Sleep patterns and sugar-sweetened beverage consumption among children from around the world

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Abstract

Objective: To examine the relationships between objectively measured sleep patterns (sleep duration, sleep efficiency and bedtime) and sugar-sweetened beverage (SSB) consumption (regular soft drinks, energy drinks, sports drinks and fruit juice) among children from all inhabited continents of the world.

Design: Multinational, cross-sectional study.

Setting: The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE).

Subjects: Children (n 5873) 9–11 years of age.

Results: Sleep duration was 12 min per night shorter in children who reported consuming regular soft drinks ‘at least once a day’ compared with those who reported consuming ‘never’ or ‘less than once a week’. Children were more likely to sleep the recommended 9–11 h/night if they reported lower regular soft drink consumption or higher sports drinks consumption. Children who reported consuming energy drinks ‘once a week or more’ reported a 25-min earlier bedtime than those who reported never consuming energy drinks. Children who reported consuming sports drinks ‘2–4 d a week or more’ also reported a 25-min earlier bedtime compared with those who reported never consuming sports drinks. The associations between sleep efficiency and SSB consumption were not significant. Similar associations between sleep patterns and SSB consumption were observed across all twelve study sites.

Conclusions: Shorter sleep duration was associated with higher intake of regular soft drinks, while earlier bedtimes were associated with lower intake of regular soft drinks and higher intake of energy drinks and sports drinks in this international study of children. Future work is needed to establish causality and to investigate underlying mechanisms.

Sugar-sweetened beverages (SSB), defined as any liquids that are sweetened with various forms of added sugars, contribute 10–15% of children’s energy intake and are the primary source of added sugar in their diet(1). SSB consumption is associated with adverse health outcomes including obesity, type 2 diabetes and CVD(2–4). Putative underlying mechanisms comprise incomplete compensation for liquid energy, adverse glycaemic effects, and increased hepatic metabolism of fructose leading to de novo lipogenesis, production of uric acid and accumulation of visceral and ectopic fat(5). Recent evidence has stimulated public health efforts to reduce SSB consumption as a means of improving childhood weight status and related health outcomes(6).

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Sports drinks
Cola
Paediatric
Factors associated with SSB consumption in children are numerous and a better understanding of these correlates can inform the development of effective interventions to reduce SSB intake. One factor that has received little attention is the role of sleep, despite accumulating evidence linking insufficient sleep (i.e. short sleep duration and/or poor sleep quality) with obesity and other adverse health outcomes. The main mechanism linking insufficient sleep to weight gain is through an increase in food intake, especially energy-dense foods. Thus, it is plausible that insufficient sleep would be associated with greater intake of SSB in children. Alternatively, SSB consumption may also be associated with insufficient sleep due to the stimulating properties of caffeine that, when consumed near bedtime, may negatively influence sleep.

Studies examining the associations between sleep and SSB consumption are sparse. Prather et al. recently showed that short self-reported sleep duration in adults was associated with greater intake of sugared caffeinated sodas. Franckle et al. reported that children who reported sleeping <10 h/d consumed soda more frequently compared with children who reported sleeping ≥10 h/d. However, to our knowledge, no studies to date have examined whether objectively measured sleep patterns (i.e. sleep duration, sleep efficiency and bedtime) are associated with SSB consumption in children from around the world. Understanding how sleep patterns may be linked to SSB consumption across countries at different levels of economic and human development is important to inform public health policies and tailor interventions that are context- and setting-specific.

The objective of the present study was to investigate the relationships between objectively measured sleep patterns and SSB consumption among a large cross-sectional sample of children from all inhabited continents of the world. We hypothesized that sleep patterns characterized by shorter sleep durations, poorer sleep efficiencies and later bedtimes would be associated with a higher frequency of SSB consumption.

Methods

Study design and setting
The International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) is a cross-sectional, multinational study designed to examine the relationships between lifestyle behaviours and obesity in twelve study sites located in Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, the UK and the USA. These countries represent a wide range of economic development (low to high income), Human Development Index (composite statistic of life expectancy, education and per capita income indicators, used to rank countries into four tiers of human development; 0-509 in Kenya to 0-929 in Australia) and inequality (Gini index of 26-9 in Finland to 63-1 in South Africa). The rationale, design and methods of ISCOLE have previously been published elsewhere. The primary sampling frame was schools, which was typically stratified by an indicator of socio-economic status to maximize variability within sites. A standardized protocol was used to collect data across all sites, and all study personnel underwent rigorous training and certification to ensure data quality. Data were collected during the school year at each study site and occurred between September 2011 and December 2013. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The Pennington Biomedical Research Center Institutional Review Board as well as institutional/ethical review boards at each site approved the study. Written informed consent was obtained from parents/legal guardians and child assent was also obtained.

Participants
ISCOLE targeted grade levels/classes likely to ensure minimal variability around a mean age of 10 years. All children within the targeted grade level/class in a sampled school were eligible to participate; hence, the sample included 9–11-year-old children. Based on a priori sample size and power calculations, each site aimed to recruit a sex-balanced sample of at least 500 children. Of the 7372 children who participated in ISCOLE, a total of 5873 remained in the present analytical data set after excluding participants without valid sleep data (n 1054), reported level of parental education (n 273), physical activity data (n 151), BMI Z-score (n 5) and SSB consumption (n 16). Exclusion of participants for invalid sleep data was mainly due to a wear time of fewer than three nights. Except for significantly higher BMI Z-scores, the descriptive characteristics of children who were excluded for missing data did not significantly differ from those who were included in the present analysis.

Measurements

Sleep patterns
Sleep duration, sleep efficiency and bedtime were all objectively assessed by 24 h, waist-worn accelerometry. An Actigraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) was worn on the waist on an elasticized belt at the right mid-axillary line. Participants were encouraged to wear the accelerometer 24 h/d (removing only for water-based activities) for at least seven days, including two weekend days. Data were collected at a sampling rate of 80 Hz, downloaded in 1 s epochs with the low-frequency extension filter using the ActiLife software version 5.6 or higher, and reintegrated to 60 s epochs for analysis. Sleep duration (h/night) was estimated using a fully automated algorithm for 24 h waist-worn accelerometers that was developed and validated for ISCOLE. This algorithm produces more precise estimates of sleep duration than previous algorithms and...
sleep durations (≥60 min/d on average) of children aged 4–9 years and were thus excluded from this analysis. However, keeping them or excluding them did not impact the results found. We also examined associations between sleep patterns and SSB consumption according to country-level World Bank classification of economic development (20). P values of less than 0.05 were considered statistically significant.

Results

Table 1 presents descriptive characteristics of the sample. The mean sleep duration was 8.8 h/night (with Portugal having the shortest sleep duration of the countries examined (8.3 h) and the UK the longest (9.5 h)) and 58% of children slept less than the recommended 9–11 h/night (long sleepers) and were thus excluded from this analysis. However, keeping them or excluding them did not impact the results found. We also examined associations between sleep patterns and SSB consumption according to country-level World Bank classification of economic development (20). P values of less than 0.05 were considered statistically significant.

Table 1 presents descriptive characteristics of the sample. The mean sleep duration was 8.8 h/night (with Portugal having the shortest sleep duration of the countries examined (8.3 h) and the UK the longest (9.5 h)) and 58% of children slept less than the recommended 9–11 h/night. Children who were very sleep efficient (96.2% sleep efficiency on average) had a mean bedtime of 22:18 (latest mean bedtime in Portugal (23:15) and earliest in Kenya (21:41)). A total of 11.6% of children reported that they consumed regular cola or soft drinks once per day or more (ranging
from 1.1% reporting consuming regular soda or soft drinks once per day or more in Finland to 31.6% in South Africa. Approximately three-quarters of children reported never consuming energy drinks (ranging from 46% reporting ‘never’ consuming energy drinks in South Africa to 95% in Finland). Approximately 45% of the sample reported that they never consumed sports drinks (ranging from 9% reporting ‘never’ consuming sports drinks in the USA to 80% in Finland). Finally, 22.4% of children reported drinking fruit juice more than once per day (ranging from 6% reporting drinking fruit juice more than once per day in China to 47% in Colombia).

We did not find significant sex interactions in the associations between sleep patterns and SSB consumption across study sites; therefore, results were pooled for presentation. Figures 1–3 show sleep patterns across levels of consumption of SSB in this sample of children. There was a significant negative trend in sleep duration across levels of consumption of regular soft drinks (Fig. 1(a)). Sleep duration was 12 min shorter in children who reported consuming regular soft drinks ‘≥ once/d’ compared with those who reported consuming regular soft drinks ‘never’ or ‘< once/week’. We also observed significant positive trends between bedtime and consumption of regular soft drinks (Fig. 3(a)), and significant negative trends between bedtime and consumption of energy drinks (Fig. 3(b)) and sports drinks (Fig. 3(c)). In particular, we observed a 25-min earlier bedtime in children who reported consuming energy drinks ‘≥ once/week’ compared with those who reported ‘never’ consuming energy drinks. Likewise, we found a 25-min earlier bedtime in children who reported consuming sports drinks ‘2–4 d/week or more’ compared with those reporting ‘never’. The other associations between sleep patterns and SSB consumption were not significant. We also did not find a significant World Bank classification of economic development-by-sleep pattern interaction for SSB consumption, suggesting that the associations did not differ between sites (e.g. low- v. high-income countries).

Table 2 presents the odds of meeting the sleep duration recommendation of 9–11 h/night (reference category) for each of the four SSB consumption variables. The cut-points for the SSB consumption variables were chosen based on the distribution of the data, to maximize power. Children who reported drinking regular soft drinks ‘once/week or more’ were less likely to sleep the recommended amount (OR = 0.79, 95% CI 0.71, 0.88) compared with those who reported consuming regular soft drinks ‘never’ or ‘< once/week’. In contrast, higher odds of meeting the sleep duration recommendation were observed in children reporting consuming sports drinks ‘< once/week or more’ (OR = 1.26, 95% CI 1.13, 1.39) compared with those reporting never consuming sports drinks. Finally, children reporting drinking fruit juice ‘once/week or more’ had higher odds of meeting the sleep duration recommendation (OR = 1.23, 95% CI 1.08, 1.40) than those indicating drinking fruit juice ‘never’ or ‘< once/week’.

**Discussion**

To our knowledge, the present study is the first to examine the relationships between sleep patterns and SSB consumption in children from twelve countries varying widely in levels of economic and human development. Collectively, we observed shorter sleep durations with higher consumption of regular soft drinks. Children were also more likely to sleep the recommended 9–11 h/night if they reported lower regular soft drink consumption or higher sports drinks or fruit juice consumption. We also observed that later bedtimes were associated with higher...
consumption of regular soft drinks. Conversely, later bedtimes were also associated with lower consumption of energy drinks and sports drinks. There was no association between sleep efficiency and SSB consumption. Similar associations between sleep patterns and SSB consumption were observed across all twelve study sites.

The present findings are in line with previous studies that have reported a significant relationship between sleep duration and SSB consumption. For example, short self-reported sleep duration (≤5 and 6 h/night) has been shown to be associated with higher intake of sugared caffeinated sodas among adults in the USA (11). In children, Franckle et al.(12) reported that students in two Massachusetts communities who reported sleeping <10 h/d consumed soda more frequently compared with students who reported ≥10 h sleep/d. However, no significant association was reported with fruit juice in their study, in agreement with the present work. Similarly, Pérez-Farinós et al.(27) reported that short sleep duration (<9.9 h/d) was associated with a greater frequency of consumption of soft drinks containing sugar but not with fruit juice in Spanish children. No studies have looked at the association of sleep quality or sleep timing (e.g. bedtime or chronotype) with SSB consumption in children.

Among the three sleep characteristics examined in the present study, bedtime was most strongly associated with SSB consumption. Similar to short sleep duration, later bedtimes were associated with greater consumption of regular soft drinks. Yet, earlier bedtimes were also associated with greater consumption of energy drinks and sports drinks. Although this may seem counter-intuitive, a greater frequency of consumption of energy and sports drinks may be a proxy for a healthier lifestyle in general. For instance, it is possible that active children go to bed earlier and may consume energy and sports drinks more frequently during the day for their physical activities (or other reasons). Energy and sports drinks may be seen as ‘good’ by children and parents despite the fact they are not healthy options according to public health authorities. Sampasa-Kanyinga and Chaput have recently reported that female adolescents who meet the recommendation of ≥60 min of moderate-to-vigorous physical activity daily are more likely to report consuming energy drinks than

![Fig. 1 Sleep duration across levels of consumption of (a) regular cola or soft drinks (P for linear trend < 0.01), (b) energy drinks (P for linear trend NS), (c) sports drinks (P for linear trend NS) and (d) fruit juice (P for linear trend NS) among children aged 9–11 years (n = 5873) from twelve study sites around the world, International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), September 2011–December 2013. Data are presented as mean values with standard deviations represented by vertical bars. Age, sex, highest level of parental education, meeting physical activity guidelines and BMI Z-score were included as covariates.](https://www.cambridge.org/core)
those who do not meet this recommendation\(^{(28)}\). Conversely, late bedtimes are generally associated with more screen time and energy-dense food snacking\(^{(29,30)}\). The present data suggest that a greater consumption of sugar-sweetened soft drinks is linked to later bedtimes in children from around the world.

Reverse causation is always a possibility with cross-sectional study designs. Thus, it is possible that SSB consumption may also impact sleep patterns, especially due to the stimulating properties of caffeine that can disrupt sleep. Although caffeine use is well known to reduce sleep quality (especially when consumed in the hours before bedtime), we did not find a significant association between sleep efficiency and SSB consumption in the present study. One explanation is the ceiling effect observed for sleep efficiency in this sample of children (mean value of 96%). It is indeed difficult to find significant associations with small inter-individual variations in the data. Although children have high sleep efficiency values in general (e.g. compared with adults), the waist-worn accelerometer protocol used in ISCOLE tends to also overestimate sleep efficiency compared with wrist-worn devices\(^{(31)}\). Future studies using more sensitive measures of sleep quality are thus required to confirm our findings. Longitudinal studies will also be needed to determine the directionality in the findings, including information about when children routinely consume the different SSB (e.g. during the day or near bedtime).

The current study included sites from countries varying widely in levels of economic and human development. However, we did not find a significant World Bank classification of economic development-by-sleep pattern interaction for SSB consumption, suggesting that the associations were similar across study sites. Although limited, the current evidence on sleep patterns as it relates to SSB consumption is mainly from high-income countries. It is thus reassuring to observe herein the same associations all over the world, thereby making future intervention strategies more generalizable. However, ISCOLE did not contain nationally representative data, so it would be prudent to design interventions that are context- and setting-specific to optimize success.

Determinants of SSB consumption in children are numerous and include things such as a child’s preference for SSB, screen time and snack consumption, lower.
parental socio-economic status, parental role modelling, using food as a reward or living near a fast-food/convenience store (7). Likewise, reasons for having inadequate sleep patterns are diverse and can include a lack of parental monitoring or rules about bedtime in the household, artificial light exposure before bedtime, electronic devices in the bedroom, unfavourable sleep environment, cultural factors, etc. Sleep duration of school-aged children is also largely influenced by the start of the school day and bedtime is therefore a key determinant of total sleep duration in such a context. A better understanding of the determinants of SSB consumption and sleep patterns is important to inform the development of effective interventions aimed at reducing SSB consumption and improving sleep hygiene of children.

The present study has several strengths and limitations that warrant discussion. An important strength is the large multinational sample of children from low- to high-income countries across several regions of the world. We also used a highly standardized measurement protocol, objective sleep measurements and a rigorous quality control programme to ensure high-quality data across all sites (13). However, our results need to be interpreted in the light of the following limitations. First, the cross-sectional nature of the data precludes inferences about causality or sleep patterns are diverse and can include a lack of parental monitoring or rules about bedtime in the household, artificial light exposure before bedtime, electronic devices in the bedroom, unfavourable sleep environment, cultural factors, etc. Sleep duration of school-aged children is also largely influenced by the start of the school day and bedtime is therefore a key determinant of total sleep duration in such a context. A better understanding of the determinants of SSB consumption and sleep patterns is important to inform the development of effective interventions aimed at reducing SSB consumption and improving sleep hygiene of children.

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**Table 2** Odds for meeting the sleep duration recommendation of 9–11 h/night (compared with <9 h/night), for each of the sugar-sweetened beverage (SSB) consumption variables, among children aged 9–11 years (n 5873) from twelve study sites around the world, International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), September 2011–December 2013

<table>
<thead>
<tr>
<th>SSB variable</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular cola or soft drinks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never or &lt;once/week</td>
<td>1.00</td>
<td>Ref.</td>
</tr>
<tr>
<td>Once/week or more</td>
<td>0.79</td>
<td>0.71, 0.88*</td>
</tr>
<tr>
<td>Energy drinks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1.00</td>
<td>Ref.</td>
</tr>
<tr>
<td>&lt;Once/week or more</td>
<td>1.08</td>
<td>0.96, 1.21</td>
</tr>
<tr>
<td>Sports drinks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1.00</td>
<td>Ref.</td>
</tr>
<tr>
<td>&lt;Once/week or more</td>
<td>1.26</td>
<td>1.13, 1.39*</td>
</tr>
<tr>
<td>Fruit juice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never or &lt;once/week</td>
<td>1.00</td>
<td>Ref.</td>
</tr>
<tr>
<td>Once/week or more</td>
<td>1.23</td>
<td>1.08, 1.40*</td>
</tr>
</tbody>
</table>

Ref., reference category.
Age, sex, highest level of parental education, meeting physical activity guidelines and BMI Z-score were included as covariates in statistical models.

*P < 0.05.
temporality. Second, accelerometers may be limited in their ability to properly distinguish between sleep and wake states, as they are based on movement detection, and wrist-worn accelerometers have been shown to overestimate absolute sleep duration and sleep efficiency compared with wrist-worn devices\(^{(31)}\). Third, ISCOLE was not designed to provide nationally representative data and therefore the degree to which the results are generalizable to the studied countries is not known. Fourth, the narrow age range limits our ability to infer our findings to other age groups and it is possible that different patterns would be observed in adolescents or adults for example. Fifth, only the frequency of SSB consumption was reported and information on energy intake (kilojoules) was not captured in ISCOLE. Reliability correlation coefficients of 0.61 (regular soft drinks), 0.68 (energy drinks), 0.78 (sports drinks) and 0.64 (fruit juice) have been reported in children who repeated this FFQ after an average of 4-9 weeks. Also, the FFQ used did not distinguish between fruit juice with or without added sugar. Finally, the potential confounding effects of unmeasured variables cannot be discounted.

**Conclusion**

In conclusion, findings from the current study show that shorter sleep duration was associated with higher intake of regular soft drinks, while earlier bedtimes were associated with lower intake of regular soft drinks and higher intake of energy drinks and sports drinks in this large multinational study of children. Further studies using longitudinal research designs are needed to better understand the prospective associations among sleep patterns and SSB consumption in children.

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**References**