placed in a broader context, pubertal-dependent changes in sleep habits might be just one manifestation of more general alterations in neural systems governing emotion or arousal regulation, affecting numerous aspects of adolescent control over affect and behavior, including alcohol use. Alternatively, sleep problems would be secondary to a certain pathological state, which would be related to alcohol use (Dahl, 1996a,b). In particular, it is possible that the relation between sleep problems and alcohol use could be explained by the presence of internalizing or externalizing problems (e.g., Wong et al., 2009), which are known to be associated with adolescent alcohol use (e.g., Steele et al., 1995). Indeed, child and adolescent sleep problems and insomnia are associated with depressive and anxiety disorders (Gregory and O’Connor, 2002; Gregory et al., 2004, 2005, 2008) and obsessive compulsive disorders (Storch et al., 2008). In addition, child and adolescent sleep problems are associated with externalizing problems, such as conduct disorders and aggression (Gregory and O’Connor, 2002; Gregory et al., 2004, 2008). Studies have shown a substantial reduction in the strength of the association between sleep problems in adolescence and alcohol use when adjusting for internalizing and externalizing problems (Johnson and Breslau, 2001), though another study examining early childhood sleep problems found no significant effect when adjusting for these different problems (Wong et al., 2009). While results with respect to this issue are mixed, it appears that systems governing sleep and emotion regulation are intertwined. When examining the relation between puberty-dependent changes in sleep regulation and problems on the one hand, and alcohol use on the other hand, it seems vital to take internalizing and externalizing problems into account.

Sex differences in the association between the sleep/wake cycle and alcohol use in adolescence have received little attention in the extant literature. The results of the few studies that did account for gender provide mixed results. Regarding the relation between sleep problems and alcohol use in adolescents, some studies reported no sex differences (Tynjälä et al., 1997; Vignau et al., 1997), while others found that childhood sleep problems predicted early onset (between 8 and 14 years) of alcohol use in boys and onset (between 15 and 17 years) of alcohol use in girls (Wong et al., 2009). When examining pubertal status, however, it is vital to examine differences between boys and girls. For instance, because girls mature earlier than boys (Tanner, 1972), it might be that girls are at a higher risk to develop sleep problems and drinking alcohol at a younger age than boys.

The main aim of the current study is to examine the relation between puberty, delayed phase preference, sleep problems, and alcohol use in early adolescents. To date, studies have mainly focused on circadian preference and sleep problems in either early childhood or middle and late adolescence, while profound puberty-dependent and puberty-independent changes in sleep patterns take place in early adolescence. Since an early onset of alcohol use predicts alcohol-related problems later in life, it is vital to delineate which factors are involved in predisposing adolescents to drink alcohol in their early teens. A secondary aim is to examine whether associations differ when adjusting for adolescent internalizing and externalizing problems. Gender differences in these associations are also considered. It is hypothesized that pubertal status will be related to a more evening-type sleep/wake rhythm and more sleep problems. Evenness and more sleep problems will be related to more alcohol use. Furthermore, pubertal status will be associated not only directly with more alcohol use, but also indirectly through eveningness and sleep problems.

METHOD

Procedure

Data were derived from a larger study assessing cognitive and psychological risk factors related to adolescents’ alcohol use. All parents/caregivers of the 1,215 pupils who attended one of the 5 participating schools received a letter by mail in which the motives for conducting the current study were explained. Parents were asked to give active informed consent for their child’s participation in the study by returning the response form. Ultimately, this resulted in a total number of 725 participants (60% of the total group of parents contacted by mail).

Data collection was divided over 2 test days. At the first day, adolescents performed several computer tasks assessing cognitive processes that are thought to be related to alcohol use (e.g., working memory capacity). Completing the computer tasks took approximately 1 hour. On the second day, adolescents were asked to fill out an extensive questionnaire in their own classroom under supervision of a trained research assistant. Completion of the questionnaire took on average 1 hour. Participants were not allowed to discuss questions or answers with each other and were instructed to consult a trained research assistant in case of any issues regarding the questionnaire. A unique subject number was assigned to each participant to guarantee anonymity.

Participants

In total, 725 children from grades 1 to 6 of Dutch high schools filled out the questionnaire, and 619 completed the computer tasks. In the current study, questionnaire data were used from the 431 adolescents (195 male) aged 11 to 14 years old (mean age = 13.66;
and conduct problems were administered in the current study (Goodman, 1997). The emotional and conduct subscale of the SDQ represent “internalizing” and “externalizing” problems, respectively. Both scales were composed of 5 items measuring the intensity of problems on a 3-point scale: (1) “Does not apply to me,” (2) “Applies a little to me,” (3) “Applies certainly to me.” The psychometric qualities of this questionnaire are good (e.g., Muris et al., 2003).

**Strategy of Analyses**

First, descriptives were calculated to examine means and standard deviations of all model variables. Potential sex or educational differences in alcohol use, circadian preference, and sleep problems were tested using a series of one-way ANOVAs. Next, correlations between all variables of interest were computed. Subsequently, 2 structural equation models were performed using the robust maximum likelihood estimator in MPlus version 5.1 (MLR: Muthén and Muthén, 1998–2007). The first model tested associations between puberty, M/E, sleep problems, and alcohol use; the second model tested these associations while adjusting for potential confounders (age, sex, educational level, internalizing and externalizing problems). For both models, the 2 alcohol measures (frequency and intensity of alcohol use) were combined into one latent factor reflecting adolescent alcohol use. Factor loadings of the alcohol construct were all above 0.84. The 3 sleep problem subscales were combined into a latent factor reflecting sleep problems. Factor loadings of sleep problems were all above .63, indicating that the underlying variables were properly reflected by the latent factor. Figure 1 displays path estimates for the 2 models. Covariates in the second model (age, gender, educational level, internalizing and externalizing problems) were included as predictors of all variables included in the first model. The correlation between sleep problems and morningness/eveningness was included in all models. The fit of the models was assessed with 3 global fit indexes: Chi-Square, Comparative Fit Index, and Root Mean Square Error of Approximation. Finally, additional multigroup analyses were performed to examine sex differences in each pathway of the model with covariates (except gender), using the adjusted \( \chi^2 \) difference test formulated by Satorra and Bentler (2001).

**RESULTS**

Means and standard deviations of all variables are reported in Table 1. A total of 43.9% of adolescents reported that they never drank alcohol, 19.6% drank alcohol once a year, 9.7% once every 6 months, 11.7% once every 3 months, 6.4% once every month, 4.6% twice a month, 2.8% once a week, and 1.3% multiple times a week. On average, adolescents drank 1 or 2 glasses per occasion. No gender differences were found on the alcohol measures (\( p > 0.05 \)). A significant difference between educational levels was found for frequency (\( p < 0.001 \)) and quantity of alcohol use (\( p < 0.001 \)). Lower educated adolescents on average drank more and more often compared to their higher educated peers. With respect to the sleep measures, boys and girls did not differ on circadian preference or the “going to bed” and “falling asleep” subscales. However, they differed with respect to the level of “cognitive load” they experienced before falling asleep (\( p < 0.05 \)). Girls experienced a higher level of “cognitive load” before falling asleep than males. Regarding pubertal status, 3.8% of male and no female adolescents were considered prepubertal, 6.9%
of male and 1.4% of female adolescents were early pubertal, 28.1% of male, and 19.7% of female adolescents were mid-pubertal, 46.2% of male, and 77.9% of female adolescents were late pubertal, and 15% of male and 1% of female adolescents were postpubertal, indicating that in this sample, girls were at higher stages of pubertal development than boys ($p < 0.05$). An ANCOVA with age as a covariate showed that mean scores of alcohol use (frequency and intensity) were different for the 5 puberty categories ($p < 0.05$), indicating that differences in pubertal status on the alcohol measures could not be explained by age effects.

Correlations

Correlations between all variables are given in Table 1. Regarding the main focus of this study, we found that puberty was positively associated with the M/E score, implying that more mature adolescents showed a relatively stronger preference for evening-type-like behavior than less mature adolescents. Puberty was also related to cognitive activity before falling asleep, which signifies that cognitive activity before falling asleep was gradually more prevalent among more mature adolescents. The associations between puberty and problems going to bed and falling asleep were nonsignificant. M/E was significantly and positively related to all types of sleep problems: more owl-like tendencies were related to more sleep problems.

Regarding the relation between M/E, sleep problems, and alcohol use, it was found that all sleep concepts (M/E, problems going to bed, problems falling asleep, and cognitive activity before falling asleep) were positively related to the frequency and intensity of alcohol use. This suggests that the more adolescents prefer evenings over mornings or the more sleep problems they experienced, the more they drink and vice versa.

Externalizing problems were positively associated with puberty and frequency and intensity of alcohol use, internalizing problems were not. Both internalizing and externalizing problems were positively related to M/E and all sleep problems, indicating that more psychopathological problems are associated with a delayed phase preference and sleep problems.

**Associations Between Puberty, Sleep Problems, Circadian Preference, and Alcohol Use Using Structural Equation Modeling**

The fit of the structural equation models was satisfactory (see Fig. 1). Associations between variables of interest in the model were all positive and statistically significant. Puberty was positively related to both M/E and sleep problems, suggesting that more mature early adolescents tend to prefer relative owl-like behavior and to experience more sleep problems, compared to their less mature peers. M/E and sleep problems were also interrelated, meaning that more owl-like tendencies were associated with more sleep problems. The more sleep problems the adolescent experienced, or the more owl-like behavior a youth preferred, the more alcohol he or she drank. In addition, pubertal status was directly and positively related to alcohol use. Adjusting for emotional problems and conduct problems (see Fig. 1 and Table 2) did not change the pattern of results, meaning that significant associations remained significant after controlling for these problems.

**Gender Differences**

We used Chi-Square difference tests to examine whether factor loadings, correlations, and regression paths in the model significantly differed for boys and girls. No gender differences emerged in the factor loadings or correlations between predictors. Of the 20 regression paths in the model, only 2 paths significantly differed for boys and girls: the path from SDQ conduct problems to morningness/eveningness ($\Delta \chi^2 = 7.054, p = 0.008$) and the path from SDQ conduct
problems to sleep problems ($D_v^2 = 6.094$, $p = 0.014$). In both instances, regression coefficients were positive and statistically significant for girls (Beta = 0.355, $p < 0.001$; Beta = 0.357, $p < 0.001$, respectively) and nonsignificant for boys (Beta = 0.109; $p = 0.147$; Beta = 0.111, $p = 0.218$, respectively). So for girls, conduct problems predicted more eveningness and more sleep problems; for boys, conduct problems were not related to sleep patterns or sleep problems.

**DISCUSSION**

The main aim of the current study was to investigate the relation between puberty, circadian phase preference, sleep problems, and alcohol use in early adolescents. Further, the role of gender, internalizing and externalizing problems was examined to infer about potential explanatory mechanisms that could account for the associations. Results showed that puberty, sleep problems, circadian phase preference, and alcohol use were all positively and significantly related, even after controlling for age, educational level, and psychopathology. Specifically, puberty was related not only directly to alcohol use, but indirectly as well through sleep problems and delayed circadian phase preference. These findings suggest that puberty-dependent changes in sleep regulation might affect adolescents’ vulnerability to drink alcoholic beverages at an early age.

Regarding the relation between puberty and sleep, a positive relation between puberty and delayed circadian phase preference, as well as puberty and sleep problems, was found. These associations did not change after adjusting for chronological age, suggesting that pubertal status is intrinsically associated with changes in sleep habits. Findings are in line with previous studies in early adolescents and imply that youths experience detrimental changes in sleep regulation while maturing (Dahl and Lewin, 2002). Sex differences regarding the association between puberty and delayed phase preference and sleep problems were not found, in spite of the fact that on average the boys in our sample were less

**Table 2. Standardized Estimates of the Additional Path Model Including Internalizing and Externalizing Problems**

<table>
<thead>
<tr>
<th>Puberty</th>
<th>Sleep problems</th>
<th>Morningness/ eveningness</th>
<th>Alcohol use</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18**</td>
<td>0.13**</td>
<td>0.13*</td>
<td></td>
</tr>
<tr>
<td>Sleep problems</td>
<td>0.59***</td>
<td>0.21*</td>
<td></td>
</tr>
<tr>
<td>Morningness/eveningness</td>
<td>0.20**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing problems</td>
<td>0.10*</td>
<td>0.24***</td>
<td>0.23***</td>
</tr>
<tr>
<td>Internalizing problems</td>
<td>-0.09</td>
<td>0.26***</td>
<td>0.10*</td>
</tr>
<tr>
<td>Age</td>
<td>0.29*</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Educational level</td>
<td>-0.11*</td>
<td>0.00</td>
<td>-0.05</td>
</tr>
<tr>
<td>Gender</td>
<td>0.17**</td>
<td>-0.01</td>
<td>-0.00</td>
</tr>
</tbody>
</table>

Figures reflect standardized regression coefficients of the regression paths in the model adjusting for internalizing and externalizing problems, age, educational level, and gender. Fit indexes of the model: $df = 25$, $X^2 = 63.537$, $p < 0.001$, Comparative Fit Index = 0.961, Root Mean Square Error of Approximation = 0.060, Standardized Root Mean Square Residual = 0.031.

*p < 0.05; **p < 0.01; ***p < 0.001.
advanced in their development than the girls. This finding corresponds with other studies that found a significant positive relation between puberty and sleep problems or delayed phase preference in girls, and a same trend in boys (Carskadon et al., 1993). Overall, gender did not moderate any of the associations tested.

Delayed circadian phase preference was positively related to alcohol use, meaning that owl-like types were relatively more involved in alcohol use than lark-like early adolescents. This finding agrees with previous studies in adolescents that reported similar differences in alcohol use between morning- and evening-types (Giannotti et al., 2002; Tynjälä et al., 1997). Likewise, sleep problems were significantly and positively related to alcohol use, which corresponds with previous studies (e.g., Johnson and Breslau, 2001). Whereas most studies to date primarily used single-item measures of sleep problems, we used multiple items to assess specific aspects of sleep problems. Trouble getting to sleep at night, for instance, because of worrying, was related to more drinking. Remarkably, controlling for internalizing problems did not affect this relation, suggesting that problems getting to sleep at night could not be explained by underlying symptoms of depression or anxiety. This indicates that trouble getting to sleep at night might be a relatively normative behavior for early adolescents, but that the degree to which an adolescent experiences these problems affects whether or not he or she will drink alcohol. Alternatively, it cannot be excluded that drinking alcohol might be the cause of trouble getting to sleep at night or the shift to later bedtimes in early adolescence. Although an intuitive explanation might be that early adolescents who drink alcohol are also the ones that go out at night, and thereby going to bed later or experience troubles with getting to sleep due to alcohol consumption, it is unlikely that this is the case in the current sample. In the Netherlands, early adolescents are not allowed to buy alcohol when they go out at night to bars and clubs, and it is therefore unlikely that early adolescents get in touch with alcohol right before bedtime, except when allowed to drink at home. It seems more apt that sleep problems in early adolescence are an important marker for adolescent alcohol use, like Wong and colleagues (2004, 2009) already showed for early childhood sleep problems. However, future prospective research should confirm our conclusions.

Puberty was also directly and positively related to alcohol use, in line with previous research (e.g., Patton et al., 2004). Moreover, our indirect path model showed that including circadian phase preference and sleep problems into the model significantly increased the proportion of explained variance in alcohol use. Whereas this study adds to the current knowledge that sleep patterns are implicated in adolescent substance use behaviors, it remains unclear what the underlying mechanism is. Although it has been postulated that sleep problems are simply an epiphenomenon of psychopathological symptoms, which are the main cause of alcohol use, this study fails to support such an explanation, at least for internalizing or externalizing problems. We believe that sleep problems in adolescence affect cognitive functioning associated with the prefrontal cortex, especially executive functioning such as inhibition, planning and goal-directed behavior. It has already been suggested that sleep problems early in life affect executive functioning (Dahl, 1996b). Furthermore, poor executive functioning has been associated with alcohol use in adolescence, e.g., in dual process model of addiction (Wiers et al., 2007). Future research should focus on executive functions as a possible mediator in the relation between sleep problems and substance use.

This study has some limitations. First, cross-sectional data were used. Although findings are promising, this study does not provide any insight into the causality of the effects. It is well possible that alcohol use, even at moderate levels and at a fairly young age, could have affected sleep problems as well, equivalent to what has been found in adult samples (e.g., Brower, 2001). Future longitudinal studies should be able to clarify this matter. Second, more objective measures of sleep, such as polysomnography, should also be considered when examining the relation between sleep problems and substance use in adolescents. However, to include these kinds of measures in a population study is costly. Third, this study specifically focused on alcohol use, while it has been shown that consumption of other substances, such as nicotine and marijuana, is also related to disturbed sleeping behavior in adolescents (e.g., Cohen-Zion et al., 2009). It would be valuable to examine whether the association between sleeping behavior and substance use is drug specific. Potentially, use of other drugs could moderate the association between alcohol use and sleep problems as well. Nevertheless, this is beyond the scope of the present manuscript. Fourth, we did not observe sleep problems in other developmental stages, such as childhood. It appears that sleep problems are a robust marker of alcohol use, even when measured early in life (Wong et al., 2004, 2009). Including both children and (early) adolescents in a longitudinal study could shed light on the mechanism by which sleep patterns affect substance use and vice versa. A methodological limitation of this study was the relatively low recruitment rate. We have no reason to think this affected the findings, but generalizability remains a concern.

Based on the current findings, it seems that puberty-dependent variations in sleep behavior are related to alcohol use. Previous studies already found that alcohol use not only causes sleep problems, but sleep problems also precede alcohol use as well, in different age groups. Since many teenagers experience sleep problems at least once in adolescence, and start experimenting with alcohol in this developmental period, further longitudinal research examining the underlying mechanism behind this relation is necessary.

REFERENCES

