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Associations among physical activity, screen time, and sleep in low socioeconomic status urban girls☆

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ABSTRACT

Insufficient sleep is associated with higher risk of poor health outcomes in low socioeconomic status (SES) urban elementary age girls. Decreased physical activity (PA) and increased screen time may be associated with poor sleep. This study examined if PA and screen time are associated with sleep in girls from a low SES urban community. Baseline data from 7 to 12 year-old girls (n = 55) from two interventions conducted in Springfield, MA between 2012 and 2015 were used. PA was measured via accelerometry for seven days. Screen time and sleep were assessed via validated questionnaires. Sleep was also assessed via accelerometry in a subsample of girls (n = 24) for 7 days. Associations among PA, screen time, and sleep were analyzed using multiple linear regression. More minutes of screen time per day ($p = 0.01$, $r^2 = 0.35$, r^2 adjusted $= 0.23$) was associated with worse sleep quality ($\beta = 0.50$, $p = 0.02$). There were negative correlations between PA and the number of awakenings per night ($r = -0.45$, $p = 0.04$) and between counts per minute and sleep fragmentation ($r = -0.65$, $p = 0.002$) assessed by accelerometer. In this population, increased screen time was associated with worse sleep quality and decreased PA was correlated with more awakenings per night and higher sleep fragmentation. These findings suggest that screen time and PA may be modifiable risk factors for interventions seeking to improve sleep in this population.

1. Introduction

Children's sleep duration (SD) and sleep quality (SQ) decline significantly as they progress from childhood into adolescence (National Sleep Foundation, 2004; Williams et al., 2013). These trends present a major public health concern, given that insufficient SD and poor SQ have been associated with an increased risk of poor physical (i.e., obesity and diabetes mellitus) and mental (i.e., cognitive function and depression) health throughout the lifespan (Cappuccio et al., 2008; O'Brien, 2009; Hjorth et al., 2014). In order to combat these trends, it is paramount to identify modifiable risk factors that are associated with SD and SQ, especially in populations at high-risk for compromised SD and SQ (Blunden et al., 2012). While SD and SQ decline in all children as they age, children living in low socioeconomic status (SES) urban communities experience a greater reduction in both SD and SQ compared to children living in more affluent communities (Sheares et al., 2013; Crosby et al., 2005; Wong et al., 2013). Several studies have indicated that increased screen time and decreased physical activity (PA) are modifiable risk factors associated with poor sleep in children (Calamaro et al., 2012; Laurson et al., n.d.; Ortega et al., 2011; Ekstedt et al., 2013). It has been suggested that children who are more physically active will be more fatigued at the end of the day, leading to improved sleep (Patel et al., 2012). With respect to screen time, research has shown that increased exposure to light emissions from media devices such as television, cell phones and tablets, especially in the evenings, delays the onset of sleep by attenuating the release of melatonin, a key hormone in initiating the sleep cycle (Chellappa et al., 2011).

Previous studies have examined the relationship between PA, screen time, and SD in children but the findings are inconsistent (Hjorth et al., 2014; Laurson et al., n.d.; Ortega et al., 2011). Furthermore, it remains unclear if decreased PA and/or increased screen time are predictive of compromised SD and SQ in elementary age children living in urban communities. Currently, no studies have examined whether PA and screen time are associated with SD and SQ in elementary age girls living in low SES urban communities (Wong et al., 2013). Therefore, the purpose of this study was to examine associations among PA, screen time,

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SD and SQ in a group of elementary age girls in a low SES urban community.

2. Methods

2.1. Participants

This study was a secondary analysis of baseline data collected from the Mothers and Daughters Dancing Together Trial (MAGNET) and the Girls Dancing and Sleeping for Health (Girls DASH) programs. The MAGNET program was a 12-week after school PA intervention aimed at improving PA levels in urban low SES African-American girls. The Girls DASH program was an 8-week after school PA and sleep education intervention aimed at improving PA and sleep levels in urban low SES girls. Girls were eligible for the MAGNET program if their primary maternal figure identified them as African-American or Black, were between the ages of 7–10 years old and able to participate in physical education at school. Girls were eligible for the Girls DASH program if they were between the ages of 7–12 years old and able to participate in physical education at school. Girls were excluded from both studies if they had any conditions limiting their ability to participate in the PA program or unable to read or understand the assent document in English. Parents and girls provided informed consent and assent, respectively, to participate in this study. The university institutional review board approved the study.

2.2. Physical activity assessment

Trained research staff members collected all data either in the participant's home or at the intervention site. Girls' PA was objectively measured using Actigraph GT3X accelerometers (Actigraph, LLC, Pensacola, FL). Monitors were set to record data in 60-second epochs during the MAGNET study. However, for Girls DASH, we opted to collect data at 15-second epochs. Therefore, all Girls DASH files were converted to 60-second epochs, so that we could employ the same data processing techniques to all accelerometer data. For both studies, girls were instructed to wear the Actigraph on a small elastic belt over their right hip for seven consecutive days excluding times when the monitor would get wet and during nighttime sleep. All data were processed using Actilife 6 software (Actigraph, LLC, Pensacola, FL). Non-wear time was identified and removed from analysis using the Choi et al. (2012) algorithm. In order to be included in the analysis, participants had to wear the monitor for at least 8 h per day and at least three days per week. The Evenson et al. (2008) cut points for children were used to categorize accelerometer counts into periods of sedentary, light PA (LPA), moderate PA (MPA) and moderate-to-vigorous PA (MVPA). Vector magnitude counts per minute (CPM) were assessed as a measure of average movement intensity without relying on categorization into activity intensity categories (Bassett and Wolff-hughes, 2014).

2.3. Child-reported screen time

Child-reported screen time was assessed using a previously validated questionnaire, which has demonstrated high reliability ($r = 0.94$) in elementary age girls living in a low SES urban community (Robinson et al., 2010). Children were asked to report the number of minutes they spent in various types of screen time (e.g. television, movies, computer/tablet) in the morning, afternoon and night on the most recent weekday and weekend day. These values were extrapolated to reflect a weekly value and divided by seven to determine minutes of screen time per day.

2.4. Parent-reported sleep duration and quality assessment

All girls average SD and SQ were assessed via parental report using the Children's Sleep Habits Questionnaire (Owens et al., 2000). This questionnaire has demonstrated high sensitivity ($r = 0.80$), specificity ($r = 0.72$) and test-retest reliability ($r = 0.79$) in identifying sleep problems in elementary age children (Owens et al., 2000). Briefly, this questionnaire is a 45-item questionnaire that asks parents to report the frequency of various sleep behaviors within several domains within a typical week as well as average nightly bed times, morning wake times and SD. The questionnaire items were then aggregated to obtain a composite SQ score (Owens et al., 2000), with a higher score indicating more frequently reported problems and worsened sleep.

2.5. Accelerometer-derived sleep duration and quality

Girls who participated in the Girls DASH program ($n = 24$) were asked to also wear a triaxial Actigraph accelerometer (Actigraph GT3x/GT3x+/ActisleepBT; Actigraph, LLC, Pensacola, FL) on their non-dominant wrist for seven consecutive days including during nighttime sleep to obtain accelerometer-derived measures of SD and SQ. Recently, the manufacturer ceased producing the Actisleep models and provided firmware and software updates which allowed all of triaxial monitors to measure sleep. Girls were instructed to only remove the wrist monitors during times when they would be completely submerged in water (i.e., swimming). All data were processed using Actilife 6 software (Actigraph, LLC, Pensacola, FL). The same accelerometer compliance procedures were used as previously stated in the physical activity assessment section. Raw acceleration data were collected at 30 Hz and reduced to 60-s epochs for the assessment of nocturnal sleep using the Sadeh et al. (1994) algorithm. This algorithm provided accelerometer-derived measures of bedtimes, wake times, number of minutes spent in bed, number of minutes spent asleep, sleep efficiency (percentage of time spent in bed spent sleeping), number and length of nighttime awakenings and sleep fragmentation index scores. The sleep fragmentation index is a multiplicative measure taking into account both the amount of movement and frequency of awakening during the night after the onset of sleep.

2.6. Physical measures

Girls' height was measured to the nearest 0.1 cm using a portable stadiometer. Girls' weight was measured to the nearest 0.1 kg using a Scale-Tronix 5125 digital scale (Scale-Tronix, LLC, White Plains, NY). BMI was calculated as kg/m^2 and BMI percentile ranks for age and gender were determined using the Center for Disease Control growth charts (Ogden et al., 2002).

2.7. Statistical analyses

Only girls with baseline PA, child-reported screen time, parent-reported SD, and parent-reported SQ data were included in the primary analysis. The PA data failed to meet the assumptions of normal distribution; therefore, a log transformation was applied. Multiple linear regressions were used to determine if PA (percent of time spent in sedentary, LPA, MVPA, and CPM) and child-reported screen time (min per day) explained significant portions of the variance in parent-reported SD and parent-reported SQ. Given that there is a known effect of obesity on sleep in children, BMI percentile was included in all regression models (Van Cauter and Knutson, 2008). In cases where PA and child-reported screen time explained significant portions of the variance in parent-reported SD and SQ, standardized regression coefficients were examined to determine which PA and/or child-reported SB variables were predictive of parent-reported SD and SQ. Given that we only had wrist and hip accelerometer data on the Girls DASH participants ($n = 24$), partial correlations were chosen rather than multiple linear regression to examine associations between PA and accelerometer-derived bedtimes, wake times, number of minutes spent in bed, number of minutes spent asleep, sleep efficiency (percentage of time spent in bed spent sleeping), number and length of nighttime awakenings and sleep fragmentation index scores. Significance for all tests were determined using an α of $p < 0.05$. All analyses were performed in SPSS (version 23, Chicago, IL).

3. Results

A total of 55 (MAGNET n = 31; Girls DASH n = 24) girls with complete PA, child-reported SB, parent-reported SD and parent-reported SQ data were included in the analyses. The majority of participants (n = 42) in the current analysis met the criteria for compromised parent-reported SQ (mean total SQ score > 41) indicating that this was indeed an at-risk population. Participants were mostly African American (n = 46), low-income and relatively inactive. Baseline characteristics are displayed in Table 1.

The regression analyses indicated that child-reported screen time explained a significant portion of the variance in parent-reported total SQ score ($F(7, 40) = 3.04$, $p = 0.01$, $r^2 = 0.35$, r^2 adjusted = 0.23). Specifically, more minutes of screen time per day was associated with worse SQ ($\beta = 0.50$, $t = 2.56$, $p = 0.02$). The regression analyses did not reveal any relationships between PA and parent-reports of child's SD or SQ. However, there were several significant correlations between PA and accelerometer-derived sleep variables in the Girls DASH subsample (n = 24). There were negative correlations between percent of time spent in LPA, MPA and VPA with the number of nighttime awakenings (LPA partial $r = -0.45$, $p = 0.04$; MPA partial $r = -0.44$, $p = 0.04$; VPA partial $r = -0.45$, $p = 0.04$). There was a negative correlation between CPM average and sleep fragmentation index score (partial $r = -0.65$, $p = 0.002$) and a positive correlation between CPM average and number of minutes spent asleep (partial $r = 0.52$, $p = 0.02$). No other significant correlations were observed between PA and accelerometer-derived sleep variables.

4. Discussion

Declining SD and SQ in children have been linked to poor mental and physical health outcomes (Cappuccio et al., 2008; O'Brien, 2009; Hjorth et al., 2014). In order to combat these trends, it is important to identify modifiable risk factors, such as decreased PA and increased screen time that may be associated with poor sleep. In this sample of elementary age girls living a low SES urban community, accumulating more daily child-reported screen time was associated with worse parent-reported SQ. One previous study investigated associations between accelerometer-derived sedentary behavior and SD and noted an inverse relationship between these two behaviors in elementary age urban children (Wong et al., 2013). The current study adds to this research by measuring SQ in addition to SD and investigating specific aspects of sedentary behavior such as screen time (Wong et al., 2013). It is important to understand risk factors that are related to SQ as well as SD, given that one previous study indicated 37% of parents report child problems in at least one SQ domain (Buxton et al., 2015). It is imperative to measure screen time in these types of studies given that increased exposure to screens (i.e., TV, tablets, smart phones) could delay the release of melatonin and subsequently compromise SD and SQ. (Chellappa et al., 2011; Cain and Gradisar, 2010) Given that the presence of a television in the bedroom has been associated with 31 fewer minutes of sleep per night in children living in low SES urban communities (Cespedes et al., 2014), this behavior should be a primary target for interventions seeking to improve sleep in this population.

In addition to parent reports of girls' SD and SQ, we collected accelerometer-derived sleep measures using a wrist-mounted monitor in a subsample of girls. In this subsample of girls, accumulating more LPA and MVPA was correlated with fewer nighttime awakenings and lower sleep fragmentation scores. Studies simply measuring children's SD may underestimate or neglect relationships between PA and SQ, such as fragmentation and nighttime awakenings, which are key components of sleep health. For example, sleep disruption in childhood has been associated with increased hyperactivity, inattention, behavioral problems, and academic difficulties (O'Brien, 2009). These findings may elucidate other potential health benefits of increasing PA in this population. It is possible that increasing PA is associated with improving aspects of sleep beyond SD. In terms of accelerometer-derived SD, we found that higher CPM during the day was correlated with and more minutes spent in bed per night. Both the current study and the Wong et al. (2013) study did not observe a relationship between MVPA and accelerometer-derived SD. It is possible that we did not observe relationships between MVPA and sleep because this population of girls was relatively inactive and we did not have a large enough distribution of activity levels to detect these relationships. There is a high degree of covariance when looking at time spent on PA, SB and sleep measured via accelerometry, given that they represent three portions of the same 24-h day. We chose to include accelerometer average CPM given that it is a measure of average movement intensity, and is not prone to these time related issues of covariance. These findings may indicate that SD is related more to total movement rather than MVPA in this population.

Given that we did not collect physiological outcome data (e.g. melatonin levels), we cannot make inferences regarding the physiological mechanisms underlying the associations between PA and screen time with SD and SQ in this population. It is possible that girls in low SES urban environments who accumulate more PA have higher levels of evening melatonin. These higher melatonin levels may make them more fatigued at night, although there is no literature examining this relationship in elementary age girls living in low SES urban environments. However, Gerra et al. (1993) previously noted an increase in the melatonin levels following a brief aerobic exercise test in adolescent boys. More work is needed to examine the relationship between PA and melatonin levels in children who are at high-risk for compromised sleep, such as elementary age girls living in low SES urban communities. Additionally, given that insufficient PA and compromised sleep patterns are both risk factors for childhood obesity (Laurson et al., 2014), future prevention strategies should examine the potential interaction between these behaviors within the obesogenic pathway.

Our findings should be interpreted in the context of several limitations. First, the use of a correlational design does not allow us to infer causality between increasing child-reported screen time, decreasing

Table 1
Descriptive characteristics.

Variable	Means ± SD
Age (years)	8.4 ± 1.7
BMI percentile	70.8 ± 31.3
LPA % time spent	31.8 ± 8.3
MVPA % time spent	3.3 ± 1.9
Wear time (days)	4.9 ± 2.4
Screen time (min/day)	250.8 ± 182.6
SD (h/day)	9.4 ± 1.4
SQ	46.7 ± 7.9
Race	
African American	83.6%
White Hispanic	12.7%
Non-White Hispanic	3.6%
Household income	
<$20,000/yr	32.7%
$20,000–40,000/yr	40.8%
>$40,000/yr	19.5%

LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; SB = child report, minutes per day of sedentary behavior; SD = parental report, child's daily sleep duration; SQ = parental report, child's composite sleep quality score. Data were collected in Springfield, MA between 2012 and 2015.

PA and sleep metrics. Second, the use of parent-reported SD and SQ and child-reported screen time may bias our results via social desirability bias and non-differential misclassification. The use of longitudinal designs and objective assessments of PA, SD and SQ in future studies would improve our understanding of the relationships between these variables in this population. Third, our sample size is small and may limit our ability to detect significant associations. Lastly, we did not assess melatonin levels, which play a key role in the relationship between light exposure and sleep. Therefore, we cannot speak to the physiological mechanisms by which increasing screen time deters SQ in this population. Despite these limitations, this study had several strengths. Most importantly, this is the first study to assess relationships among PA, screen time, SD and SQ in a homogenous sample of girls living in a low SES urban environment. Additionally, we used an objective measurement tool and validated techniques to assess PA. We also examined these relationships using objective assessments of sleep behaviors in a subsample of our population. Finally, while the use of self-report tools is considered a limitation, the SD and SQ questionnaire used has demonstrated high validity and reliability in the population of interest (Owens et al., 2000).

5. Conclusions

In summary, this study provides initial evidence that higher child-reported screen time and lower PA were associated with compromised parent-reported SQ in urban girls. These findings provide potential target behaviors for interventions seeking to improve sleep in this at-risk population. Future studies should be conducted using objective assessment techniques to measure sleep, longitudinal designs, larger samples and the assessment of underlying physiological mechanisms to confirm the nature and existence of these relationships.

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