Published in final edited form as:
Chronobiol Int. 2016 ; 33(1): 10–21. doi:10.3109/07420528.2015.1107729.

Ethnic differences in sleep duration and morning–evening type in a population sample

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Abstract

This cross-sectional population study examined associations of sleep duration and morning–evening type with sociodemographic and cardiometabolic disease in adults participating in the UK Biobank study (N = 439 933). Multivariable Poisson regression models of sleep duration and morning–evening type with a robust error variance were generated to estimate adjusted prevalence ratios and their 95% confidence intervals. All models were adjusted for sex, race, college attendance, employment status and age. Twenty five percent of the sample reported short sleep; 27% were morning, 64% intermediate and 9% evening type. Black ethnicity emerged as most strongly associated with sleep behavior. Short sleep was twice as prevalent, and morning versus intermediate type was 1.4 times more prevalent in Black than White participants. The greater prevalence of short sleep and morning type among Blacks suggests that sleep-based approaches to improving cardiometabolic outcomes may require a more multidimensional approach that encompasses adequate sleep and circadian alignment in this population.

Keywords

sleep duration; chronotype; cardiometabolic; race/ethnicity; morning/evening type

Introduction

Advances in the treatment of cardiometabolic disease have led to steady declines in both incidence and morbidity from stroke and myocardial infarction since the 1980s (Koton et al., 2014; Krumholz et al., 2014). While much of this progress has been attributed to enhanced pharmacotherapeutic and surgical approaches, there is some evidence that intensive approaches to modify cardiovascular behavioral risk factors (i.e. smoking cessation, physical activity, dietary intake) can also regress disease progression (Koton et al., 2014; Krumholz et al., 2014; Ornish, 1990). Despite this progress, 63% of worldwide deaths are still a result of obesity, diabetes, hypertension and hypercholesteremia; ideal levels of cardiovascular risk

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

factors are achieved by less than 5% of the population; and low-income and underserved groups are disproportionately represented among those at greatest risk for poor cardiometabolic health and outcomes (Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration, 2014; Lloyd-Jones et al., 2014; Roger et al., 2012). Continuing and even accelerating declines in cardiometabolic disease morbidity and mortality may warrant consideration of a broader array of risk factors for cardiometabolic disease beyond the traditional triad of tobacco use, physical inactivity and unhealthy diet (Lloyd-Jones et al., 2014).

Sleep has been seen as a “non-traditional” risk factor for cardiometabolic disease (Chaput et al., 2010; Martinez-Gomez et al., 2013). Supporting this premise is evidence that cardiometabolic disease is more prevalent in short (≤6 h) and long (≥9 h) sleepers (Chaput et al., 2009, 2008; Grandner et al., 2014). Chronotype (preferred sleep–wake timing), or the extent to which an individual is a morning or an evening person (Di Milia et al., 2013; Zavada et al., 2005), is another sleep metric that has been associated with cardio-metabolic risk behaviors and disease (Di Milia et al., 2013; Kanerva et al., 2012; Merikanto et al., 2013; Yu et al., 2015; Zavada et al., 2005). Extending sleep by an average of 35 to 45 min per night for 6 weeks in habitual short sleepers has led to improved insulin sensitivity and blood pressure (Haack et al., 2013; Leproult et al., 2015). While these studies do provide a signal for sleep as a viable target for improving cardiometabolic outcomes, the generalizability of this work is hampered by small sample sizes and stringent inclusion criteria that prevented the enrollment of participants with morning and evening chronotypes (Haack et al., 2013; Leproult et al., 2015). These limitations point to the need to elucidate the relationship between sleep duration and chronotype with cardiometabolic outcomes at the population level.

Relevant to the consideration of sleep as a possible target for cardiometabolic disease are data showing that demographic and socioeconomic status confounds the relationship between sleep duration and cardiometabolic health (Krueger & Friedman, 2009). Disparities in cardiometabolic health have been widely reported. Black ethnicity, lower income and lower educational attainment have been consistently associated with poorer cardiometabolic outcomes and short sleep at the population level (Patel et al., 2010; Roger et al., 2012). Demographic variation in chronotype (variation in sleep–wake timing) is less well elucidated. Given that chronotype can be modified by environmental factors such as light exposure, this sleep metric has the potential to be a target for efforts to improve cardiometabolic health (Wright et al., 2013).

National sleep goals have called for a greater understanding of racial/ethnic and socioeconomic disparities in sleep, as well as the exploration of chronobiological factors, such as chronotype, related to physical health across age groups and among diverse racial/ethnic and socioeconomic groups (US Department of Health and Human Services, National Institute of Health, & National Heart Lung and Blood Institute, 2011; Zee et al., 2014). The lines of evidence presented here suggest that sleep duration, and to a lesser extent, chronotype may be viable targets for approaches to improve cardiometabolic health outcomes. However, this literature is hampered by small sample sizes and limited representation of morning and evening chronotypes. In response to the national sleep goals and to address the limited generalizability of studies to date, the current study examines associations between sociodemographic characteristics and cardiometabolic diseases across sleep duration and morning–evening categories in a large population sample of adults (N = 439 933). Results from this analysis are expected to clarify and identify the associations between sleep duration and chronotype with sociodemographic and cardiometabolic outcomes at the population level and in doing so, present hypotheses for how sleep can be recognized as a multidimensional behavior from which targeted approaches to improving cardiometabolic health can be developed.

Methods

Study design and participants

Data for the current analysis were obtained from The United Kingdom (UK) Biobank (Application #3474). Complete details of the rationale, design and survey methods for UK Biobank have been described elsewhere and information on data available and access procedures are given on the study website (UK Biobank, 2015). Briefly, using patient registers for the UK National Health Service (HNS), adults aged 40–69 years who lived within a 10-mile radius of one of the UK Biobank's 35 assessment centers were invited to participate. At a baseline visit, participants provided written informed consent and completed a touch screen questionnaire assessing sociodemographic, lifestyle and cardiometabolic disease variables. Between 2006 and 2010, 502 656 UK eligible and consenting adults provided baseline data. The University of Pennsylvania Institutional Review Board approved this study.

Measures

Outcome variables

Sleep duration: Sleep duration was assessed with the survey item "About how many hours sleep do you get in every 24 hours? (Please include naps)." Responses were coded in integers and categorized into the following categories for analysis: very short (<5 h), short (5–6 h), adequate (7–8 h) and long (≥9 h) (Grandner et al., 2014).

Chronotype: Chronotype was assessed using a single item that asked participants to rate themselves as definitely a morning person, more a morning than an evening person, more an evening than a morning person, definitely an evening person. The validity of self-reported morning–evening type has been established (Koskenvuo et al., 2007).

Health status variables

Body mass index (BMI): BMI was calculated using measured height and weight with the formula weight (kg)/height (m) squared (Keys et al., 1972). Standing was measured using a Seca 202 height measure. A single weight measurement was taken after participants removed their shoes, socks/tights, heavy outer clothing and emptied their pockets using a Tanita BC-418 MA body composition analyzer. Correlations of BMI with absolute fat mass measured by densitometry range from 0.82 to 0.91(Spiegelman et al., 1992). BMI was categorized as underweight (<18.5), normal range (18.5–24.9), overweight (≥25.0–29.9) and obese (≥30.0) (World Health Organization, 2015).

Single survey items were used to assess the diagnosis of cardiometabolic diseases including heart attack, angina, stroke, hypertension and diabetes. Each diagnosis was coded as yes, no or don't know/prefer not to answer. Daytime dozing/narcolepsy was coded as yes (often/all the time) or no (never/rarely/sometimes) and sleeplessness/insomnia was coded as yes (usually) or no (never/rarely/ sometimes).

Sociodemographic variables—Sociodemographic variables known to influence sleep or morning–evening type were included in this analysis. These included age at recruitment (categorized as <50, 50–69, >70), sex (male/ female), ethnicity (coded as White, Asian/ Asian British/Chinese, Black/Black British, mixed/ other), attended college (coded as yes/no) and employment (coded as employed, not-employed or retired). Shift work and night shift work were recoded as yes (sometimes/usually/always) or no (never/rarely).

Analysis

UK Biobank baseline data from 501 766 participants were obtained. Participants with responses coded "don't know," "prefer not to answer" or missing data for sleep duration, morning/evening person, or BMI variables were excluded leaving 439 933 participants in the final sample. Participants included in the final analysis were significantly more likely to be female, white, non-college attendees and employed. Multivariable models were adjusted for these variables given these differences.

To test the association between sleep duration and morning–evening type with sociodemographic and cardiometabolic variables, descriptive and multivariable analyses were run. All continuous variables were described using means and standard deviations; categorical variables as frequencies and percentages. To examine the distribution of sociodemographic and cardiometabolic variables across sleep duration [short (≤6), adequate (7–8) and long (≥9)] and morning—evening type categories (morning, intermediate and evening), stratified models were also run.

Multivariable Poisson regression models of sleep duration and morning–evening type with a robust error variance were generated to estimate adjusted prevalence ratios (aPRs) and their 99.9% confidence intervals. Separate models for short versus adequate sleep, long versus adequate sleep, morning versus intermediate and evening versus intermediate type were run. All models were adjusted for sex, race, college attendance, employment status and age. Given the large sample size and correspondingly high power to detect statistically significant differences, aPR less than or equal to 0.50 or greater than or equal to 1.90 were considered to have greater clinically meaningful differences (Canfield et al., 2014).

Results

Participant characteristics

Participant characteristics are listed in Table 1. Briefly, participants were mostly white adults (95%) with a mean age of 56.5 ± 8.1. Among these 439 933 participants, 56% were female, 33% attended college and 58% were employed with 10% of employed participants reporting shift work. Sixty seven percent of the participants were overweight or obese. Twenty seven percent of the sample reported having hypertension. Twenty-eight percent reported sleeplessness or insomnia. Fewer than 5% reported ever having a heart attack, stroke, angina or diabetes. Similarly fewer than 5% reported daytime dozing/narcolepsy.

Sociodemographic and health status variation in sleep duration

The distribution of sociodemographic and health status variables in each sleep duration category is provided in Table 1. Of the total sample, 1% reported very short sleep, 25% reported short sleep, 68% reported adequate sleep and 8% reported long sleep. A U-shaped pattern in the distribution of sleep duration with several cardio-metabolic diseases emerged. For example, among participants who reported ever having a heart attack, 5.6% reported very short sleep, 2.5% reported short sleep, 1.9% had adequate sleep and 4.0% had long sleep. This "U"-shaped association whereby a higher prevalence for the outcome of interest was seen for short and long than adequate sleep was also observed in females, unemployed and retired participants, definitely evening chronotype, "not at all easy" and "not very easy" ease of getting up in the morning, obesity, all chronic health conditions (heart attack, angina, stroke, hypertension, diabetes) and dozing/ narcolepsy.

Sociodemographic and health status variation in morning–evening type

The distribution of sociodemographic and health status variables among sleep duration categories is provided in Table 2. Of this total sample, 27% were morning types, 64% were intermediate types ("more morning than evening" or "more evening than morning") and 9% were evening types. A U-shaped pattern in the distribution of morning–evening type emerged for all non-White ethnic groups, unemployed participants, shift workers and night shift workers, very short and short sleepers, underweight and obese participants, all chronic health conditions (heart attack, angina, stroke, hypertension, diabetes), sleeplessness/ insomnia and dozing/narcolepsy.

Adjusted prevalence ratios for adequate sleep by sociodemographic and health status characteristics

Table 3 provides the aPRs and 99.9% confidence intervals for the association between adequate sleep and sociodemographic and cardiometabolic disease variables. Focusing on statistically significant results with an association less than or equal to 0.50 and greater than or equal to 1.90, Black/Black British ethnicity and sleeplessness/ insomnia were strongly associated with short versus adequate sleep. Black/Black British adults reported a two times greater prevalence of short versus adequate sleep compared to Whites (aPR = 1.9632, 99.9% CI = 1.8704–2.0206). Participants reporting sleeplessness/insomnia had approximately three times greater prevalence of short versus adequate sleep compared to those without these sleep conditions (aPR = 2.5720, 99.9% CI = 2.5243–2.6205).

Sociodemographic and cardiometabolic disease variables showing a strong association (aPR less than or equal to 0.50 and greater than or equal to 1.90) with long versus adequate sleep included employment, ease of getting up in the morning and daytime dozing/narcolepsy. Unemployed participants reported a three times greater prevalence of long versus adequate sleep (aPR = 3.0410, 99.9% CI = 2.8612–3.2320). Retired participants reported a two times greater prevalence of long versus adequate sleep (aPR = 2.3565, 99.9% CI = 2.2433–2.4755). Participants reporting that it was "not at all easy" (versus very easy) to get up in the morning were approximately three times more likely to report long versus adequate sleep (aPR = 2.9740, 99.9% CI = 2.5942–3.0092). Participants reporting dozing/narcolepsy reported a two times greater prevalence of long versus adequate sleep (aPR = 2.0212, 99.9% CI = 1.8544–2.2030).

Adjusted prevalence ratios for morning–evening type by sociodemographic and health status characteristics

Table 4 provides the aPRs and 99.9% confidence interval showing the associations between morning–evening type with sociodemographic and cardiometabolic disease variables. Focusing on statistically significant results with an association less than or equal to 0.50 and greater than or equal to 1.90, only the ease of getting up in the morning variable was strongly associated with evening versus intermediate type. Participants reporting that it was not at all easy to get up in the morning had a 11 times greater prevalence of evening versus intermediate type (aPR = 10.8567, 99.9% CI = 10.1004–11.6697). Those reporting that it was not very easy to get up in the morning had a six times greater prevalence of evening versus intermediate type (aPR = 5.9958, 99.9% CI = 5.5952–6.4252), while those reporting that it was fairly easy to get up in the morning, compared to very easy to get up in the morning, had a two times greater prevalence of being evening versus intermediate type (aPR = 1.9045, 99.9% CI = 1.7761–2.0422).

Discussion

We examined the association between sociodemographic and cardiometabolic disease variables with sleep duration and morning–evening type in a large population of adults from the United Kingdom who were part of the National Health Service. One quarter of the population reported short sleep (24.5%) and 68% reported adequate sleep. For morning–evening type, intermediate was most common, with 63.9% reporting some combination of morningness and eveningness, 27.1% reported definitely morning and 9.0% reported definitely evening. While the associations between sociodemographic and cardiometabolic disease variables with sleep duration and morning–evening type were statistically significant for most variables, the variables most strongly associated with sleep duration were ethnicity, employment, ease of getting up in the morning and sleep problems. Ease of getting up in the morning showed the strongest association with morning–evening type than any other exposure variable.

Our finding that adequate sleep was less prevalent in Black ethnicity supports and extends earlier work. Epidemiologic studies have consistently shown that self-reported and actigraphy-monitored sleep is shorter in Black than White adults (Nunes et al., 2008; Sands et al., 2012). One reason for disparities in sleep duration may be that Blacks are more likely to reside in “sleep polluted” urban neighborhoods that are less conducive to adequate sleep because of noise, crowding, ambient light at night and higher crime rates (Hale & Phuong, 2007). When urban versus rural residence is controlled, racial differences in sleep duration have been reported to be no longer significant (Gamaldo et al., 2013). Short sleep is a demonstrated predictor for cardiometabolic disease (Grandner et al., 2014) and Black adults bear a disproportionate burden of cardiometabolic morbidity and mortality (Grandner et al., 2014; Roger et al., 2012). Together, these data suggest that lack of adequate sleep may be a high-priority risk factor for cardiometabolic disease among Blacks.

Our data showed that morning type (versus intermediate) were more prevalent in Black adults. This racial difference in morning–evening type may stem from racial differences in biological, socio-occupational and environmental factors that affect morningness–eveningness. From a biological perspective, tau is a factor that contributes to the extent that someone is a morning or an evening type: a shorter tau contributes to morningness and a longer tau contributes to eveningness. Blacks have been found to have shorter tau's (and therefore potentially more likely to be morning type) than other races (Eastman et al., 2012; Smith et al., 2009). Data from this study are one of the first to translate these clinical findings to racial/ethnic differences in chronotype at the population level.

From a socio-occupational perspective, racial/ ethnic differences in work schedules (e.g. shift work) exist. Blacks are more likely to be employed in shift work and be exposed to factors that contribute to delayed sleep such as less flexible work schedules, less predictable work, more job-related stress and greater urban living (Ertel et al., 2011; Golden, 2001; Jackson et al., 2013; Presser, 2003). These factors can delay sleep onset and are particularly deleterious to morning types. For example, morning types who work night shifts experience reduced REM sleep, longer REM latency, shorter sleep, greater sleep–wake irregularity and poorer sleep quality (Juda et al., 2013; Narciso et al., 2013). Combined, the biological predisposition to morning type but the socio-occupational demands for night work disproportionately experienced by Blacks could result in circadian misalignment by requiring Blacks to adapt sleep patterns counter to their endogenous biological rhythms. Relevant to this hypothesis are data showing that as compared to other racial groups, Blacks are less able to phase delay or are less apt to transition to an evening schedule in response to extraneous factors (Smith et al., 2009).

Racial differences in response to light/dark cues could also explain the higher prevalence of morningness in Blacks. Blacks are more responsive to morning light that promotes early waking than Whites. Data suggest that Blacks advance their sleep–wake times three times as great in response to morning light than Whites (Smith et al., 2009). By contrast, Blacks are less responsive to evening light that delays sleep onset than Whites. Blacks delay their sleep–wake times only half as much as Whites in response to evening light (Smith et al., 2009). These data underscore that Blacks adapt more strongly to environmental cues that promote morningness and are less able to adapt to environmental cues that promote eveningness. In sum, racial difference in chronotype at the population level is a novel and potentially important finding that brings together these lines of evidence of racial differences in biological, soio-occupational and environmental factors affecting morningness/eveningness.

Evidence that morning types have better cardiometabolic outcomes seems incongruent with the disproportionate burden of cardiometabolic disease in Blacks, especially given the higher prevalence of morning types in Blacks shown by our data (Merikanto et al., 2013). One reason for this discrepancy is the possibility of widespread circadian misalignment that may be experienced by Black individuals who are biologically predisposed to morningness, but required to live an evening-type schedule because of occupational constraints (e.g. shift work) (Smith et al., 2009). Contributing to this hypothesis are recent data showing that rotating night shift work among nurses was associated with an increased risk of hypertension in Blacks but not in Whites (Lieu et al., 2012). Therefore, one implication of these data is that improving cardiometabolic outcomes may hinge on promoting circadian alignment in addition to adequate sleep in Blacks

Extreme difficulty in getting up in the morning was approximately three times more prevalent in long versus adequate sleep and approximately eleven times more prevalent in evening versus intermediate types. Our data also showed that cardiometabolic diseases were more prevalent in long versus adequate sleepers. Greater difficulty rising in long sleepers may be related to the greater prevalence of cardiometabolic disease in this group (Cappuccio et al., 2010). Greater difficulty getting up in the morning reported by evening types suggests that they are rising earlier in their circadian cycles than morning and intermediate types (Duffy et al., 1999). In a broader context, this may also be attributed to greater sleep-related complaints (e.g. nightmares, sleeping pill use) among evening types (Merikanto et al., 2012). Difficulty getting up in the morning is implicated in individuals with depressive disorders. These data would suggest that considering depression and negative affect in relation to sleep duration and chronotype is necessary (Chellappa et al., 2009).

The multivariable nature of sleep was underscored by our finding that sleep duration and morning–evening type varied significantly for nearly all sociodemographic and cardiometabolic health outcomes. While the causal association between sleep duration and morning–evening type with the cardiometabolic diseases cannot be examined in these cross-sectional data, we can hypothesize about the complex interplay of variables linking sleep with cardiometabolic health. A growing movement in the chronic disease field is the clustering of health risk behaviors and the scientific acknowledgement that cardiovascular diseases, such as angina, are the product of several modifiable risk behaviors (Jensen et al., 2008; Notara et al., 2014). The American Heart Association's "heart score" is a clinical representation of this line of work that defines risk of cardiovascular events based on obesity, tobacco use, dietary behavior and physical activity behaviors (American Heart Association, 2015; Eckel et al., 2014). Sleep, as a modifiable risk factor that has been shown to relate to cardiovascular disease, has yet to be fully considered in this landscape of risk factor clustering in the etiology of cardiometabolic diseases. Data from this study would suggest that future studies should more fully consider how sleep relates to the prevalence and co-occurrence of other cardiometabolic risk behaviors.

Data from this study should be interpreted with consideration of the cross-sectional and self-report nature of the study methodology. The temporal relationship between the variables studied (i.e. sleep duration and angina) cannot be determined. Participants were not queried about sleep quality or differences in work-day and free-day sleep duration. This limited our ability to elucidate relationships between these aspects of sleep and cardiometabolic disease. A further limitation was that circadian preference was determined by participants' responses to one question about whether they considered themselves . . . definitely a morning person, more a morning than an evening person, more an evening than a morning person, definitely an evening person. Nevertheless, this is one of the largest population level examinations of demographic and health status by sleep duration and the first population level examinations of demographic and health status by morning–evening type. Consistent with previous studies, Black ethnicity was associated with short sleep. Novel to this field is the finding that morning type had a significantly higher prevalence in Black adults. Together, these findings present the hypothesis that circadian-misalignment may be more prevalent among Blacks who may be forced to late or irregular sleep times that are incompatible with morning types because of environmental and scheduling factors. Future research to examine treatment response to targeted interventions designed to promote adequate sleep through circadian alignment in Black adults as well as efforts to consider the role of sleep in the myriad of tobacco use, physical inactivity and poor dietary intake risk factors on cardiometabolic disease are needed.

Acknowledgments

This research has been conducted using the UK Biobank Resource.

Funding

Funding for this study was provided by the Robert Wood Johnson Health and Society Scholars Program at the University of Pennsylvania. This funding source did not influence the study design, the collection, analysis and interpretation of data, the writing of the report, nor the decision to submit the article for publication.

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Table 1

Prevalence of very short, short, adequate and long sleep for participant sociodemographic and cardiometabolic characteristics.

Sleep		Very short	Short	Adequate	Long
	Total sample ***N*** **= 439 933**	**<5 h** ***N*** **= 4691**	**5–6 h** ***N*** **= 103 435**	**7–8 h** ***N*** **= 297 914**	**≥9 h** ***N*** **= 33 893**
	n **(*XX, xx*)**	***n*** **(*XX, xx*)**	***n*** **(*XX, xx*)**	***n*** **(*XX, xx*)**	***n*** **(*XX, xx*)**
Sociodemographic characteristics					
Age^					
<50	102 949 (23.4)	1021 (21.8, 0.2)	23 243 (22.5, 5.3)	72 579 (24.4, 16.5)	6106 (18.0, 1.4)
50–69	334 850 (76.1)	3654 (77.9, 0.8)	79 724 (77.1, 18.1)	223 923 (75.2, 50.9)	27 549 (81.3, 6.3)
≥70	2134 (0.5)	16 (0.3, 0)	468 (0.5, 0.1)	1412 (0.5, 0.3)	238 (0.7, 0.1)
Sex					
Female	245 079 (55.7)	2745 (58.5, 0.6)	56 431 (54.6, 12.8)	166 452 (55.9, 37.8)	19 451 (57.4, 4.4)
Male	194 854 (44.3)	1946 (41.5, 0.4)	47 004 (45.4, 10.7)	131 462 (44.1, 29.9)	14 442 (42.6, 3.3)
Ethnic group					
Mixed/other	6298 (1.4)	141 (3.0, 0.03)	1976 (1.9, 0.5)	3718 (1.2, 0.9)	463 (1.4, 0.1)
Asian	9597 (2.2)	169 (3.6, 0.04)	2698 (2.6, 0.6)	5992 (2.0, 1.4)	738 (2.2, 0.2)
Black	6601 (1.5)	263 (5.6, 0.06)	2741 (2.6, 0.6)	3172 (1.1, 0.7)	425 (1.3, 0.1)
White	416 106 (94.6)	4658 (87.1, 1.1)	95 645 (92.5, 21.8)	284 224 (95.4, 64.8)	32 152 (94.9, 7.3)
Employment					
Unemployed	35 829 (8.1)	1207 (26.1, 0.3)	9123 (8.8, 2.1)	20 507 (6.9, 4.7)	4992 (14.7, 1.1)
Retired	146 531 (33.3)	1547 (33.0, 0.4)	30 121 (29.1, 6.9)	97 787 (32.8, 22.4)	17 076 (50.4, 3.9)
Employed	253 835 (57.7)	1869 (39.8, 0.4)	63 254 (61.2, 14.5)	177 240 (59.5, 40.6)	11 472 (33.8, 2.6)
Attended college					
Yes	142 955 (32.5)	777 (16.6, 0.2)	29 927 (28.9, 8.3)	103 936 (34.9, 28.7)	8315 (24.5, 2.3)
No	218 815 (49.7)	2220 (47.3, 0.6)	52 525 (50.8, 14.5)	147 599 (49.5, 40.8)	16 471 (48.6, 4.6)
Shift work					
Yes	43 073 (9.9)	578 (12.3, 0.1)	13 474 (13.2, 3.1)	26 731 (9.1, 6.1)	2290 (6.8, 0.5)
No	392 597 (90.1)	4031 (1.0, 0.9)	88 897 (22.6, 20.4)	268 462 (68.3, 61.6)	31 207 (8.0, 7.2)
Night-shift work					
Yes	21 695 (5.0)	352 (7.6, 0.1)	7411 (7.2, 1.7)	12 783 (4.3, 2.9)	1149 (3.4, 0.3)

Sleep		Very short	Short	Adequate	Long
	Total sample ***N*** **= 439 933**	**<5 h** ***N*** **= 4691**	**5–6 h** ***N*** **= 103 435**	**7–8 h** ***N*** **= 297 914**	**≥9 h** ***N*** **= 33 893**
	n **(*XX*, *xx*)**	***n*** **(*XX*, *xx*)**	***n*** **(*XX*, *xx*)**	***n*** **(*XX*, *xx*)**	***n*** **(*XX*, *xx*)**
No	414 241 (95.0)	4264 (92.4, 1.0)	95 030 (92.8, 21.8)	282 579 (95.6, 64.8)	32 368 (96.6, 7.4)
Sleep behavior characteristics					
Chronotype					
Definitely morning	119 110 (27.1)	1647 (35.1, 0.4)	32 023 (31.0, 7.3)	77 126 (25.9, 17.5)	8314 (24.5, 1.9)
More morning than evening	156 149 (35.5)	1295 (27.6, 0.3)	33 845 (32.7, 7.7)	109 841 (36.9, 25.0)	11 168 (33.0, 2.5)
More evening than morning	125 117 (28.4)	1113 (23.7, 0.3)	26 884 (26.0, 6.1)	86 596 (29.1, 1, 9.7)	10 524 (31.1, 2.4)
Definitely evening	39 557 (9.0)	636 (13.6, 0.1)	10 683 (10.3, 2.4)	24 351 (8.2, 5.5)	3887 (11.5, 0.9)
Ease of getting up in the morning					
Not at all easy	17 288 (3.9)	621 (13.2, 0.1)	4865 (4.7, 1.1)	8986 (3.0, 2.0)	2816 (8.3, 0.6)
Not very easy	62 604 (14.2)	880 (18.8, 0.2)	15 360 (14.9, 9.2)	40 379 (13.6, 9.2)	5985 (17.7, 1.4)
Fairly easy	217 511 (49.4)	1475 (31.6, 0.3)	47 234 (45.7, 10.8)	153 592 (51.6, 34.9)	15 210 (44.9, 3.5)
Very easy	142 181 (32.3)	1697 (36.3, 0.4)	35 846 (34.7, 8.2)	94 788 (31.8, 21.7)	9850 (29.1, 2.2)
Cardiometabolic characteristics					
BMI[^^]					
<18.5	2305 (0.5)	34 (0.7, 0.01)	571 (0.6, 0.1)	1506 (0.5, 0.3)	194 (0.6, 0.04)
18.5–24.9	143 441 (32.6)	1187 (25.3, 0.3)	30 498 (29.5, 6.9)	102 253 (34.3, 23.2)	9503 (28.0, 2.2)
25.0–29.9	186 566 (42.4)	1728 (36.8, 0.4)	43 065 (41.6, 9.8)	127 674 (42.9, 29.0)	14 099 (41.6, 3.2)
≥30	107 621 (24.5)	1742 (37.1, 0.4)	29 301 (28.3, 6.7)	66 481 (22.3, 15.1)	10 097 (29.8, 2.3)
Health problems					
Heart attack	9892 (2.2)	264 (5.6, 0.1)	2608 (2.5, 0.6)	5674 (1.9, 1.3)	1346 (4.0, 0.3)
Angina	13 896 (3.2)	377 (8.0, 0.1)	3785 (3.7, 0.9)	7920 (2.7, 1.8)	1814 (5.4, 0.4)
Stroke	6525 (1.5)	165 (3.5, 0.04)	1709 (1.7, 0.4)	3685 (1.2, 0.8)	966 (2.9, 0.2)
Hypertension	118 803 (27.0)	1774 (37.8, 0.4)	30 267 (29.3, 6.9)	75 482 (25.3, 17.2)	11 280 (33.3, 2.6)
Diabetes	21 710 (4.9)	444 (9.5, 0.1)	5662 (5.5, 1.3)	12 751 (4.3, 2.9)	2853 (8.4, 0.7)
Sleep problems					
Sleeplessness/insomnia	123 869 (28.2)	4009 (85.5, 0.9)	50 501 (48.9, 11.5)	62 072 (20.8, 14.1)	7287 (21.5, 1.7)
Dozing/narcolepsy	12 101 (2.8)	367 (7.9, 0.1)	3864 (3.8, 0.9)	5965 (2.0, 1.4)	1894 (5.6, 0.4)

Note: *N*: count, *XX*: column percent, *xx*: overall percent, h: hours, CI: confidence interval,

^Mean age (sd): overall 56.5 (8.1), very short 56.7 (7.8), short 56.4 (7.9), adequate 56.4 (8.1), long 58.5 (8.0),

^^Mean BMI (sd): overall 27.4 (4.8), very short 29.1 (5.9), short 27.9 (5.1), adequate 27.2 (4.6), long 28.1 (5.2).

Table 2

Prevalence of morningness–eveningness categories for participant sociodemographic and cardiometabolic characteristics.

		Intermediate type		
	Morning *N* = 119 110 (27.1%)	**More morning than evening *N* = 156 149 (35.5%)**	**More evening than morning *N* = 125 117 (28.4%)**	***Evening N* = 39 557 (9.0%)**
Total sample	***n* (*XX*, *xx*)**	***n* (*XX*, *xx*)**	***n* (*XX*, *xx*)**	***n* (*XX*, *xx*)**
Sociodemographic characteristics				
Age^				
<50	23 060 (19.4, 5.2)	34 443 (22.1, 7.8)	33 568 (26.8, 7.6)	11 878 (30.0, 2.7)
50–69	95 427 (80.1, 21.7)	120 939 (77.5, 27.5)	90 980 (72.7, 20.7)	27 504 (69.5, 6.3)
≥70	623 (0.5, 0.1)	767 (0.5, 0.2)	569 (0.5, 0.1)	175 (0.4, 0.04)
Sex				
Female	67 296 (56.5, 15.3)	87 647 (56.1, 19.9)	69 035 (55.2, 15.7)	21 101 (53.3, 4.8)
Male	51 814 (43.5, 11.8)	68 502 (43.9, 15.6)	56 082 (44.8, 12.6)	18 456 (46.7, 4.2)
Ethnic group				
Mixed/other	1946 (1.6, 0.4)	1783 (1.2, 0.4)	1816 (1.5, 0.4)	753 (1.9, 0.2)
Asian	3564 (3.0, 0.8)	2763 (1.8, 0.6)	2385 (1.9, 0.5)	885 (2.3, 0.2)
Black	2287 (1.9, 0.5)	1872 (1.2, 0.4)	1779 (1.4, 0.4)	663 (1.7, 0.2)
White	110 941 (93.4, 25.3)	142 292 (95.9, 34.0)	118 798 (95.2, 27.1)	37 075 (94.2, 8.5)
Employment				
Unemployed	9227 (7.8, 2.1)	10 931 (7.1, 2.5)	11 092 (8.9, 2.5)	4579 (11.7, 1.1)
Retired	42 586 (36.1, 9.8)	54 154 (34.9, 12.4)	38 815 (31.3, 8.9)	10 976 (28.0, 2.5)
Employed	66 161 (56.1, 15.2)	89 889 (58.0, 20.6)	74 201 (59.8, 17.0)	23 584 (60.3, 5.4)
Attended college				
Yes	35 203 (38.2, 9.7)	51 653 (39.6, 14.3)	40 508 (38.6, 11.2)	15 591 (45.4, 4.3)
No	56 956 (61.8, 15.7)	78 733 (60.4, 21.8)	64 385 (61.4, 17.8)	18 741 (54.6, 5.2)
Shift work				
Yes	11 499 (9.8, 2.6)	13 563 (8.8, 3.1)	13 200 (10.7, 3.0)	4811 (12.3, 1.1)
No	106 288 (90.2, 24.4)	141 277 (91.2, 32.4)	110 762 (89.4, 25.4)	34 270 (87.7, 7.9)
Night-shift work				
Yes	5430 (4.6, 1.3)	6363 (4.1, 1.5)	6963 (5.6, 1.6)	2939 (7.5, 0.7)
No	112 440 (95.4, 25.8)	148 545 (95.9, 34.1)	117 086 (94.4, 26.9)	36 170 (92.5, 8.3)
Sleep behavior characteristics				
Sleep duration ^^				
<5 h	1647 (1.4, 0.4)	1295 (0.8, 0.3)	1113 (0.9, 0.3)	636 (1.6, 0.1)
6–7 h	32 023 (26.9, 7.3)	33 845 (21.7, 7.7)	26 884 (21.5, 6.1)	10 683 (27.0, 2.4)
7–8 h	77 126 (64.8, 17.5)	109 841 (70.3, 25.0)	86 596 (69.2, 19.7)	24 351 (61.6, 5.5)
>9 h	8314 (7.0, 1.9)	11 168 (7.2, 2.5)	10 524 (8.4, 2.4)	3887 (9.8, 0.9)
Ease of getting up in the morning				
Not at all easy	1217 (1.0, 0.3)	2159 (1.4, 0.5)	6 941 (5.5, 1.6)	6971 (17.7, 1.6)
Not very easy	3781 (3.2, 0.9)	13 304 (8.5, 3.0)	30 945 (24.8, 7.0)	14 574 (36.9, 3.3)

Total sample	Morning *N* = 119 110 (27.1%)	*Intermediate type* More morning than evening *N* = 156 149 (35.5%)	More evening than morning *N* = 125 117 (28.4%)	*Evening N* = 39 557 (9.0%)
	n (*XX*, *xx*)	*n* (*XX*, *xx*)	*n* (*XX*, *xx*)	*n* (*XX*, *xx*)
Fairly easy	43 569 (36.6, 9.9)	89 258 (57.2, 20.3)	70 285 (56.2, 16.0)	14 399 (36.5, 3.3)
Very easy	70 477 (59.2, 16.0)	51 367 (32.9, 11.7)	16 831 (13.5, 3.8)	3506 (8.9, 0.8)
Cardiometabolic characteristics				
Body mass index^^^				
<18.5	653 (0.6, 0.2)	810 (0.5, 0.2)	620 (0.5, 0.1)	222 (0.6, 0.1)
18.5–24.9	37 609 (31.6, 8.6)	53 667 (34.4, 12.2)	40 346 (32.3, 9.2)	11 819 (29.9, 2.7)
25.0–29.9	50 240 (42.2, 11.4)	66 458 (42.6, 15.1)	53 623 (42.9, 12.2)	16 245 (41.1, 3.7)
≥30	30 608 (25.7, 7.0)	35 214 (22.6, 8.0)	30 528 (24.4, 6.9)	11 271 (28.5, 2.6)
Health problems				
Heart attack	2863 (2.4, 0.7)	3353 (2.2, 0.8)	2715 (2.2, 0.6)	961 (2.4, 0.2)
Angina	4098 (3.4, 0.9)	4704 (3.0, 1.1)	3796 (3.0, 0.9)	1298 (3.3, 0.3)
Stroke	1979 (1.7, 0.5)	2068 (1.3, 0.5)	1813 (1.5, 0.4)	665 (1.7, 0.2)
Hypertension	34 139 (28.7, 7.8)	41 332 (26.5, 9.4)	32 762 (26.2, 7.5)	10 570 (26.7, 2.4)
Diabetes	6375 (5.4, 1.5)	6801 (4.4, 1.6)	6078 (4.9, 1.4)	2456 (6.2, 0.6)
Sleep problems				
Sleeplessness/ insomnia	34 280 (28.8, 7.8)	42 611 (27.3, 9.7)	34 409 (27.5, 7.8)	12 569 (31.8, 2.9)
Daytime dozing / narcolepsy	3816 (3.2, 0.9)	3567 (2.3, 0.8)	3160 (2.5, 0.7)	1558 (4.0, 0.4)

Note: *n*: count, *XX*: column percent, xx: overall percent, h: hours, CI: confidence interval,

^Mean age (sd): morning 57.4 (7.8), more morning than evening 56.8 (8.0), more evening than morning 55.8 (8.3), evening 55.1 (8.3),

^^Mean sleep duration (h): morning 7.1 (1.1), more morning than evening 7.1 (1.0), more evening than morning 7.2 (1.1), evening 7.1 (1.2),

^^^Mean body mass index (sd): morning 27.6 (4.9), more morning than evening 27.2 (4.6), more evening than morning 27.5 (4.8), evening 28.0 (5.2).

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Table 3

Adjusted prevalence ratios for short versus adequate and long versus adequate sleep for participant sociodemographic and cardiometabolic characteristics.

	Short versus adequate sleep		Long versus adequate sleep	
	aPR	**99.9% CI**	**aPR**	**99.9% CI**
Sociodemographic characteristics				
Age				
>70	REF	REF	REF	REF
50–70	0.9896[^]	0.7174– 0.8354	0.9963[^]	0.7649–1.2977
<50	0.8510[^]	0.8354–0.7174	1.0500[^]	0.8016–1.3753
Sex				
Male	REF	REF	REF	REF
Female	0.9440	0.9257–0.92626	1.0573	1.0153–1.1011
Ethnic group				
White	REF	REF	REF	REF
Mixed/other	1.4617	1.3712–1.5582	1.1611[^]	0.9834–1.3708
Asian/Asian British/Chinese	1.2956	1.2221–1.3735	1.1434[^]	0.9963–1.3121
Black/Black British	1.9632	1.8704–2.0606	1.1893[^]	0.9967–1.4192
Employment				
Employed	REF	REF	REF	REF
Unemployed	1.1098	1.0713–1.1497	3.0410	2.8612–3.2320
Retired	0.8152	0.7954–0.8355	2.3565	2.2433–2.4755
Attended college				
No	REF	REF	REF	REF
Yes	0.8329	0.8160–0.8501	0.7871	0.7543–0.8213
Shift work				
No	REF	REF	REF	REF
Yes	0.7781	0.7562–0.8007	0.7583	0.6984–0.8234
Night-shift work				
No	REF	REF	REF	REF
Yes	0.7310	0.7056–0.7574	0.7397	0.6634–0.8247
Sleep behavior characteristics				
Chronotype				
Intermediate	REF	REF	REF	REF
Morning	1.2207	1.1943–1.2467	0.9622[^]	0.9166–1.0101
Evening	1.3243	1.2842–1.3657	1.3938	1.3118–1.4811
Ease of getting up in the morning				
Very easy	REF	REF	REF	REF
Not at all easy	1.2984	1.2414–1.3581	2.9740	2.5942–3.0092
Not very easy	1.0039[^]	0.9740–1.0348	1.5791	1.4854–1.6788
Fairly easy	0.8659	0.8466–0.8856	1.0601	1.0093–1.1134

	Short versus adequate sleep		Long versus adequate sleep	
	aPR	**99.9% CI**	**aPR**	**99.9% CI**
Cardiometabolic characteristics				
BMI				
Underweight (<18.5)	0.9113^	0.8008–1.0370	0.8267^	0.6384–1.0704
Normal range (18.5–24.9)	0.7668	0.7472–0.7868	0.7040	0.6879–0.7422
Overweight (25.0–29.9)	0.8296	0.8102–0.8494	0.7924	0.7549–0.8318
Obese (≥30)	REF	REF	REF	REF
Health problems (reference number)				
Heart attack	1.2127	1.1354–1.2953	1.5213	1.3605–1.7010
Angina	1.2322	1.1647–1.3037	1.4365	1.3026 – 1.5842
Stroke	1.2547	1.1606—1.3564	1.5716	1.3853–1.7831
Hypertension	1.1376	1.1126–1.1631	1.2312	1.1784–1.2863
Diabetes	1.1652	1.1152–1.2174	1.5859	1.4723–1.7082
Sleep problems (reference number)				
Sleeplessness/insomnia	2.5720	2.5243–2.6205	0.9622^	0.9163 – 1.0105
Daytime dozing/narcolepsy	1.5185	1.4479–1.5925	2.0212	1.8544–2.2030

Note: aPR: adjusted prevalence ratio, adjusted for age, sex, and ethnicity, employment, and college attendance; CI: confidence interval;

^ not statistically significant ($p > 0.001$).

Table 4

Adjusted prevalence ratio's for morning versus intermediate and evening versus intermediate sleep for participant sociodemographic and cardiometabolic characteristics.

	Morning versus intermediate chronotype		Evening versus intermediate chronotype	
	aPR	**99.9% CI**	**aPR**	**99.9% CI**
Sociodemographic characteristics				
Age				
>70	REF	REF	REF	REF
50–70	1.0019[^]	0.9188–1.0925	1.1341[^]	0.8495–1.5139
<50	0.8235	0.7108–0.9541	0.9569[^]	0.7185–1.2745
Sex				
Male	REF	REF	REF	REF
Female	1.0315	1.0124–1.0509	0.9207	0.8903–0.9522
Ethnic group				
White	REF	REF	REF	REF
Mixed/other	1.2500	1.1666–1.3395	1.2438	1.1036–1.4018
Asian/Asian British/Chinese	1.4112	1.3216–1.4858	1.0503[^]	0.9367–1.1776
Black/Black British	1.4057	1.3216–1.4950	1.1452[^]	1.0078–1.3012
Employment				
Employed	REF	REF	REF	REF
Unemployed	0.9694[^]	0.9338–1.0063	1.4242	1.3484–1.5043
Retired	0.9796[^]	0.9586–1.0011	0.9455	0.9055–0.9872
Attended college				
No	REF	REF	REF	REF
Yes	0.9689	0.9506–0.9876	1.2438	1.2028–1.2863
Shift work				
No	REF	REF	REF	REF
Yes	0.9657	0.9356–0.9968	0.7752	0.7353–0.8172
Night-shift work				
No	REF	REF	REF	REF
Yes	1.0061[^]	0.9628–1.0514	0.6716	0.6297–0.7163
Sleep behavior characteristics				
Sleep duration (h)				
Very short (<5)	1.4330	1.3067– 1.5704	1.2781	1.0960–1.4904
Short (6–7)	1.2465	1.1952–1.2999	0.9899[^]	0.9281–1.0557
Adequate (7–8)	1.0361[^]	0.9958–1.0781	0.7164	0.6748–0.7605
Long (>9)	REF	REF	REF	REF
Ease of getting up in the morning				
Very easy	REF	REF	REF	REF
Not at all easy	0.1696	0.1507–0.1909	10.8567	10.1004–11.6697
Not very easy	0.1234	0.1159–0.1315	5.9958	5.5952–6.4252

	Morning versus intermediate chronotype		Evening versus intermediate chronotype	
	aPR	**99.9% CI**	**aPR**	**99.9% CI**
Fairly easy	0.4036	0.3960–0.4112	1.9045	1.7761–2.0422
Cardiometabolic characteristics				
BMI				
Underweight (<18.5)	1.0186^	0.9028–1.1492	0.8064^	0.6434–1.0107
Normal range (18.5–24.9)	0.9225	0.8998–0.9457	0.7086	0.6778–0.7407
Overweight (25.0–29.9)	0.9381	0.9162–0.9605	0.7940	0.7622–0.8271
Obese (≥30)	REF	REF	REF	REF
Health problems (reference number)				
Heart attack	1.0216^	0.9538–1.0943	1.1732	1.0410–1.3222
Angina	1.0212^	0.9630–1.0830	1.1466	1.0367–1.2739
Stroke	1.0946^	1.0120–1.1841	1.1855	1.0278–1.3675
Hypertension	1.0413	1.0193–1.0638	1.0917	1.0493–1.1358
Diabetes	1.0501^	1.0050–1.0971	1.3628	1.2673–1.4654
Sleep problems (reference number)				
Sleeplessness/insomnia	1.0516	1.0300–1.0736	1.2346	1.1940–1.2804
Daytime dozing/narcolepsy	1.2090	1.1468–1.2745	1.5101	1.3841–1.6476

Note: aPR: adjusted prevalence ratio, adjusted for age, sex, and ethnicity, employment, and attended college; CI: confidence interval,

^ not statistically significant ($p > 0.001$).