Supplement Article

The relation between sleep duration and sedentary behaviours in European adults

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Summary

Too much sitting, and both short and long sleep duration are associated with obesity, but little is known on the nature of the relations between these behaviours. We therefore examined the associations between sleep duration and time spent sitting in adults across five urban regions in Europe.

We used cross-sectional survey data from 6,037 adults (mean age 51.9 years (SD 16.4), 44.0% men) to assess the association between self-reported short (<6 h per night), normal (6–8 h per night) and long (>8 h per night) sleep duration with self-report total time spent sitting, time spent sitting at work, during transport, during leisure and while watching screens. The multivariable multilevel linear regression models were tested for moderation by urban region, age, gender, education and weight status. Because short sleepers have more awake time to be sedentary, we also used the percentage of awake time spent sedentary as an outcome. Short sleepers had 26.5 min day^{-1} more sedentary screen time, compared with normal sleepers (CI 5.2; 47.8). No statistically significant associations were found with total or other domains of sedentary behaviour, and there was no evidence for effect modification. Long sleepers spent 3.2% higher proportion of their awake time sedentary compared with normal sleepers.

Shorter sleep was associated with increased screen time in a sample of European adults, irrespective of urban region, gender, age, educational level and weight status. Experimental studies are needed to assess the prospective relation between sedentary (screen) time and sleep duration.

Keywords: SPOTLIGHT, sedentary behaviour, sitting, sleep.

Abbreviations: BMI, body mass index; CI, confidence interval; SD, standard deviation; and SES, socioeconomic status.

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Introduction

Sedentary behaviour and sleeping are low energy expenditure behaviours, but one is a risk factor for obesity (if carried out in prolonged bouts), and the other may be protective against weight gain (if carried out in 'healthy' amounts). With sedentary behaviour (any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalent while in a sitting or reclining posture) (1), the low energy expenditure itself may contribute to weight gain, but it might also prompt higher energy intake and less exercise (2,3). The purported association between sleep and obesity is less clear. Whereas some studies have shown that *long* sleep is associated with obesity,(4) cross-sectional, longitudinal and experimental studies are consistent in demonstrating an association of *short* sleep with increased risk of weight gain and obesity (4–8). Although sleep duration guidelines recommend 7–9 h of sleep for adults (9), studies using <6 h and ≥8 h per night as cut-offs for short and long sleep duration have found the strongest associations (10). The underlying mechanism by which sleep is associated with weight gain has not been established but may involve hunger-regulatory hormone changes (11), thermoregulatory processes, and/or an impact on physical activity and sedentary behaviours (12,13).

The evidence linking both sedentary behaviour and sleep with obesity raises a question of whether and how these two factors are linked. Both short and long sleep duration may lead to feelings of tiredness and exhaustion, which may lead to more sedentary behaviour (12,14–18). Or, conversely, spending more sedentary time – especially in front of screens – may reduce sleep quality and, consequently, quantity (19,20). This association may be different between obese and non-obese adults.

Current evidence for any association between sleep duration and sedentary behaviour is, however, scarce and inconsistent. Whereas some previous studies have found no association (16,17), one found that adults at risk of type 2 diabetes who habitually curtail their sleep were more sedentary than those who slept at least 6 h per night (18). Consequently, there is a need to understand better the existence and nature of any such association, as this may provide entry points for targeted obesity prevention interventions. It would therefore be especially interesting to understand whether short or long sleep duration is associated with specific domains of sedentary behaviour, such as sitting at work or sitting during transport. This goes beyond existing work that has focused on watching TV (19). To our knowledge, only one study has looked at possible associations between sleep duration and time spent sitting at work or sitting during leisure time, but found no such associations (21).

We examined the associations of short, normal and long sleep duration with total sedentary behaviours and sedentary behaviours in the following domains: at work, during transport, during leisure, and screen time sedentary behaviours among adults in a cross-sectional European study. Next, we explored whether these associations differed by weight status, gender, age and across urban regions in Europe. Lastly, because short sleepers have more time awake to spend sedentary, we examined associations with percentage of time awake spent sedentary as an outcome.

Methods

Study design and sampling

This study was part of the SPOTLIGHT project (22), conducted in five urban regions across Europe: Ghent and suburbs (Belgium), Paris and inner suburbs (France), Budapest and suburbs (Hungary), the Randstad (including the cities of Amsterdam, Rotterdam, The Hague and Utrecht in the Netherlands) and Greater London (United Kingdom). The sampling and recruitment strategy have been described in detail elsewhere (23). Briefly, sampling of neighbourhoods in the five urban zones was based on a combination of residential density and socioeconomic status (SES) data at neighbourhood level. In each country, three neighbourhoods of each neighbourhood type (high SES/high residential density, low SES/high residential density, high SES/low residential density, low SES/low residential density) were randomly sampled (i.e. 12 neighbourhoods per country, 60 neighbourhoods in total). Subsequently, a random sample of adult inhabitants was invited to participate in an online survey. Participants were eligible to participate if they were 18 years or older and able to provide informed consent. The survey contained questions on demographics, neighbourhood perceptions, social environmental factors, health, motivations and barriers for healthy behaviour, physical activity, sedentary behaviour, dietary habits, and weight and height. A total of 6,037 (10.8%, out of 55,893) individuals participated in the study between February and September 2014.

Measures

Sleep duration

Participants provided information on their hours of sleep during an average night. The response options ranged from 4 to 16 h per night (in half-hour intervals). Because both short and long sleep have previously been associated with unfavourable health outcomes, we classified sleep in three categorical variables: short sleep duration (<6 h), normal sleep duration (6–8 h) and long sleep duration (>8 h), according to cut-off points used in previous studies (10,12,24).

Sedentary behaviours

The Marshall questionnaire was used to collect data on sedentary behaviour (25). This questionnaire assesses time spent sitting on weekdays and weekend days: (i) while travelling; (ii) at work; (iii) watching television; (iv) using a computer or tablet at home; and (v) for leisure except for watching television. We added the option 'tablet' given their increasing substitution for computer use. Marshall *et al.* showed that criterion validity was highest for weekday sitting time at work and using a computer at home ($r = 0.69$–0.74) (25). The validity of weekend-day sitting time items were found to be low with the exception of computer use and (only for women) watching television (25).

Based on the self-reported domain-specific sitting times, five dependent variables were created: sedentary behaviour at work (only for those in employment), during transport, during leisure (excluding screen time) and screen time sedentary behaviour. Total sedentary behaviour was calculated by adding up the several domains of sedentary time (with 0 min added for sedentary behaviour at work, for those without work), truncated to a maximum of 16 h day^{-1}.

Covariates and effect modifiers

Standard demographic characteristics were obtained from the survey questionnaire, including age, gender, household composition, employment and education status. Level of education was treated as dichotomous, with higher education defined as a college or university degree and lower education as all other educational levels. Participants also reported on their height, weight and smoking status. A continuous variable for body mass index (BMI) was created by dividing weight in kilograms over the height squared in metres. Then, BMI was categorized as normal weight (including underweight) – defined as having a BMI < 25, overweight (BMI ≥25 and <30) and obese (BMI ≥30), consistent with World Health Organization criteria (26). Mobility problems were assessed by questions on any long-standing illness, disability or infirmity that limits daily activities or work (yes/no).

Statistical analysis

A total of 137 individuals had missing data on the neighbourhood identifier and were thus excluded from further analysis (final $n = 5{,}900$). We used ANOVAs and chi-squared tests to examine differences in socio-demographic and behavioural characteristics between short (<6 h per night), normal (6–8 h per night) and long sleepers (>8 h per night). Missing values were handled with multiple imputation. Assuming that data were missing at random, missing values for all variables used (between <1% to 22% per item) were imputed using Predictive Mean Matching in SPSS version 22.0. All variables described in the Methods section were used in the model with 20 imputed datasets, and the country and neighbourhood identifiers were used as predictors. The −2 Log likelihood test indicated that data were clustered both at neighbourhood and urban region level; therefore, both levels were included and controlled for in a multilevel linear regression analysis with random intercepts for neighbourhood and country.

We examined associations between the three categories of sleep duration with total and domain-specific sedentary behaviour. We tested whether age group, gender, education, urban region, physical activity level or weight status (normal weight, overweight and obesity) moderated the association between sleep and sedentary behaviours. Stratified analyses were performed for effect modifiers if their interaction term was significant ($p < 0.1$ in this case). Additionally, age, gender, education, BMI, physical activity, household composition, employment status, comorbidities, smoking and alcohol use were examined as possible confounders. Only age, gender, comorbidities, BMI, employment status and smoking changed the effect estimates of sleep by more than 10% and were retained in the models.

As a sensitivity analysis, we took percentage awake time spent sedentary as outcome. In addition, as robustness tests, we performed analyses with a different categorization of short and long sleepers (sleeping < 5.5 h and sleeping > 9 h, respectively), and performed a complete case analysis (with unimputed data). These latter two analyses yielded comparable results (Tables S1 and S2).

p values of <0.05 were considered statistically significant. All statistical analyses were performed using IBM version 22.0.

Results

The analysis included a total of 5,900 participants (44% men) with a mean age of 51.9 (SD 16.4) years. Table 1 shows the descriptive characteristics of the study participants. The average sleep duration was 7.1 h (SD 1.1) per night, and the average time spent sedentary was almost 10 (SD 3.5) h day^{-1} for those who were employed, and 7.6 (SD 3.6) h day^{-1} for those who were not. Short sleepers had a higher BMI than normal or long sleepers ($F = 37.5$, $p < 0.001$). Normal sleepers tended to be younger than short and long sleepers ($F = 20.3$, $p < 0.001$). The largest proportion of long sleepers was retired, while the majority of short and normal sleepers were currently employed individuals (chi-square = 189.5, $p < 0.001$). Participants reported, on average, spending approximately 53% of their awake time sitting. This differed between countries, ranging from approximately

Table 1 Descriptive characteristics (means [SD] or percentages) of the SPOTLIGHT survey participants

	Total $n = 5,900$*	Short sleepers (<6 h per night) $n = 386$	Normal sleepers (6–8 h per night) $n = 4,436$	Long sleepers (>8 h per night) $n = 589$
Age (years)	51.9 (16.4)	55.6 (15.6)	51.1 (16.0)	54.0 (19.0)
Gender (% men)	44.0	46.6	43.8	39.6
Hours of sleep per night	7.1 (1.1)	4.9 (0.5)	7.1 (0.7)	9.0 (0.7)
BMI (kg/m^2)	25.2 (4.5)	27.1 (5.5)	25.1 (4.4)	24.8 (4.4)
Weight status (%)				
Normal weight†	54.3	38.8	55.4	55.9
Overweight‡	33.0	37.6	32.7	31.4
Obese§	12.7	23.6	11.8	12.7
Employment (%)				
Currently employed	54.7	46.9	58.6	32.3
Currently not employed	7.3	9.3	6.5	11.5
Retired	29.3	33.9	26.6	43.5
In education	3.7	2.3	3.3	8.3
Homemaker	5.1	7.5	4.7	4.3
Education (% lower)	46.6	65.1	44.2	52.1
Sedentary behaviour (min day^{-1})				
Total (employed)	587.8 (211.7)	615.0 (247.9)	589.6 (208.2)	559.0 (208.2)
Total (not employed)¶	454.5 (218.6)	477.1 (215.6)	454.2 (219.2)	447.3 (217.5)
At work‖	257.0 (154.8)	250.2 (189.3)	259.4 (152.8)	226.5 (164.9)
During transport	82.8 (87.4)	96.5 (109.4)	81.7 (84.8)	80.1 (86.8)
During leisure	92.0 (102.5)	89.7 (111.0)	92.5 (101.0)	90.8 (109.6)
Screen time**	267.6 (179.1)	326.9 (209.6)	261.7 (177.2)	288.0 (179.4)

*Four hundred eighty-nine individuals did not report their sleep duration and could therefore not be classified into short, normal and long sleepers.
Dividing weight in kilograms over the height squared in metres.
†BMI < 25 (including underweight, 3.9%).
‡BMI ≥ 25 and <30.
§BMI ≥ 30.
¶Including those who were retired, in education or homemaker.
‖Only for those who were currently employed ($n = 3,438$).
**Including watching television and using a computer or tablet.
BMI, body mass index.

Table 2 Multilevel multivariable linear regression coefficients (95%CI) for the association of sleep duration with total and domain-specific sedentary behaviours (min day^{-1})

	Total sedentary behaviour B (95%CI)	Sedentary behaviour at work B (95%CI)	Sedentary behaviour during leisure time B (95%CI) B (95%CI)	Sedentary behaviour during transport B (95%CI)	Screen time B (95%CI)	% awake time spent sedentary B (95%CI)
Short sleep (<6 h per night, $n = 386$)	18.0 (−9.5; 45.5)	9.0 (−17.5; 35.6)	2.0 (−10.1; 14.1)	9.8 (−0.8; 20.5)	26.5 (5.2; 47.8)*	−2.6 (−4.2; −1.0)*
Normal sleep (6–8 h per night, $n = 4,436$) (Ref)	-	-	-	-	-	-
Long sleep (>8 h per night, $n = 589$)	−8.6 (−28.4; 11.3)	−20.6 (−41.6; 0.3)	1.2 (−7.9; 10.2)	−3.9 (−12.4; 4.6)	7.9 (−8.9; 24.7)	3.2 (1.9; 4.4)*

These models are adjusted for age, gender, education, comorbidities, body mass index, employment status and smoking. Analysis with work sitting time only includes participants who were employed, and this model is not adjusted for employment.
*p value < 0.05.

61% in the UK to 44% in France. About 5% of the participants reported spending >90% of their awake time sitting.

Short sleepers spent significantly more minutes per day sitting in front of screens than normal sleepers ($B = 26.5$, 95%CI = 5.2; 47.8). We did not find evidence of a significant association between sleep duration and other domain-specific sedentary behaviour or total sedentary behaviour, and no evidence was found for moderation by age, gender, education, urban region or weight status.

The results when using 'percentage awake time spent sedentary' as an outcome showed that short sleepers spent a slightly smaller proportion of their awake time sedentary ($B = -2.6$, 95%CI = −4.2; −1.0) and longer sleepers a slightly higher proportion ($B = 3.2$, 95%CI = 1.9; 4.4) as compared with normal sleepers.

Discussion

In a large sample of European adults, we examined the cross-sectional association between sleep duration and total time spent sitting, time spent sitting at work, during transport, during leisure and while watching screens. Shorter sleep duration was associated with more screen time sitting. No significant associations were found with total or other domains of sedentary behaviour. The observed (lack of) associations were consistent across the five countries under study, and we did not find differences by gender, age or weight status.

The results support earlier findings that short sleep is associated with more television viewing or computer use (27). One of the explanations is that short sleepers may trade sleep for other activities including television watching (27). Alternatively, it could be that more extensive exposure to screens causes sleep disturbances leading to less average sleep duration (19,20). Although engaging in less screen time might be beneficial for health in its own right (3,28,29), reducing screen time may have a 'double' health benefit, if it reduces sleep deprivation as well. A recent modelling study found that replacing sedentary time with equal amounts of sleeping (in participants who sleep $< 7\,\text{h day}^{-1}$) may indeed have beneficial effects on all-cause mortality (30). Other recent studies have also assumed that sleeping, physical activity and sedentary behaviours are co-dependent, and explored how reallocations in daily proportions of these behaviours would relate to obesity and cardio-metabolic health markers (31,32). The findings of these studies suggested that decreasing sedentary time and maintaining or increasing time spent in moderate to vigorous physical activity would contribute towards a more favourable cardio-metabolic risk profile. Next to such compositional data analysis approaches, experimental studies are needed to confirm whether reducing sedentary (screen) time results in higher amounts of more healthy behaviours (e.g. normal sleep duration) and if this has beneficial health effects (e.g. on weight status).

Although sedentary behaviour and physical activity may be co-dependent from a compositional point of view, there is evidence suggesting that these behaviours act independently towards disease outcomes (33). In our study, we have tested whether leisure time physical activity confounded or moderated the sedentary behaviour–sleep associations, which it did not and was thus not retained in the models (34).

There was no significant difference in sedentary time at work between long and normal sleepers. The relatively small group of long sleepers that were employed may have reduced the power to reach significance.

The results of our analyses where we analysed sedentary behaviour as a proportion of total waking time showed that short sleepers spent slightly less of their waking time sitting than long sleepers. It is important to note here that although examining the proportion of awake time spent sitting may help to understand the sleep-sedentary behaviour relationship, for negative health outcomes associated with sedentary behaviour, the absolute amount of sedentary behaviour (rather than the relative amount) is likely to be more relevant, although further research is needed to confirm this.

A strength of our study is the assessment of the different sedentary behaviour domains in relation to sleep duration. Further strengths include the large study population and the inclusion of data from regions in five European countries. To our knowledge, this is the first study that examined this association in this context.

The main limitations are (i) the cross-sectional nature of the study, so we were not able to study predictive or causal relationships; (ii) the low response rate (10%), a common problem among large European surveys (35); and (iii) that all data were self-reported, which may be subject to bias and possible underestimation of sedentary behaviour because of social desirability bias (36). This underestimation may have occurred in particular in those who were unemployed. However, an advantage of using questionnaires over accelerometers to measure sedentary behaviour is that it is possible to assess domain-specific sedentary behaviours. Further limitations include that sedentary behaviours and sleep duration can vary during weekdays and weekends (27,37), but because this study only assessed sleep duration using a single question and thus not separately for weekdays and weekend days, these possible differences could not be studied, nor were we able to take daytime napping into account. Lastly, sleep quality, stress, pregnancy, medication use and sleep disturbances, all of which are known to have an impact on levels of tiredness and could possibly lead to a less active lifestyle, were not assessed.

In conclusion, in this cross-European study, we found that short sleep duration was associated not only with absolute higher amounts of screen time but also with a relatively smaller proportion of awake time spent sedentary. Associations between sleep and other domains of sedentary behaviours were not found.

Declaration of interests

The authors have no conflicts of interest to declare.

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