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Sleeping on the Edge: Adolescents Living at Moderate Altitude Report Greater Sleep Need

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Abstract

Purpose: Research in adults suggests that altitude impacts the restorative properties of sleep and increases risk for mental health concerns. The aim of this study was to extend this research to an adolescent sample to examine how living at altitude may be associated with greater sleep need and mental health symptoms during a period of the life-span when risk for insufficient sleep and mental health difficulties is high.

Methods: Data were collected from 105 adolescents aged 10-17 years residing at moderate-high altitudes. Parents reported on sociodemographics and adolescent depressive and anxiety symptoms, and adolescents reported on their subjective sleep need and sleep duration. Altitude was calculated using U.S. Geological Survey data.

Results: Adjusting for age, sex, socioeconomic status, rurality, and sleep duration, living at higher altitude was associated with reports of greater sleep need. Altitude was unrelated to mental health symptoms.

Discussion: The majority of adolescents do not obtain the recommended amount of sleep. These findings suggest that adolescents living at moderate-high altitudes may be at further risk due increased sleep need at higher elevations.

Keywords: altitude, rural health, sleep quality, internalizing symptoms, pediatric health

Sleep is important for adolescent health and development, yet the majority of adolescents report feeling like they need more sleep than they currently obtain [1]. There are numerous biological and social changes that may impact sleep duration during adolescence [2], but less is known regarding individual differences in sleep need (i.e., the minimum number of hours of sleep needed to feel well rested) during this period of the life-span. Importantly, sleep differs across geographical locations across the world [4,5]. One geographical attribute that may influence the restorative properties of sleep is altitude.

Findings in adults have shown that sleep disturbances are common upon ascent to higher altitude [7-9]. Specifically, studies have found that sleeping at high altitude reduces slow wave delta (0.8–4.6 Hz) activity [10], which is a biomarker of sleep homeostasis. Reduced delta may result in an inability to effectively dissipate sleep pressure and can increase the amount of sleep needed to feel well-rested [11]. In addition, higher altitudes have also been associated with increased depression and anxiety symptoms [12]. However, research to date on altitude has been limited to adult samples. Understanding these associations is important during the adolescent period, when sleep disturbances are common [1-2] and risk for mental health symptoms dramatically increases [13].

The current study examined associations between moderate-high altitude on individual differences in sleep need and mental health in adolescents. Based on prior research in adults, it was expected that adolescents living at higher altitude would report greater sleep need. It was also expected that higher altitude would be associated with greater depression and anxiety symptoms.

Methods

Participants and Procedures

Adolescents ($N = 105$) between the ages of 10-17 years ($M = 13.29$, $SD = 2.06$) were recruited from the Mountain West region of the United States for a study on rural sleep health. Participants were recruited using targeted postcard mailings to obtain a geographically representative sample of adolescents from the region. Adolescents were half female (47.6%) and primarily non-Hispanic white (87.6% white, 9.5% multiracial, 1% American Indian/Alaskan Native, 1% Asian, 1% other; 2.9% Hispanic/Latino). Participants and their parent completed informed consent/assent, questionnaires, and provided their home address, which was used to calculate altitude using U.S. Geological Survey data (usgs.gov). Participants were provided with a giftcard for participation. All procedures were approved by the Institutional Review Board at Montana State University.

Measures

Sleep Need. Participants reported on their subjective sleep need by responding to the item “How often do you think that you need more sleep?” from the Pediatric Daytime Sleepiness Scale [14] from 1 (*Never*) to 5 (*Very Often/Always*). Participants also indicated how much longer they would like to sleep each night if they had the opportunity from 1 (*I sleep enough*) to 5 (*I want 4+ extra hours*). Responses were dichotomized (1 = gets enough sleep, 2 = wants 1+ more hours of sleep).

Sleep Duration. Adequate sleep duration was assessed based on age-specific recommendations from the American Academy of Pediatrics [15]. Adolescents reported whether they sleep between 9-12 hours per day (for 10-12 year olds) or between 8-10 hours per day (for 13-17 year olds) on a 3-point scale from 1 (*rarely/never*) to 3 (*usually/always*).

Depression and Anxiety Symptoms. Parents reported on their child's depression and anxiety symptoms in the last 6 months using DSM-oriented subscales of the Child Behavior Checklist [16]

Sociodemographic Covariates. Parents reported on adolescent age, sex, family income and education, and household rurality.

Statistical Analysis

We examined the association between altitude, sleep need, and mental health symptoms using a series of linear and logistic regression models using the `lm` and `glm` function in R version 4.2.0. All models adjusted for age, sex, income, parental education, rurality, and sleep duration. Models included altitude as the independent variable and sleep need as the dependent variable. First, a linear regression was conducted to assess the frequency with which adolescents reported that felt like they needed more sleep, adjusting for sociodemographics and whether they regularly obtained an age-appropriate sleep duration. A logistic regression was then conducted to examine whether adolescents reported feeling like they need more sleep (1+ extra hour), adjusting for whether they obtained the recommended sleep duration and sociodemographics. Finally, two linear regressions were also conducted to examine the association between altitude and mental health symptoms (depressive symptoms, anxiety symptoms), adjusting for sleep duration and sociodemographics.

Results

The average altitude where participants resided was 3,569 ft (SD = 762, range = 1,938-5,325). A linear regression adjusting for sociodemographics and whether or not teens regularly obtained an age-appropriate sleep duration indicated that living at higher altitude was positively associated with adolescent reports that they need more sleep more often ($\beta = .24, t = 2.53, p =$

.013; Figure 1A). A logistic regression adjusting for whether teens obtained the recommended sleep duration and sociodemographics indicated that altitude was also positively associated with reports of needing 1+ extra hour of sleep (Estimate = .68, SE = .26, $p = .009$, McFadden's $R^2 = .12$; Figure 1B).

Linear regressions adjusting for sleep duration and sociodemographics indicated that altitude was not significantly associated with mental health symptoms. Specifically, altitude was not related to depression ($\beta = -.10$, $t = -.96$, $p = .339$) or anxiety symptoms ($\beta = -.15$, $t = -1.42$, $p = .16$). Full model statistics are available in the Supplemental File.

Discussion

The current study is the first to our knowledge to examine altitude, sleep, and mental health in a sample of adolescents. Findings suggest that living at higher altitude was associated with greater sleep need, even after adjusting for sociodemographics and actual sleep duration. These findings are in line with adult studies which suggest that higher altitudes may reduce the restorative properties of sleep [6-10]. The majority of adolescents do not obtain adequate sleep, and these findings suggest that this risk may be further exacerbated for teens living at higher altitudes who may have a higher sleep need. Despite prior studies on altitude and mental health in adults, there were no significant associations between altitude and depression and anxiety in the current adolescent sample. Numerous maturational risk factors for mental health difficulties emerge during adolescence, which may explain why altitude may differentially relate to psychiatric risk in this age.

Limitations

This study is not without limitations. First, sleep need and sleep duration were assessed using self-report. Future research should examine sleep using objective methods like actigraphy,

or polysomnography to uncover neurobiological mechanisms that may underlie changes to adolescent sleep need (e.g., delta power). In addition, mental health was assessed via parent-report. Our sample was also primarily non-Hispanic white and lived in a rural region of the Mountain West in the United States. Future research should examine adolescents living at higher altitudes and samples with greater racial/ethnic diversity. Future research should also investigate changes to sleep when ascending to higher altitudes to better determine causality. Finally, this study did not include a control group of adolescents living at low altitude.

Conclusion

In sum, sleep is an important catalyst of healthy physical, cognitive, and socioemotional development in adolescence. The current findings suggest that sleep during adolescence may be compromised at higher altitudes. While future research is needed to build on this preliminary study, altitude may be an important factor to consider when tailoring personalized sleep recommendations and in developing region-specific policies related to sleep in adolescents (e.g., determining appropriate school start times).

References

- [1] Center for Disease Control and Prevention. High school students sleep data. Available at: <https://www.cdc.gov/sleep/data-and-statistics/high-school-students.html>. Accessed February 17, 2023.
- [2] Crowley SJ, Wolfson AR, Tarokh L, et al. An update on adolescent sleep: new evidence informing the perfect storm model. *J Adolesc* 2018;67:55-65. doi: 10.1016/j.adolescence.2018.06.001.
- [3] National Sleep Foundation. 2002 “Sleep in America” poll. Available at: <https://www.thensf.org/wp-content/uploads/2021/03/2002-SleepInAmericaPoll.pdf>. Accessed February 17, 2023.
- [4] Grandner MA, Smith TE, Jackson N, et al. Geographic distribution of insufficient sleep across the United States: a county-level hotspot analysis. *Sleep Health* 2015;1(3):158-165. doi: 10.1016/j.sleh.2015.06.003.
- [5] Olds T, Blunden S, Petkov J, Forchino F. The relationships between sex, age, geography and time in bed in adolescents: A meta-analysis of data from 23 countries. *Sleep Med Rev* 2010; 14(6): 371-378.
- [6] Liu S, Chow IHI, Lu L, et al. Comparison of sleep disturbances between older nursing home residents in high- and low- altitude areas. *J Ger Psych Neuro* 2020; 33(6): 370-376. doi: 10.1177/0891988719892335.
- [7] Jafarian S, Gorouhi F, Taghva, et al. High-altitude sleep disturbance: results of the Groningen sleep quality questionnaire survey. *Sleep Med* 2008;9(4):446-9. doi: 10.1016/j.sleep.2007.06.017.

- [8] De Aquino Lemos V, Antunes HK, dos Santos RV, et al. High altitude exposure impairs sleep patterns, mood, and cognitive functions. *Psychophysiology*. 2012;49(9):1298-1306. doi: 10.1111/j.1469-8986.2012.01411.x
- [9] Latshang TD, Lo Cascio CM, Stadelmann K, et al. Are sleep, nocturnal breathing and daytime performance impaired at moderate altitude? *Europ Resp J* 2011;38:3462.
- [10] Stadelmann K, Latshang TD, Lo Cascio CM, et al. Quantitative changes in the sleep EEG at moderate altitude (1630 m and 2590 m). *Plos One* 2013;8(10):e76945. doi: 10.1371/journal.pone.0076945.
- [11] Long S, Ding R, Wang J, Yu Y, Lu J, Yao D. Sleep quality and electroencephalogram delta power. *Front Neurosci* 2021; 15. <https://doi.org/10.3389/fnins.2021.803507>
- [12] Kioussis BM, Bakian A, Zhao J, Mickey B, Guille C, Renshaw P, Sen S. Altitude and risk of depression and anxiety: findings from the Intern Health Study. *Int Rev Psychiatry* 2019; 31(7-8): 637-645.
- [13] Lee FS, Heimer H, Giedd JN, Lein ES, Šestan N, Weinberger DR, Casey BJ. Adolescent mental health – opportunity and obligation. *Science* 2014; 346(6209): 547-549.
- [14] Drake C, Nickel C, Burduvali E, et al. The Pediatric Daytime Sleepiness Scale (PDSS): sleep habits and school outcomes in middle-school children. *Sleep* 2003; 26(4):455-458. doi: 10.1093/sleep/26.4.455.
- [15] Paruthi S, Brooks LJ, D'Amrosio C, Hall WA, Kotagal S, Lloyd RM, Malow BA, Maski K, Nichols C, Quan SF, Rosen CL, Troester MM, Wise MS. Recommended amount of sleep for pediatric populations: a consensus statement of the American Academy of Sleep Medicine. *J Clin Sleep Med* 2016; 12(6): 785-786.

[16] Achenbach TM. The child behavior checklist and related instruments. In ME Maurish (Ed.), *The use of psychological testing for treatment planning and outcomes assessment* (pp. 429-466). Lawrence Erlbaum Associates Publishers.

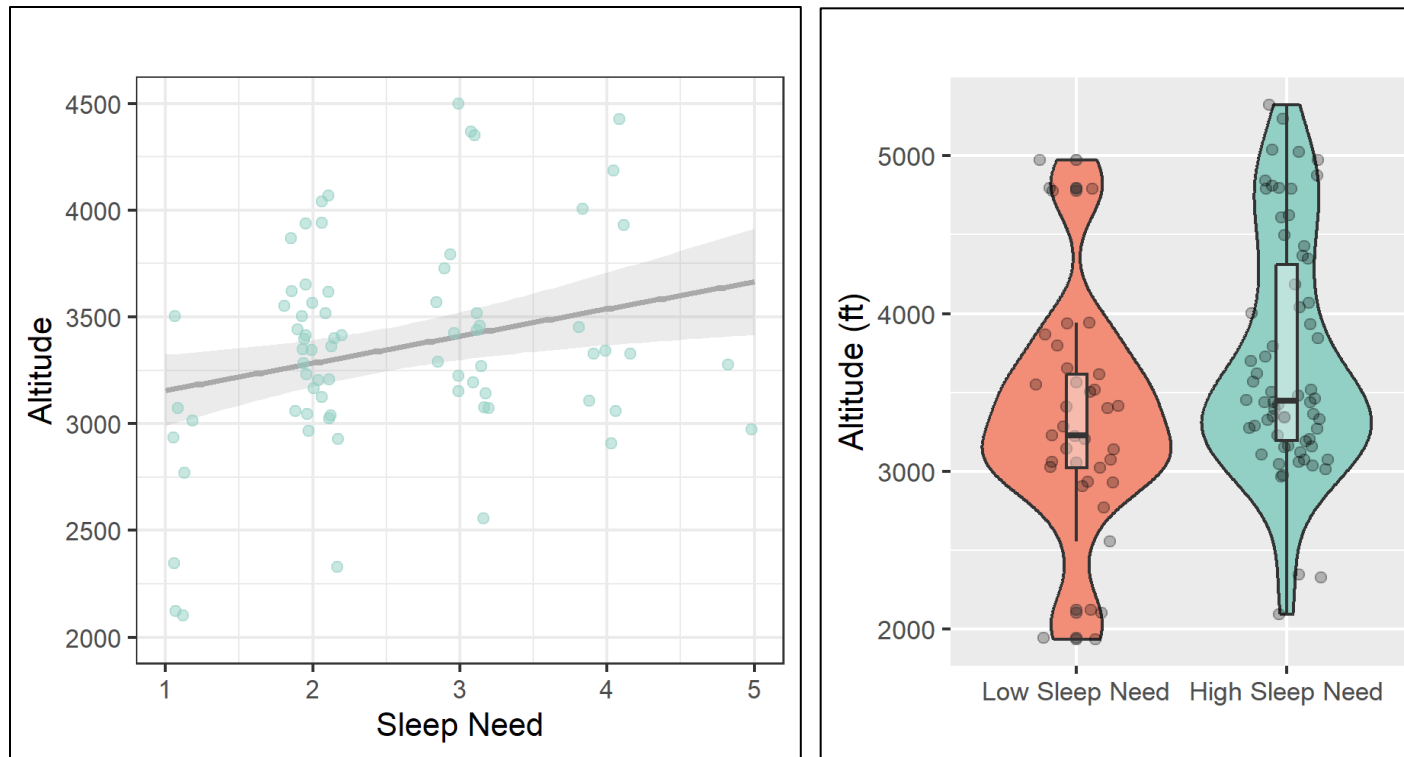


Figure 1A-B. Association between altitude and sleep need. Figure 1A displays the association between altitude and the frequency of experiencing increased sleep need from 1 (Never) to 5 (Very Often/Always). Figure 1B displays the association between altitude and reports of needing 1+ extra hour of sleep (high sleep need) or no extra sleep (low sleep need). The boxplot displays the median and the first and third quartile ranges. Individual data points are displayed, and each set of data are outlined by the density distribution.