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Interactive effects of sleep duration and morning/evening preference on cardiovascular risk factors

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Background: Sleep duration and morningness/eveningness (circadian preference) have separately been associated with cardiovascular risk factors (i.e. tobacco use, physical inactivity). Interactive effects are plausible, resulting from combinations of sleep homeostatic and circadian influences. These have not been examined in a population sample. **Methods**: Multivariable regression models were used to test the associations between combinations of sleep duration (short [≤6 h], adequate [7–8 h], long [≥9 h]) and morning/evening preference (morning, somewhat morning, somewhat evening, evening) with the cardiovascular risk factors of tobacco use, physical inactivity, high sedentary behaviour, obesity/overweight and eating fewer than 5 daily servings of fruit and vegetables, in a cross-sectional sample of 439 933 adults enrolled in the United Kingdom Biobank project. **Results**: Participants were 56% female, 95% white and mean age was 56.5 (SD = 8.1) years. Compared with adequate sleep with morning preference (referent group), long sleep with evening preference had a relative odds of 3.23 for tobacco use, a 2.02-fold relative odds of not meeting physical activity recommendations, a 2.19-fold relative odds of high screen-based sedentary behaviour, a 1.47-fold relative odds of being obese/overweight and a 1.62-fold relative odds of <5 fruit and vegetable daily servings. Adequate sleep with either morning or somewhat morning preference was associated with a lower prevalence and odds for all cardiovascular risk behaviours except fruit and vegetable intake. **Conclusions**: Long sleepers with evening preference may be a sleep phenotype at high cardiovascular risk. Further work is needed to examine these relationships longitudinally and to assess the effects of chronotherapeutic interventions on cardiovascular risk behaviours.

Introduction

Cardiovascular disease is the largest contributor to global mortality[1] with the triad of behavioural risk factors for cardiovascular diseases—tobacco use, physical inactivity and poor dietary intake, accounting for much of the incidence of poor cardiovascular health outcomes such as stroke, angina and hypertension.[2] Sleep is an independent risk factor for cardiovascular risk behaviours and outcomes. As a complex set of physiological functions, sleep patterns are regulated by two independent but related biological systems—sleep–wake homeostasis and circadian rhythms. The homeostatic process mediates the rise of sleep propensity across the day and its dissipation during sleep; this homeostatic process is directly implicated in sleep duration.[3] Circadian rhythms are a clocklike mechanism that function independently of prior sleep and waking and determine the alternation and timing of periods with high and low sleep propensity.[4] Sleep "chronotype" (degree to which an individual prefers morning or evening) is directed by circadian processes.[4] Circadian phase, circadian period, and wake time are highly correlated with morningness and eveningness, or self-reported preference for morning or evening time.[5]

Both sleep duration and sleep timing preference, as independent but related constructs, are part of the aetiology of cardiovascular risk behaviours and outcomes.[6] For example, short- and long-sleep durations have been associated with stroke,[7] coronary artery disease[7] and arterial stiffness.[8] Evening chronotypes have higher odds of type-2 diabetes than morning chronotypes.[9] In terms of cardiovascular risk behaviours, short- and long-sleep duration have been related to increased odds of tobacco use[10] and greater sedentary time.[6] Chronotype has been shown to influence dietary intake such that late chronotypes consume more calories in the evening,[11] eat fewer fruits and vegetables and more saturated fats[11] than early chronotypes. Evening chronotypes have also been found to have higher odds of tobacco use.[6]

This body of work convincingly presents a case for the main effects of these sleep metrics (duration and morning/evening preference) on cardiovascular risk factors and outcomes. What has yet to be understood are the interactive effects of sleep duration and morning/evening preference on cardiovascular risk behaviours. To address this question, we examined the interactive effects of sleep duration and chronotype on the prevalence and odds of the cardiovascular risk factors of tobacco use, physical inactivity, high sedentary behaviour, obesity/overweight, and fruit and vegetable intake in a population sample. This study is another step toward identifying a sleep phenotype for poor cardiovascular health.

Methods

Study design and participants

To examine the interactive relationship between sleep duration and chronotype with tobacco use, physical inactivity, high sedentary behaviour, obesity/overweight, low fruit and vegetable intake, and high stress/anxiety, population data from the United Kingdom (UK) Biobank (application # 3474) were analysed. The UK Biobank is a prospective cohort study that began in 2005. Using patient registers from the UK National Health Service (NHS), adults aged 40–69 years who live within a 10-mile radius of one of the UK Biobank's 35 assessment centres were invited to participate. At a baseline visit, participants provided written informed consent and completed a touch screen questionnaire that assessed socio-demographic, lifestyle and health behaviour variables. Between 2006 and 2010, 502 656 eligible and consenting adults provided baseline data. More expansive details about the rationale, design and survey methods for UK Biobank have been described elsewhere.[12] Study procedures were approved by the UK Biobank Institutional Review Board.

Measures

Independent variables

Sleep duration was assessed with the survey item 'About how many hours sleep do you get in every 24 h?' Responses were coded in integers and categorized as short (≤6 h), adequate (7–8 h) and long (≥ 9 h) duration.[13]

Morning/evening preference was assessed using the question 'Do you consider yourself to be. . .?' (definitely a morning person, more a morning than an evening person, more an evening than a morning person, definitely an evening person). For the current analysis, morning/evening preference was categorized as morning ('definitely a morning person'), somewhat morning ('more a morning than an evening person'), somewhat evening ('more an evening than a morning person') and evening ('definitely an evening person').[14]

Dependent variables

Physical inactivity: Participants estimated how many days in a typical week they engaged in walking, moderate, and vigorous activity for 10 or more minutes.[15] Minutes per week spent in each activity (walking, moderate, vigorous) were calculated. Consistent with physical activity guidelines, participants not accruing 150 min a week of moderate intensity, or 75 min a week of vigorous-intensity activity were coded as inactive.

High screen-based sedentary behaviour: Participants estimated how many hours per day they spend using a computer and watching TV on a typical day. Participants who fell in the upper quartile of hours of sedentary behaviour per day (>5 h) were defined as 'high' sedentary.

Tobacco use: Self-reported smoking status was evaluated using a single item: 'Do you smoke tobacco now?' Participants who reported smoking cigarettes on 'most or all days' (versus occasionally or never) were categorized as smokers.

Obese or overweight: Measured height and weight were used to calculate body mass index (kg/m^2) and determine if an individual was obese (BMI ≥30 kg/m^2) or overweight (BMI ≥25 kg/m^2).

Fruit and vegetable intake: Diet intake was reported using the Food Frequency Questionnaire.[16] Information on fresh/dried fruit, salad and cooked/raw vegetables were combined to create a binary variable to identify individuals who did and did not meet the recommended five or more daily servings of fruit and vegetables (<5/day).

Control variables

Socio-demographic variables included in the analysis were age, sex (male/female), race (coded as White, Asian/Asian British/Chinese, Black/Black British, and mixed/other), attended college (coded as yes/no), employment (coded as employed, not-employed, or retired), shift-work (coded as yes/no) and urban vs. rural residence (coded as urban or rural). Bipolar/major depression disorder status was assessed as a dichotomous variable (yes/no). Participants whose medical chart record indicated ever having a diagnosis of these conditions were coded as 'yes'.

Cross-sectional data from 502 656 participants were obtained. Participants with missing data for any of the study variables were excluded leaving 439 933 participants in the analytic sample. Participants included in the final analysis were significantly more likely to be female, white, non-college attendees, and employed, thus all multivariable analyses were adjusted for these variables. A logistic regression model for each cardiovascular risk factor was generated, regressing each binary outcome on the 12-level variable representing the combinations of sleep duration (short, adequate and long) and timing preference (morning, somewhat morning, somewhat evening, evening). Adequate sleep duration and morning timing preference was used as the reference group for odds ratio calculation. All models were adjusted for the socio-demographic characteristics. Models were also re-run to include the potential confounder of bipolar/major depression disorder status (yes/no). This variable was not included in the main analyses because only ∼100 000 cases had completed this assessment; the findings of this study were not changed by the addition of bipolar/major depression disorder status to the models. Lastly, the prevalence of total cardiovascular risk factors (0–5) for each sleep category was generated using Poisson regression models and the relative rate estimated. Statistical significance is taken at the 0.05 level. All statistical analyses were completed using SAS V9.4 (SAS Institute, Cary, NC).

Results

Descriptive characteristics

In the analytic sample (N = 439 933), 56% were female, 95% were white, and mean age was 56.5 (SD = 8.1) years. Sixty-eight percent reported adequate sleep duration (7–8 h), 36% reported somewhat morning preference. Seven percent of the sample were smokers, 51% were physically inactive, 18% had high levels of sedentary behaviour,

Table 1 Sample characteristics

Characteristic	Total sample, *N* = 439 933
Age [mean (SD)]	59.5 (8.1)
Sex [*N* (%)]	
Male	194 854 (44.3)
Female	245 079 (55.7)
Race [*N* (%)]	
Mixed/other	6298 (1.4)
Asian/Asian British/Chinese	9597 (2.2)
Black/Black British	6601 (1.5)
White	416 106 (94.9)
Attended college [*N* (%)]	
Yes	142 955 (39.5)
No	218 815 (60.5)
Employment status [*N* (%)]	
Unemployed	35 829 (8.2)
Retired	146 531 (33.6)
Employed	253 835 (58.2)
Shift work [*N* (%)]	
Yes	43,073 (9.9)
No	392,597 (90.1)
Residence [*N* (%)]	
Urban	369 446 (84.8)
Rural	66 052 (15.2)
Sleep duration [*N* (%)]	
Short	108 126 (24.6)
Adequate	297 914 (67.7)
Long	33 893 (7.7)
Timing preference [*N* (%)]	
Morning	119 119 (27.1)
Somewhat morning	156 149 (35.5)
Somewhat evening	125 117 (28.4)
Evening	39 557 (9.0)

67% were overweight or obese and 74% consumed <5 daily servings of fruit and vegetables (see table 1 for full listing).

Tobacco use associated with sleep

Across sleep duration categories, adequate sleepers had the lowest smoking rate of 6.4%, while short sleepers had the highest rate of 9.4% (table 2). Across morning/evening preference categories, somewhat morning types had the lowest smoking prevalence at 5.3%, while evening types had the highest rate at 14.1%. The range of smoking prevalence across the 12 possible interactive categories of sleep duration and morning/evening preference was 12.2%: adequate sleepers with somewhat morning preference had the lowest rate of 4.7%, while short sleepers with evening preference had a smoking prevalence of 16.9% (see tables 2 and 3). Tests of the interaction effects of sleep duration and timing preference showed that compared with adequate sleepers with morning preference, short sleepers with evening preference had a more than 3-fold greater odds of tobacco use (aOR = 3.37; 95% CI= 3.14–3.61, P<0.0001) (table 2).

Physical inactivity associated with sleep

As with our previous report, physical inactivity levels differed across sleep duration and morning/evening preferences.[6] For example, 50.3% of long sleepers and 53.8% of those with evening preference did not meet physical activity recommendations (table 2). Across the sleep duration and morning/evening preferences, the range of not meeting physical activity recommendations was 15.2% (table 3). Specifically, 58% of participants who reported being long sleepers with an evening preference reported not meeting physical activity guidelines as compared with 42.8% of adequate sleepers with morning preference (aOR = 2.19; CI = 2.02–2.38) (table 2).

High sedentary behaviour associated with sleep

High sedentary behaviour was most prevalent among long sleepers (24.9%) and least prevalent among adequate sleepers (16.4%). One quarter of evening types (24.4%) reported sedentary behaviour and 15.9% of somewhat morning preference (table 2). Across the interactive sleep duration and morning/evening preferences, the range of high sedentary behaviour was 19.7% (see table 3): the highest prevalence of 34.4% was reported in adults who reported being long sleepers with an evening preference, while the lowest prevalence of 14.7% was reported by adequate sleepers with a somewhat morning preference (table 2). In the multivariable model, long sleepers with an evening preference had a more than 2-fold odds of sedentary behaviour than adequate sleepers with morning preference (aOR = 2.19, 95% CI = 2.02–2.38) (table 2).

Obesity or overweight associated with sleep

The prevalence of obesity or overweight was 65.2%, 70.2% and 71.4% for adequate, short and long sleepers, respectively. Across the morning/evening preference categories, 65.2% of somewhat morning preference and 69.6% of evening types were overweight or obese (table 2). Across the sleep duration and morning/evening preferences, the range of overweight or obese status was 10.4% (see table 3): the highest prevalence was reported in adults who were long sleepers with an evening preference (74.0%) and the lowest in adequate sleepers who reported a somewhat morning preference (63.6%) (table 2). In the multivariable model of obese/overweight, long sleepers who were evening types had a 47% increased odds of being overweight/obese as compared adequate sleepers with morning preference (aOR = 1.47; 95% CI = 1.35–1.60) (table 2).

Fruit and vegetable intake associated with sleep

The prevalence of not meeting the recommended 5 or more daily servings of fruit and vegetables was 74.9%, 73.0% and 75.4% for adequate, short and long sleepers, respectively. Across morning/evening preference categories, 69.6% of morning preference and 78.1% of evening preference participants reported eating <5 daily servings of fruit and vegetables (table 2). Across the interactive sleep duration and morning/evening preferences, the range of eating < 5 daily servings of fruit and vegetables was 10.5% (see table 3): the highest prevalence was reported in adults who were long sleepers and an evening preference (79.3%), and the lowest in those with short duration and morning preference (68.8%) (table 2). In the multivariable model of eating < 5 daily servings of fruit and vegetables, long sleepers who were evening types had a 62% greater relative odds of eating <5 daily servings of fruit and vegetables as compared adequate sleepers with morning preference (aOR = 1.62; 95% CI = 1.48–1.78) (table 2).

Total cardiovascular risk factor count associated with sleep

Overall, most participants reported 1 (22%), 2 (37%) or 3 (28%) cardiovascular risk factors; 8% reported 4, 5% reported 0 and 1% reported 5 (table 4). Compared with adequate sleepers, the expected number of cumulative cardiovascular risk factors was 8% higher among long sleepers and 5% higher among short sleepers. Compared with adults with morning timing preference, the expected number of cumulative cardiovascular risk factors was 18% higher among those with evening preference, 9% higher for somewhat evening preference and 2% higher among those with somewhat morning preference (table 4). When the interactive models of sleep duration and morning/evening preferences were considered, adults who reported long sleep and an evening preference had a 29% higher expected number of cumulative cardiovascular risk factors than adequate sleepers with morning preference (table 4).

Table 2 Prevalence and odds (OR) of cardiovascular risk factors for each sleep category among UK Biobank participants, 2005

Sleep category	Cardiovascular[a] risk factor: Tobacco use % (OR, 95% CI)	Does not meet physical activity guidelines (OR, 95% CI)	High sedentary behaviour % (OR, 95% CI)	Obese/overweight % (OR, 95% CI)	Low fruit and vegetable intake % (OR, 95% CI)
Short sleep, N = 108 126	9.4% (**1.35**, 1.31–1.40) p < .0001	49.2% (**1.11**, 1.09–1.12) p < .0001	20.4% (**1.26**, 1.24–1.29) p < .0001	70.2% (**1.21** 1.19–1.23) p < .0001	73.0% (**0.90**, 0.89–0.92) p < .0001
Adequate sleep (REF), N = 297,914	6.4% (REF)	46.4% (REF)	16.4% (REF)	65.2% (REF)	74.9% (REF)
Long sleep, N = 33 893	8.9% (**1.29**, 1.22–1.35) p < .0001	50.3% (**1.21**, 1.17–1.24) p < .0001	24.9% (**1.35**, 1.31–1.40) p < .0001	71.4% (**1.25**, 1.22–1.29) p < .0001	75.4% (**1.03**, 1.00–1.06) p = 0.1002
Morning preference (REF), N = 119 110	6.0% (REF)	43.8% (REF)	17.4% (REF)	67.9% (REF)	69.6% (REF)
Somewhat morning preference, N = 156 149	5.3% (**0.90**, 0.87–0.94) p < .0001	46.6% (**1.15**, 1.13–1.17) p < .0001	15.9% (**0.92**, 0.90–0.94) p < .0001	65.2% (**0.91**, 0.89–0.92) p < .0001	74.8% (**1.29**, 1.26–1.31) p < .0001
More evening than morning preference, N = 125 117	9.1% (**1.53**, 1.47–1.59) p < .0001	49.7% (**1.29**, 1.27–1.31) p < .0001	19.3% (**1.14**, 1.12–1.17) p < .0001	67.3% (**1.01**, 0.99–1.03) p = 0.2118	77.6% (**1.47**, 1.44–1.50) p < .0001
Evening preference, N = 39,557	14.1% (**2.57**, 2.46–2.69) p < .0001	53.8% (**1.55**, 1.51–1.59) p < .0001	24.4% (**1.59**, 1.54–1.64) p < .0001	69.6% (**1.19**, 1.16–1.22) p < .0001	78.1% (**1.52**, 1.48–1.57) p < .0001
Short sleep + morning preference, N = 33 670	7.8% (**1.43**, 1.34–1.52) p < .0001	45.6% (**1.10**, 1.07–1.13) p < .0001	19.5% (**1.23**, 1.18–1.28) p < .0001	71.1% (**1.21**, 1.17–1.25) p < .0001	68.8% (**0.95**, 0.92–0.98) p < .0007
Short sleep + somewhat morning, N = 35 140	6.9% (**1.23**, 1.15–1.31) p < .0001	48.7% (**1.29**, 1.25–1.32) p < .0001	18.0% (**1.14**, 1.09–1.18) p < .0001	68.4% (**1.08**, 1.05–1.12) p < .0001	73.4% (**1.18**, 1.14–1.22) p < .0001
Short sleep + somewhat evening, N = 27,997	11.5% (**2.11**, 1.99–2.24) p < .0001	51.4% (**1.41**, 1.37–1.46) p < .0001	21.7% (**1.42**, 1.37–1.48) p < .0001	70.3% (**1.21**, 1.17–1.25) p < .0001	76.1% (**1.32**, 1.28–1.37) p < .0001
Short sleep + evening, N = 11 319	16.9% (**3.37**, 3.14–3.61) p < .0001	56.1% (**1.72**, 1.64–1.80) p < .0001	27.0% (**1.97**, 1.87–2.07) p < .0001	72.6% (**1.45**, 1.38–1.53) p < .0001	76.6% (**1.37**, 1.31–1.45) p < .0001
Adequate sleep + morning, N = 77 126	5.2% (REF)	42.8% (REF)	16.0% (REF)	66.1% (REF)	69.9% (REF)
Adequate sleep + somewhat morning, N = 109 841	4.7% (**0.94**, 0.89–0.99) p = 0.0203	45.7% (**1.15**, 1.13–1.17) p < .0001	14.7% (**0.92**, 0.89–0.95) p < .0001	63.6% (**0.92**, 0.90–0.94) p < .0001	75.3% (**1.30**, 1.27–1.33) p < .0001
Adequate sleep + somewhat evening, N = 86 596	8.1% (**1.61**, 1.53–1.69) p < .0001	48.8% (**1.29**, 1.26–1.32) p < .0001	17.6% (**1.13**, 1.09–1.16) p < .0001	65.8% (**1.02**, 1.00–1.05) p < 0.0589	77.9% (**1.48**, 1.45–1.52) p < .0001
Adequate sleep + evening, N = 24 351	12.4% (**2.67**, 2.51–2.83) p < .0001	52.1% (**1.50**, 1.46–1.55) p < .0001	21.6% (**1.52**, 1.46–1.58) p < .0001	67.5% (**1.17**, 1.13–1.21) p < .0001	78.6% (**1.55**, 1.49–1.61) p < .0001
Long sleep + morning, N = 8314	6.9% (**1.27**, 1.13–1.44) p < .0001	45.9% (**1.16**, 1.10–1.23) p < .0001	21.7% (**1.18**, 1.10–1.27) p < .0001	71.4% (**1.21**, 1.14–1.29) p < .0001	70.8% (**1.03**, 0.97–1.09) p = 0.3515
Long sleep + somewhat morning, N = 11 168	6.3% (**1.19**, 1.07–1.32) p = 0.0013	48.3% (**1.30**, 1.24–1.36) p < .0001	21.5% (**1.17**, 1.10–1.25) p < .0001	70.2% (**1.15**, 1.09–1.21) p < .0001	74.8% (**1.30**, 1.23–1.37) p < .0001
Long sleep + somewhat evening, N = 10 524	10.5% (**1.86**, 1.70–2.03) p < .0001	53.0% (**1.57**, 1.50–1.65) p < .0001	27.7% (**1.58**, 1.49–1.68) p < .0001	71.8% (**1.28**, 1.21–1.35) p < .0001	78.2% (**1.48**, 1.40–1.57) p < .0001
Long sleep + evening, N = 3887	16.2% (**3.23**, 2.89–3.62) p < .0001	58.0% (**2.02**, 1.87–2.18) p < .0001	34.4% (**2.19**, 2.02–2.38) p < .0001	74.0% (**1.47**, 1.35–1.60) p < .0001	79.3% (**1.62**, 1.48–1.78) p < .0001

a: Models adjusted for age, college, employment status, shift work, urban vs. rural residence, race, sex.

Table 3 Interactive sleep categories with highest and lowest prevalence for each risk behaviour among UK Biobank participants, 2005

Risk factor	Highest prevalence	Lowest prevalence	Range (%)
Tobacco use	Short duration, evening preference (16.9%) Long duration, evening preference (16.2%)	Adequate duration, more morning than evening preference (4.7%)	12.2
Physical inactivity	Long duration, evening preference (58.0%)	Adequate duration, morning preference (42.8%)	15.2
High sedentary Behaviour	Long duration, evening preference (34.4%)	Adequate duration, more morning than evening preference (14.7%)	19.7
Overweight/obesity	Long duration, evening preference (74.0%)	Adequate duration, more morning than evening preference (63.6%)	10.4
Low fruit and vegetable intake	Long duration, evening preference (79.3%)	Short duration, morning preference (68.8%)Adequate duration, morning preference (69.9%)	10.5
Total risk	Long duration, evening preference	Adequate duration, morning preferenceAdequate duration, more morning than evening preference	

Table 4 Prevalence and relative rate (RR) of total cardiovascular risk factors for each sleep category among UK Biobank participants, 2005

		No. risk factors					
Sleep category	**RR[a] (95% CI)**	**0 (%)**	**1 (%)**	**2 (%)**	**3 (%)**	**4 (%)**	**5 (%)**
Overall	X	5	22	37	28	8	1
Short sleep	1.05 (1.04–1.05)	4.6	20.4	35.8	29.2	9.0	1.0
Adequate sleep (REF)	REF	5.2	23.0	37.6	26.9	6.8	0.5
Long sleep	1.08 (1.07–1.09)	3.5	19.3	34.9	30.2	11.0	1.2
Morning preference (REF)	REF	6.1	24.2	37.3	25.5	6.4	0.5
Somewhat morning	1.02 (1.02–1.03)	5.2	23.4	37.7	26.9	6.3	0.4
Somewhat evening	1.09 (1.08–1.10)	4.0	20.1	36.7	29.5	8.9	0.9
Evening preference	1.18 (1.17–1.19)	3.2	16.9	33.7	32.0	12.5	1.7
Short sleep + morning preference	1.05 (1.04–1.06)	5.3	22.7	36.5	27.1	7.7	0.7
Short sleep + somewhat morning	1.26 (1.24–1.28)	4.9	21.5	36.8	28.6	7.6	0.7
Short sleep + somewhat evening	1.14 (1.13–1.15)	3.8	18.2	35.5	30.9	10.3	1.3
Short sleep + evening preference	1.24 (1.22–1.26)	3.0	15.2	31.8	33.3	14.3	2.4
Adequate sleep + morning preference (REF)	REF	6.5	25.1	37.8	24.6	5.6	0.4
Adequate sleep + somewhat morning	1.03 (1.02–1.04)	5.5	24.3	38.1	26.1	5.7	0.3
Adequate sleep + somewhat evening	1.09 (1.08–1.10)	4.2	21.0	37.4	28.8	8.0	0.7
Adequate sleep + evening preference	1.17 (1.16–1.19)	3.5	18.2	35.2	31.0	10.8	1.3
Long sleep + morning preference	1.06 (1.04–1.08)	4.6	22.6	36.1	27.6	8.2	0.9
Long sleep + somewhat morning	1.09 (1.07–1.11)	3.8	21.2	36.7	29.1	8.6	0.7
Long sleep + somewhat evening	1.17 (1.16–1.19)	3.0	17.0	33.7	31.7	13.1	1.5
Long sleep + evening preference	1.29 (1.26–1.32)	2.0	13.2	30.0	34.9	17.6	2.4

a: Models adjusted for age, college, employment status, shift work, urban vs. rural residence, race, sex.

Post-hoc analysis

To further elucidate the interactive relationship between extreme sleep duration categories (i.e. ≤ 5 h and ≥ 10 h) with timing preference on the odds of engaging in the five target cardiovascular risk factors, a post-hoc analysis using a 5-level sleep duration variable (≤ 5 h, 6 h, 7–8 h, 9 h and ≥ 10 h) was conducted. The results of this analysis did not significantly change the study findings. Specifically, long duration and evening preference remained a high-risk profile, while adequate duration and morning preference was a low-risk profile. The full results from this post-hoc analysis can be found in the Supplementary materials for this manuscript.

Discussion

Inadequate sleep is a demonstrated risk factor for cardiovascular disease and a correlate of cardiovascular risk behaviours[6]; however, the extent to which sleep duration interacts with other sleep metrics to influence cardiovascular risk behaviours is not known. In addressing this gap, results from this study have shown that long-sleep duration interacted with evening preference to emerge as the sleep combination that had the highest, or next to the highest, prevalence and odds (as compared to adequate sleepers with morning preference) for all five cardiovascular risk factors examined (tobacco use, physical inactivity, high sedentary behaviour, obesity/overweight and eating < 5 daily servings of fruit and vegetables). Whereas adequate sleep duration with a morning, or somewhat morning, preference was associated with the lowest prevalence and odds for all risk factors, except fruit and vegetable intake (where short-sleep and morning preference had the lowest prevalence and odds). These are some of the first population data to begin to define a sleep risk phenotype for cardiovascular risk.

Our finding that long sleepers with evening preference had the highest prevalence for all cardiovascular risk factors examined in this study builds on previous studies showing that as independent constructs, long sleepers (versus adequate sleepers) and evening types have a higher likelihood of cardiovascular risk behaviours including tobacco use,[17,18] obesity[19] and lower levels of physical activity.[20] Possible explanations for why the risk factors of chronic tobacco use, physical inactivity, high levels of sedentary time, obesity/overweight and eating < 5 daily servings of fruit and vegetables are more prevalent among long sleepers with evening preference may relate to shared cognitive and hedonic characteristics that are common to these risk factors[21,22] and this sleep pattern.[23,24]

From a cognition perspective, habitual tobacco use, lower levels of physical activity, higher levels of sedentariness and obesity/overweight have all been related to poorer cognitive and executive functions.[25] From a reward or hedonics perspective, limited self-regulation capacity, that is common in hyper-activated reward pathways,[26] has been associated with overeating, tobacco use and low adherence to physical activity.[27,28] Long-sleep duration and evening preference, the sleep risk phenotype identified by this study, have also been related to poorer cognitive function[29] and self-regulation.[23,30] While these data suggest a cognitive and neurological connection between the targeted cardiovascular risk factors in this study and poor sleep (i.e. long-sleep duration and evening preference), the temporal association between these variables is less clear, and whether, for instance, earlier sleep timing can enhance self-regulation.

Another important finding of this study was that within each category of sleep duration, adults with evening preference had a higher prevalence of cardiovascular risk compared with adults with morning or intermediate preferences. Earlier studies have reported that evening preference is associated with cardiovascular risk behaviours, such as tobacco use[31] and physical inactivity.[32] One possible reason for greater cardiovascular risk in evening types is circadian misalignment, or the lack of synchrony among behavioural, environmental or endogenous rhythms.[33] Elevated post-prandial glucose, reduced insulin sensitivity, reduced appetite satiety hormone (leptin), higher waking mean arterial blood pressure and increased inflammation have all been associated with circadian misalignment in controlled laboratory conditions.[34–36] Although chronic circadian misalignment can occur across morning/evening preferences, the magnitude of circadian misalignment is greatest in evening types[37,38]

These results should be interpreted with the consideration of the fact that these population data are cross-sectional and that the sleep duration variable did not distinguish between workdays and free days.[39] Moreover, chronotype was estimated using self-categorization, and not clock times that would have allowed the identification of the sleep mid-point.[40] Reporting of the cardiovascular risk factors including tobacco use, fruit and vegetable intake, physical activity and sedentary behaviour, were also self-report and subject to bias. Despite these limitations, this study is the first to show that long duration and evening preference sleepers have a higher prevalence and odds for several key cardiovascular risk factors. Further work is needed to validate these findings in the longitudinal context and to determine the effects of sleep improvement (i.e. movement toward adequate sleep) in non-clinical populations on cardiovascular risk and outcomes across time. Future studies would also benefit from examining the moderating effects of socio-demographic factors (i.e. employment status and race) and chronic disease status (i.e. type 2 diabetes) on the relationship between sleep patterns and cardiovascular risk behaviours and outcomes. Advances in this work have the potential to define sleep as a viable target for cardiovascular disease prevention at the clinical, community and population level.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- Sleep is a common behaviour that has been associated with cardiovascular disease.
- This study, for the first time, examined the interactive effects of two sleep metrics: sleep duration and morning/evening preference (morning, somewhat morning, somewhat evening, evening) on several key cardiovascular risk factors.
- Long sleepers [≥9 h] with evening preference types had a significantly higher relative odds of tobacco use, not meeting physical activity recommendations, high screen-based sedentary behaviour, obese/overweight and <5 fruit and vegetable daily servings than adequate sleepers who had a morning preference.
- Adequate sleep with either morning or somewhat morning preference was associated with a lower prevalence and odds for all cardiovascular risk behaviours except fruit and vegetable intake.
- Further work is needed to test the effects of chronotherapeutic interventions on cardiovascular risk behaviours.

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Dietary inflammatory index and acute myocardial infarction in a large Italian case–control study

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Background: Diet and inflammation have been implicated to play a role in the incidence of acute myocardial infarction (AMI). **Methods:** In this Italian case–control study conducted between 1995 and 2003, we explored the association between the dietary inflammatory index (DII^{TM}) and AMI. Cases were 760 patients, below age 79 years, with a first episode of nonfatal AMI and controls were 682 patients admitted to hospital for acute conditions unrelated to diet. The DII was computed based on dietary intake assessed using a reproducible and validated 78-item food frequency questionnaire. Odds ratios (OR) were estimated through logistic regression models adjusting for age, sex, total energy intake, tobacco, body mass index, hypertension, hyperlipidemia and other recognized confounding factors. **Results:** Higher DII scores (i.e., indicating a more pro-inflammatory diet) were associated with increased likelihood of AMI when expressed both as continuous ($OR_{continuous}$=1.14, 95% confidence interval, CI:1.05, 1.24; one-unit increase in DII score corresponding to $\approx$9% of the range of DII) and as quartiles ($OR_{Quartile4vs1}$= 1.60, 95%, CI 1.06, 2.41; *P*-trend = 0.02). Stratified analyses produced slightly stronger associations between DII and AMI among women, $\geq$60 years, never smokers, subjects with history of hypertension and subjects with no family history of AMI, however, in the absence of heterogeneity across strata. **Conclusion:** A pro-inflammatory diet as indicated by higher DII scores is associated with increased likelihood of AMI.