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Associations between Neighborhood Context, Physical Activity, and Sleep in Adolescents

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Abstract

Objective—This study examined how neighborhood access to recreation facilities and physical activity are linked to multiple indices of adolescent sleep. Physical activity was also assessed as a mediator of the association between access to recreation facilities and sleep.

Design—The study used a cross-sectional design and path modeling analysis techniques.

Setting—Participants were recruited from small towns and semi-rural communities in Alabama.

Participants—Participants were 231 adolescents (55% female) with an average age of 16.75 years (*SD* = .81). Sixty-seven percent of the youth were European American and 33% were African American. The sample was socioeconomically diverse with more than a third of participants living at or below the poverty line and less than half from middle class families.

Measurements—Adolescent neighborhood access to recreation facilities and physical activity were assessed via self-report. Sleep minutes, efficiency, and schedule were measured using actigraphy.

Results—Access to recreation facilities was associated with more sleep minutes and later morning wake time, as well as a trend towards increased sleep efficiency. Access to recreation facilities was also linked to more physical activity, and physical activity was related to more sleep minutes, later wake time, and less wake time variability. Physical activity was a mediating and intervening link between access to recreation facilities and these sleep parameters.

Conclusions—Findings implicate physical activity as one mechanism linking neighborhood context to adolescent sleep. The results suggest that establishing more neighborhood opportunities for physical activity may have cascading effects on multiple aspects of adolescent physical health.

Keywords

Neighborhood; sleep; actigraphy; physical activity; adolescence

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Inadequate sleep in adolescence is of growing national and international concern (1), and therefore it is important to identify factors that may facilitate sufficient and good quality sleep. In a small literature with typically developing youth, physical activity has been implicated in promoting longer sleep (2–5); opposite and null effects have also been reported (6, 7). Most of this literature has utilized self-report measures of sleep with few objective assessments of multiple sleep parameters. Neighborhood characteristics, including access to recreation facilities, may facilitate physical activity, which in turn could influence adolescents' sleep. To our knowledge, this pathway of effects has not been addressed in the field. Building on this scant literature, we examined how access to recreation facilities and physical activity are associated with several actigraphy-derived sleep parameters. We also assessed the role of physical activity as a mediator of effects in these associations.

Sleep insufficiency is prevalent in youth. Although the National Sleep Foundation recommends that teenagers sleep between 8–10 hours per night (8), recent estimates indicate that adolescents on average report obtaining 7 hours of nighttime sleep (9), with many obtaining less based on actigraphy (10). Reduced sleep in turn has been shown to have negative consequences for adolescent functioning across multiple domains, including physical and mental health (11–13), cognitive functioning (14), and academic achievement (15). Greater variability in sleep schedule has also been linked to higher body mass index (BMI) (16) and symptoms of anxiety and depression (17). It is critical, therefore, to identify factors that may facilitate longer sleep and healthier sleep patterns in this population.

An emerging body of literature has explored how characteristics of the neighborhood context are associated with child and adolescent well-being (18), and in particular sleep. For example, better neighborhood condition has been linked to falling asleep earlier on the weekends (19) and less neighborhood distress is related to longer and less variable sleep duration (16). Sleep environmental conditions, including less noise and light as well as comfortable bedding and room temperature, were found to act as an intervening process linking higher socioeconomic status to less variability in sleep schedule in preadolescents (20) (although conducted by the same research group, that study used an independent sample from the one utilized in the present paper). As outlined by Hale et al. (21), health behaviors represent another mechanism through which neighborhood context may influence sleep, such as via space to exercise.

Elucidating contextual influences on the degree to which adolescents are physically active is important because they have less autonomy than adults and therefore may be more affected by how much their environment promotes exercise (22). Proximity to neighborhood recreation facilities has been linked to more physical activity in adolescents (22, 23). When recreation facilities, such as parks, swimming pools, and running tracks are closer to individuals' homes, they may be more likely to use them. In light of recent estimates suggesting that less than 10% of adolescents in the United States achieve the recommended amount of daily physical activity (24), it is important to identify factors that may encourage activity as well as to examine how improving physical activity may have bearing on other domains of health such as sleep.

Several studies with adolescent samples have detected concurrent linkages between greater physical activity and indicators of better sleep, including earlier bedtime (25), shortened latency to fall asleep and fewer awakenings (2), and less daytime sleepiness (26). Although there are reciprocal relationships between greater physical activity and better sleep (27), there is evidence that physical activity plays an important role in driving this relationship. For example, moderate levels of physical activity have been shown to predict increased sleep efficiency the following night (6), and an intervention that required adolescents to run for 30 minutes a day led to improvement in subjective ratings of their sleep quality and objective sleep EEG recordings (4). Physical activity is theorized to be linked to changes in the physiology of sleep, such as greater slow-wave intensity, that are consistent with better sleep regulation (2). However, some studies with children and adolescents have found contradictory effects. For example, in the only study we are aware of that examined physical activity and sleep in youth using actigraphy, more vigorous physical activity was linked to more wake bouts (6). Another study examining adolescent self-report of physical activity and several sleep parameters (e.g., bedtime, sleep latency, waking bouts) did not detect any linkages (7). These discrepancies may be due to differences in measurement of physical activity or sleep, or to differences in neighborhood characteristics (e.g., urban vs. rural, access to recreation facilities, safety, exposure to violence). There are few studies examining physical activity and sleep that have incorporated objective measures of sleep in adolescents. Further explication of the relationships between exercise and sleep in youth is warranted using objective measures of sleep duration, quality, and schedule.

In the current study, we examined the relationships between access to recreation facilities and sleep parameters in adolescents, and assessed physical activity as a mediator of these linkages. Consistent with current recommendations for the assessment of multiple sleep parameters (28), we examined actigraphy-derived sleep minutes (total number of minutes in bed spent asleep), efficiency (percent of total minutes in bed spent asleep), schedule (bedtime and morning wake time, variability in sleep onset and wake time), as well as long wake episodes (number of wake episodes > 5 minutes).

Methods

Participants

Participants were part of a larger longitudinal investigation (Family Stress Study; Auburn University). Data for the current investigation were drawn from the 5th study wave, which took place in 2013–2014. At the first study wave (T1), 251 children and their families were recruited from local elementary schools in 2005. All children were from two-parent homes and did not have a diagnosis of attention deficit hyperactivity disorder, developmental delay, or chronic illness. To increase sample size, an additional 53 adolescents were recruited into the study at the 4th wave (T4) from the same schools as the original sample, utilizing the same inclusion criteria. There were no differences on primary study variables between participants recruited at T1 versus T4.

The full analytic sample consisted of 231 adolescents (55% female; M_{age} = 16.75 years, *SD* = .81). Sixty-seven percent of the youth were European American and 33% were African American, which is representative of the area. Family income-to-needs ratio, defined as annual family income divided by the poverty threshold with respect to family size (U.S. Department of Commerce, 2013), indicated that 38% of adolescents were from families living at or below the poverty line (ratio < 2), 19% were lower middle class (ratio between 2 and 3), and 43% were from middle class families (ratio ≥ 3). Mean BMI was 25.4 (*SD* = 5.90).

Procedure

Parents provided written consent and adolescents provided assent to participate in the study. All procedures were approved by the university's institutional review board and followed a standardized protocol for the longitudinal study (29). Adolescents were instructed to wear an actigraph on their non-dominant wrist for seven consecutive nights during the school year. Families then visited the laboratory on campus an average of 2.24 days (*SD* = 7.8) following actigraphy data collection. Both parents and adolescents completed questionnaires. Parents reported on demographics and adolescents provided information regarding their physical activity levels and access to recreation facilities. Adolescent height and weight were obtained to calculate BMI.

Measures

Access to recreation facilities—Access to recreation facilities was examined with the pertinent scale from the well-established Neighborhood Environment Walkability Scale-Youth (NEWS-Y), which has adequate test-retest reliability (23). This scale consists of 14 items measuring availability of places where one may engage in exercise such as a swimming pool, running track, and basketball court. Youth select the number of minutes it would take to walk to each place from 6 choices (1–5min, 6–10, 11–20, 21–30, 31+, I don't know). According to established scoring guidelines (23), these answer choices are reversed and converted to a 0–5 numerical scale with 0 representing I don't know (if the adolescent does not know how long it takes to walk to a location it is considered a long walk) and 5 representing a 1–5 minute walk. Scores were averaged across the items to create an overall score ranging from 0–5 in the current sample, with higher scores denoting greater neighborhood access to recreation facilities.

Physical activity—Adolescents reported their physical activity level using the weekly physical activity levels subscale of the Physical Activity Questionnaire for adolescents (PAQ-A) (30), which has well-established validity (30). For each day of the preceding week, adolescents marked how often they engaged in physical activity (such as playing sports, games, doing dance, or any other physical activity) on a scale from 1–5 (1 = None, 5 = Very often). Scores were averaged across the 7 days to create a mean weekly physical activity score, which ranged from 1–5 in the current sample. Internal consistency for the weekly physical activity subscale in the current study was good (α = .91).

Sleep—Nighttime sleep was assessed via a Motionlogger Octagonal Basic actigraph (Ambulatory Monitoring Inc., Ardsley, NY). Motion was measured in 1-minute epochs, from which mean nighttime sleep minutes, wake time, variability in wake time, and sleep efficiency were derived using Sadeh's algorithm (31). Sleep minutes were defined as the number of 1-minute epochs scored as sleep between sleep onset and wake time. Variability in sleep onset and variability in morning wake time were each calculated as coefficients of variance across all available nights. Sleep efficiency was calculated as the percent of epochs scored as sleep between sleep onset and wake time. Long wake episodes were scored as the number of wake bouts longer than 5 minutes that took place between sleep onset and wake time. Following established guidelines (32), only actigraphy information for adolescents with valid data across all sleep variables for 5 or more nights (64% of the sample) was included in the analyses; actigraphy data and not cases were removed for youth with less than 5 nights of valid actigraphy data (36%). Reasons for missing data included forgetting to wear the actigraph or medication use before bed (in which case the data were excluded from analysis).

Control variables—Participant sex, ethnicity, family income-to-needs ratio, and standardized BMI (zBMI) were statistically controlled in all analyses. Parents reported ethnicity and family income, and the latter was used to calculate income-to-needs ratio. A Tanita digital weight scale (Model BC-418) and wall-mounted stadiometer (Arlington Heights, IL) were used to collect adolescent weight and height respectively for assessing BMI. Standardized BMI was calculated using a SAS program developed by the Centers for Disease Control (33).

Plan of Analysis

The direct associations among access to recreation facilities, physical activity, and sleep were tested, and physical activity was examined as a mediator of the link between access to recreation facilities and adolescents' sleep. Four sleep parameters were of interest: sleep minutes, wake time, variability in wake time, and sleep efficiency. Sleep onset time, variability in sleep onset, and long wake episodes were also examined in preliminary analyses but did not result in significant effects and are not presented. The four sleep variables were entered into the same model and allowed to covary to discern the unique effects of access to recreation facilities and physical activity on each sleep parameter.

Mediation was tested by estimating the paths between access to recreation facilities and physical activity (path a), physical activity and the sleep variables (b) and between access to recreation facilities and the sleep variables (c'). The direct relationships between access to recreation facilities and sleep (c) were tested by fixing the paths between access to recreation facilities and physical activity and between physical activity and sleep to 0. Paths a, b, and c must be significant and path c' non-significant to show evidence of full mediation (34). However, if path c is not significant but both a and b are, there may still be evidence of an intervening relationship, meaning that the association between two variables is contingent on a third (35). Therefore, in the absence of evidence of mediation but significant a and b paths, we tested physical activity as an intervening variable. The strength of these indirect effects (mediational or intervening) were tested using Monte Carlo simulation (36, 37). This method produces confidence intervals for the indirect effects; a significant effect is indicated when the confidence interval does not contain zero. Participant sex (0 = girls, 1 = boys), race/ethnicity (0 = European American, 1 = African American), family income-to-needs ratio, and zBMI (33) were all covaried. Model fit was considered good if it satisfied 2 of 3 criteria: $\chi^2/df \leq 3$, comparative fit index (CFI) ≥ 90, and root mean square error of approximation (RMSEA) ≤ .08 (38). In reporting the results, we describe prediction in the statistical rather than causal sense.

Analyses were conducted using the Amos Graphics add-on for SPSS 21, which uses full information maximum likelihood estimation (FIML) to account for missing data. Including participants whose actigraphy data were excluded due to having fewer than 5 nights of useable data, rates of missing data for actigraphy, physical activity, and access to recreation facilities were 36%, 11%, and 10% respectively. The amount of missingness is well within the acceptable range for FIML (39). In simulation studies, FIML has been shown to be the best statistical method for handling missing data, resulting in the least biased estimates and fewest Type I error rates (39).

Results

Preliminary Analyses

Descriptive statistics were run for each variable to check for outliers and skewness. Values for all study variables were within 4 SD's of the mean with skewness less than 2.0. Means, standard deviations, and bivariate correlations for all main study variables are in Table 1. For succinctness, control variables are not included in the table. On average, adolescents did not report high levels of neighborhood access to recreation facilities, were moderately physically active, and slept about 7 hours per night. All variables were standardized prior to analysis.

Primary Analyses

Control variables and direct effects—The direct effects between access to recreation facilities, physical activity, and the sleep variables were tested, controlling for sex, race/ethnicity, income-to-needs, and zBMI. In relation to control variables, African Americans and boys slept fewer minutes, p's < .01, and boys' sleep was less efficient, $p < .01$. Adolescents reporting greater access to recreation facilities came from families with higher income-to-needs ratios, $p < .01$, and African American race/ethnicity was correlated with lower income-to-needs ratio, $p < .01$. Non-significant covariances stemming from the control variables were trimmed to increase model degrees of freedom. Standardized BMI was not related to any study variables and was removed from the model.

Controlling for the aforementioned variables, greater access to recreation facilities was linked to more sleep minutes, $B = .18$, $p < .05$ and later wake time, $B = .27$, $p < .01$. These results signify that each unit increase in recreation facilities access corresponded to 9 more minutes of sleep and to a morning awakening time of 12 minutes later. A positive association between access to recreation facilities and greater sleep efficiency approached significance, $B = .15$, $p = .07$. Access to recreation facilities was not directly associated with variability in wake time. Greater physical activity was linked to more sleep minutes, $B = .25$, $p < .01$, later wake time, $B = .18$, $p < .05$, and less variability in wake time, $B = -.17$, $p = .05$, meaning that a one unit increase in physical activity was linked to 13 more minutes of sleep, a wake time of 8 minutes later, and 2% less variability in wake time. Physical activity was not associated with sleep efficiency.

Indirect effects—A model testing physical activity as a mediator or intervening variable linking access to recreation facilities to the adolescent sleep variables was tested (Figure 1). Model fit was good, $\chi^2/df = 1.49$, CFI = .91, RMSEA = .04. Access to recreation facilities predicted more physical activity. More physical activity, in turn, was associated with more sleep minutes, later wake time, and less variability in wake time. The direct association between access to recreation facilities and wake time remained significant in this model. The direct paths linking access to recreation facilities to sleep minutes, sleep efficiency, and wake time variability did not reach significance. The association between physical activity and sleep efficiency was also not significant. Overall, the model explained 4% of the variance in physical activity, 23% in sleep minutes, 3% in wake time, and 3% in wake time variability.

We next tested the strength of the indirect associations using Monte Carlo simulation. As noted previously, access to recreation facilities was associated with physical activity, which in turn was linked to more sleep minutes. The direct association between access to recreation facilities and sleep minutes was reduced to non-significance when physical activity was included in the model and the indirect effect was significant (95% CI .01 to .095), suggesting that physical activity fully mediated the link between access to recreation facilities and sleep minutes.

We next tested whether physical activity mediated the relationship between access to recreation facilities and wake time. The direct association between physical activity and wake time remained significant when physical activity was included in the model, $p < .05$. Monte Carlo simulation indicated that the indirect effect did reach significance, however (95% CI .001 to .085). This suggests that the relationship between access to recreation facilities and wake time was partially mediated by physical activity.

Although there was not a direct association between access to recreation facilities and variability in wake time, the significant associations between access to recreation facilities and physical activity and between physical activity and variability in wake time suggested the possibility of an intervening relationship. Indeed, the indirect effect was significant, (95% CI −.085 to −.001), suggesting that the relationship between access to recreation facilities and variability in wake time was contingent upon physical activity.

Finally, to discern whether the higher rate of missing actigraphy data influenced the results, we ran secondary analyses including the data for participants with a minimum of three nights of data (80% of the sample). The results were identical with the exception of two paths that did not reach significance in the secondary analyses. Therefore we have presented the results using the more stringent set of inclusion criteria.

Discussion

In a sample of typically developing adolescents, we examined the relationships among access to recreation facilities and various sleep parameters. We also assessed regular physical activity as a mediator of these associations. Findings make novel contributions to the literature and suggest that access to recreation facilities is related to longer and less variable sleep schedules in youth. Further, the results provide evidence supporting physical activity as a mechanism linking access to recreation facilities with more sleep minutes and with later and less variable morning wake times.

The first pathway of interest was the relationship between access to recreation facilities and adolescent sleep. Results were consistent with other work showing that individuals living in neighborhoods characterized by better conditions and less distress have longer sleep and a less variable sleep schedule (16, 19). Our findings suggest that access to recreation facilities is an additional aspect of the neighborhood that is associated with adolescent sleep minutes and schedule. It may be that access to recreation facilities is a proxy for other neighborhood contextual variables that have direct relationships with sleep such as reduced neighborhood noise or disorder. Access to these facilities may also be related to sleep via other pathways, such as by promoting physical activity. In this vein, access to recreation facilities was found to predict more physical activity in the current investigation, consistent with previous work (23).

Second, we were interested in the associations between physical activity and sleep. Using objective measures of sleep, our results support prior work based largely on self-report that suggested a link between physical activity and sleep in adolescents (2, 25, 26). Our findings show that youth who reported being more physically active had longer sleep, particularly in the mornings. These results contrast somewhat with previous work that has documented a relation between higher levels of physical activity and earlier bedtime (25) rather than later morning wake time. However, being more physically active is linked to differences in sleep physiology, in particular more deep, slow-wave sleep (2). Thus, it is plausible that youth who exercise more may experience better sleep regulation and be less likely to be awakened in the morning. This relation requires further explication, as it may also be that later rise times result from increased tiredness or difficulty waking up. Importantly, the results held even when controlling for family income-to-needs ratio, reducing the possibility that the findings were accounted for by other aspects of neighborhood context related to socioeconomic status that may predict earlier morning awakening such as further distance from school.

Finally, we explored physical activity as a mechanism of effects linking access to recreation facilities with sleep. Although to our knowledge this pathway has not been previously empirically tested, Hale et al. (21) argued that availability of space and facilities to exercise may be one way through which neighborhood context affects sleep. Our findings support this contention via three significant indirect effects, two of which support the role of physical activity as a mediator (sleep minutes, wake time) and a third that supports intervening effects (variability in wake time). These results suggest that when adolescents have access to a variety of recreation facilities in their neighborhood, they may be more likely to use them. Of course, given that we did not test the use of recreation facilities, this observation is speculative. Lack of facilities and space for exercise, however, may contribute to reduced adolescent physical activity and in turn reduced sleep minutes. All sleep outcomes were covaried in the analyses, suggesting that the effects on each sleep variable were unique.

Findings need to be interpreted in the context of the study design and limitations. Adolescents resided primarily in semi-rural communities and small towns in Alabama and thus the results may not generalize to other populations and geographic locales (e.g., urban areas with access to public transportation). It is also important to distinguish between results examining the effects of regular exercise, as examined in the present study, and the effects of exercise measured on the same day as sleep (6). Future work could collect daytime actigraphy data in addition to nighttime in order to objectively assess adolescent physical activity. Furthermore, all variables were assessed at the same time point and therefore a longitudinal design is needed to fully evaluate the direction of effects. Other mechanisms and moderators of effects in the association between access to recreation facilities and adolescents' sleep are likely operative and further explication of these processes and variables are warranted. Also, while adolescent BMI was considered as a control variable in the analyses, it was not related to any primary study variable including exercise or sleep. This surprising finding may be associated with sample characteristics and should be considered tentatively. Finally, although the findings were statistically significant, the size of the path coefficients and percent of variance explained in the sleep outcomes was relatively modest, with the exception of sleep minutes for which the model explained 23% of variance. Thus, the results suggest physical activity is one of several potential mechanisms linking neighborhood characteristics to adolescent sleep.

Conclusions

The results of the current investigation demonstrate that when adolescents have greater access to recreation facilities in the neighborhood, they are more physically active, which in turn predicts several indicators of their sleep duration and schedule. Given the small proportion of adolescents who obtain recommended amounts of daily exercise and the related negative health outcomes, it is imperative to determine aspects of adolescents' environment that may encourage physical activity. Together, these findings suggest that establishing more neighborhood opportunities for physical activity may have cascading effects on multiple aspects of adolescent physical health.

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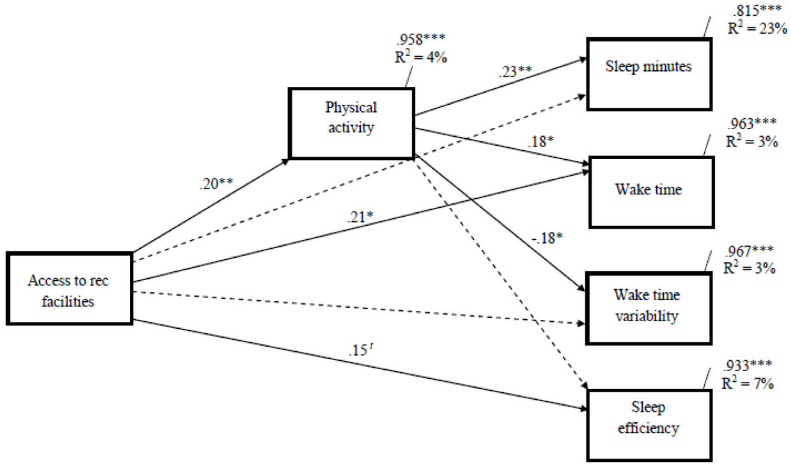

Figure 1.

Path model of physical activity as a mediator of the associations between access to recreation facilities and sleep. Sex, race, and income-to-needs ratio were covaried and allowed to predict the sleep outcomes. Controls and covariances between the sleep variables are not depicted for simplicity. For ease of interpretation, statistically significant lines are solid and nonsignificant lines are dotted.

Model fit: χ^2 = 29.78 ns, χ^2/df = 1.49, CFI = .91, RMSEA = .04

R^2 = .40

$^t p < .10$, $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 1

Bivariate correlations, means, and standard deviations for main study variables

	1. Access to recreation facilities	2. Physical activity	3. Sleep minutes	4. Wake time	5. Variability wake time	6. Sleep efficiency
1	--	--	--	--	--	--
2	.19**	--	--	--	--	--
3	.16	.15	--	--	--	--
4	.25**	.17*	.22*	--	--	--
5	−.13	−.17	−.01	.08	--	--
6	.13	.02	.49**	.01	.09	--
M	1.31	2.92	408 min	6:33am	.16	91.43
SD	1.14	1.21	50 min	46 min	.09	6.54

Note. These bivariate correlations did not covary the controls and therefore the coefficients vary slightly from the direct associations reported in-text with sex, race, and income-to-needs ratio controlled.

* $p < .05$,

** $p < .01$