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Original Article

Dim Light Melatonin Onset and Affect in Adolescents With an Evening Circadian Preference

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A B S T R A C T

Purpose: A shift toward an evening circadian preference and the onset of mood problems often occur during adolescence. Although these changes are linked to poorer outcomes, few studies have considered how positive and negative affect are related to the circadian rhythm during adolescence. This study examined the relationship between evening and morning affect ratings and dim light melatonin onset (DLMO), a measure of endogenous circadian rhythm. Age and sex were tested as moderators.
Methods: This study is based on a subset of 163 (94 female, age = 14.7) adolescents with an evening circadian preference from a National Institute of Child Health and Human Development-funded study. Participants provided saliva for melatonin analysis and rated evening and morning affect.
Results: Higher evening negative affect was related to a later DLMO. Evening positive affect was not significantly related to DLMO timing. Age but not sex was a significant moderator such that higher negative and lower positive affect were related to a later DLMO for 10- to 13-year-olds, whereas higher positive affect was related to a later DLMO for 17- to 18-year-olds. DLMO was not significantly related to morning affect ratings.
Conclusions: There is evidence that higher negative and lower positive affect may be related to the shift toward an evening circadian preference observed in adolescents, particularly for younger adolescents.

IMPLICATIONS AND CONTRIBUTION

Adolescence is associated with sleep changes and the onset of mood difficulties. This study examined if ratings of affect were associated with a measure of the endogenous circadian rhythm. Findings suggested that lower evening affect may be related to the shift toward an evening circadian preference, particularly for younger adolescents.

Adolescence is a developmental stage associated with change across important domains of life. Adolescence is also a period of increased risk for mental illness, behavioral problems, substance use, and relationship difficulties. Given the potential for long-term consequences, there is a need to identify mechanisms contributing to vulnerability among adolescents. One potential contributor is the shift toward an evening circadian preference that occurs during adolescence and may be triggered by the onset of puberty [1–3]. An evening circadian preference is characterized by physical and mental activity in the evening compared to the morning. An individual's circadian preference is influenced by genetic variation in circadian polymorphisms (e.g., PER3, CLOCK, or BMAL1) and environmental factors (e.g., light exposure, exercise, or socializing), which are orchestrated by the circadian rhythm oscillator in the suprachiasmatic nucleus (SCN) [4,5]. Approximately 40% of adolescents have an evening circadian preference [6,7]. The onset of puberty in combination with social changes including reduced parental involvement with sleep and evening electronic use may contribute to the shift toward an evening circadian preference in adolescence [8,9]. Sleep behaviors characteristic of an evening circadian preference (e.g., late bedtimes or a

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large discrepancy between weeknight and weekend sleep patterns) may combine with early morning school start times to contribute to other sleep-related changes observed during adolescence such as inadequate sleep duration and daytime sleepiness [10–12].

An evening circadian preference may be connected to the increase in mood difficulties observed during adolescence [13,14]. Adolescents with an evening circadian preference experience increased depression symptoms compared with adolescents with a morning circadian preference [15,16]. In a large sample of adolescents ages 12–16, an evening circadian preference was also linked to high anxiety symptoms [17]. Adolescents with an evening circadian preference also differ in terms of self-reported mood and affect. Ratings of momentary mood at three time points during the school day indicated that adolescents with an evening preference experience lower mood compared with adolescents with a morning or no circadian preference [18]. Additionally, an experimental sleep deprivation study with adolescents ages 10–16 reported that those with an evening circadian preference experienced less positive affect compared with adolescents with a morning circadian preference [19]. Later bedtime but not short sleep duration has also been prospectively linked to increased emotional distress 6–8 years later [20]. Although previous research provides encouraging evidence that mood and affect are related to an evening circadian preference, it has been noted that studies have typically relied upon measures that may reflect mood or affect over the past week or month rather than current affective state [19]. This is potentially problematic given evidence that adolescent mood increases throughout the school day independent of circadian preference as well as evidence that women with high depression symptoms experience increased positive affect in the evening compared to the morning [18,21]. Measuring affect in the evening and morning may help to further elucidate the relationship between circadian preference and positive or negative affect.

An objective measure of the circadian rhythm may also help to further clarify the relationship between affect and circadian changes in adolescents. Melatonin is a hormone secreted by the pineal gland that has a diurnal pattern whereby circulating levels of melatonin remain low during the day, quickly increase in the evening, peak at night, and decrease in the morning. Dim light melatonin onset (DLMO) is an accurate, noninvasive, and reliable measure of the endogenous circadian rhythm [22], and has been validated in adolescents [23,24]. Circulating melatonin levels are a preferred circadian marker because they are comparatively robust and less prone to masking from other external influences compared with measures such as core body temperature, cortisol, and heart rate [24,25]. However, bright light in the evening can suppress, or "mask," nighttime melatonin production [22], which necessitates its measurement in dim light conditions. DLMO is associated with self-reported sleep and wake parameters for adolescents during both the school year and the summer [23], and a later DLMO is indicative of a delayed circadian rhythm. DLMO may also be connected with affect, given that mood ratings are lowest during the morning on school days and early risetimes and shorter time in bed on weekdays are related to higher anxiety [17,18]. Further, reduced melatonin secretion has been observed among individuals aged 12–30 with an affective disorder [26,27]. Despite promising evidence that DLMO and affect may be connected, it remains unclear whether a biological index of the circadian rhythm may also be related to affect among adolescents.

The overall aim of this study was to examine the relationship between affect and DLMO in adolescents with an evening circadian preference, and determine if this relationship is moderated by age and sex. The first aim was to test the hypothesis that higher negative and lower positive affect measured the night of melatonin collection will be associated with a later DLMO. The second aim was to test the hypothesis that a later DLMO will be related to higher negative and lower positive affect measured the morning following melatonin collection. Given that adolescence is a period marked by rapid developmental changes that occur at varied rates for males and females, this study will also test if the preceding hypotheses are moderated by age and sex.

Methods

Participants

The 163 participants (94 female and 69 male) for the current study were drawn from a subset of those enrolled in a National Institute of Child Health and Human Development randomized controlled trial. A total of 396 participants were assessed for eligibility, and 220 (55.6%) were excluded for not meeting inclusion criteria (n = 154) or refusing to participate (n = 66). There were 176 participants enrolled and all provided saliva samples for melatonin assay. Thirteen (7.4%) participants were not included because a DLMO was not observed during the sampling period. Participants were eligible if they scored within the lowest quartile of the Children's Morningness-Eveningness Preferences Scale (27 or lower); had a 7-day sleep diary showing a sleep onset time of 10:40 PM or later for 10- to 13-year-olds, 11:00 PM or later for 14- to 16-year-olds, and 11:20 PM or later for 17- to 18-year-olds at least nights nights per week; and had a current pattern of late bedtimes for the last 3 months. These age-group cutoffs reflect developmental changes in sleep [28,29]. Pretreatment demographic, DLMO, sleep, and affect characteristics are displayed in Table 1. All study procedures were approved by the

Table 1
Means, standard deviations, and/or percentages for demographic variables, dim light melatonin onset, affect, and sleep

Characteristic	M or N	% or SD
Age (years)	14.7	1.8
Age group		
10–13 years old	42	25.8%
14–16 years old	92	56.4%
17–18 years old	29	17.8%
Female	94	57.7%
Dim light melatonin onset[a]	21.31	1.08
Positive and negative affect		
Negative affect (PM)	2.96	1.10
Positive affect (PM)	2.83	1.11
Negative affect (AM)	1.39	.70
Positive affect (AM)	2.85	1.12
Sleep		
Bedtime	23.10	1.04
Waketime	7.56	.76
Time in bed	524.37	67.15
Total sleep time	462.22	67.45

[a] Decimal hours.