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Measuring Sleep Duration in Adolescence: Comparing Subjective and Objective Daily Methods

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Abstract

Objectives—This study provides the first investigation into the correspondence between self-reported and actigraph-measured nighttime sleep duration in adolescents that disambiguates between- vs. within-person associations. Moderators were evaluated to determine if between- and within-person correspondence vary by participant characteristics.

Methods—150 adolescents (14–21 yrs) reported sleep time for one week, while wearing an actigraph, and reported on moderators, including demographics (i.e., sex, age, ethnicity, socioeconomic status), depressive symptoms, and perceived stress. Mixed effects models evaluated within- and between-person associations between self-reported and actigraph-measured sleep, and examined whether these associations differed by possible moderators.

Results—Results indicated significant between- (b=.77, SE=.08, p<.001) and within-person (b=.51, SE=.04, p<.001) associations between self-reported and actigraph-measured sleep duration, with no significant moderation effects.

Conclusions—Our results support the use of either self-reports or actigraphs to examine within-person nighttime sleep duration in adolescent community samples.

Keywords

sleep; within-person; adolescence

An emerging trend in the study of adolescent (10–25 yrs[1]) sleep involves capturing within-person variation in sleep, typically with self-report diaries[2]. Although actigraphy is a valid measurement strategy for sleep aggregated over the week in non-clinical adolescent samples[3], using actigraphy to capture within-person variation is relatively new. There is significant intraindividual variability in adolescent sleep as measured by actigraphy (and verified by self-reports)[4]; this intraindividual variability is predictive of important

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developmental outcomes such as psychopathology, stress, and cognitive functioning[2]. Although there is concordance between sleep diaries and actigraphy in adolescents at the level of sleep aggregated across days[5–7], few studies have compared *daily* sleep reports to objective *daily* sleep actigraphy, especially in adolescents. There are multiple methodological benefits of assessing daily sleep via actigraphs, notably reducing recall bias and inflated associations between sleep and other variables as a result of single-reporter bias and/or characteristics of the participant (e.g., positive affect)[8]. Actigraphs are also ideal for adolescents because devices can be unobtrusively and continuously worn, requiring no participant reporting[2,4].

One study of adolescents found modest within-person correlations between sleep diaries and actigraphic reports of sleep duration, with diary estimates being longer[9], but did not statistically disaggregate between- vs. within-person associations of diary and actigraphy estimates. When repeated measures are collected, resulting data has information about differences between *and* within people, and statistical models need to be specified so that the two are not confounded[10]. Without statistical disaggregation, within-person correlations (as estimated in recent work[9]) confound average sleep with daily variations, making it unclear if associations are driven by between-person differences (i.e., that those who sleep longer on average also report longer sleep) and whether correspondence holds up within-person.

Moreover, individual characteristics may increase or decrease discrepancies between these methods. There is some evidence that pubertal status and sex predict discrepancies between daily diaries and actigraphy[9,11], but it is unknown what individual differences account for discrepancies beyond these variables. We examined whether age, sex, ethnicity, and socioeconomic status (SES) moderated associations between self-reported and actigraph-measured sleep. Two mental health characteristics – depressive symptoms and perceived stress – were also explored as moderators, as they may alter the association between self-reported and actigraphic-measured sleep duration[12]. Sleep problems are a critical behavioral marker of depression[13], and sleep disorders and depression are distinct but highly comorbid[14,15]. Also, sleep problems that often accompany depression predict less accurate sleep evaluations[12]. Similarly, stressful experiences have both short- and long-term effects on sleep[16–18]. In individuals with insomnia, stress predicts poorer subjective sleep that is not matched by changes in objective EEG assessments of sleep, suggesting that stress may cause discrepancies between objective and subjective sleep[15]. To address these gaps and inform future methodological decisions in daily adolescent sleep research, we examine between-person and within-person associations between actigraphic and self-report sleep methods, and evaluate potential moderators. We focus on duration as the sleep construct of interest, given prior validation studies indicating that actigraphic and polysomnography (i.e., the gold standard of measurement) agreement is most promising with sleep duration as opposed to other variables[3].

Method

Participants

Participants were 150 adolescents (14–21yrs, *M*=17.86, *SD*=2.14; 59% female) who participated in a larger study of family relationships and health. Adolescents were recruited from a United States mid-western community (36%) and university (64%).

Procedure

Parents and adolescents provided informed consent and assent, respectively. Adolescents visited our laboratory twice, one-week apart, to complete questionnaires. Every day between visits, participants wore an Actiwatch Spectrum Plus device (Philips Respironics) on their non-dominant wrist and completed daily diaries online. Adolescents were provided partial course credit or payment for participating.

Measures

Actigraphs were configured to collect activity data in 30-second epochs and score nighttime sleep and off-wrist periods across a 24-hour period. Data were cleaned in Actiware 6.0.9 according to procedures that were developed to improve the integrity of the data, following procedures in Marino et al[19]. See Figure 1 for specific decision rules about identifying and excluding individual days of data. Once the data were cleaned, the daily and average nighttime sleep duration estimates were automatically derived from the standard Actiware algorithm.

Each evening, adolescents reported the time they turned off the lights to go to sleep the previous night and the time they got out of bed that morning[20]. Nighttime sleep duration in minutes was calculated. In addition, at the lab, adolescents reported symptoms of depression over the last week using the Center for Epidemiological Studies Depression Scale[21] (Cronbach's alpha=.89, *M*=13.41, *SD*=9.25), and the extent to which they experienced stress over the last month using the Perceived Stress Scale[22] (Cronbach's alpha=.85, *M*=1.71, *SD*=.55), as well as age, sex, ethnicity, family yearly income, and maternal education. Income and maternal education were standardized and averaged to represent SES.

Data Analysis

Mixed effects models run using Stata 15 were used to examine both between-person (mean levels of sleep by person, averaged across time) and within-person (deviations from mean levels by person, or daily variations) associations between objective and subjective assessments; objective assessments were used to predict next day self-reports (of sleep the night before). To examine moderation in the context of between-person associations, multiplicative interaction terms were calculated, tested, and interpreted using best practice recommendations[23]. Moderators of within-person associations were tested using the random coefficient prediction method in MPlus[24] (see more details in supplemental material).

Results

Adolescents were: 72% non-Hispanic Caucasian, 7% Hispanic, 3% Asian/Pacific Islander, 2% African American, 1% American Indian, and 16% other or multiple ethnicities; 1.3% did not report their ethnicity. Yearly family income ranged from <$35,000 a year to > $150,000 (*M* = $95,000-$109,000).

On average (see Figure 1), participants reported 495.60 minutes of nighttime sleep duration (*SD* = 90.91). The actigraphic estimate of nighttime sleep duration was, on average, 413.63 minutes (*SD* =82.39); within-person, self-reports of nighttime sleep duration were on average 79.34 minutes longer than objectively measured sleep.

There were significant between- as well as within-person associations of daily actigraph-measured and self-reported nighttime sleep duration (Table 1). On average, adolescents with longer actigraphic sleep durations reported significantly more sleep. In addition, on days when adolescents had longer actigraphic sleep durations (relative to their own average), they also reported longer sleep. These associations were not moderated by depressive symptoms, perceived stress, age, sex, ethnicity, or SES.

Discussion

We conducted the first estimation of the between- and within-person associations between daily self-reported and actigraph-measured nighttime sleep duration in adolescence. Consistent with past research that confounded between- and within-person estimates[9], we found that 1) adolescents who report greater average nighttime sleep also have longer average actigraphic sleep duration, and 2) on days when adolescents report more sleep, they are objectively observed to sleep for longer. This finding is an important extension of past work, and supports the use of both self-reported and actigraph-measured sleep to explore daily variations in sleep duration. Also consistent with past work[9], self-reports of sleep were longer than actigraph-measured nighttime sleep duration. This discrepancy may be because participants are instructed to report the time they turned out the lights to go to sleep and the time they got out of bed in the morning. In contrast, actigraphic algorithms score the actual sleeping period, removing time where the participant is resting but not asleep. As such, actigraphy likely allows for a more precise estimate of sleep start and end times, and subsequently overall sleep duration.

There was no evidence that these associations were moderated by demographic or mental health characteristics (see more discussion in supplemental material, including past studies with similar patterns of results), providing no evidence that these factors change the strength of the association between diary and actigraphic reports of sleep in adolescent samples. Although previous work has detected sex differences in agreement between diary and actigraph measures of sleep[9], Short et al.'s adolescent participants represented a different age range (13–18 years) and were from an Australian sample, and sleep patterns have been shown to be influenced by environmental factors such as culture[25]. Further, despite evidence from clinical adult research that depression and stress reduce the accuracy of perceived

sleep[13,15], we found no evidence that the association between self-report and actigraph measurements of sleep duration is weakened by mental health characteristics.

It is important for research to incorporate polysomnography to truly validate both self-reports and actigraph measures of sleep at the daily level. Additionally, we focused on nighttime sleep duration because the validity of actigraphy is lower for indicators of sleep quality, such as wake after sleep onset[26], although future research could explore other sleep characteristics (e.g., indicators of sleep quality, variability of bed and wake times). Although length of data collection may vary, future researchers should consider including 14 days of data to more reliably capture weekday versus weekend differences. In addition, future research should examine these issues in less homogenous samples and based on multiple reporters of important moderators (e.g., parent reports of family income and adolescent mental health). Despite these limitations, this study makes important contributions to the study of adolescent sleep, and supports the use of both self-reports and actigraphs to assess daily variations in adolescent nighttime sleep duration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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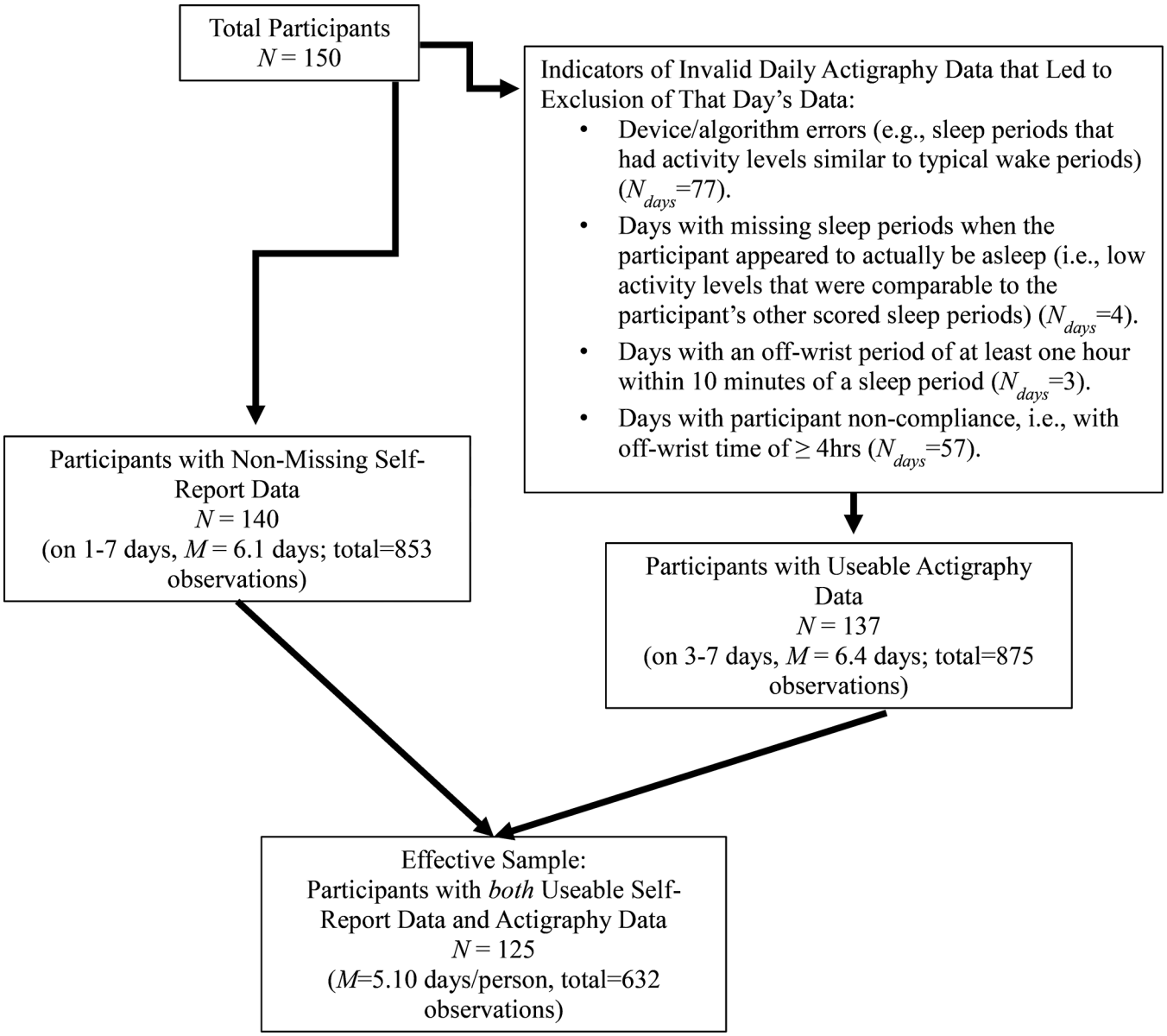

Figure 1.

A flow diagram representing how many participants were excluded and for what reasons. *Note:* As a conservative approach, we required a minimum of 3 valid days of actigraphy data, in part because Marino and colleagues'[19] validation paper was based on an average of 3.2 nights, but also because 98.6% of the sample had at least 3 valid days of actigraphy data. This decision rule led to the exclusion of two participants (i.e., 1.4% of the sample) who only had one valid day of sleep data.

Table 1

Associations between Actigraph-Measured Sleep Duration and Self-Reported Sleep Duration, and Moderation by Demographic and Mental Health Characteristics

	b	SE	p
Actigraph-measured sleep duration			
Between person	.77***	.08	<.001
Within-person	.51***	.04	<.001
Interactions between average actigraph-measured sleep duration and:			
Depressive symptoms	−.21	.18	.25
Perceived stress	−.07	.19	.71
Age	−.01	.05	.86
Sex	−.01	.16	.95
White	−.02	.20	.92
SES	.16	.12	.21
Interactions between daily deviations from average actigraph-measured sleep duration and:			
Depressive symptoms	.01	.92	.99
Perceived stress	.13	1.24	.91
Age	.87	2.69	.75
Sex	−.91	.79	.25
White	1.35	1.31	.30
SES	−.29	2.31	.90

Note: Given the demographic composition of the sample, ethnicity was dichotomized as White vs. non-White. SES = socioeconomic status.