Bidirectional associations of sleep and discretionary screen time in adults: longitudinal analysis of the UK Biobank

Short title: Sleep and discretionary screen time

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Conflicts of interest
The authors have no conflicts of interest to disclose.

Author contributions
All authors were involved in the design of the study and interpretation of the data. BHH conducted the statistical analyses. HSK and JPC drafted the manuscript. All authors revised it critically for its intellectual content and approved the final version of the manuscript.

Word count: 2,971 words Number of references: 29

ABSTRACT

The direction of the association between discretionary screen time (DST) and sleep in the adult population is largely unknown. We examined the bidirectional associations of DST and sleep patterns in a longitudinal sample of adults in the general population. A total of 31,361 UK Biobank study participants (52% female, 56.1 ± 7.5 years) had two repeated measurements of DST (TV viewing and leisure-time computer use) and self-reported sleep patterns (5 sleep health characteristics) between 2012 and 2018 (follow-up period of 6.9 ± 2.2 years). We categorized daily DST into three groups (low, <3 h/d; medium, 3 to 4 h/d; and high, >4 h/d), and calculated a sleep pattern composite score comprising morning chronotype, adequate sleep duration (7–8 h/d), never or rare insomnia, never or rare snoring, and infrequent daytime sleepiness. Overall sleep pattern was categorized into three groups (healthy: ≥ 4; intermediate: 2–3; and poor: ≤ 1 healthy sleep characteristic). Multiple logistic regression analyses were applied to assess associations between DST and sleep with adjustments for potential confounders. Participants with either an intermediate (OR: 1.40; 95% CI: 1.15, 1.71) or a poor (OR: 1.16; 95% CI: 1.10, 1.24) sleep pattern at baseline showed higher odds for high DST at follow-up, compared to those with a healthy baseline sleep pattern. Participants with medium (OR: 1.40; 95% CI: 1.14, 1.71) or high DST (OR: 1.62; 95% CI: 1.30, 2.00) at baseline showed higher odds for poor sleep at follow-up, compared to participants with a low DST. In conclusion, our findings provide consistent evidence that high DST at baseline is associated with poor sleep over a nearly 7-year follow-up period, and vice versa.

Key words: chronotype, sleep duration, insomnia, snoring, daytime sleepiness, recreational screen time

INTRODUCTION

Non-occupational screen time is a key modifiable marker of sedentary behaviour. Moderate levels of discretionary screen time (DST, i.e., screen time for leisure outside of work such as watching TV) and healthy sleep have been associated with favourable health outcomes in adults (Chaput et al., 2020a; Chaput et al., 2020b; Saunders et al. 2020). DST and sleep not only impact health outcomes, but they may also influence one another. Excessive screen time is associated with short sleep duration among children, adolescents, and adults (Hisler et al., 2020; Vallance et al., 2015; Hale & Guan, 2015). Short-duration sleepers also tend to engage in more recreational screen time (Chaput & Dutil, 2016), thereby creating the risk of a vicious cycle between excessive screen use and poor sleep.

While the bidirectional association between screen time and sleep is relatively well documented in the pediatric population (Magee et al., 2014; Lin et al., 2018), the evidence is scarce in the adult population and mainly comes from cross-sectional studies. Based on a study of more than 6,000 adults from five urban regions in Europe, Lakerveld et al. (2016) found that short sleep duration was associated with increased screen time, but not with total or other domains of sedentary behaviour. Most adult studies relied on sleep duration as the main sleep characteristic and ignored other important aspects of sleep health, such as sleep quality, timing, and daytime sleepiness (Buysse, 2014). However, research has shown that sleep quality and timing (e.g., snoring and chronotype) are associated with DST in adult population (Vallance et al., 2015; Buman et al., 2015). Yet, these studies were all cross-sectional. The objective of this study was to examine the bidirectional association between DST and sleep patterns in a sample of UK general population adults over nearly seven years of average follow up.

METHODS

The UK Biobank is a large, population-based prospective cohort of adults recruited across the UK between 2006 and 2010. Around 9.2 million invitations were mailed to recruit 502,616 adults (response rate: 5.5%) aged 40-69 years between 2006 and 2010 from 22 centers across the UK to reflect a diverse socioeconomic demographic and mixture of urban and rural residents. Participants completed interviews, physical measurements, and questionnaires at the baseline visit. Detailed information on study methods has been published elsewhere (Sudlow et al., 2015). All participants provided informed consent, and ethical approval was provided by the National Health Service, National Research Ethics Service (Fan et al., 2020).

Two repeated measurements occurred between 2012 and 2018. Participants completing at least one repeat measurement of both DST and sleep were included in the present study. We excluded participants who had no information on DST and sleep (n=96,383) or covariates (n=36,656) at baseline. The final analytic sample comprised 31,361 adults for this analysis. A flowchart of participants included in the present study is presented in Fig. 1.

Measures

Daily DST was calculated as the sum of TV viewing time plus (non-occupational) leisure time computer use. Participants were asked: ‘In a typical day, how many hours do you spend watching TV?’ They were also asked about time spent using a computer: ‘In a typical day, how many hours do you spend using the computer? (Do not include using a computer at work)'. For analysis purpose, DST was categorized into three groups (low, <3 h/d; medium, 3 to 4 h/d; and high, >4 h/d) based on data distribution. In a sensitivity analysis, DST was categorized into two groups (≤3 hours and >3 hours) to align with the cut-point used in the Canadian 24-Hour Movement Guidelines (Ross et al., 2020).

Sleep patterns were self-reported and determined based on a method described in detail previously (Fan et al., 2020; Huang et al., in press). In brief, overall sleep pattern score was defined based on five sleep health characteristics (chronotype, duration, insomnia, snoring, and excessive daytime sleepiness). Healthy sleep characteristics included morning chronotype, adequate sleep duration (7–8 h/d), never or rare insomnia, never or rare snoring, and infrequent daytime sleepiness. Overall sleep pattern was categorized into three groups based on the total number of healthy sleep characteristics, namely healthy: ≥ 4; intermediate: 2–3; and poor: ≤ 1. This method has shown its clinical utility for identifying high-risk sleep patterns for cardiovascular diseases over 8.5 years of follow-up (Fan et al., 2020).

Potential confounders were selected a priori due to their documented association with sleep and DST and included age, sex, follow-up time, body mass index (BMI), socioeconomic status (Townsend area deprivation index), physical activity level, diet quality, shift work, cigarette smoking, alcohol consumption, mental health issues, and history of major cardiovascular disease and cancer. Details about how these variables were assessed and classified are included in Appendix A.

Statistical analysis

All analyses were performed using SAS 9.4 or R 3.6.3. We used a similar analytic design to a recent UK Biobank study (Huang et al., 2021). Using multiple logistic regression, we examined the multivariable-adjusted association of baseline DST (or sleep) with poor sleep (or high DST) at follow-up, with low DST (or healthy sleep) serving as a reference. Another set of logistic regression models examined the association of temporal changes in DST (or sleep patterns) with poor sleep (or high DST) at follow-up, with maintaining a low DST (or healthy sleep) at both

time points serving as a reference. To examine whether some sleep characteristics are driving the associations more than others, additional analyses examined each of the five individual sleep components separately. To do so, we categorized each of the five sleep variables as "healthy-unhealthy" and reran the first set of analyses, as described above. All analyses were adjusted for age, sex, follow-up time, BMI, socioeconomic status, physical activity level, vegetable and fruit intake, shift work, cigarette smoking, alcohol consumption, mental health issues, and history of major cardiovascular disease and cancer. Models were also mutually adjusted for baseline sleep or DST (in addition to other covariates), as appropriate. We conducted a sensitivity analysis using two categories of DST (≤3 hours and >3 hours) to align with the cut-point used in the Canadian 24-Hour Movement Guidelines (Ross et al., 2020). Models were two-sided, and Dunnett's correction was applied for multiple comparisons.

RESULTS

Baseline characteristics of the sample stratified by baseline DST patterns are summarized in Table 1. Of the 31,361 participants, 52% were female, with a mean age of 56.1 ± 7.5 years and a mean follow-up duration of 6.9 ± 2.2 years. At baseline, the mean duration of DST was 3.7 hours per day, and 2% of participants had a poor sleep pattern. Nearly 37% had a late chronotype, 28% had insuficient sleep duration, and 25% had insomnia symptoms. Just over one-third (37%) indicated snoring, and 2% of the participants reported daytime sleepiness. Participants with high DST were more likely to be older and males and to have poor or intermediate sleep quality, late chronotype, insufficient sleep duration, insomnia symptoms, reporting snoring and daytime sleepiness. They were also more likely to have higher BMI, lower physical activity level, and other risk behaviours and health problems.

Table 2 presents the bidirectional associations between baseline sleep (or DST) and DST (or sleep) at follow-up. Compared to participants with a healthy sleep pattern at baseline, those with either an intermediate or a poor sleep pattern showed higher odds for high DST at follow-up (adjusted odds ratio (AOR): 1.40 [1.15, 1.71] and 1.16 [1.10, 1.24], respectively). Results further indicated that those with a late chronotype (AOR: 1.17; 95% CI: 1.10, 1.24), short sleep duration (AOR: 1.10; 95% CI: 1.03, 1.18), and insomnia symptoms (AOR: 1.10; 95% CI: 1.03, 1.18) were more likely to have higher odds for high DST at follow-up. On the other hand, compared to participants with a low DST, those with either medium (AOR: 1.40; 95% CI: 1.14, 1.71) or high DST (AOR: 1.62; 95% CI: 1.30, 2.00) at baseline showed higher odds of poor sleep at follow-up. In the sensitivity analysis, when DST was defined based on the Canadian 24-Hour Movement Guidelines, only those with an intermediate sleep pattern showed higher odds for high DST at follow-up (AOR: 1.13; 95% CI: 1.06, 1.19).

The association of changes in sleep with follow-up high DST are illustrated in Fig. 2A. Compared to participants maintaining a healthy sleep pattern, those changing their sleep pattern from healthy to intermediate (AOR: 1.25; 95% CI: 1.15, 1.37) or from intermediate to poor (AOR: 1.60; 95% CI: 1.28, 2.00) and those keeping their sleep pattern poor (AOR: 1.46; 95% CI: 1.01, 2.09) or indermediate (AOR: 1.27; 95% CI: 1.18, 1.37) showed higher odds for high DST at follow-up. However, changing sleep pattern from healthy to poor (AOR: 1.07; 95% CI: 0.62, 1.86) or from poor to healthy (AOR: 1.43; 95% CI: 0.76, 2.70) showed no significant differences in odds of high DST at follow-up.

Fig. 2B displays the association of changes in various sleep characteristics with high follow-up DST. Compared to participants maintaining a healthy sleep pattern, those shifting from healthy to unhealthy for daytime sleepiness (AOR: 1.44; 95% CI: 1.17, 1.76), chronotype (AOR: 1.26; 95% CI: 1.11, 1.44), and sleep duration (AOR: 1.16; 95% CI: 1.06, 1.26) or kept unhealthy for

insomnia symptoms (AOR: 1.12; 95% CI: 1.03, 1.21), chronotype (AOR: 1.23; 95% CI: 1.15, 1.31), and sleep duration (AOR: 1.13; 95% CI: 1.04, 1.23) had higher odds for high DST at follow-up. However, all improvements in sleep characteristics (i.e., from unhealthy to healthy) showed no significant differences in odds of high DST at follow-up for all sleep indicators, except sleep duration. A shift from unhealthy sleep duration to healthy sleep duration was associated with greater odds of high DST at follow-up (AOR: 1.15; 95% CI: 1.04, 1.26) compared to adults that kept their healthy sleep duration pattern.

Fig. 2C displays the association of changes in DST with poor follow-up sleep pattern. Compared to participants maintaining their DST low, changing DST from high to medium (AOR: 1.76; 95% CI: 1.31, 2.38), from medium to high (AOR: 1.98; 95% CI: 1.44, 2.71), or keeping it at high (AOR: 1.74; 95% CI: 1.32, 2.29) or medium (AOR: 1.50; 95% CI: 1.15, 1.97) was associated with higher odds of poor sleep at follow-up. However, changing DST from high to low, from medium to low, from low to high, or low to medium showed no significant differences in odds of poor sleep at follow-up.

Results of the sensitivity analysis examining the association of changes in sleep with follow-up high DST defined based on the Canadian 24-Hour Movement Guidelines are displayed in Fig. 3. Compared to participants maintaining a healthy sleep pattern, those shifting to a unhealthier sleep category over time or maintaining a unhealthier sleep category had higher odds for high DST at follow-up, except those who shifted from healthy to poor sleep and those who kept a poor sleep pattern. However, those who improved their sleep patterns showed no significant differences in odds of high DST at follow-up.

DISCUSSION

Numerous studies have suggested a bidirectional relationship between high DST and poor sleep among children and adolescents (Magee et al., 2014; Leonard et al., 2021; Kim et al., 2020; Bani-Issa et al., in press); however, such evidence in the adult population is scarce. Our study examined the bidirectional association between DST and sleep patterns in a sample of UK general population adults over nearly seven years of average follow up. The present study is the largest of its kind to examine this knowledge gap and aims to provide critical information that can help to inform public health initiatives and future interventions.

Poor sleep at baseline was associated with high DST at follow up, and vice-versa. Participants with either an intermediate or a poor sleep pattern showed higher odds for high DST at follow-up compared with participants having a healthy sleep pattern. Adults with late chronotype, short sleep duration, and insomnia symptoms were more likely to have higher odds for high DST at follow-up. Individuals with either medium or high DST patterns at baseline showed higher odds for poor sleep at follow-up. Individuals keeping or shifting their DST from medium to high over time were more likely to report poor sleep at follow-up.

The finding that poor sleep at baseline was associated with high DST at follow-up, and vice-versa, is behaviourally and biologically plausible. High levels of exposure to DST (e.g., habitual use of TV, computers, mobile devices, and video games) is associated with poor sleep, such as delayed bedtime and short sleep duration, in cross-sectional studies (Jeong et al., 2021; Stefan et al., 2019). In a large sample of more than 1000 adults from the 2005-2006 US National Health and Nutrition Examination Survey, Vallance et al. (2015) found that participants with the longer screen time (>6 h/day) were more likely to report trouble falling asleep and waking up

during the night, compared to those with the shortest screen times (<2 h/ day). However, they also found accelerometer-assessed sedentary time was not associated with sleep outcomes (Vallance et al., 2015). Similarly, Buman et al. (2015) found that each additional hour of television viewing while sitting per day was associated with greater odds of long sleep onset latency, waking up too early in the morning, poor sleep quality, and high risk for obstructive sleep apnea in a sample of 1000 adults from the 2013 National Sleep Foundation Sleep in America Poll. Christensen et al. (2016) found that longer screen time was associated with shorter sleep duration and worse sleep efficiency in a sample of more than 600 adults enrolled in an internet-based study. They also found that longer screen time around bedtime was associated with poorer sleep quality, decreased sleep efficiency, and longer sleep onset latency (Christensen et al., 2016).

Other research studies have posited that poor sleep is associated with high DST in adults (Mikulovic et al., 2014). For example, Lakerveld et al. (2016) found that short sleep duration was associated with increased screen time, but not with total or other domains of sedentary behaviour in a sample of more than 6,000 adults from five urban regions in Europe. These findings and those from others suggest that screen time may be a more important determinant of poor sleep than total sedentary time or time spent in other domains of sedentary behaviour (Vallance et al., 2015; Lakerveld et al., 2016; Buman et al., 2015). Our findings are consistent with previous studies indicating that high DST is an important determinant of poor sleep, and vice-versa. However, most of the available evidence in the literature comes from cross-sectional data. Our study extends those studies by documenting a prospective bidirectional relationship between high DST and poor sleep patterns. Although with some exceptions, our results underscore the need for consistency and improvement in health behaviours by providing evidence that high DST is associated with poor sleep at follow-up, while low DST over time partially attenuates the unfavorable effect of baseline DST. However, the lack of association in

some cases could be explained by a lower statistical power as translated into large confidence intervals or by the over-reporting of sleep duration and the subsequent ceiling effect, which may have compromised our ability to detect self-reported changes in sleep duration. We also relied on two time points separated by about seven years; behaviours are likely to change over time and it is not possible to capture the true evolution in between data collection.

High DST can result in poor sleep owing to the shift of the circadian clock to a later point in time, the blue light of screens which suppresses melatonin secretion and delays sleep onset, and possible negative impacts on mental health (Sampasa-Kanyinga et al., 2018). Alternatively, poor sleep could lead to high DST as a result of the shift towards later bedtimes, which offers more opportunity for DST (Taillard et al., 2021); or a maladaptive coping strategy for the underlying problem that initiated poor sleep (e.g., stress, anxiety and depressive symptoms) and subsequent daytime sleepiness and fatigue. It is also possible that poor sleep and high DST coexist because risk behaviours tend to cluster within individuals (Teh et al., 2019).

This study has several strengths. First, this study is among the first to examine the prospective bidirectional association between DST and sleep patterns in the adult population. Second, it uses a large prospective study design permitting an assessment of temporality between DST and sleep with the use of repeated measures for both indicators. Third, our analyses were adjusted for a broad range of potential confounders, thus providing greater confidence about the observed associations. Fourth, contrary to previous studies that mostly relied on sleep duration as the main sleep characteristic, the present study examined other important aspects of sleep health, such as chronotype, insomnia, snoring, and excessive daytime sleepiness. Finally, a sensitivity analysis was run grouping DST into two groups (≤3 hours and >3 hours), to confirm that the results did not materially change based on the current Canadian 24-hour Movement Guidelines (Ross et al., 2020).

This study has several limitations worth mentioning. First, DST and sleep indicators were self-reported, which might introduce measurement errors and social desirability bias. The psychometric properties of the tools are also unknown. Second, although this study used a large sample, it may not be representative of the broader population (Fry et al., 2017). However, a recent UK Biobank analysis showed that multivariable adjusted associations of health-related behaviours are not materially influenced by poor representativeness (Stamatakis et al., 2021). Third, this study did not examine the association between different types of screen time activities (or specifically screen time while in bed) and sleep. Research has shown that types of screen time are differentially associated with sleep duration in adolescents (Hisler et al., 2020); future studies should add smartphone use as it is now omnipresent in the daily life of people around the world. Another limitation is related to the possibility of residual confounding from unknown or unmeasured factors, which cannot be excluded in observational studies. Finally, there is a lack of repeated measures for the potential confounders. Future studies with repeated measurements of potential confounders in addition to those of exposure and outcome are needed to investigate the bidirectional association between DST and sleep. Future studies should also examine whether the association between DST and sleep has changed since the emergence of COVID-19, with evidence showing increased screen time and more sleep disturbances during the COVID-19 pandemic.

Conclusions

In conclusion, this study provides the first set of evidence of a bidirectional relationship between DST and sleep in adults. These findings support interventions that concurrently target DST and sleep to enhance improvements in both health behaviours. Future studies using device-based measures of sleep duration and quality are necessary to replicate these findings and get a more in-depth understanding of the underlying mechanisms that explain these associations.

Acknowledgements

This research has been conducted using the UK Biobank Resource under Application Number 25813. JPC is supported by the Canadian Institutes of Health Research and the CHEO Research Institute. BH is a PhD student supported by the Taiwanese Ministry of Education and the University of Sydney. MJD is supported by a Career Development Fellowship (APP1141606) from the National Health and Medical Research Council. ES is funded by the Australian National Health and Medical Research Council through an Investigator Grant Level 2 (APP1194510).

Data availability statement

The data that support the findings of this study are available on reasonable request from Emmanuel Stamatakis (emmanuel.stamatakis@sydney.edu.au). The data are not publicly available due to privacy or ethical restrictions.

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Table 1. Baseline characteristics of participants stratified by discretionary screen time (DST) level.

Variable	Total	Low DST	Medium DST	High DST
Total N (%)	31,361	10,350 (33)	12,195 (39)	8,816 (28)
DST (h/d), Mean (SD) [a]	3.7 (1.9)	1.8 (0.6)	3.5 (0.5)	6.1 (1.7)
Composite Sleep Pattern, N (%) [b]				
Poor	578 (2)	120 (1)	215 (2)	243 (3)
Intermediate	11,602 (37)	3,234 (31)	4,580 (38)	3,788 (43)
Healthy	19,181 (61)	6,996 (68)	7,400 (61)	4,785 (54)
Morning Chronotype, N (%)				
No	11,666 (37)	3,606 (35)	4,492 (37)	3,568 (40)
Yes	19,695 (63)	6,744 (65)	7,703 (63)	5,248 (60)
Adequate Sleep Duration (7 to <9 h/d), N (%)				
No	8,733 (28)	2,564 (25)	3,393 (28)	2,776 (31)
Yes	22,628 (72)	7,786 (75)	8,802 (72)	6,040 (69)
Never or rare Insomnia, N (%)				
No	7,900 (25)	2,317 (22)	3,093 (25)	2,490 (28)
Yes	23,461 (75)	8,033 (78)	9,102 (75)	6,326 (72)
Never or rare Snoring, N (%)				
No	11,601 (37)	3,187 (31)	4,614 (38)	3,800 (43)
Yes	19,760 (63)	7,163 (69)	7,581 (62)	5,016 (57)
Infrequent Daytime Sleepiness, N (%)				
No	677 (2)	196 (2)	251 (2)	230 (3)
Yes	30,684 (98)	10,154 (98)	11,944 (98)	8,586 (97)
Age at Enrollment, Mean (SD)	56.1 (7.5)	54.5 (7.5)	56.3 (7.5)	57.7 (7.3)
Sex, N (%)				
Female	16,281 (52)	6,203 (60)	6,168 (51)	3,910 (44)
Male	15,080 (48)	4,147 (40)	6,027 (49)	4,906 (56)
Follow-up (y), Mean (SD)	6.9 (2.2)	7.0 (2.2)	6.9 (2.2)	6.8 (2.2)
BMI (kg/m^2), Mean (SD)	26.7 (4.3)	25.6 (3.9)	26.9 (4.2)	28.0 (4.6)

Townsend area deprivation index, Mean (SD) [c]	-2.1 (2.6)	-2.1 (2.5)	-2.2 (2.6)	-2.0 (2.7)
Physical Activity (MET h/wk), Mean (SD) [d]	40.3 (44.0)	40.6 (43.3)	41.7 (45.3)	38.0 (42.9)
Diet Quality, N (%) [e]				
Poor	1,860 (6)	453 (4)	707 (6)	700 (8)
Intermediate	19,155 (61)	6,130 (59)	7,488 (61)	5,537 (63)
Healthy	10,346 (33)	3,767 (36)	4,000 (33)	2,579 (29)
Cigarette Smoking, N (%)				
Never	18,789 (60)	6,763 (65)	7,281 (60)	4,745 (54)
Cessation	10,624 (34)	3,051 (29)	4,115 (34)	3,458 (39)
Current	1,948 (6)	536 (5)	799 (7)	613 (7)
Shift Work, N (%)				
Retired/not in the workforce	10,761 (34)	2,385 (23)	4,169 (34)	4,207 (48)
Employed not in shift work	17,890 (57)	7,029 (68)	6,954 (57)	3,907 (44)
Employed in night shift work	1,370 (4)	463 (4)	534 (4)	373 (4)
Employed in day shift work	1,340 (4)	473 (5)	538 (4)	329 (4)
Alcohol Drinking, N (%) [f]				
Never	790 (3)	302 (3)	275 (2)	213 (2)
Quit	743 (2)	236 (2)	282 (2)	225 (3)
< 14 UK Units/wk	17,169 (55)	5,962 (58)	6,621 (54)	4,586 (52)
14 to <28 UK Units/wk	7,822 (25)	2,535 (24)	3,051 (25)	2,236 (25)
≥ 28 UK Units/wk	4,837 (15)	1,315 (13)	1,966 (16)	1,556 (18)
Mental Health Issues, N (%) [g]				
No	21,007 (67)	6,974 (67)	8,304 (68)	5,729 (65)
Yes	10,354 (33)	3,376 (33)	3,891 (32)	3,087 (35)
Major CVD History, N (%) [h]				
No	30,199 (96)	10,108 (98)	11,761 (96)	8,330 (94)
Yes	1,162 (4)	242 (2)	434 (4)	486 (6)
Major Cancer History, N (%)				
No	29,504 (94)	9,787 (95)	11,486 (94)	8,231 (93)
Yes	1,857 (6)	563 (5)	709 (6)	585 (7)

DST: discretionary screen time; SD: standard deviation; BMI: body mass index; UK: United Kingdom; CVD: cardiovascular disease.

[a] DST was measured using a combination of items measuring time spent viewing TV and leisure time spent using a computer in hours per day.

[b] Sleep patterns were categorized based on the presence of five healthy characteristics (morning chronotype, adequate sleep duration (7–8 h/d), never or rarely insomnia, no snoring, and infrequent daytime sleepiness): healthy, 4–5; intermediate, 2–3; poor, 0–1.

[c] Townsend area deprivation index assigns each participant a score based on postcodes. Higher scores represent greater socioeconomic deprivation.

[d] Weekly Metabolic Equivalent of Task (MET mins/wk) was quantified using the short-form International Physical Activity Questionnaire.

[e] Self-reported daily intake of fruits and vegetables served as a proxy for dietary quality by asking, for example, “about how many pieces of fresh fruit would you eat per day?”

[f] Self-reported alcohol consumption was converted into UK unit (1 unit = 10 mL alcohol) and further categorized based on the UK guideline (14 UK units/ wk).

[g] Mental health issues were defined as the self-reported history by asking, “have you ever seen a general practitioner (GP) for nerves, anxiety, tension, or depression?”

[h] ICD 10-based inpatient cardiovascular diseases and cancer history.

Table 2. Multivariable-adjusted association of baseline sleep pattern (or DST) with high DST (or poor sleep) at follow-up, with healthy sleep (or low DST) serving as a reference.

	OR	95% CI
Baseline sleep and follow-up high DST		
Baseline sleep (Poor vs healthy)	**1.40**	**1.15 - 1.71**
Baseline sleep (Intermediate vs healthy)	**1.16**	**1.10 - 1.24**
Baseline sleep characteristic and follow-up high DST		
Baseline chronotype (Unhealthy vs healthy)	**1.17**	**1.10 - 1.24**
Baseline duration (Unhealthy vs healthy)	**1.10**	**1.03 - 1.18**
Baseline insomnia (Unhealthy vs healthy)	**1.10**	**1.03 - 1.18**
Baseline snoring (Unhealthy vs healthy)	1.03	0.97 - 1.09
Baseline daytime sleepiness (Unhealthy vs healthy)	1.01	0.84 - 1.23
Baseline DST and follow-up poor sleep		
Baseline DST (Medium vs low)	**1.40**	**1.14 - 1.71**
Baseline DST (High vs low)	**1.62**	**1.30 - 2.00**
Baseline sleep and follow-up high DST based on the Canadian 24-Hour Movement Guidelines [1]		
Baseline sleep (Poor vs healthy)	1.07	0.86 - 1.32
Baseline sleep (Intermediate vs healthy)	**1.13**	**1.06 - 1.19**

DST: discretionary screen time; OR: odds ratio; CI: confidence interval.
Sleep patterns were categorized based on the number of healthy sleep characteristics (healthy, 4–5; intermediate, 2–3; poor, 0–1).
Discretionary scree time was categorized in three groups (low, <3 h/d; medium, 3 to 4 h/d; and high, >4 h/d).
[1]Discretionary scree time was categorized in two groups (≤3 h/d vs. >3 h/d) based on the Canadian 24-Hour Movement Guidelines for this additional analysis.
The model was adjusted for age, sex, follow-up time, body mass index, socioeconomic status, physical activity level, vegetable and fruit intake, shift work, cigarette smoking, alcohol consumption, mental health issues, history of major cardiovascular disease and cancer, and mutually adjusted for sleep or DST, as appropriate. Dunnett's correction was applied for multiple comparisons.

Figure 1. Flowchart of participants included in the study.

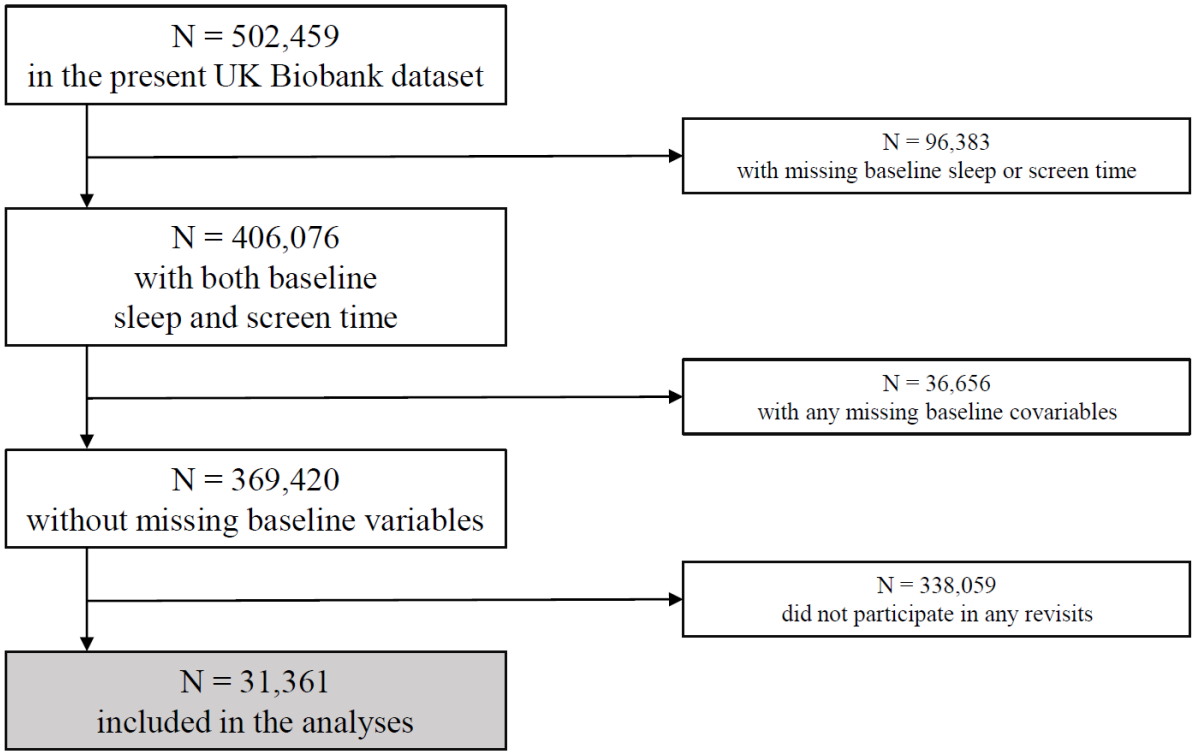
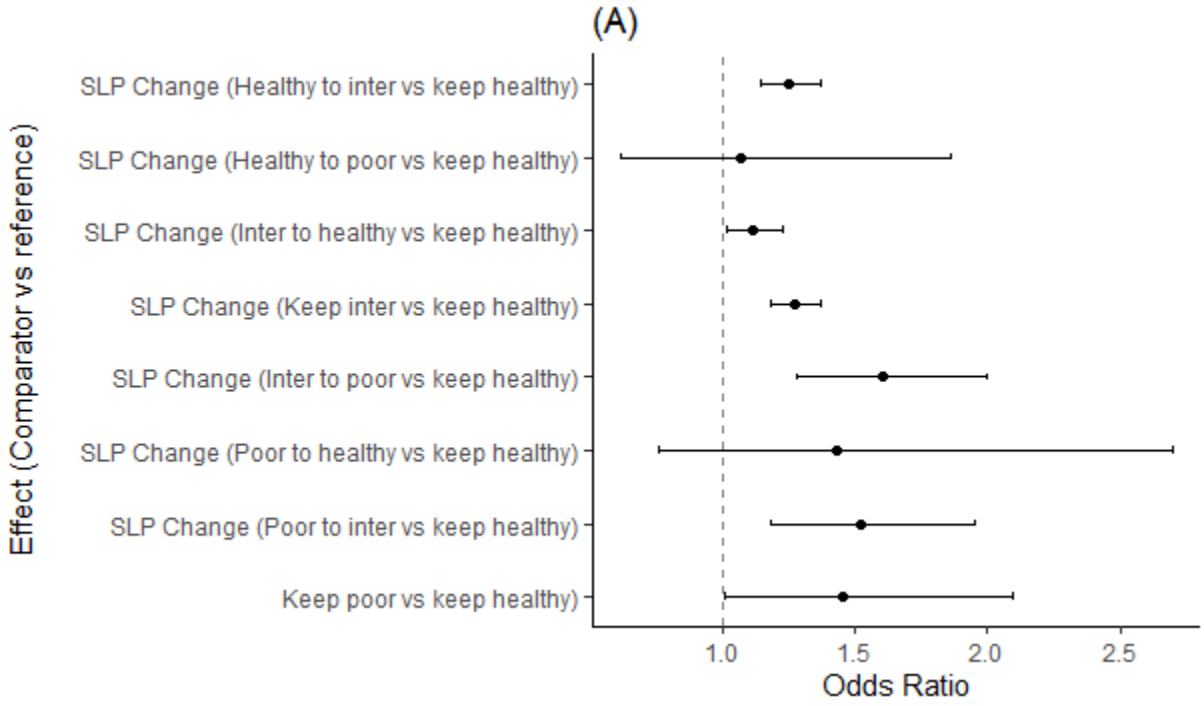
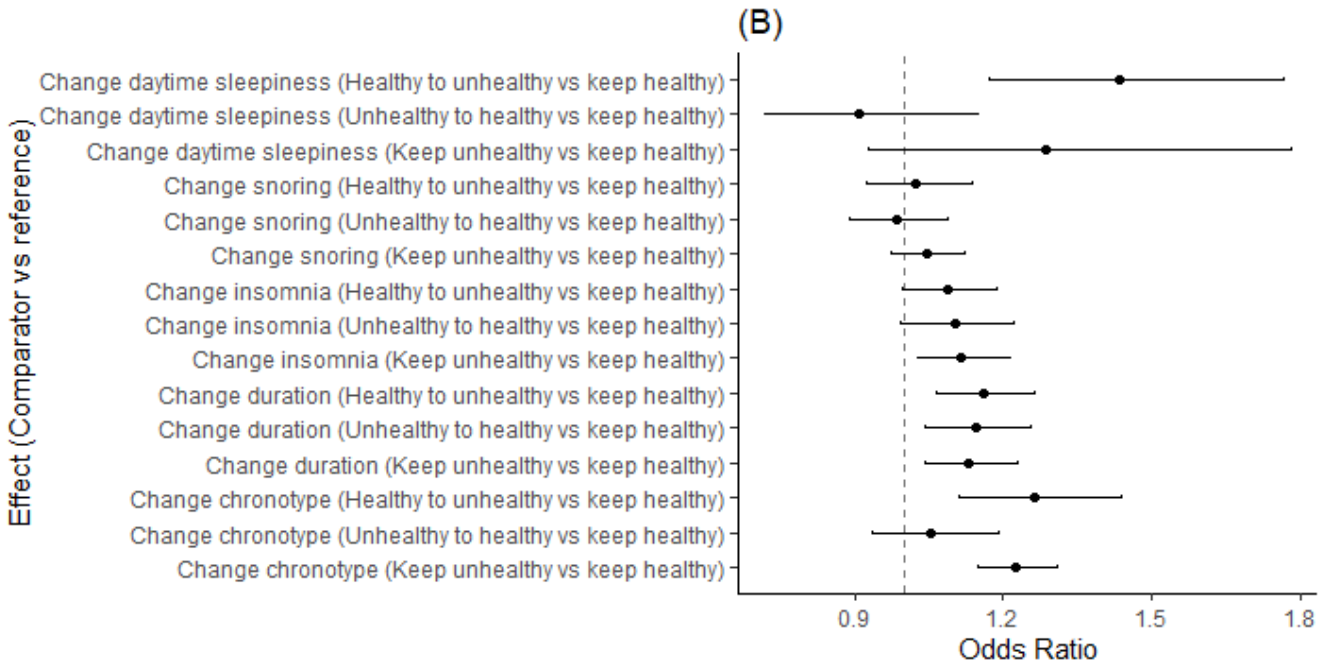


Figure 2. Associations of (A) changes in sleep (SLP) with follow-up high discretionary screen time (DST); (B) changes in specific sleep characteristics with follow-up high DST; and (C) changes in DST with follow-up poor sleep pattern. Discretionary screen time was categorized in three groups (low, <3 h/d; medium, 3 to 4 h/d; and high, >4 h/d). Sleep patterns were categorized based on the number of healthy sleep characteristics (healthy, 4–5; intermediate, 2–3; poor, 0–1). The model was adjusted for baseline outcome, age, sex, follow-up time, body mass index, socioeconomic status, physical activity level, vegetable and fruit intake, shift work, cigarette smoking, alcohol consumption, mental health issues, history of major cardiovascular disease and cancer, and mutually adjusted for sleep or DST, as appropriate. Dunnett's correction was applied for multiple comparisons.




(B)
Change daytime sleepiness (Healthy to unhealthy vs keep healthy)
Change daytime sleepiness (Unhealthy to healthy vs keep healthy)
Change daytime sleepiness (Keep unhealthy vs keep healthy)
Change snoring (Healthy to unhealthy vs keep healthy)
Change snoring (Unhealthy to healthy vs keep healthy)
Change snoring (Keep unhealthy vs keep healthy)
Change insomnia (Healthy to unhealthy vs keep healthy)
Change insomnia (Unhealthy to healthy vs keep healthy)
Change insomnia (Keep unhealthy vs keep healthy)
Change duration (Healthy to unhealthy vs keep healthy)
Change duration (Unhealthy to healthy vs keep healthy)
Change duration (Keep unhealthy vs keep healthy)
Change chronotype (Healthy to unhealthy vs keep healthy)
Change chronotype (Unhealthy to healthy vs keep healthy)
Change chronotype (Keep unhealthy vs keep healthy)
Effect (Comparator vs reference)
0.9
1.2
1.5
1.8
Odds Ratio

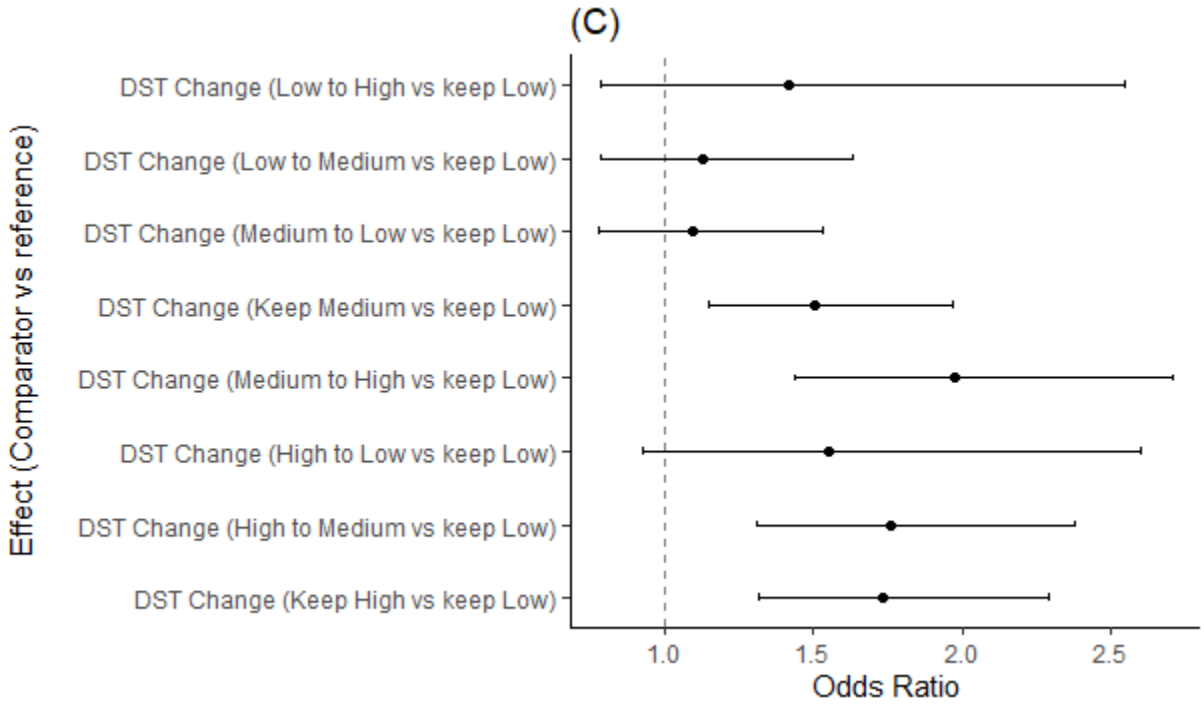

(C)
Effect (Comparator vs reference)
DST Change (Low to High vs keep Low)
DST Change (Low to Medium vs keep Low)
DST Change (Medium to Low vs keep Low)
DST Change (Keep Medium vs keep Low)
DST Change (Medium to High vs keep Low)
DST Change (High to Low vs keep Low)
DST Change (High to Medium vs keep Low)
DST Change (Keep High vs keep Low)
1.0
1.5
2.0
2.5
Odds Ratio

Figure 3. Association of changes in sleep with follow-up high discretionary screen time (DST). Sleep patterns were categorized based on the number of healthy sleep characteristics (healthy, 4–5; intermediate, 2–3; poor, 0–1). Discretionary screen time was categorized in two groups (≤3 h/d vs. >3 h/d) based on the Canadian 24-Hour Movement Guidelines for this additional analysis. The model was adjusted for baseline outcome, age, sex, follow-up time, body mass index, socioeconomic status, physical activity level, vegetable and fruit intake, shift work, cigarette smoking, alcohol consumption, mental health issues, history of major cardiovascular disease and cancer, and mutually adjusted for sleep or DST, as appropriate. Dunnett's correction was applied for multiple comparisons.