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【Doctoral Dissertation】

“The association between social jetlag and metabolic syndrome in the  
Japanese working population “

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Student ID Number: 62145003

Name: Keiko Meguro

Research Supervisor: Kanami Tsuno

Assistant Supervisor: Aya Kuchiba, and Thomas Svensson

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## I Introduction

Non-communicable diseases are known as chronic diseases such as cardiovascular diseases, diabetes, cancers, and chronic respiratory diseases<sup>1</sup>. It is important to implement preventive measures for non-communicable diseases since non-communicable diseases have become a primary reason for the causes of death in recent years<sup>2</sup>. In addition, the World Health Organization (WHO) explains that the increasing number of non-communicable diseases is a critical issue in public health<sup>3</sup>, and metabolic syndrome is related to lifestyle diseases such as hypertension, cardiovascular diseases, stroke, and diabetes.

According to the Japanese Ministry of Health, Labor and Welfare (MHLW), the Japanese MetS criteria consist of visceral obesity, high blood pressure, dyslipidemia, and borderline diabetes. High blood pressure, dyslipidemia, and borderline diabetes are risk factors for the onset of cardiovascular diseases and stroke<sup>4</sup>. In order to avoid the onset of these diseases, it is important to prevent or retard the progress of MetS. Even though self-awareness is one of the key aspects to prevent it, being not having typical symptoms does not allow individuals with MetS to induce their self-awareness. To complement self-awareness and detect individuals with risk factors for MetS or lifestyle diseases, there are also the Japanese criteria of a pre-MetS. The Japanese criteria for MetS is 1) waist circumference  $\geq 85$  cm in men and  $\geq 90$  cm in women, and two or more from 2) high triglyceride  $\geq 150$  mg/dl or low high-density lipoprotein cholesterol (HDL-C)  $< 40$  mg/dl, 3) systolic blood pressure  $\geq 130$  mmHg or diastolic blood pressure  $\geq 85$  mmHg, and 4) high fasting blood glucose  $\geq 110$  mg/dl.<sup>4</sup> Pre-MetS criteria, on the other hand, is 1) waist circumference  $\geq 85$  cm in men and  $\geq 90$  cm in women, and one from 2) high triglyceride  $\geq 150$  mg/dl or low HDL-C  $< 40$

mg/dl, 3) systolic blood pressure  $\geq 130$  mmHg or diastolic blood pressure  $\geq 85$  mmHg, and 4) high fasting blood glucose  $\geq 110$  mg/dl<sup>4</sup>. As a Japanese trend in MetS, MHLW has reported that the standardized proportion of prevalence of combined pre-MetS and MetS in 2019 was roughly 40 percent in those over middle age, and the proportion is becoming larger in older adults<sup>5</sup>.

MetS is related to our habitual behaviors and unhealthy lifestyles<sup>6</sup>, and sleep is one of the lifestyle factors of MetS. According to Organization for Economic Co-operation and Development (OECD), Japan has shorter sleep time than the other OECD countries<sup>7</sup>. The MHLW also reports that roughly 40% of individuals over age 30 to 59 have shorter average daily sleep hours than 6 hours in a population-based survey of 2019 in Japan<sup>8</sup> even though the National Sleep Foundation does not recommend less than 6-hour sleep duration in those aged 26-64<sup>9</sup>. However, these data were based on self-reported questionnaires and their actual total sleep time (TST) and sleeping-waking schedules are unclear. Besides, Japan is a country with shorter amounts of sleep in the world, and there are no studies using objective sleep measures that have been followed up for several years and examined by gender and age group in Japan. Even though there are researches that sleep duration increased with objective indicators in the U.S and Europe countries due to the corona pandemic<sup>10,11</sup>, there are hardly examined similar results with objective sleep indicators in Japan.

A previous study has shown an inverse association between nightly sleep duration and hemoglobin A1c<sup>12</sup>, and other studies reported that self-reported short or long sleep duration (less than 6 hours, and 8 or 9 hours more) was associated with MetS and low HDL-C<sup>13,14</sup>. HDL-C is one of the components of MetS determination. Also, some studies have



reported that irregular sleep patterns and social jetlag, a discrepancy in TST on weekdays and weekends, are associated with lifestyle diseases<sup>15,16</sup> and increased risk of cardiovascular diseases<sup>17</sup>. Social jetlag is considered that there is misalignment between individuals' sleep preferences and societal schedules, which increases sleep debt on a weekday. Consequently, the individuals compensate for their sleep time on weekends<sup>18</sup>.

Even though these previous studies have shown the association between sleep patterns and MetS, the sleep measures were mostly self-reported. Self-reported data collection may be prone to a recall bias, as a study has reported that self-reported sleep measure is likely to be 30 minutes longer than objective measure<sup>19</sup>.

Although using objective sleep measures may promise to reduce recall bias, previous studies relating irregular sleep patterns or social jetlag with objective sleep measures in Japan have not been reported before. There is a few studies of irregular sleep patterns or social jetlag using objective sleep measure in the U.S. and Luxembourg<sup>17,20</sup>. Huang found that higher variations in sleep period and timing were both associated with increased risk of cardiovascular diseases<sup>17</sup>. Aguayo found that greater social jetlag was associated with elevated hemoglobin A1c<sup>20</sup>. Even though objective sleep measures using wearable devices have been used for many studies in recent years, the number of longitudinal studies is still scarce. In addition, most of the study duration of the longitudinal studies relating to sleep and using wearable devices is less than 1 year. Also, a large-scale study has shown the discrepancies in sleep duration, weekday and weekend sleep using objective sleep measures among countries, age groups, and gender<sup>21</sup>. The results suggest that large-scale sleep data may allow us to realize cultural factors and sleep tendency<sup>21</sup>.

Therefore, to overcome these limitations, we conducted three studies using a validated wearable device, Fitbit, in a working population in Japan. The objectives of our studies are 1) to examine the cross-sectional association between TST and HDL-C, one of the components of MetS, 2) to describe three-year sleep tendencies including social jetlag, sleeping-waking schedules and TST on weekdays and weekends in 2019-2022, and 3) to examine the longitudinal association between sleep including social jetlag and MetS indices.

## II Methods

### 1 Study design and participants

#### (1) Study 1: TST and HDL-C analysis<sup>22</sup>

The participants of Study 1 were part of a lifestyle intervention study (conducting from December 3<sup>rd</sup>, 2018 to March 2<sup>nd</sup>, 2019) that recruited participants from 5 companies in Tokyo. Each of the companies had more than 1000 employees, and all participants were full-time professionals, managerial or clerical workers. The details of the study have been described elsewhere<sup>23</sup>. In brief, 272 participants were enrolled in a 3-month randomized controlled trial (RCT) for lifestyle change. Of these, 181 were randomized to the intervention group and 71 as controls. The 179 eligible participants in the intervention group were given a wearable device at the start of the study and asked to use it around the clock, in addition to a dedicated mobile application, for the duration of the 3-month study period. Participants in the control group were asked to complete a web-based questionnaire and were gifted the wearable device at the end of the study period. Study 1 was a secondary analysis of a subset of participants from the RCT. Annual health check-ups (AHC) are obligatory in Japan<sup>24</sup>.

Participants were recruited among 7437 employees who had completed the AHC and had been categorized with MetS or at risk of MetS based on their AHC data.

All research was conducted in accordance with relevant ethical guidelines and regulations. All participants received detailed information about the study and its purpose. Information was provided in writing as well as during a face-to-face explanation. All participants understood that participation was entirely voluntary and could be discontinued at any time and for any reason without any penalty or disadvantage. All participants provided written informed consent and the study was approved by the Ethical Committee of the School of Engineering, The University of Tokyo (approval number: KE18-44). As an incentive to participate, participants were provided the wearable device if they completed the required final questionnaire. The research was supported by the Center of Innovation Program from the Japan Science and Technology Agency (Grant Number JPMJCE1304), and Kanagawa prefecture's "A project to expand the use of metabolic syndrome risk index in municipalities" (2018). The funders had no role in the design of the study; collection, analysis, and interpretation of data; writing of the report; or decision to submit the paper for publication.

For the purpose of Study 1, we focused on the participants in the intervention group. Two of the participants originally randomized to the intervention arm declined to provide consent before the start of the study and were thus excluded. The remaining 179 individuals with 16,110 observations were eligible for analysis. Given the nature of repeated measures data, a participant may have had missing observations for one or several days (for example, if the participant did not wear the wearable device) yet be included in the analysis. We excluded participants who did not complete the intervention ( $n = 1$ ; 90 observations) and

those with missing data of main outcomes (n = 2; 180 observations) or unreasonable values (LDL-C of 50 mg/dl: n = 1; 90 observations) for the main outcomes, HDL-C and LDL-C; missing data (n = 0; 3,154 observations) or unreasonable values (TST of 0 minutes: n = 0; 5 observation) for the main exposure, TST; and those with unreasonable values (daily step count < 1000: n = 0; 218 observations) or missing data (n = 2; 4,050 observations) for covariates (Figure 1). Finally, 173 participants with 8,323 observations were used for analyses.

## (2) Study 2: sleep analysis

Study 2 used sleep data measured by a validated wearable device, the Fitbit, included in the personal health record (Pep Up, <https://pepup.life>) provided by JMDC Inc.<sup>25</sup>. Health insurance associations sometimes provide Fitbits to their members for free or some participants purchased; however, it is not possible to determine how each participant obtained a Fitbit. The study duration was 3 years, from April 2019 to March 2022. The baseline characteristics (e.g., gender and age) and health-related information, including disease and injury diagnoses, were derived from the JMDC Claims Database, which includes anonymized health claim data obtained from monthly and annual health checkup information with a total population of approximately 17 million people. The participants agreed to have their data analyzed when they linked them to the personal health record. The sleep data and health claims data were anonymized. This study was approved in 2022 by the Ethical Committee of the School of Health Innovation, Kanagawa University of Human Services, and does not require ethical review (approval number: SHI-14).

Study 2 included 20,886 individuals (6,280,850 sleep observations) insured by Japanese health insurance associations (approximately 100 associations) in collaboration with JMDC Inc., and who had Fitbit-based sleep records<sup>26</sup> collected from April 2019 to March 2022. The participants continuously belonged to the Japanese Health Association during the study period.

In Japan, there are three types of health insurance systems: National Health Insurance, which is mainly for the self-employed; Employee's Health Insurance (Association Health Insurance, Health Insurance Association, and Mutual Aid Association), which is mainly for company and public employees; and the Late-Stage Senior Citizen's Health Care System for those aged  $\geq 75$  years. Participants in this study were full-time employees, covered by health insurance associations, or those who work more than three-quarters of the required hours in large-sized enterprises<sup>27</sup>.

The first day of sleep recording during the study period was defined as the entry point for each participant. The study eligibility criteria and participant flow are presented in Figure 2. To measure the TST under normal conditions, we excluded participants who had sleep apnea syndrome (SAS) ( $n = 302$ ; 100,001 observations) or received psychotropic medication ( $n = 793$ ; 281,095 observations). In addition, people who were pregnant or postpartum were excluded as they are likely to have sleep problems<sup>28</sup>. In addition, people who were pregnant or gave birth with medical treatment (e.g., treatments covered by insurance, such as caesarean section and threatened premature birth) ( $n = 38$ ; 11,291 observations) in the month of entry were excluded. Overall, we excluded 1,090; 378,495 observations and some exclusion criteria overlapped (cumulative total:  $n = 1,133$ ; 392,387 observations). Cases of natural

childbirth and undiagnosed disease and injury could not be identified and excluded and may have been included in the analysis. In some cases, sleep observations were included before an event and excluded thereafter; thus, the number of participants additionally excluded in this procedure was zero (SAS: 45,474 observations from 141 participants; psychotropic medication: 307,578 observations from 1,072 participants; and pregnancy or giving birth with medical treatment: 27,510 observations 142 participants). Finally, we excluded participants who had insufficient sleep data (less than 25% of eligible sleep records:  $n = 9,126$ ; 382,507 observations). Finally, 10,670 participants with 5,156,835 observations were included in the analysis.

### (3) Study 3: social jetlag and MetS analysis

The sleep data and the anonymized health claim data were used as well as Study 2. In addition to Study 2, the AHC data obtains the individuals' questionnaire data at AHC. This database has patients' demographic characteristics (e.g., gender and age), and linkage with the sleep data<sup>25</sup>. This study was approved by the Ethical Committee of School of Health Innovation, Kanagawa University of Human Services as a study which does not require ethical review (approval number: SHI-14).

We set three study samples in different time series to assess the association between sleep and MetS in a year. Sample 1 was set baseline in 2019 fiscal year and outcome measures in 2020 fiscal year (Figure 3). Sample 2 (Figure 4) was set baseline in 2020 fiscal year and outcome measures in 2021 fiscal year. Sample 3 was set baseline in 2021 fiscal year and outcome measures in 2022 fiscal year (Figure 5). We set a baseline on the day of an AHC,

and sleep data was used from 180 days before AHC until the baseline day. The study participants were used from the JMDC database as well as the sleep analysis in Study 2.

To measure TST under normal conditions, we excluded participants who had sleep apnea syndrome (SAS) (Sample 1; n = 83; 7,100 observations, Sample 2; n = 145, 14,917 observations, Sample 3; n = 232; 24,968 observations), which may influence on sleep, had psychotropic medication (Sample 1; n = 408; 26,125 observations, Sample 2; n = 816; 72,351 observations, Sample 3; n = 1,317; 120,968 observations) that are likely to affect sleep. In addition, pregnant women are likely to have sleep problems<sup>28</sup>, eating disorders and malignant neoplasm may influence metabolism. There was a that spontaneous childbirths with undiagnosed injuries or illnesses were included in the participants since they could not be determined based on the health claim data and could not be excluded. We, therefore, excluded pregnant women and women who gave birth with medical treatment (Sample 1; n = 42; 1,806 observations, Sample 2; n = 63; 3,694 observations, Sample 3; n = 88; 5,772 observations), eating disorders (Sample 1; n = 1; 59 observations, Sample 2; n = 2; 16 observations, Sample 3; n = 5, 395 observations), and malignant neoplasm (Sample 1; n = 92; 6,666 observations, Sample 2; n = 177; 16,840 observations, Sample 3; n = 354; 57,281 observations) at the baseline including sleep data period until measure outcome of Sample 1 (total: n = 541; 39,101 observations since some of the excluded participants had one or more exclusion criteria [cumulative total: n = 626; 41,851 observations]), Sample 2 (total: n = 1,043; 100,588 observations since some of the excluded participants had one or more exclusion criteria [cumulative total: n = 1,203; 107,818 observations]), and Sample 3 (total: n = 1,697; 171,586 observations since some of the excluded participants had one or more exclusion criteria

[cumulative total: n = 1,996; 184,220 observations]). We excluded participants who had unreasonable sleep data (less than 25% of the number of sleep records on both weekdays and weekends before 180 days until baseline AHC date; Sample 1; n = 1,367; 27,646 observations, Sample 2; n = 1,790; 34,609 observations, Sample 3; n = 2,957; 57,350 observations) from eligible participants after entry. We additionally excluded the participants with MetS determinations and undeterminable MetS criterion at baseline ( Sample 1; n = 280; 33,004 observations, Sample 2; n = 733; 97,069 observations, Sample 3; n = 1,226; 168,392 observations), the participants with missing data of main outcomes at the baseline and outcome AHC date (Sample 1; n = 208; 20,396 observations, Sample 2; n = 453; 58,527 observations, Sample 3; n = 757; 99,956 observations), the participants with missing data or unreasonable values on covariates at the baseline (Sample 1; n = 134; 16,554 observations, Sample 2; n = 316; 45,526 observations, Sample 3; n = 495; 75,615 observations).

Finally, 810 participants with 91,903 observations for Sample 1, 1,930 participants with 258,601 observations for Sample 2, and 3,315 participants with 454,829 observations for Sample 3 were used for the association between social jetlag and incidence of MetS analyses. In addition, to analyze the association between social jetlag and each MetS component, we additionally excluded the participants who were under medication of hypoglycemic drug (Sample 1; n = 10, Sample 2; n = 35, Sample 3; n = 62) for the association between social jetlag and fasting blood glucose level, under medication of dyslipidemia treatment drug (Sample 1; n = 58, Sample 2; n = 147, Sample 3; n = 280) for the association between social jetlag and triglyceride/HDL cholesterol level, and under medication of



antihypertensive (Sample 1; n = 81, Sample 2; n = 158, Sample 3; n = 308) for the association between social jetlag and blood pressure values.

#### A The population in the JMDC database without sleep data linkage

To assess whether participants with sleep data in this study did not have particularly good or poor values at their AHC, basic statistics of AHC values (i.e., waist circumference, fasting blood glucose, triglyceride, HDL-C, systolic blood pressure, diastolic blood pressure, and assessment of MetS) for the population in the JMDC database without sleep data linkage were calculated mean and standard deviation (SD). We set 3 basic statistics for fiscal year 2019, 2020, and 2021. Each population was applied the same exclusion criteria with the study participants. AHC values were used the first one if there were two or more data in each fiscal year. The number of samples was 2,110,491 in fiscal year 2019, 2,412,987 in fiscal year 2020, and 2,890,967 in fiscal year 2021.

## 2 Measurements

### (1) Study 1: TST and HDL-C analysis<sup>22</sup>

#### A Wearable device

The Fitbit Versa (FV) is a consumer wearable device manufactured by Fitbit Inc. Details of the FV can be found on the company website (<https://www.fitbit.com>). In brief, the FV connects with a dedicated smartphone app using Bluetooth technology and provides the user with information about measures related to sleep (e.g., TST, sleep stage, sleep efficiency), physical activity (e.g., step count and distance), and others. Sleep can be

registered using one of two modes: stages (provides detailed information on sleep) and classic (provides a simplified sleep pattern without any information on sleep stages). The latter occurs if the device is worn too loosely; the user manually enters sleep mode; the user sleeps for less than 3 hours; or the battery is insufficiently charged. All sleep records were tracked using the "normal" setting.

All participants of Study 1 received written instructions and a demonstration on how to wear the FV in accordance with the manual. Each participant was provided with a unique Fitbit username and password to allow: 1) synchronization of the device with the mobile app throughout the study period, and 2) retrieval of data recorded on the Fitbit using application programming interface calls. All researchers were blinded to the allocation of usernames to study participants.

## B Main exposures

The main exposures of Study 1 were the self-reported Brief Job Stress Questionnaire (BJSQ) and TST, obtained using a wearable device.

The MHLW initiated use of the BJSQ in 2015 and provides it to assess occupational stress level and prevent psychological distress for employees<sup>29</sup>. Our present participants answered the BJSQ as baseline questionnaire at the start of the 3-month study period. The BJSQ consists of 57 items which assess job stressors, psychological and physical stress responses, buffering factors, and job and life satisfaction. The BJSQ score is calculated from all questions except two items (job and life satisfaction). Following guidance from the MHLW<sup>30</sup>, we summed the 4-point Likert scale responses, which ranged from 1 (low stress)

to 4 (high stress), with reverse-scoring of questions 1 to 7, 11 to 13, 15, and 18 to 20. The maximum score was 200 points. Two criteria are used to assess high stress: the first considers a cutoff minimum score of 77 for psychological and physical stress response, while the second considers a combined score of 76 or more for job stressor and job and life satisfaction, in addition to a minimum score of 63 for psychological and physical stress response. We obtained a binary variable (low stress and high stress) based on these cutoff criteria. Moreover, we used the total score and the SD for the whole sample as a continuous variable, in which each incremental increase corresponded to one SD increase in BJSQ score.

TST was obtained using FV's "stage" mode, and has been validated for use in naturalistic epidemiological studies<sup>31</sup>. For the purpose of this study, we used the TST obtained from night-time weekday and weekend sleep. Each participant's TST data was used to calculate a participant-specific mean TST for the entire 3-month study period. TST was converted from minutes to hours (TST in minutes/60) and considered as a categorical variable based on terciles: 4.0-5.3 hours, 5.4-5.9 hours, and 5.9-7.2 hours. Tercile 3 (T3; 5.9-7.2 hours) was used as the reference category. Terciles were chosen to allow for a sufficient number of participants in each quantile.

## C Outcome measures

Outcome measures of Study 1 were LDL-C, HDL-C, and LDL-C/HDL-C ratio. Blood samples were collected at different healthcare facilities in the Tokyo area, and participants were instructed to fast for at least 10 hours before the blood sampling<sup>32</sup>. Cholesterol levels were obtained from AHC in the latest fiscal year before the start of Study 1. Under MHLW

regulations, Japanese employers are required to provide employees with an AHC at least once a year<sup>33</sup>.

#### D Covariates

Age (continuous) was considered at the time of participation in Study 1; smoking status was a categorical variable defined as non-smoker, past-smoker, current smoker <20 cigarettes, or current smoker  $\geq 20$  cigarettes; mean alcohol consumption (continuous) for the entire study period was calculated for each participant based on the daily amount of beer, sake, shochu, chu-high (a Japanese drink made of shochu and carbonated water), cocktail, wine, whiskey, and plum wine; body mass index (BMI) was used as a variable categorized according to Japanese population criteria, i.e., < 18.5 kg/m<sup>2</sup>, 18.5 – 25 kg/m<sup>2</sup>, 25 – 30 kg/m<sup>2</sup>, or  $\geq 30$  kg/m<sup>2</sup>; hemoglobin A1c (HbA1c [%]; continuous); the mean number of servings per day of staple foods, i.e., rice, noodles of any kind, bread, and cereal; the mean number of servings per day of main dishes, including eggs, fish, meat and soybeans; the mean number of servings per day of dairy products, including milk, cheese, and yogurt; mean standardized daily step count (continuous per 100 steps), mean sleep satisfaction of the preceding night's sleep ranging from 1 = very unsatisfied to 5 = completely satisfied, snoring (yes/no), and consistent bedtime ( $\geq 4$  days per a week; yes/no). Gender, age, smoking status, snoring, consistent bedtime, waist circumference, BMI, and HbA1c were obtained at the time of the baseline questionnaire. Alcohol consumption, sleep satisfaction, and number of servings of food were assessed daily throughout the study period. Step count and TST were obtained using the wearable device. For the variables that were collected on a daily basis (through

daily questionnaires and the wearable device), a single mean value for the entire study period was calculated and subsequently used in the statistical analyses.

## (2) Study 2: sleep analysis

### A Sleep variables

The sleep variables used in Study 2 were waking up during the day, main sleep, TST (i.e., the minutes being asleep in the sleep period), minutes being awake during the sleep period (wake time), time starting sleep (start time), minutes from start time to wake up time (sleep period, i.e., TST + wake time), minutes of deep sleep in the sleep period (deep sleep time), and social jetlag. We calculated the wake-up time (start time + sleep period) and the midpoint sleep period (mid-sleep time; start time + sleep period/2). Each sleep variable was converted from minutes to hours. Each weekday or weekend sleep variable was calculated by dividing the within-subject averages by the number of weekdays and weekends during the study period.

### B Main sleep

The participants' sleep duration was based on the time of waking up. The longest sleep record per day was used as the main sleep record if the participant had two or more sleep records per day. The number of main sleep observations was 983,800 ( $n = 4,386$ ) in 2019 fiscal year, 1,631,505 ( $n = 6,386$ ) in 2020 fiscal year, 2,357,220 ( $n = 8,918$ ) in fiscal year 2021. The participants' sleep records from Monday to Friday were considered weekday data, and those from Saturdays and Sundays were considered weekend data. In addition to

the Japanese national holidays, New Year's Eve, New Year's Day, and January 2<sup>nd</sup> to 3<sup>rd</sup> were included as weekends. The number of main sleepers on weekdays was 3,467,371 and the number of main sleepers on weekends was 1,689,464. Daytime sleep was defined as waking time between 12:00 and 24:00, bedtime between 6:00 and 18:00, and mid-sleep time between 9:00 and 21:00, and was also included as main sleep if it was the longest sleep in a day. The number of daytime sleep observations on weekdays was 19,668 (mean = 9.1; min = 1; max = 491 per person) (n = 2,161) and 16,571 observations on weekends (mean = 4.9; min = 1; max = 240 per person) (n = 3,380).

#### C Social jetlag

Social jetlag refers to the absolute difference (weekends – weekdays) in the midpoint sleep period between weekdays and weekends<sup>18</sup>. We calculated the midpoint time of the sleep period and divided it into three groups based on the number of sleep hours that were the differences between weekends and weekdays (0–1 h, 1–2 h, and  $\geq 2$  h). Although most participants had positive values (i.e., later midpoint sleep period in weekends than weekdays, there were 875 participants (men; n = 784, women; n = 91) with negative values (i.e., later midpoint sleep period in weekdays). Having social jetlag in this study was defined as a  $\geq 1$  h or  $< 2$  h sleep pattern difference between weekdays and weekends<sup>16</sup>.

### (3) Study 3: social jetlag and MetS analysis

#### A Sleep data and main exposures

The number of sleep records differed among the participants (the number of sleep observations on weekdays: mean = 325.0; min = 62; max = 730, the number of sleep observations on weekends: mean = 158.3; min = 31; max = 366). Each sleep data has information on whether or not determined as main sleep (i.e., longer sleep) by Fitbit, and the longest sleep record at night was used if the participants had two or more sleep records per day. The number of sleep records was 1,053,072 (n = 6,029) in the 2019 fiscal year, 1,704,245 (n = 8,003) sleep records in the 2020 fiscal year, 2,399,518 (n = 9,793) sleep records in the 2021 fiscal year, respectively. The definition of main sleep, weekday sleep, and weekend sleep was as well as Study 2.

The participants' sleep data were used as well as Study 2. Sleep variables of Study 3 for sleep and MetS analysis were used, TST, sleep period, mid-sleep time, and social jetlag. There were 64 participants (men; n = 58, women; n = 6) with negative values of social jetlag in the 2019 fiscal year, 216 participants (men; n = 194, women; n = 22) in the 2020 fiscal year, 431 participants (men; n = 380, women; n = 51) in the 2021 fiscal year, respectively. Social jetlag was considered both categorical variable ( $\geq 2$  hours,  $\geq 1$  hour and  $< 2$  hours, and  $< 1$  hour) and continuous variables.

## B Outcome measures

Japanese MetS criteria were used for MetS determinations, MetS or pre-MetS<sup>3</sup>.

- MetS criteria (A and two or more from B, C, and D)<sup>4</sup>.
  - Waist circumference  $\geq 85$  cm in men and  $\geq 90$  cm in women

- High triglyceride triglyceride  $\geq 150$  mg/dl, low HDL-C  $< 40$  mg/dl, or current use of dyslipidemia treatment drug.
- Systolic blood pressure  $\geq 130$  mmHg, diastolic blood pressure  $\geq 85$  mmHg, or current use of antihypertensive.
- High fasting blood glucose  $\geq 110$  mg/dl or current use of hypoglycemic drug.
- Pre-MetS criteria (A and one from B, C, and D)<sup>4</sup>.
  - Waist circumference  $\geq 85$  cm in men and  $\geq 90$  cm in women
  - High triglyceride  $\geq 150$  mg/dl, low HDL-C  $< 40$  mg/dl, or current use of dyslipidemia treatment drug.
  - Systolic blood pressure  $\geq 130$  mmHg, diastolic blood pressure  $\geq 85$  mmHg, or current use of antihypertensive.
  - High fasting blood glucose  $\geq 110$  mg/dl or current use of hypoglycemic drug.

To assess incidence of MetS and pre-MetS after 1-year follow-up AHC, we defined not having MetS or pre-MetS at baseline. However, we did not consider that the participants might have been with MetS or pre-MetS in the past. The participants had AHC in different timing both baseline and outcome measures of AHC. The mean of days between baseline and outcome was 381.2 days (min; 153 days, max; 705 days) in Sample 1, 346.2 days (min; 71 days, max; 621 days) in Sample 2, and 363.1 days (min; 77 days, max; 724 days) in Sample 3.



## C Covariates

AHC consists of health examinations and lifestyle habits questionnaires. Age was used from AHC data and was considered on the AHC date at baseline as a continuous variable. The questionnaires were used to collect information of lifestyle habits, smoking status (current smoker, current non-smoker), skipping breakfast more than three times a week (yes, no), frequency of drinking such as Japanese sake, shochu, beer, wine, whisky, or brandy (every day, sometimes, rarely drink), amount of alcohol (Japanese sake; 180 ml, beer; 500 ml, 25% of shochu; 110 ml, double whisky; 60 ml, two glasses of wine; 240 ml) per a day if you drink (less than 180 ml, 180-360 ml, 360-540 ml, more than 540 ml), having enough sleep to get a good rest (yes, no). These lifestyle habits were used as categorical variables. BMI was used both a categorical variable ( $< 25$ ,  $\geq 25$ ) and continuous variables, LDL-C and HbA1c [%] were used as continuous variables. Average TST, average mid-sleep time, and average number of steps per a day were obtained using wearable device. These were used as numeric variables. In addition, an interaction term between gender and TST was used as a covariate for the outcome of HDL-C.

## 3 Statistical Analysis

### (1) Study 1: TST and HDL-C analysis<sup>22</sup>

To statistically compare baseline characteristics, the t-test was used for continuous variable and the chi-square test for categorical variables.

Multiple linear regression models were used to determine the association between stress level and TST, respectively, and cholesterol level. Model 1 was adjusted for gender

and age. Model 2 was additionally adjusted for smoking status and mean alcohol consumption. Model 3 was additionally adjusted for BMI, HbA1c, and mean number of servings per day of staple foods, main dish, and dairy products. Model 4 was further adjusted for mean daily step count, mean sleep satisfaction, snoring, and consistent bedtime.

All statistical analyses were performed using Stata/MP version 17.0 (StataCorp LP, College Station, TX).

## (2) Study 2: sleep analysis

During the coronavirus disease 2019 pandemic, some studies have reported that sleep time measured by an objective method has become longer than before the pandemic in the United States (US) and European countries<sup>11,21</sup>. Therefore, we investigated whether there were any differences in TST across fiscal years. The t-test was used for gender-based comparisons of continuous variables. Gender-based pairwise comparisons were performed among age groups. The chi-square test was used to assess social jetlag. The significance level was set at p-values of 0.05 for all comparisons. However, given the large sample size, our emphasis was placed on the magnitude of the difference rather than on its statistical significance. All statistical analyses were performed using R version 4.2.2 (The R Foundation for Statistical Computing, Vienna, Austria).

## (3) Study 3: social jetlag and MetS analysis

To statistically compare baseline characteristics and 1-year follow up incidence of MetS and pre-MetS among three groups (social jetlag  $\geq 2$  hours,  $\geq 1$  hour and  $< 2$  hours, and  $< 1$

hour), the analysis of variance was used for continuous variables and Fisher's exact test for categorical variables.

Modified Poisson regression models were used to estimate risk ratio and 95% confidence interval (CI) the association between social jetlag and incidence of MetS and pre-MetS. Model 1 was adjusted for gender and age. Model 2 was additionally adjusted for smoking status, frequency of drinking, amount of alcohol. Model 3 was additionally adjusted for BMI, LDL-C, HbA1c, and skipping breakfast. Model 4 was further adjusted for average TST, average mid-sleep time, sleep satisfaction, and average daily step count.

Multiple linear regression models were used to examine the association between social jetlag and MetS components (waist circumference, triglyceride, HDL-C, systolic and diastolic blood pressure, and fasting blood glucose). We also examined the interaction term between gender and TST for the outcome of HDL-C.

The participants had AHC in different timing both baseline and outcome measures of AHC, and the days between baseline and outcome differed. As sensitivity analysis, we estimated risk ratio and 95% CI the association between social jetlag and incidence of MetS and pre-MetS with exclusion less than 180 days between baseline and outcome ( $n = 2$  in Sample 1,  $n = 23$  in Sample 2, and  $n = 10$  in Sample 3). The final number of participants was  $n = 808$  in Sample 1,  $n = 1,907$  in Sample 2, and  $n = 3,305$  in Sample 3. Significant level was set at 0.05 for all statistical tests. All statistical analyses were performed using R version 4.3.1 (The R Foundation for Statistical Computing, Vienna, Austria).

### III Results

## 1 Study 1: TST and HDL-C analysis<sup>22</sup>

Table 1 shows baseline characteristics of the participants according to low and high levels of the BJSQ. Individuals in the high stress group were 4.7 years younger ( $P = 0.03$ ) and reported lower mean sleep satisfaction ( $P = 0.01$ ). Although not significantly different, the high stress group had a higher prevalence of current smokers ( $< 20$  cigarettes/day), and severe obesity. In addition to these factors, individuals in the high stress group were more likely to have lower mean daily alcohol consumption and had a slightly lower mean daily step count.

Stress levels assessed using the BJSQ were inversely associated with LDL-C (Model 1:  $-4.26$  mg/dl; 95% CI:  $-8.68, 0.17$ ) per SD increase (Table 2). The association was significant in models 2-4 (Model 4:  $-7.12$  mg/dl; 95% CI:  $-11.78, -2.45$ ). The BJSQ was inversely associated also with LDL-C/HDL-C ratio (Model 1:  $-0.07$  mg/dl; 95% CI:  $-0.18, 0.05$ ) per SD increase. This association became significant in models 3 and 4 (Model 4:  $-0.16$  mg/dl; 95% CI:  $-0.27, -0.04$ ). There was no association between incremental increases per SD of the BJSQ and HDL-C. When considering the results of the BJSQ as a binary variable, a high stress level when compared to the low stress group, was not significantly associated with LDL-C, HDL-C or LDL-C/HDL-C ratio.

The shortest TST (T1), when compared to T3, was significantly and inversely associated with HDL-C in all models. The effect size was the largest in Model 1 ( $-6.18$  mg/dl; 95% CI:  $-10.65, -1.72$ ), and was only slightly attenuated with the addition of covariates (Model 4:  $-4.82$  mg/dl; 95% CI:  $-9.22, -0.43$ ). No association was seen between TST and either LDL-C or LDL-C/HDL-C ratio.

## 2 Study 2: sleep analysis

The proportion of men in the study was 72.6%. The mean age at entry was 45.5 (standard deviation [SD]: 9.60) years (range: 18–71 years). The largest groups comprised men in their 40s and 50s. Most participating women were in the age range of 40–50 years.

Table 3 shows age-based comparisons of sleep variables by fiscal year. The number of average main sleep observations was 224.30 (SD: 78.74) in fiscal year 2019, 255.48 (SD: 87.73) in fiscal year 2020, and 264.32 (SD: 83.21). The average TST combined on weekdays and weekends was less than 6 h for all fiscal years. The differences in the TST between fiscal years were within a few minutes. The TST in fiscal year 2019 was 2–4 minutes shorter than that in fiscal year 2020 or 2021. Given these small differences, we decided to combine all data across fiscal years.

Table 4 shows comparisons of age and sleep variables by gender. The number of average main sleep observations was 483.30 (SD: 282.12), 490.30 (SD: 285.49) in men and 464.74 (SD: 272.13) in women. Average TST overall was 5.84 h, while in women and men it was 5.98 and 5.79 h, respectively. The differences in TST (effect point estimate [comparing means]: -0.19 h; 95% confidence interval [CI]: -0.22, -0.17) and sleep period (effect point estimate: -0.17 h; 95% CI: -0.20, -0.14) by gender showed that women slept approximately 10 minutes longer than men. Although women tended to wake up a few minutes later than men, the differences in pairwise comparisons of sleep time were small (effect point estimate: -0.04 h and 95% CI: -0.08, 0.00). Deep sleep time estimates in men and women were 0.99 (SD: 0.21) and 1.01 (SD: 0.20) h, respectively. Some men and women had more than 2 h of social jetlag (2.96% and 3.63%, respectively), while most participants had less than 1 h

(78.37% and 66.66%, respectively) and 1–2 h (18.67% and 29.72%, respectively) of social jetlag. The prevalence of social jetlag of 1–2 h was higher in women than in men (29.72% and 18.67%, respectively).

In addition, TST on weekdays was approximately 0.5–1.0 h shorter than on weekends for both men and women of all ages. Women were more likely than men to have a greater gap between weekdays and weekends in mid-sleep time (effect point estimate: -0.23 h and 95% CI: -0.25, -0.20) and in asleep time (effect point estimate: -0.26 h and 95% CI: -0.28, -0.23) since women woke up later on weekends than men (effect point estimate: -0.36 h and 95% CI: -0.40, -0.33) (Table 5, Figure 6, and Figure 7). The number of average main sleep observations on weekdays was 329.54 (SD: 191.04) and on weekends was 160.76 (SD: 95.11) in men. The number of average main sleep observations on weekdays was 312.84 (SD: 182.51) and on weekends was 151.90 (SD: 90.41) in women.

Unlike women, men in their 40s and older had little difference in asleep time as they got older (40s–50s, effect point estimate: 0.03; 95% CI: -0.01, 0.06; 40s vs. 60s–70s, effect point estimate: -0.05; 95% CI: -0.11, 0.01; 50s vs. 60s–70s, effect point estimate: -0.07; 95% CI: -0.14, -0.01). In addition, the pairwise difference in the mid-sleep time was larger in men between youngest and oldest men (10s–20s vs. 50 s, effect point estimate: 1.19; 95% CI: 1.09, 1.29; 10s–20s vs. 60s–70s, effect point estimate: 1.41; 95% CI: 1.27, 1.55). A similar pattern was observed among women with some effects being larger than those among men (10s–20s vs. 50s, effect point estimate: 0.76; 95% CI: 0.64, 0.88; 10s–20s vs. 60s–70s, effect point estimate: 1.00; 95% CI: 0.81, 1.19) (Table 6).

As shown in Table 7 and Figures 8–11, TST on weekdays and weekends in men by age group hardly differed over the age of 40 years, while that in women hardly differed over the age of 50 years. In addition, the youngest participants had an approximately 0.5 h longer TST on weekdays and weekends, compared to that of participants older than 50 years, with the longest gap between men and women. Among women, the gap between weekdays and weekends in the TST did not differ among age groups.

Age-based comparisons in mid-sleep time on weekends among men are presented in Table 7. The youngest participants woke significantly later than the older participants. The youngest participants woke approximately an hour later than those aged 60s–70s on weekdays and weekends Table 8.

### 3 Study 3: social jetlag and MetS analysis

Table 9 shows the baseline characteristics of the participants in Sample 1 according to social jetlag  $\geq 2$  hours,  $\geq 1$  hour and  $< 2$  hours, and  $< 1$  hour. The number of average main sleep was 126.44 (SD: 38.24) in social jetlag  $\geq 2$  hours, 134.08 (SD: 40.98) in social jetlag  $\geq 1$  hour and  $< 2$  hours, and 120.16 (SD: 41.48) in social jetlag  $< 1$  hour. Comparing these three groups, the gap of proportion by gender (men 58.3%, women 41.7%) in the social jetlag  $\geq 2$  hours was smaller than the other groups ( $p = .04$ ). In the social jetlag  $\geq 1$  hour and  $< 2$  hours group was youngest ( $p = .03$ ), mean of the mid-sleep time was roughly 30 minutes gap (the latest;  $4:08 \pm 1.4$  hours in the social jetlag  $\geq 2$  hours, the earliest;  $3:11 \pm 0.8$  hours in the social jetlag  $< 1$  hour group) ( $p < .001$ ). Even though not significantly different, social jetlag

$\geq 2$  hours group had slightly shorter mean TST, lower mean step count, and the proportion of skipping breakfast was larger than the other groups.

Table 10 shows the association between social jetlag  $\geq 2$  hours and incidence of MetS and pre-MetS. The association was significant in Model 4: risk ratio 2.81 (95% CI: 1.03; 7.69) compared with social jetlag  $< 1$  hour. Table 10 shows the association between social jetlag  $\geq 2$  hours and incidence of MetS and pre-MetS with excluded less than 180 days between baseline and outcome. The association was significant in Model 4: risk ratio 2.81 (95% CI: 1.03; 7.69) compared with social jetlag  $< 1$  hour.

Table 11 shows that social jetlag  $\geq 2$  hours was associated with systolic blood pressure in all models (Model 4: 11.24 mmHg; 95% CI: 4.26; 20.55) increase compared with social jetlag  $< 1$  hour. The social jetlag  $\geq 2$  hours was also associated with HDL-C levels in model 4 (9.10 mg/dl; 95% CI: 1.06; 17.13) and continuous social jetlag in crude model and model 4 (Model 4: 2.39 mg/dl; 95% CI: 0.28; 4.49) per 1-hour social jetlag increase.

Table 12 shows the baseline characteristics of the participants in Sample 2 according to social jetlag  $\geq 2$  hours,  $\geq 1$  hour and  $< 2$  hours, and  $< 1$  hour. The number of average main sleep was 126.44 (SD: 38.24) in social jetlag  $\geq 2$  hours, 134.08 (SD: 40.98) in social jetlag  $\geq 1$  hour and  $< 2$  hours, and 134.22 (SD: 41.18) in social jetlag  $< 1$  hour. Comparing these three groups, gender, age, smoking status, skipping breakfast, frequency of drinking, sleep satisfaction, and mean mid-sleep time were significantly different ( $p < .001$ ).

Table 13 shows that there was no statistically significant association between social jetlag and incidence of MetS and pre-MetS. Table 14 shows that continuous social jetlag was inversely associated with waist circumference and fasting blood glucose in non-adjusted



model (crude model: -0.71 cm; 95% CI: -1.34; -0.08, and crude model: -1.18 mg/dl; 95% CI: -2.04; -0.33) per 1-hour social jetlag increase.

Table 15 shows the baseline characteristics of the participants in Sample 3 according to social jetlag  $\geq 2$  hours,  $\geq 1$  hour and  $< 2$  hours, and  $< 1$  hour. The number of average main sleep was 127.00 (SD: 40.38) in social jetlag  $\geq 2$  hours, 133.27 (SD: 41.68) in social jetlag  $\geq 1$  hour and  $< 2$  hours, and 138.41 (SD: 39.42) in social jetlag  $< 1$  hour. Comparing these three groups, gender ( $p < .001$ ), age ( $p < .001$ ), skipping breakfast ( $p = .001$ ), frequency of drinking ( $p = .03$ ), sleep satisfaction ( $p < .001$ ), categorical BMI ( $p = .03$ ), mean TST ( $p < .001$ ), mean sleep duration ( $p < .001$ ), and mean mid-sleep time ( $p < .001$ ) were significantly different.

Table 16 shows that there was no statistically significant association between social jetlag and incidence of MetS and pre-MetS. Table 17 shows that the  $\geq 1$  hour and  $< 2$  hours social jetlag was inversely associated with waist circumference in non-adjusted model and models 1-2 and 4 (Model 4: -0.40 cm; 95% CI: -0.79; -0.01) decrease compared with social jetlag  $< 1$  hour. In addition, continuous social jetlag was also inversely associated with waist circumference in non-adjusted model (crude model: -0.81 cm; 95% CI: -1.29; -0.33) per 1-hour social jetlag increase. The  $\geq 1$  hour and  $< 2$  hours social jetlag was inversely associated with fasting blood glucose (crude model: -1.54 mg/dl; 95% CI: -2.39; -0.69) and continuous social jetlag was inversely associated with fasting blood glucose (crude model: -0.91 mg/dl; 95% CI: -1.55; -0.28) per 1-hour social jetlag increase. The  $< 2$  hours social jetlag was associated with diastolic blood pressure in models 2-4 (Model 4: 2.98 mmHg; 95% CI: 0.47; 5.49) increase compared with social jetlag  $< 1$  hour.

Table 18-20 show basic statistics of AHC values by the population with sleep data linkage and the population in the JMDC database without sleep data linkage each fiscal year.

#### IV Discussion

Study 1 showed that shorter TST was inversely associated with HDL-C in a cross-sectional study in a Japanese office worker population in Tokyo. However, the population in Study 1 was not representative of a Japanese working population enough, and future studies will need to do a prospective investigation of the association between TST with lipid profiles. Furthermore, although the actual prevalence of irregular sleep schedules and social jetlag in Japan's working population is uncertain, not only sleep duration but also irregular sleep schedules and social jetlag are associated with components of lifestyle-related diseases and MetS. Previous researches have demonstrated that they are related. In Study 2, large-scale sleep data described that average sleep-wake schedules and the prevalence of social jetlag in Japan's working population.. Based on the results from Study 2, Study 3 demonstrated that greater social jetlag was not consistently associated with the risk of MetS in the short term, which is contrary to our hypothesis. On the other hand, greater social jetlag was consistently associated with HDL-C and systolic blood pressure values the components of MetS assessment.

##### 1 Study 1<sup>22</sup>

Study 1 shows that increasing stress levels are inversely associated with LDL-C and LDL-C/HDL-C ratio, and that the shortest TST is inversely associated with HDL-C. The

inverse association of increasing stress and LDL-C and LDL-C/HDL-C ratio, respectively is contrary to our hypothesis, whereas the association of short TST and HDL-C is consistent with it.

One notable finding about the association between work-related stress and cholesterol level is that stress was inversely associated with LDL-C in all but the minimally adjusted model when the BJSQ was evaluated in terms of incremental increases per SD. Moreover, each incremental SD increase of the BJSQ score was inversely associated also with LDL-C/HDL-C ratio. When considering both of these results, we find that, contrary to our expectations, incrementally increasing stress is associated with more beneficial cholesterol profiles. There are at least two possible explanations for these paradoxical results. First, we need to take into consideration residual confounding. Although several important variables have been considered in the models, as discussed below, there may be additional confounders that need to be accounted for. Second, these associations are found when stress is treated as a continuous variable that does not distinguish between established low- and high stress groups. As such, although a statistically significant association appears, there may be no meaningful interpretation of such a result. Indeed, when the BJSQ was considered as a binary variable in accordance with recommended cut-offs, high stress compared to low stress was not associated with any of the outcome measures. However, care needs to be taken also when interpreting this result as the number of participants in the high stress group was limited to only 14 individuals, which may have limited the statistical power to detect associations for this specific exposure. Moreover, it is possible that a different BJSQ cut-off would show different results. Indeed, one study showed that high job stress using the BJSQ was associated

with low LDL-C<sup>34</sup>, although the researchers used only 17 of the BJSQ's 57 items in constructing the binary cut-off between low and high stress, and the study participants were all women engaged in shift work. The study population thus differed from ours, which was predominantly men without shift work.

Overall, psychological stress at work is associated with both high LDL-C<sup>23</sup> and low HDL-C<sup>23,35</sup>. Although moderate physical work and psychological stress are not associated with high LDL-C and moderate and heavy physical work are also not associated with high LDL-C or low HDL-C, psychological stress is associated with low HDL-C regardless of physical work. Suitable physical work may reduce dyslipidemia, as previously reported<sup>23</sup>. Even though our present participants were office workers and were assumed to have less work activity than other physical occupations, our analyses were adjusted for daily step count. This indicates that the found effects of stress on LDL-C and LDL-C/HDL-C ratio in the present study are independent of at least one physical activity measure. Assessing work-related stress level using different measures have shown the same association<sup>23</sup>.

Lipid profile is influenced by dietary characteristics, such as consumption of dietary fat and carbohydrates, and amount of food intake. Some foods reduce cholesterol levels, while others raise them, and food combination is also associated with cholesterol levels<sup>36</sup>. Food selection and amount of food intake depend on the individual, and are influenced by appetite and dietary literacy. One study reported that well-educated people are more likely to have beneficial information and knowledge on leading a healthier lifestyle, including food intake, and to consequently have lower LDL-C levels than those with lower educational attainment<sup>37,38</sup>. The participants of the present study were office workers, and relatively well educated.

LDL-C level remained lower with the continuous BJSQ scoring even after adjustment for eating habits and food intake in the daily questionnaire.

In Study 1, an average TST of 5.9-7.2 hours (T3) was used as reference as it is closer to the recommended sleep duration. Our study showed that an average TST between 4.0-5.3 hours is inversely associated with HDL-C. Sleep deprivation leads to low HDL-C levels <sup>39</sup>, and work-related stress is associated with sleep problems and increased total cholesterol levels <sup>40</sup>. Previous studies have indicated that both short <sup>41</sup> and long <sup>42</sup> sleep durations were associated with significantly lower HDL-C. In our study population of Japanese office workers, TST might have been shorter than in the general population therefore limiting the possibility of detecting any associations between long average TST and HDL-C.

Study 1 did not find any association between TST and LDL-C. A previous study, however, reported that - compared to 7 hours - a sleep duration of 8, but not 9, hours was associated with abnormal (high) LDL-C<sup>43</sup>. Several reasons may explain these contradictory results. First, whereas the above study used self-reported sleep duration, our present study relied on objective measurement of TST. Self-reported sleep time is likely to be longer than observed objective sleep time <sup>19</sup>, and subjective measures of sleep may be prone to recall bias. However, a recent study found no significant association of objective sleep duration with HDL-C or LDL-C, despite using repeated measures analyses of both the exposure and outcome over the course of 12 months <sup>44</sup>. This result does not directly contradict our present findings, but instead may serve as an indicator that time periods longer than one year need to be considered in studies aiming to prospectively detect any association between sleep time and corresponding change in cholesterol levels. Second, given that the present study was

conducted in an occupational cohort with predominantly male participants, there may be a difference in population characteristics. Indeed, at least one study using a population with similar characteristics to our own supported our findings of a positive association between longer sleep duration and HDL-C <sup>45</sup> . However, that study considered <5 hours as referent sleep duration, which is far from ideal given that sleep durations <5 hours are known to be associated with a number of incident disease <sup>44,46</sup> and mortality <sup>47</sup> outcomes. Further investigation of the association between longer TST and HDL-C and LDL-C in studies with larger populations and objectively measured TST are thus encouraged.

Objective measures may have a key role not only in providing more precise assessments but also in disease prevention and in policy recommendations. Using a wearable device might facilitate the detection of associations in real-world contexts. Indeed, wearable devices allow for the seamless collection of validated sleep data in larger populations than in the present study, as recent studies have demonstrated. An experimental study showed how self-regulation influences physical activity and the association between physical activity and well-being <sup>48</sup>. The collection of objective markers such as TST and physical activity data within a company may provide important information on employee health and recognize discrepancies in lifestyle-related indices between divisions within a company. Such information can potentially be used to identify individuals at risk of developing lifestyle-related diseases. Moreover, companies or divisions that have a high proportion of employees with unhealthy lifestyle patterns could be mandated to undergo more frequent stress checks in order to improve working conditions. This may be particularly important among Japanese workers who often report long working hours, in particular overtime working hours among

men<sup>49</sup>, albeit in the positive context of the overtime work being appreciated by co-workers and senior employees<sup>50</sup>. Longer working hours are not only associated with high job stress<sup>51</sup> but also the cause of shortened sleep time in both Japanese men and women<sup>52</sup>.

In study 1, we found no associations of average TST with LDL-C/HDL-C ratio. This result might have been related to the inverse associations between average TST and HDL-C and no association between average TST and LDL-C. To our knowledge, only a few studies have investigated the association between sleep and LDL-C/HDL-C ratio. One study found a significant association between obstructive sleep apnea (OSA) severity and atherogenic index of plasma using LDL-C/HDL-C ratio to assess lipid profile<sup>53,54</sup>. Indeed, OSA needs to be considered in research investigating the association between TST and cardiovascular risk factors. In the present study, we adjusted our statistical models for snoring and BMI, which combined could be considered a proxy for OSA. Another study reported that total cholesterol (TC)/HDL-C ratio may be more useful as a marker of the cluster of metabolic abnormalities than LDL-C/HDL-C ratio in men<sup>54</sup>. The use of TC/HDL-C ratio may need to be considered in future studies.

Study 1 has a few limitations. First, cholesterol levels were retrieved from the latest AHC preceding the start of the study. This is a major limitation of the study and warrants follow-up analyses in studies where cholesterol levels are measured in conjunction with remaining questionnaire- and wearable device data. Future studies are therefore encouraged to replicate our findings. However, it should be mentioned that it is unlikely that cholesterol levels, in particular HDL-C, would have notably changed before the start of the study. Second, the study population may not be representative of the Japanese general population. Nevertheless,

the results are generalizable to the occupational settings of Japanese office workers. Third, LDL-C values were used as they were provided by each health check-up center. LDL-C can be either directly measured or calculated using the Friedewald formula; however, this information was not provided by the health check-up centers. Fourth, our analyses are cross-sectional in nature and future studies should consider using repeated measures not only for TST but also for HDL-C and LDL-C. This may allow the identification of prospective associations.

Allowing for these limitations, the study also has several strengths. First, we used validated TST obtained from objective measures to construct the average TST of each participant for the study period. This is in contrast to most previous studies that have used subjective self-reported sleep measures. Second, the participants were asked to wear the wearable device continuously round the clock during the study, thereby allowing us to capture lifestyle-related indices such as step count. Third, our analyses were adjusted for a number of covariates known to be associated with both exposure and outcome measures. Finally, stress levels were assessed using guidelines from the MHLW of Japan, and the results are therefore relevant for the definition of stress in Japanese occupational settings.

In conclusion, this study presents two main findings: 1) incremental increases in occupational stress are inversely associated with LDL-C and LDL-C/HDL-C ratio; and 2) average TST between 4.0-5.3 hours is inversely associated with HDL-C when compared to average TST between 5.9-7.2 hours. Future studies should prospectively investigate the association of occupational stress and TST with lipid profiles.



## 2 Study 2

In Study 2, we aimed to describe sleep tendencies, including TST, social jetlag, and sleep-wake schedules, and compare them by gender, age, and weekday/weekend using real-world data from Japanese employees equipped with health insurance and an activity tracker. The results showed that the average sleep duration in this population was shorter than the recommended sleep duration, even with objective sleep measures. The prevalence of social jetlag larger than 2 h was low but that of social jetlag in the range of 0–2 h was 20%–30%. In addition, statistically significant differences were observed between weekdays and weekends in the TST, sleep period, waking time, and mid-sleep time. Moreover, TST, sleep-wake schedules, and social jetlag differed by gender and age. In the younger age groups, both men and women had longer sleep durations, but the difference was greater in women. Although the proportion of social jetlag larger than 2 h and within 1–2 h was higher in women than those in men, since wake-up time on weekends in women was later than in men, there was no substantial difference on weekdays by gender. These results suggest that weekend sleep might compensate for insufficient weekday sleep. This compensation tendency was slightly higher among women.

Comparing the results of this study with those of other studies using Fitbit in the US, the TST for both men and women was 30–40 min shorter in Japan<sup>11</sup>. Compared to the findings of another large-scale study using a Fitbit in Oceania and East Asian countries, the TST was approximately 1 h shorter in Japan on weekdays and weekends, respectively<sup>21</sup>. In addition, compared with East Asian countries, the TST in Japan is approximately 30 min shorter on weekdays and weekends. These discrepancies in findings may be accounted for

by the differences in participant demographic characteristics. In this study, most participants were male, aged 18–73 years, whereas previous studies included participants aged 15–80 years. Furthermore, in Oceania, the age distribution was equal for all age groups. In addition, this study included a working population, whereas previous studies were not limited to working populations. Moreover, the research period in the previous study was one month while it was 3 years in this study, which was significantly longer. The mean TST of the participants was less than 6 h regardless of gender, even though the mean sleep period was > 6 h. Although this is in line with the MHLW survey that reported roughly half of middle-aged Japanese people have less than 6 h of sleep<sup>8</sup>, TST in this study was approximately 1.5 h shorter than that reported for Japan by the OECD<sup>7</sup>. Compared with OECD countries, Japan has the shortest average daily sleep. The OECD report used data from the Japanese Survey on Time Use and Leisure Activities (2016), which included participants older than 10 years<sup>55</sup>. In addition, the OECD survey included unemployed persons. According to the MHLW's 2017 report, Japanese full-time workers tend to work about 2 hours longer, including overtime hours, than part-time workers<sup>56</sup>. In addition to working hours, Japanese full-time workers tended to commute longer than part-time workers in 2018<sup>57</sup>. The median commuting time for a person employed by a company, organization, public corporation, or individual, except part-time employees, nationwide in Japan was 59.2 minutes, while that for part-time employees was 45.8 minutes. Japanese full-time workers tend to have long commuting and working hours, which may result in relatively short sleep hours.

Although the start time of sleep on weekdays was roughly 20 min earlier than on weekends for both men and women, weekday TST and sleep period were approximately 30

min to 1 h shorter than those on weekends. In addition, wake-up time on weekends was more delayed than on weekdays, and the midpoint of sleep time on weekends was consequently delayed, regardless of gender. This sleep pattern trend was also observed in East-Asian participants in a previous study using an objective sleep measure<sup>21</sup>. The proportions of participants' social jetlag of less than 1 h or more than 2 h were approximately 60% and 3%, respectively. In contrast, Ong<sup>21</sup> reported that social jetlag (weekend–weekday sleep duration) was less than 1 h. The differences between this previous survey and this study are not only in the research period, and the countries and employment status of the participants, but also in the fact that this survey excluded people who use psychotherapeutic drugs and those with sleep apnea syndrome. It is possible that the presence of these patients affected our results.

However, the results of studies using self-reported sleep measures differ from those of studies using objective sleep measures. In a study using self-reported sleep measures in the US, the mean start time of sleep on working days was approximately 11:00 pm, and the wake-up time was approximately 6:40 am<sup>58</sup>. On free days, the mean sleep start time was approximately 11:30 pm, and the mean wake-up time was approximately 7:40 am. Approximately half of the participants had a 1-h social jetlag, and 20 percent of them had a 2-h social jetlag. The proportion of 2-h social jetlag was greater than that in the present study and a previous study using objective sleep measures. A longitudinal study using self-reported sleep measures in South Korea reported changes in sleep characteristics from 2009 to 2018<sup>58</sup>. Although the study was longitudinal, the results in 2018 showed that the sleep onset latency time on workdays was approximately 0:15 am, almost the same as in the present study, and the wake-up time was 6:40 am, roughly 20 min later than in the present study. The rates of

social jetlag of 1–2 h and over 2 h were higher than those in the present study. One of the differences between previous studies and the present study is the working status. Approximately 40% of the participants were unemployed in the US and South Korea studies, whereas the participants in the present study were mostly full-time employees.

When compared by gender, the gap in the mean sleep time, sleep period, and the midpoint of sleep time in women was roughly 15 minutes larger than that in men (i.e., women had more gaps than men between weekdays and weekends, and women slept more on weekends). A study that examined the relationship between working hours on weekdays and short sleeping hours (less than 6 h) on weekdays and weekends found that working hours longer than the reference value (7–9 working hours) were associated with shorter sleeping hours on both weekdays and weekends<sup>59</sup>. As explained by the study authors, if persons have matters that cannot be done on weekdays, it may result in a lack of sleep on weekends (i.e., gaps between weekday and weekend sleep hours are less likely to occur). Moreover, the 2021 Survey on Time Use and Leisure Activities indicated that men spend slightly more time on hobbies and amusement than women<sup>60</sup>. Therefore, men may be less prone to sleep gaps between weekdays and weekends if they work relatively long hours on weekdays and spend more time on hobbies or other activities.

There was a difference in the mean sleep time and sleep-wake schedules between the age groups and genders. Both younger men and women were more likely to sleep more than their older counterparts. These results indicate trends similar to those reported by the MHLW in 2019<sup>8</sup>. While younger people tended to sleep more than older people, the difference among age groups in women was approximately 35 minutes and 10–15 minutes larger than that in

men. The mean sleep time in men between the younger and older age groups on weekdays and weekends showed 10–20-minute and 20–30-minute gaps, respectively. In contrast, the difference in mean sleep time in women among the age groups showed almost the same tendency on both weekdays and weekends. The reason women aged over 50 years had about 35 minutes shorter sleep than the youngest women may be accounted for by the differences in obligations, including care responsibilities. According to the 2021 Survey on Time Use and Leisure Activities, women spend on average more than 2 h weekly providing nursing care<sup>60</sup>. In addition, the proportion of caregivers in the population of this survey by gender and age was roughly three to four times higher in women in the 50s–60s age group than in the younger groups. Since most participants in this study were full-time workers, fulfilling care responsibilities may have accounted for the shorter sleeping time among older women. In a previous study in South Korea, sleep duration on workdays in women aged 40s–50s was shorter than that in other age groups, and a similar pattern was observed among men, including on free days<sup>61</sup>. Although the South Korean study used self-reported sleep measures, middle-aged people may have had shorter sleep durations, as suggested by the present and previous studies.

The midpoint of sleep time among the age groups was later for the younger than for the older people on both weekdays and weekends. For both men and women, the differences on weekends were greater than those on weekdays. A study in Germany, Switzerland, and Austria that described social jetlag indicated that middle sleep time on holidays in the younger population tended to be late<sup>18</sup>. Even though there was no employment information in the study, the mean middle sleep time on holidays for people aged 14–25 years old was

close to 5:00 a.m., which was later than that for the other age groups (26–40 years, 4:25; 41–60 years, 3:42; over 60 years, 3:17). If the same trend is observed in the Japanese population, assuming similar weekday working patterns, a greater social jetlag may occur in younger groups.

Although this study showed the actual sleep patterns of the Japanese working population measured using wearable devices, there were several limitations. First, the participants' occupations and shift work status were unknown. Occupation and shift work, as well as lifestyle habits, could affect TST and sleep-wake schedules. In addition, the participants' medical histories were not available; instead, their health claim records were used to determine eligibility. The patient's medical history, including SAS or other psychiatric disorders, may have affected sleep. Second, the participants were not asked to wear Fitbit continuously. Some participants had daily sleep records, while others did not. Consequently, the number of main sleep sessions differed among participants. Nevertheless, the mean sleep data were assumed to be equivalent. Third, because the study population comprised only members of a health insurance association and who were linkage sleep data with Fitbit, it was not representative of the Japanese working population.

This study had several strengths. First, our data included many participants and sleep observations captured with objective sleep measures over a long period. Second, several conditions that have been shown to affect sleep were excluded based on the participants' health insurance claim records, which are reliable data.

### 3 Study 3

Overall, there was no shown association consistently between social jetlag and incidence of MetS and pre-MetS in Study 3. On the other hand, HDL-C and Systolic blood pressure in the assessment component of MetS were consistently associated with the incidence of MetS and pre-MetS. Sample 1 (i.e., baseline 2019 fiscal year and outcome measures in 2020 fiscal year) had the association between over 2-hour social jetlag and incidence of MetS and pre-MetS compared to less than 1-hour social jetlag while Sample 2 (i.e., baseline 2020 fiscal year and outcome measures in 2021 fiscal year) and Sample 3 (baseline 2021 fiscal year and outcome measures in 2022 fiscal year) had no association. One of those possible reasons is that the participants had their AHC different timing, and the duration of baseline and outcome differed. While the mean of days between baseline and outcome was 381.2 days (min; 153 days, max; 705 days) in Sample 1, 346.2 days (min; 71 days, max; 621 days) in Sample 2, and 363.1 days (min; 77 days, max; 724 days) in Sample 3. Although the participants with an extremely short period before outcome evaluation (i.e., less than 180 days) were excluded from the analysis, there was no significant changes were observed in the results. In general, it is known that developing MetS takes long time and chronically progress. In Sample 2 and 3 included roughly 1.5 months later outcome. According to previous studies, three or more follow-up year was set to examine the association between habitual sleep and MetS<sup>16,62</sup>.

In these Sample 1-3, the incidence of metabolic syndrome was less than 10% in each fiscal year, and it appears to be a rare case. The case of MetS was 27 (3%) and pre-MetS was 57 (7%) in Sample 1, the case of MetS was 42 (2%) and pre-MetS was 105 (5%) in Sample 2, and the case of MetS was 53 (2%) and pre-MetS was 164 (5%) in Sample 3. Compared with the basic statistics of the population that was not linked to sleep data, the case of MetS

and pre-MetS were less than several percent respectively. Therefore, if we roughly divide the groups into those with and without sleep data coordination, it can be said that the group with sleep coordination has a characteristic in which there are fewer cases of MetS diagnosis.

The results of each MetS component show that HDL-C was positively associated with over 2-hour and continuous in the fully adjusted model, and systolic blood pressure was also positively associated with over 2-hour social jetlag in Sample 1. In Sample 2, systolic blood pressure was positively associated with over 1 hour and less than 2 hours social jetlag and continuous social jetlag. In Sample 3, there was inverse association between waist circumference and over 1 hour and less than 2 hours social jetlag. These Samples' trend demonstrated that HDL-C and blood pressure were positively associated with social jetlag even though that was not strongly consistent. These results show that, especially in the Samples where no association with MetS was observed, there were significant differences when looking at the association with each factor alone, so it is beneficial to check the association with these factors as well.

Comparing the results of this study with a previous study, Islam demonstrates the association between over 2-hour social jetlag and having MetS and greater social jetlag was associated with high waist circumference. In Islam's analyses, they excluded shift workers and those on flextime workers for their analysis. In addition, they adjusted job type (blue collar or white collar), marital status, overtime work, eating habits such as snacking at night for statistical models<sup>16</sup>. These types of information were lacked in the present study. We, on the other hand, used objective sleep measure to assess TST and social jetlag even though Islam used self-reported sleep data.



Another study conducting in urban areas in the USA demonstrated that there was not association between MetS and social jetlag<sup>63</sup>. This study used objective sleep measure although only recorded 7 days and included 5 or more than 5 days of valid sleep data, and they analyzed the association using cross-sectional study. In addition, they used different MetS criteria with that Study 3 used MetS criteria. For these reasons, it is difficult to compare the previous study and Study 3. On the other hand, as they mentioned that longitudinal studies are needed even though they did not indicate specific study duration. If we analyze the present study more than 1 year follow-up study duration, we may find other findings.

Study 3 for social jetlag and incidence MetS analysis had some strengths. First, we analyzed the association between both categorical and continuous social jetlag and MetS/pre-MetS and Mets components. Even though there was no association between social jetlag and MetS, MetS components may show association. In the analysis about MetS, we should include MetS component as well. Second, we used objective sleep measures using a wearable device and used daily step count to adjust daily physical activity. However, there were some limitations. First, relatively larger distribution in the duration between baseline and outcome. Although the present study applied exclusion of the participants with less than 180 days the duration between baseline and outcome as sensitivity analysis. Future studies should be also considered the duration between baseline and outcome. Second, lack of information about occupations, working style, and habitual eating behaviors. Some previous studies had this type of information and included into analyzed model as confounders. For future studies, confounders are used as possible as we could do.

## V Conclusion

In conclusion, Study 1 showed that shorter TST was inversely associated with HDL-C in a cross-sectional study in a Japanese office worker population in Tokyo. Future studies will need to do a prospective investigation of the association between TST with lipid profiles. In Study 2, large-scale sleep data described that the actual average sleep duration in this population was shorter than the recommended sleep duration, even with objective sleep measures. The prevalence of social jetlag larger than 2 h was low but that of social jetlag in the range of 0–2 h was 20%–30%. These sleep tendencies differ among age and gender. Based on the results from Study 2, Study 3 demonstrated that greater social jetlag was not consistently associated with the risk of MetS in the short term, which is contrary to our hypothesis. On the other hand, greater social jetlag was consistently associated with HDL-C and systolic blood pressure values the components of MetS assessment. Although greater social jetlag may be associated with the risk of MetS in a short term, the number of sleep observations, sleep calculations, and the duration between baseline and outcomes should be reconsidered to appropriately examine the association between social jetlag and the incidence of MetS for the next analyses. Further studies will warrant exploration of the longitudinal association between social jetlag and the incidence of MetS.

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Table 1. Study 1: Baseline characteristics according to the Brief Job Stress Questionnaire score

<b>Characteristics</b>	<b>BJSQ low stress <i>n</i> = 159</b>	<b>BJSQ high stress <i>n</i> = 14</b>	<b><i>P</i> value <sup>a</sup></b>
Men (%)	93.08	92.86	0.98
Age at screening [mean (years $\pm$ SD)]	43.8 $\pm$ 7.7	39.1 $\pm$ 9.6	0.03
<b>Lifestyle factors</b>			
Smoking status (%)			0.83
Non-smoker	44.0	35.7	
Past smoker	28.9	35.7	
Current smoker (< 20 cigarettes/day)	15.7	21.4	
Current smoker ( $\geq$ 20 cigarettes/day)	11.3	7.1	
Snoring (%)	69.8	78.6	0.49
Consistent bedtime $\geq$ 3 days/week (%)	96.2	100.0	0.46
Body mass index kg/m <sup>2</sup> (%)			0.10
< 25	34.6	35.7	
25 – 29.9	59.1	42.9	
$\geq$ 30	6.3	21.4	
HbA1c [mean (% $\pm$ SD)]	5.4 $\pm$ 0.3	5.3 $\pm$ 0.2	0.11
	<b><i>n</i> = 159, observations 7693</b>	<b>= <i>n</i> = 14, observations = 630</b>	
<b>Daily components</b>			
Alcohol consumption [mean (ethanol g/day $\pm$ SD)]	36.4 $\pm$ 35.2	25.4 $\pm$ 17.6	0.25
Sleep satisfaction (5-point scale) [mean $\pm$ SD]	3.5 $\pm$ 0.5	3.2 $\pm$ 0.5	0.01
Number of servings of staple foods [mean $\pm$ SD]	4.3 $\pm$ 0.9	4.5 $\pm$ 0.6	0.31
Number of servings of main dish [mean $\pm$ SD]	4.3 $\pm$ 1.1	4.7 $\pm$ 0.8	0.15
Number of servings of dairy product [mean $\pm$ SD]	36.4 $\pm$ 35.2	25.4 $\pm$ 17.6	0.25
Number of steps/day [mean $\pm$ SD]	11120.4 $\pm$ 2658.8	10281.4 $\pm$ 2014.0	0.25
Total sleep (hours)/day [mean $\pm$ SD]	5.6 $\pm$ 0.6	5.6 $\pm$ 0.6	0.98

Abbreviation: BJSQ, the Brief Job Stress Questionnaire, SD: standard deviation

<sup>a</sup>t-test for age at screening and HbA1c; Chi-square test for categorical variables; generalized estimating equations for daily component variables

Table 2. Study 1: The association of the Brief Job Stress Questionnaire and total sleep time with cholesterol levels ( $n = 173$ )

<b>LDL-cholesterol</b>		<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>The BJSQ</b>	Low	Reference	Reference	Reference	Reference
	High	-8.33 (-24.61, 7.95)	-9.33 (-25.60, 6.94)	-14.29 (-30.72, 2.13)	-16.04 (-32.91, 0.84)
	Continuous	-4.26 (-8.68, 0.17)	<b>-5.04<sup>e</sup> (-9.47, -0.61)</b>	<b>-5.98<sup>f</sup> (-10.40, -1.56)</b>	<b>-7.12<sup>f</sup> (-11.78, -2.45)</b>
<b>Average total sleep time</b>	4.0-5.3 h	0.73 (-10.12, 11.58)	0.18 (-10.71, 11.07)	0.89 (-10.05, 11.82)	0.15 (-10.99, 11.28)
	5.4-5.9 h	-3.67 (-14.55, 7.20)	-3.86 (-14.75, 7.04)	-4.74 (-15.68, 6.21)	-5.18 (-16.27, 5.91)
	5.9-7.2 h	Reference	Reference	Reference	Reference
<b>HDL-cholesterol</b>		<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>The BJSQ</b>	Low	Reference	Reference	Reference	Reference
	High	-1.23 (-7.92, 5.46)	-0.73 (-7.25, 5.79)	-1.45 (-7.94, 5.04)	-1.54 (-8.21, 5.12)
	Continuous	-0.17 (-2.00, 1.67)	0.30 (-1.50, 2.09)	0.55 (-1.22, 2.32)	0.57 (-1.30, 2.45)
<b>Average total sleep time</b>	4.0-5.3 h	<b>-6.19<sup>f</sup> (-10.65, -1.72)</b>	<b>-6.17<sup>f</sup> (-10.53, -1.81)</b>	<b>-4.74<sup>e</sup> (-9.06, -0.42)</b>	<b>-4.82<sup>e</sup> (-9.22, -0.43)</b>
	5.4-5.9 h	-3.65 (-8.12, 0.83)	-3.39 (-7.76, 0.98)	-1.69 (-6.02, 2.63)	-1.62 (-5.10, 2.76)
	5.9-7.2 h	Reference	Reference	Reference	Reference
<b>LDL/HDL ratio</b>		<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>The BJSQ</b>	Low	Reference	Reference	Reference	Reference
	High	-0.09 (-0.52, 0.34)	-0.12 (-0.54, 0.29)	-0.18 (-0.59, 0.24)	-0.22 (-0.64, 0.20)
	Continuous	-0.07 (-0.18, 0.05)	-0.10 (-0.21, 0.02)	<b>-0.13<sup>e</sup> (-0.24, -0.02)</b>	<b>-0.16<sup>f</sup> (-0.27, -0.04)</b>
<b>Average total sleep time</b>	4.0-5.3 h	0.22 (-0.07, 0.51)	0.21 (-0.07, 0.49)	0.17 (-0.11, 0.44)	0.15 (-0.13, 0.43)
	5.4-5.9 h	0.04 (-0.52, 0.34)	0.02 (-0.26, 0.30)	-0.06 (-0.34, 0.21)	-0.08 (-0.36, 0.20)
	5.9-7.2 h	Reference	Reference	Reference	Reference

Abbreviations; BJSQ: the Brief Job Stress Questionnaire, LDL: Low-density lipoprotein, HDL: High-density lipoprotein, LDL/HDL ratio: Low-density lipoprotein/High-density lipoprotein ratio.

Bold values denote statistically significant results.

<sup>a</sup> Model 1 is adjusted for gender and age.

<sup>b</sup> Model 2 is additionally adjusted for smoking and average alcohol consumption.

<sup>c</sup> Model 3 is additionally adjusted for body mass index, waist circumference, HbA1c, and food intake.

<sup>d</sup> Model 4 is additionally adjusted for average steps, average sleep satisfaction, snoring and consistent bedtime.

<sup>e</sup>  $p < 0.05$ . <sup>f</sup>  $p < 0.01$

Table 3. Study 2: Comparisons of sleep characteristics by fiscal year.

	<b>FY2019: n = 4,386</b>	<b>FY2020: n = 6,386</b>	<b>FY2021: n = 8,918</b>
<b>Number of main sleep/participant (mean <math>\pm</math> SD)</b>	<b>224.30 <math>\pm</math> 78.74</b>	<b>255.48 <math>\pm</math> 87.73</b>	<b>264.32 <math>\pm</math> 83.21</b>
<b>Variables</b>	<b>Mean <math>\pm</math> SD</b>		
Age at screening (years)	45.32 $\pm$ 9.52	46.57 $\pm$ 9.36	46.87 $\pm$ 9.55
TST (hour)	5.78 $\pm$ 0.64	5.85 $\pm$ 0.68	5.83 $\pm$ 0.68
Sleep period (hour)	6.65 $\pm$ 0.74	6.75 $\pm$ 0.78	6.73 $\pm$ 0.78
Wake time (hour)	0.88 $\pm$ 0.16	0.89 $\pm$ 0.17	0.89 $\pm$ 0.17
Deep sleep time (hour)	0.97 $\pm$ 0.20	0.99 $\pm$ 0.21	0.99 $\pm$ 0.21
Start time (clock time)	23:59 $\pm$ 1:02	23:55 $\pm$ 1:11	23:52 $\pm$ 1:11
Wake up time (clock time)	6:38 $\pm$ 0:55	6:41 $\pm$ 1:04	6:37 $\pm$ 1:05
Mid-sleep time (clock time)	3:19 $\pm$ 0:55	3:18 $\pm$ 1:04	3:14 $\pm$ 1:04

Abbreviations; FY: fiscal year, SD: standard deviation, CI: confidence interval, TST: total sleep time.

Table 3 (cont). Study 2: Comparisons of sleep characteristics by fiscal year.

<b>Variables</b>	<b>Comparing FY2019 and FY2020</b>	<b>Comparing FY2019 and FY2021</b>	<b>Comparing FY2020 and FY2021</b>
	<b>Effect point estimate (95% CI)</b>		
Age at screening (years)	-1.26 (-1.62; -0.89)	-1.56 (-1.90; -1.21)	-0.30 (-0.61; 0.00)
TST (hour)	-0.08 (-0.10; -0.05)	-0.06 (-0.08; -0.03)	0.02 (-0.00; 0.04)
Sleep period (hour)	-0.09 (-0.12; -0.06)	-0.07 (-0.10; -0.04)	0.02 (-0.00; 0.05)
Wake time (hour)	-0.02 (-0.02; -0.01)	-0.01 (-0.02; -0.01)	0.00 (-0.00; 0.01)
Deep sleep time (hour)	-0.02 (-0.02; -0.01)	-0.01 (-0.02; -0.01)	0.00 (-0.01; 0.01)
Start time (clock time)	0.06 (0.02; 0.10)	0.11 (0.07; 0.15)	0.05 (0.01; 0.09)
Wake up time (clock time)	-0.04 (-0.08; 0.01)	0.02 (-0.02; 0.06)	0.06 (0.03; 0.10)
Mid-sleep time (clock time)	0.01 (-0.03; 0.05)	0.07 (0.03; 0.10)	0.06 (0.02; 0.09)

Abbreviations; FY: fiscal year, SD: standard deviation, CI: confidence interval, TST: total sleep time.



Table 4. Study 2: Comparisons of sleep variables by gender (2019-2021)

	<b>Total <math>n = 10,67</math></b>	<b>Men: <math>n = 7,74</math></b>	<b>Women: <math>n = 2,92</math></b>	<b>Comparison by gender</b>
<b>Number of main sleep/participant (mean <math>\pm</math> SD)</b>	<b>483.30 <math>\pm</math> 282.12</b>	<b>490.30 <math>\pm</math> 285.49</b>	<b>464.74 <math>\pm</math> 272.13</b>	
<b>Variables</b>	<b>Mean <math>\pm</math> SD</b>	<b>Mean <math>\pm</math> SD</b>	<b>Mean <math>\pm</math> SD</b>	<b>Effect point estimate (95% CI)</b>
Age (years)	45.52 $\pm$ 9.60	46.02 $\pm$ 9.56	44.21 $\pm$ 9.56	1.80 (1.39; 2.21)
TST (hour)	5.84 $\pm$ 0.66	5.79 $\pm$ 0.65	5.98 $\pm$ 0.67	-0.19 (-0.22; -0.17)
Sleep period (hour)	6.73 $\pm$ 0.76	6.68 $\pm$ 0.75	6.85 $\pm$ 0.78	-0.17 (-0.20; -0.14)
Wake time (hour)	0.89 $\pm$ 0.16	0.90 $\pm$ 0.16	0.87 $\pm$ 0.16	0.02 (0.02; 0.03)
Deep sleep time (hour)	0.99 $\pm$ 0.20	0.99 $\pm$ 0.21	1.01 $\pm$ 0.20	-0.02 (-0.03; -0.01)
Start time (clock time)	23:54 $\pm$ 1:09	23:55 $\pm$ 1:11	23:52 $\pm$ 1:03	0.04 (-0.01; 0.09)
Wake up time (clock time)	6:39 $\pm$ 1:02	6:37 $\pm$ 1:04	6:44 $\pm$ 0:56	-0.11 (-0.15; -0.06)
Mid-sleep time (clock time)	3:19 $\pm$ 1:15	3:17 $\pm$ 1:03	3:18 $\pm$ 0:55	-0.04 (-0.08; 0.00)
Social jetlag (hour)	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	<b>Chi-squared</b>
$\geq 0$ & $< 1$ (%)	8020 (75.16)	6073 (78.37)	1947 (66.66)	161.03 **
$\geq 1$ & $< 2$ (%)	2315 (21.70)	1447 (18.67)	868 (29.72)	
$\geq 2$ (%)	335 (3.14)	229 (2.96)	106 (3.63)	

Abbreviations; SD: standard deviation, TST: total sleep time, CI: confidence interval.

\*\*  $p < 0.01$

Table 5. Study 2: Comparisons of sleep variables by gender on weekends and weekdays, and the gap between weekends and weekdays (2019-2021).

	Men <i>n</i> = 7,749			Women <i>n</i> = 2,921		
	Weekend	Weekday	Gap	Weekend	Weekday	Gap
<b>Number of main sleep/participant (mean <math>\pm</math> SD)</b>	<b>160.76 <math>\pm</math> 95.11</b>	<b>329.54 <math>\pm</math> 191.04</b>	<b>490.30 <math>\pm</math> 285.49</b>	<b>151.90 <math>\pm</math> 90.41</b>	<b>312.84 <math>\pm</math> 182.51</b>	<b>464.74 <math>\pm</math> 272.13</b>
<b>Sleep variables</b>	<b>Mean <math>\pm</math> SD</b>					
TST (hour)	6.12 $\pm$ 0.78	5.62 $\pm$ 0.68	0.50 $\pm$ 0.62	6.49 $\pm$ 0.78	5.73 $\pm$ 0.71	0.76 $\pm$ 0.63
Sleep period (hour)	7.08 $\pm$ 0.89	6.49 $\pm$ 0.79	0.59 $\pm$ 0.71	7.44 $\pm$ 0.91	6.57 $\pm$ 0.82	0.87 $\pm$ 0.72
Wake time (hour)	0.96 $\pm$ 0.18	0.87 $\pm$ 0.16	0.09 $\pm$ 0.10	0.95 $\pm$ 0.18	0.83 $\pm$ 0.16	0.12 $\pm$ 0.10
Deep sleep time (hour)	1.04 $\pm$ 0.22	0.96 $\pm$ 0.21	1.04 $\pm$ 0.22	1.08 $\pm$ 0.21	0.98 $\pm$ 0.20	1.08 $\pm$ 0.21
Start time (clock time)	0:08 $\pm$ 1:19	23:48 $\pm$ 1:10	0.32 $\pm$ 0.53	0:08 $\pm$ 1:09	23:44 $\pm$ 1:02	0.40 $\pm$ 0.46
Wake up time (clock time)	7:16 $\pm$ 1:24	6:19 $\pm$ 1:01	0.95 $\pm$ 0.91	7:38 $\pm$ 1:14	6:19 $\pm$ 0:55	1.31 $\pm$ 0.84
Mid-sleep time (clock time)	3:42 $\pm$ 1:16	3:04 $\pm$ 1:01	0.63 $\pm$ 0.62	3:53 $\pm$ 1:06	3:02 $\pm$ 0:53	0.86 $\pm$ 0.57

Abbreviations; TST: total sleep time, SD: standard deviation.

Table 5 (cont.). Study 2: Comparisons of sleep variables by gender on weekends and weekdays, and the gap between weekends and weekdays (2019-2021).

<b>Comparison by gender</b>			
Sleep variables	Weekend	Weekday	Gap
	Effect point estimate (95% CI)		
TST (hour)	-0.37 (-0.40; -0.33)	-0.11 (-0.14; -0.08)	-0.26 (-0.28; -0.23)
Sleep period (hour)	-0.36 (-0.40; -0.32)	-0.08 (-0.11; -0.04)	-0.29 (-0.32; -0.26)
Wake time (hour)	0.005 (-0.00; 0.01)	0.03 (0.03; 0.04)	-0.03 (-0.03; -0.02)
Deep sleep time (hour)	-0.04 (-0.05; 0.03)	-0.02 (-0.02; -0.01)	-0.02 (-0.03; -0.02)
Start time (clock time)	0.01 (-0.07; 0.04)	0.06 (0.02; 0.11)	-0.08 (-0.10; -0.06)
Wake up time (clock time)	-0.36 (-0.42; -0.30)	0.005 (-0.04; 0.05)	-0.36 (-0.40; -0.33)
Mid-sleep time (clock time)	-0.19 (-0.24; -0.14)	0.03 (-0.01; 0.08)	-0.23 (-0.25; -0.20)

Abbreviations: CI: confidence interval, TST: total sleep time.

Table 6. Study 2: Pairwise comparisons by age group of total sleep time and mid-sleep time.

Unit: hour	Men		Women	
	TST	Mid-sleep time	TST	Mid-sleep time
Age groups	Effect point estimate (95% CI)		Effect point estimate (95% CI)	
10s-20s×30s	0.16 (0.10; 0.22)	0.59 (0.49; 0.70)	0.11 (0.03; 0.20)	0.33 (0.18; 0.47)
10s-20s×40s	0.32 (0.26; 0.38)	0.86 (0.76; 0.95)	0.32 (0.24; 0.40)	0.64 (0.53; 0.76)
10s-20s×50s	0.35 (0.28; 0.41)	1.19 (1.09; 1.29)	0.57 (0.48; 0.66)	0.76 (0.64; 0.88)
10s-20s×60s-70s	0.28 (0.19; 0.36)	1.41 (1.27; 1.55)	0.54 (0.41; 0.68)	1.00 (0.81; 1.19)
30s×40s	0.16 (0.13; 0.20)	0.27 (0.20; 0.33)	0.21 (0.14; 0.27)	0.32 (0.23; 0.41)
30s×50s	0.19 (0.15; 0.23)	0.59 (0.53; 0.66)	0.19 (0.39; 0.53)	0.43 (0.33; 0.53)
30s×60s-70s	0.12 (0.06; 0.18)	0.82 (0.71; 0.92)	0.43 (0.30; 0.56)	0.67 (0.47; 0.88)
40s×50s	0.03 (-0.01; 0.06)	0.33 (0.27; 0.38)	0.25 (0.19; 0.31)	0.12 (0.04; 0.19)
40s×60s-70s	-0.05 (-0.11; 0.01)	0.55 (0.46; 0.64)	0.22 (0.10; 0.35)	0.36 (0.19; 0.52)
50s×60s-70s	-0.07 (-0.14; -0.01)	0.22 (0.13; 0.32)	0.03 (-0.17; 0.11)	0.24 (0.07; 0.41)

Abbreviations; CI: confidence interval, TST: total sleep time.

Table 7. Study 2: Pairwise comparisons by age group of total sleep time on weekends and weekdays.

**Men**

Unit: hour	Weekends	Weekdays	Gap
Age groups	Effect point estimate (95% CI)		
10s-20s×30s	0.23 (0.16; 0.30)	0.13 (0.06; 0.19)	0.10 (0.04; 0.17)
10s-20s×40s	0.39 (0.32; 0.47)	0.30 (0.23; 0.36)	0.09 (0.03; 0.16)
10s-20s×50s	0.47 (0.39; 0.55)	0.30 (0.06; 0.19)	0.17 (0.11; 0.23)
10s-20s×60s-70s	0.45 (0.35; 0.54)	0.20 (0.11; 0.29)	0.25 (0.17; 0.32)
30s×40s	0.16 (0.11; 0.21)	0.17 (0.13; 0.21)	-0.01 (-0.05; 0.03)
30s×50s	0.24 (0.19; 0.29)	0.17 (0.13; 0.22)	0.07 (0.03; 0.11)
30s×60s-70s	0.22 (0.14; 0.29)	0.07 (0.01; 0.14)	0.14 (0.08; 0.20)
40s×50s	0.08 (0.04; 0.12)	0.002 (-0.04; 0.04)	0.08 (0.04; 0.11)
40s×60s-70s	0.06 (-0.02; 0.13)	-0.10 (-0.16; -0.03)	0.15 (0.10; 0.21)
50s×60s-70s	0.02 (-0.10; 0.05)	-0.10 (-0.16; -0.03)	0.08 (0.02; 0.13)

Abbreviations; CI: confidence interval.

Table 7 (cont.). Study 2: Pairwise comparisons by age group of total sleep time on weekends and weekdays.

**Women**

Unit: hour	Weekends	Weekdays	Gap
Age groups	Effect point estimate (95% CI)		
10s-20s×30s	0.09 (-0.01; 0.20)	0.13 (0.04; 0.22)	-0.04 (-0.14; 0.06)
10s-20s×40s	0.26 (0.16; 0.36)	0.36 (0.27; 0.44)	-0.09 (-0.18; -0.01)
10s-20s×50s	0.55 (0.44; 0.65)	0.59 (0.04; 0.22)	-0.05 (-0.13; 0.04)
10s-20s×60s-70s	0.58 (0.42; 0.74)	0.54 (0.39; 0.68)	0.04 (-0.10; 0.18)
30s×40s	0.17 (0.09; 0.24)	0.22 (0.16; 0.29)	-0.06 (-0.12; 0.01)
30s×50s	0.45 (0.37; 0.54)	0.46 (0.39; 0.54)	-0.01 (-0.08; 0.06)
30s×60s-70s	0.49 (0.33; 0.64)	0.41 (0.27; 0.54)	0.08 (-0.06; 0.22)
40s×50s	0.29 (0.22; 0.36)	0.24 (0.18; 0.30)	0.05 (-0.01; 0.10)
40s×60s-70s	0.32 (0.17; 0.47)	0.18 (0.05; 0.31)	0.14 (0.01; 0.26)
50s×60s-70s	0.03 (-0.13; 0.19)	-0.06 (-0.20; 0.09)	0.09 (-0.03; 0.21)

Abbreviations; CI: confidence interval.

Table 8. Study 2: Pairwise comparisons by age group of mid-sleep time on weekends and weekdays.

**Men**

Unit: hour	Weekends	Weekdays	Gap
Age groups	Effect point estimate (95% CI)		
10s-20s×30s	0.87 (0.73; 1.00)	0.48 (0.38; 0.59)	0.38 (0.31; 0.46)
10s-20s×40s	1.17 (1.05; 1.29)	0.74 (0.65; 0.83)	0.43 (0.37; 0.49)
10s-20s×50s	1.49 (1.37; 1.62)	1.07 (0.97; 1.17)	0.42 (0.36; 0.48)
10s-20s×60s-70s	1.75 (1.58; 1.91)	1.28 (1.15; 1.41)	0.47 (0.38; 0.55)
30s×40s	0.30 (0.23; 0.37)	0.25 (0.19; 0.31)	0.05 (0.01; 0.09)
30s×50s	0.62 (0.55; 0.70)	0.59 (0.52; 0.65)	0.04 (-0.002; 0.08)
30s×60s-70s	0.88 (0.75; 1.01)	0.80 (0.70; 0.90)	0.08 (0.02; 0.14)
40s×50s	0.32 (0.26; 0.39)	0.33 (0.28; 0.38)	-0.01 (-0.04; 0.02)
40s×60s-70s	0.58 (0.47; 0.69)	0.55 (0.46; 0.64)	0.04 (0.02; 0.09)
50s×60s-70s	0.26 (0.14; 0.37)	0.21 (0.12; 0.30)	0.04 (0.01; 0.10)

Abbreviations; CI: confidence interval.

Table 8 (cont.). Study 2: Pairwise comparisons by age group of mid-sleep time on weekends and weekdays.

<b>Women</b>			
Unit: hour	Weekends	Weekdays	Gap
Age groups	Effect point estimate (95% CI)		
10s-20s×30s	0.46 (0.28; 0.63)	0.28 (0.14; 0.42)	0.18 (0.08; 0.27)
10s-20s×40s	0.83 (0.70; 0.97)	0.57 (0.46; 0.68)	0.26 (0.19; 0.34)
10s-20s×50s	0.99 (0.85; 1.13)	0.67 (0.56; 0.79)	0.32 (0.24; 0.39)
10s-20s×60s-70s	1.26 (1.03; 1.49)	0.90 (0.72; 1.08)	0.36 (0.23; 0.48)
30s×40s	0.38 (0.27; 0.49)	0.29 (0.20; 0.38)	0.08 (0.03; 0.14)
30s×50s	0.53 (0.42; 0.65)	0.39 (0.30; 0.49)	0.14 (0.08; 0.20)
30s×60s-70s	0.80 (0.56; 1.05)	0.62 (0.42; 0.82)	0.18 (0.05; 0.31)
40s×50s	0.16 (0.07; 0.25)	0.10 (0.03; 0.17)	0.05 (0.01; 0.10)
40s×60s-70s	0.43 (0.23; 0.62)	0.33 (0.17; 0.49)	0.09 (-0.01; 0.20)
50s×60s-70s	0.27 (0.07; 0.47)	0.23 (0.07; 0.39)	0.04 (-0.06; 0.14)

Abbreviations; CI: confidence interval.



Table 9. Study 3 (Sample 1): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 12</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 171</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 h n = 627</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>126.4 ± 38.2</b>	<b>134.1 ± 41.0</b>	<b>120.2 ± 41.5</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>Gender</b>				
Men (%)	7 (58.3)	109 (63.7)	457 (72.9)	0.04
Women (%)	5 (41.7)	62 (36.3)	170 (27.1)	
<b>Age on the baseline AHC date [mean (years ± SD)]</b>	49.8 ± 7.0	45.3 ± 8.1	46.7 ± 7.4	0.03
<b>Smoking status</b>				
Non-smoker (%)	9 (75.0)	146 (85.4)	551 (87.9)	0.22
Smoker (%)	3 (25.0)	25 (14.6)	76 (12.1)	
<b>Skipping breakfast</b>				
Yes (%)	4 (33.3)	32 (18.7)	87 (13.9)	0.06
No (%)	8 (66.7)	139 (81.3)	540 (86.1)	
<b>Frequency of drinking</b>				
Every day (%)	4 (33.3)	36 (21.1)	158 (25.2)	0.71
Sometimes (%)	6 (50.0)	92 (53.8)	330 (52.6)	
Rarely (%)	2 (16.7)	43 (25.1)	139 (22.2)	
<b>Alcohol consumption</b>				
Less than 180 ml (%)	4 (33.3)	81 (47.4)	266 (42.4)	0.48
180-360 ml (%)	5 (41.7)	48 (28.1)	220 (35.1)	
360-540 ml (%)	1 (8.3)	27 (15.8)	92 (14.7)	
More than 540 ml (%)	2 (16.7)	15 (8.8)	49 (7.8)	
<b>Sleep satisfaction</b>				
Satisfied (%)	7 (58.3)	84 (49.1)	389 (62.0)	0.20
Not satisfied (%)	5 (41.7)	87 (50.9)	238 (38.0)	
<b>Body mass index (kg/m<sup>2</sup>)</b>				
< 25 (%)	11 (91.7)	151 (88.3)	548 (87.4)	0.93
≥25 (%)	1 (8.3)	20 (11.7)	79 (12.6)	
<b>Body mass index (kg/m<sup>2</sup>)</b>	22.1 ± 2.8	22.3 ± 2.7	22.3 ± 2.6	0.96

Table 9 (cont.). Study 3 (Sample 1): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 12</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 171</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 h n = 627</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>126.4 ± 38.2</b>	<b>134.1 ± 41.0</b>	<b>120.2 ± 41.5</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>LDL-C</b> [mean(mg/dl) ± SD]	127.1 ± 19.4	120.1 ± 29.4	121.6 ± 30.1	0.67
<b>HbA1c</b> [mean (%) ± SD]	5.5 ± 0.5	5.4 ± 0.4	5.4 ± 0.4	0.45
<b>WC</b> [mean(cm) ± SD]	80.5 ± 6.2	78.8 ± 7.4	79.5 ± 6.9	0.43
<b>FBG</b> [mean(mg/dl) ± SD]	96.0 ± 7.2	92.6 ± 10.7	93.4 ± 10.0	0.72
<b>TG</b> [mean(mg/dl) ± SD]	82.8 ± 22.3	81.9 ± 42.1	90.0 ± 50.7	0.06
<b>HDL-C</b> [mean(mg/dl) ± SD]	75.5 ± 14.5	66.6 ± 14.8	65.7 ± 16.2	0.11
<b>SBP</b> [mean(mmHg) ± SD]	119.3 ± 10.4	113.5 ± 13.6	115.3 ± 12.9	0.37
<b>DBP</b> [mean(mmHg) ± SD]	75.3 ± 7.1	71.4 ± 10.5	72.8 ± 10.1	0.32
<b>Pre-MetS/MetS incidence</b>	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	
None	9 (75.0)	158 (92.4)	559 (89.2)	0.10
Total incidence	3 (25.0)	13 (7.6)	68 (10.8)	
Pre-Mets	3 (25.0)	8 (4.7)	46 (7.3)	
MetS	0	5 (2.9)	22 (3.5)	
<b>Lifestyle factors from Fitbit data</b>				
<b>TST</b> [mean (hour) ± SD]	6.0 ± 0.6	5.8 ± 0.7	5.8 ± 0.6	0.61
<b>Sleep period</b> [mean (hour) ± SD]	6.9 ± 0.7	6.6 ± 0.7	6.7 ± 0.7	0.49
<b>Mid-sleep time</b> [mean (clock time) ± SD (hour)]	4:08 ± 1.4	3:40 ± 0.8	3:11 ± 0.8	<0.001
<b>Number of step counts/day</b> [mean (count) ± SD]	8976.8 ± 2318.7	10970.5 ± 3091.9	10951.3 ± 3263.7	0.11

Abbreviations; MetS: metabolic syndrome, AHC: annual health check-up, SD: standard deviation, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, TST: total sleep time.

Statistical test; Fisher's exact test for categorical variables and analysis of variance for continuous variables.

Table 10. Study 3 (Sample 1): Modified Poisson regression for the association between social jetlag and Mets.

Risk ratio (95% Confidence Interval)							
Social jetlag	Total n (%)	Case of pre-Mets and Mets n (%)	Crude model	Model 1 <sup>a</sup>	Model 2 <sup>b</sup>	Model 3 <sup>c</sup>	Model 4 <sup>d</sup>
< 1h	627 (77.4)	Pre-Mets: 46 (7.3) Mets: 22 (3.5)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	171 (21.1)	Pre-Mets: 8 (4.7) Mets: 5 (2.9)	0.70 (0.40; 1.24)	0.78 (0.44; 1.38)	0.75 (0.42; 1.32)	0.68 (0.39; 1.21)	0.75 (0.43; 1.33)
≥ 2h	12 (1.5)	Pre-Mets: 3 (25.0) Mets: 0 (0.0)	2.31 (0.84; 6.30)	2.43 (0.89; 6.67)	2.02 (0.74; 5.51)	2.43 (0.89; 6.65)	<b>2.81<sup>e</sup> (1.03; 7.69)</b>
Exclude less than 180 days until outcome: n= 808							
< 1h	627 (77.4)	Pre-Mets: 46 (7.3) Mets: 22 (3.5)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	169 (20.9)	Pre-Mets: 8 (4.7) Mets: 5 (3.0)	0.71 (0.40; 1.25)	0.79 (0.45; 1.39)	0.76 (0.43; 1.33)	0.69 (0.39; 1.22)	0.76 (0.43; 1.34)
≥ 2h	12 (1.5)	Pre-Mets: 3 (25.0) Mets: 0 (0.0)	2.31 (0.84; 6.30)	2.44 (0.89; 6.67)	2.02 (0.74; 5.51)	2.43 (0.89; 6.65)	<b>2.81<sup>e</sup> (1.03; 7.69)</b>

Abbreviations: Mets: metabolic syndrome, BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c.

Bold values denote statistically significant results.

<sup>a</sup>Model 1: gender and age adjusted.

<sup>b</sup>Model 2: additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3: additionally adjusted BMI (numeric), LDL-C, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4: additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps.

<sup>e</sup> $p < .05$ .

Table 11. Study 3 (Sample 1): Multiple linear regression for the association between social jetlag and MetS components.

<b>WC: n = 810</b>	<b>Crude model</b>	<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.25 (-1.50; 1.00)	0.15 (-1.08; 1.38)	0.19 (-1.04; 1.42)	0.01 (-0.76; 0.78)	-0.06 (-0.85; 7.29)
≥ 2h	0.37 (-3.85; 4.59)	0.66 (-3.47; 4.79)	0.39 (-3.75; 4.52)	0.65 (-1.95; 3.24)	0.16 (-2.46; 2.79)
Continuous (h)	-0.48 (-1.50; 0.53)	0.02 (-0.99; 1.02)	0.00 (-1.01; 1.01)	0.17 (-0.46; 0.81)	0.03 (-0.64; 7.01)
<b>FBG: n = 800</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.33 (-1.98; 1.32)	0.46 (-1.13; 2.05)	0.58 (-1.01; 2.17)	0.85 (-0.59; 2.28)	0.78 (-0.69; 2.26)
≥ 2h	2.59 (-3.15; 8.34)	2.54 (-2.99; 8.07)	2.40 (-3.14; 7.93)	2.35 (-2.63; 7.34)	2.16 (-2.93; 7.24)
Continuous (h)	-0.47 (-1.82; 0.88)	0.38 (-0.93; 1.70)	0.42 (-0.90; 1.73)	0.59 (-0.60; 1.78)	0.51 (-0.76; 1.77)
<b>TG: n = 752</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-3.62 (-13.27; 6.02)	-0.69 (-10.18; 8.80)	-1.70 (-11.15; 7.76)	-1.32 (-10.24; 7.61)	-4.67 (-13.78; 4.45)
≥ 2h	17.19 (-14.08; 48.46)	18.51 (-12.16; 49.17)	13.87 (-16.65; 44.39)	7.84 (-21.05; 36.72)	-3.18 (-32.16; 25.79)
Continuous (h)	-3.9 (-11.62; 3.81)	-0.44 (-8.08; 7.20)	-1.94 (-9.56; 5.68)	-1.43 (-8.63; 5.78)	-6.49 (-1.41; 1.08)
<b>HDL-C: n = 752</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.85 (-1.94; 3.63)	0.37 (-2.33; 3.07)	0.47 (-2.17; 3.12)	0.36 (-2.13; 2.85)	0.71 (-1.82; 3.24)
≥ 2h	8.06 (-0.98; 17.10)	6.09 (-2.63; 14.81)	5.53 (-3.01; 14.06)	6.08 (-1.99; 14.14)	<b>9.10<sup>e</sup></b> (1.06; 17.13)
Continuous (h)	<b>2.45<sup>e</sup></b> (0.22; 4.67)	1.58 (-0.59; 3.75)	1.72 (-0.41; 3.85)	1.40 (-0.61; 3.41)	<b>2.39<sup>e</sup></b> (0.28; 4.49)
<b>SBP: n = 729</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.36 (-2.02; 2.74)	1.18 (-1.11; 3.47)	1.22 (-1.06; 3.50)	1.11 (-1.15; 3.37)	1.12 (-1.21; 3.46)
≥ 2h	<b>12.49<sup>f</sup></b> (4.05; 20.93)	<b>12.50<sup>f</sup></b> (4.40; 20.60)	<b>10.99<sup>f</sup></b> (2.91; 19.07)	<b>11.86<sup>f</sup></b> (3.84; 19.89)	<b>11.24<sup>f</sup></b> (4.26; 20.55)
Continuous (h)	0.42 (-1.58; 2.41)	1.49 (-0.43; 3.42)	1.30 (-0.62; 3.21)	1.34 (-0.57; 3.25)	1.43 (-0.60; 3.47)

Table 11 (cont.). Study 3 (Sample 1): Multiple linear regression for the association between social jetlag and MetS components.

<b>DBP: n = 729</b>	<b>Crude model</b>	<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.45 (-1.39; 2.29)	1.12 (-0.64; 2.88)	1.15 (-0.59; 2.90)	1.05 (-0.67; 2.78)	1.34 (-0.43; 3.12)
≥ 2h	4.08 (-2.44; 10.60)	4.11 (-2.11; 10.34)	3.05 (-3.11; 9.21)	3.67 (-2.45; 9.79)	4.84 (-1.35; 11.03)
Continuous (h)	-0.24 (-1.77; 1.29)	0.62 (-0.85; 2.10)	0.49 (-0.97; 1.95)	0.51 (-0.94; 1.96)	0.96 (-0.58; 2.51)

Abbreviations; WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c.

FBG (n = 800): excluded 10 participants who were under medication of hypoglycemic drug.

TG and HDL-C (n = 752): excluded 58 participants who were under medication of dyslipidemia treatment drug.

SBP and DBP (n = 729): excluded 81 participants who were under medication of antihypertensive.

<sup>a</sup>Model 1: gender and age.

<sup>b</sup>Model 2 : additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3 : additionally adjusted BMI(numeric), LDL-cholesterol, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4 : additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps.

Bold values denote statistically significant results: <sup>e</sup> $p < .05$  and <sup>f</sup> $p < .01$ .

Table 12. Study 3 (Sample 2): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 50</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 367</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 n = 1,513</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>126.4 ± 38.2</b>	<b>134.1 ± 41.0</b>	<b>134.2 ± 41.2</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>Gender</b>				
Men (%)	30 (60.0)	223 (60.8)	1,078 (71.2)	<0.001
Women (%)	20 (40.0)	144 (39.2)	435 (28.8)	
<b>Age on the baseline AHC date [mean (years ± SD)]</b>	45.0 ± 9.8	45.7 ± 9.0	48.0 ± 7.8	<0.001
<b>Smoking status</b>				
Non-smoker (%)	42 (84.0)	299 (81.5)	1,348 (89.1)	<0.001
Smoker (%)	8 (16.0)	68 (18.5)	165 (10.9)	
<b>Skipping breakfast</b>				
Yes (%)	10 (20.0)	71 (19.3)	182 (12.0)	<0.001
No (%)	40 (80.0)	296 (80.7)	1,331 (88.0)	
<b>Frequency of drinking</b>				
Every day (%)	9 (18.0)	88 (24.0)	457 (30.2)	0.01
Sometimes (%)	22 (44.0)	166 (45.2)	679 (44.9)	
Rarely (%)	19 (38.0)	113 (30.8)	377 (24.9)	
<b>Alcohol consumption</b>				
Less than 180 ml (%)	27 (54.0)	199 (54.2)	767 (50.7)	0.67
180-360 ml (%)	15 (30.0)	104 (28.3)	481 (31.8)	
360-540 ml (%)	4 (8.0)	46 (12.5)	194 (12.8)	
More than 540 ml (%)	4 (8.0)	18 (4.9)	71 (4.7)	
<b>Sleep satisfaction</b>				
Satisfied (%)	16 (32.0)	218 (59.4)	1,074 (71.0)	<0.001
Not satisfied (%)	34 (68.0)	149 (40.6)	439 (29.0)	
<b>Body mass index (kg/m<sup>2</sup>)</b>				
< 25 (%)	47 (94.0)	312 (85.0)	1,335 (88.2)	0.10
≥25 (%)	3 (6.0)	55 (15.0)	178 (11.8)	
<b>Body mass index (kg/m<sup>2</sup>)</b>	21.5 ± 2.3	22.1 ± 3.0	22.2 ± 2.6	0.08

Table 12 (cont.). Study 3 (Sample 2): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 50</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 367</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 n = 1,513</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>126.4 ± 38.2</b>	<b>134.1 ± 41.0</b>	<b>134.2 ± 41.2</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>LDL-C</b> [mean(mg/dl) ± SD]	123.4 ± 33.3	118.8 ± 29.6	122.3 ± 29.4	0.12
<b>HbA1c</b> [mean (%) ± SD]	5.4 ± 0.3	5.4 ± 0.3	5.4 ± 0.4	0.27
<b>WC</b> [mean(cm) ± SD]	77.6 ± 7.2	78.8 ± 7.9	79.3 ± 7.0	0.13
<b>FBG</b> [mean(mg/dl) ± SD]	93.3 ± 9.5	92.5 ± 9.9	94.5 ± 11.6	0.01
<b>TG</b> [mean(mg/dl) ± SD]	101.5 ± 81.0	82.2 ± 45.1	88.4 ± 49.5	0.01
<b>HDL-C</b> [mean(mg/dl) ± SD]	64.9 ± 15.4	66.7 ± 15.6	66.4 ± 16.5	0.77
<b>SBP</b> [mean(mmHg) ± SD]	114.9 ± 12.8	115.3 ± 13.4	116.8 ± 13.6	0.13
<b>DBP</b> [mean(mmHg) ± SD]	70.3 ± 9.7	72.2 ± 9.9	73.5 ± 10.4	0.01
<b>Pre-MetS/MetS incidence</b>	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	
None	44 (88.0)	340 (92.6)	1,399 (92.5)	0.47
Total incidence	6 (12.0)	27 (7.4)	114 (7.5)	
Pre-Mets	4 (8.0)	18 (4.9)	83 (5.5)	
MetS	2 (4.0)	2 (4.0)	31 (2.0)	
<b>Lifestyle factors from Fitbit data</b>				
<b>TST</b> [mean (hour) ± SD]	5.6 ± 0.67	5.8 ± 0.7	5.8 ± 0.7	0.07
<b>Sleep period</b> [mean (hour) ± SD]	6.5 ± 0.8	6.7 ± 0.8	6.7 ± 0.8	0.09
<b>Mid-sleep time</b> [mean (clock time) ± SD (hour)]	4:35 ± 1.11	3:42 ± 1.4	3:10 ± 1.3	<0.001
<b>Number of step counts/day</b> [mean (count) ± SD]	9345.9 ± 3873.4	9866.2 ± 3528.3	9923.6 ± 4040.1	0.59

Abbreviations; MetS: metabolic syndrome, AHC: annual health check-up, SD: standard deviation, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, TST: total sleep time.

Statistical test; Fisher's exact test for categorical variables and analysis of variance for continuous variables.

Table 13. Study 3 (Sample 2): Modified Poisson regression for the association between social jetlag and MetS.

Risk ratio (95% Confidence Interval)							
Social jetlag	Total n (%)	Case of pre-Mets and Mets n (%)	Crude model	Model 1 <sup>a</sup>	Model 2 <sup>b</sup>	Model 3 <sup>c</sup>	Model 4 <sup>d</sup>
< 1h	1531 (78.4)	Pre-Mets: 83 (5.5) MetS: 31 (2.0)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	367 (19.0)	Pre-Mets 18 (4.9) Mets 9 (2.5)	1.00 (0.97; 1.03)	1.01 (0.98; 1.04)	1.01 (0.98; 1.04)	1.01 (0.98; 1.04)	1.01 (0.98; 1.04)
≥ 2h	50 (2.6)	Pre-Mets 4 (8.0) Mets 2 (4.0)	1.04 (0.96; 1.13)	1.05 (0.97; 1.14)	1.05 (0.97; 1.14)	1.07 (0.98; 1.16)	1.07 (0.99; 1.17)
Exclude less than 180 days until outcome: n = 1,907							
< 1h	1498 (78.6)	Pre-Mets: 81 (5.4) MetS: 30 (2.0)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	360 (18.9)	Pre-Mets 16 (4.4) Mets 9 (2.5)	1.00 (0.97; 1.02)	1.01 (0.98; 1.03)	1.00 (0.98; 1.03)	1.00 (0.98; 1.03)	1.01 (0.98; 1.03)
≥ 2h	49 (2.6)	Pre-Mets 4 (8.2) Mets 2 (4.1)	1.05 (0.96; 1.14)	1.06 (0.97; 1.15)	1.05 (0.97; 1.14)	1.07 (0.99; 1.16)	1.08 (0.99; 1.17)

Abbreviations: Mets: metabolic syndrome, BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c.

Bold values denote statistically significant results.

<sup>a</sup>Model 1: gender and age adjusted.

<sup>b</sup>Model 2: additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3: additionally adjusted BMI (numeric), LDL-C, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4: additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps.



Table 14. Study 3 (Sample 2): Multiple linear regression for the association between social jetlag and MetS components.

<b>WC: n = 1,930</b>	<b>Crude model</b>	<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.73 (-1.58; 0.12)	-0.20 (-1.04; 0.64)	-0.28 (-1.13; 0.56)	-0.11 (-0.63; 0.41)	-0.12 (-0.65; 0.40)
≥ 2h	-1.34 (-3.45; 0.76)	-0.74 (-2.80; 1.31)	-0.88 (-2.93; 1.18)	0.67 (-0.60; 1.93)	0.53 (-0.75; 1.82)
Continuous (h)	<b>-0.71<sup>e</sup></b> (-1.34; -0.08)	-0.13 (-0.75; 0.50)	-0.20 (-0.83; 0.43)	-0.10 (-0.48; 0.29)	-0.15 (-0.55; 0.25)
<b>FBG: n = 1,895</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-1.50 (-2.65; -0.34)	-0.36 (-1.47; 0.74)	-0.19 (-1.30; 0.91)	-0.34 (-1.35; 0.67)	-0.16 (-1.18; 0.87)
≥ 2h	-0.55 (-3.41; 2.31)	0.85 (-1.88; 3.57)	1.02 (-1.68; 3.71)	0.85 (-1.62; 3.33)	1.28 (-1.24; 3.80)
Continuous (h)	<b>-1.18<sup>f</sup></b> (-2.04; -0.33)	-0.16 (-0.99; 0.66)	0.01 (-0.81; 0.83)	-0.01 (-0.76; 0.75)	0.15 (-0.64; 0.93)
<b>TG: n = 1,783</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-5.39 (-12.03; 1.25)	-2.35 (-0.96; 4.25)	-3.62 (-10.26; 3.02)	-2.68 (-9.10; 3.74)	-1.85 (-8.32; 4.61)
≥ 2h	4.46 (-12.34; 21.27)	8.03 (-8.56; 24.62)	5.68 (-10.90; 22.26)	6.60 (-9.42; 22.62)	6.90 (-9.31; 23.10)
Continuous (h)	-2.24 (-7.20; 2.73)	1.27 (-3.71; 6.25)	0.003 (-5.02; 5.03)	0.85 (-4.01; 5.70)	1.18 (-3.82; 6.18)
<b>HDL-C: n = 1,783</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.69 (-1.24; 2.62)	0.11 (-1.72; 1.94)	0.44 (-1.37; 2.24)	0.03 (-1.66; 1.72)	-0.69 (-2.37; 0.98)
≥ 2h	-0.49 (-5.37; 4.39)	-0.70 (-5.31; 3.90)	-0.12 (-4.63; 4.39)	-1.22 (-5.44; 2.99)	-2.14 (-6.34; 2.06)
Continuous (h)	0.96 (-0.48; 2.40)	-0.01 (-1.39; 1.37)	0.39 (-0.97; 1.76)	0.13 (-1.14; 1.41)	-0.43 (-1.73; 0.86)
<b>SBP: n = 1,772</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.24 (-1.42; 1.91)	1.20 (-0.44; 2.84)	1.40 (-0.25; 3.04)	1.46 (-0.16; 3.08)	<b>1.77<sup>e</sup></b> (0.13; 3.42)
≥ 2h	-0.62 (-4.66; 3.41)	0.43 (-3.52; 4.38)	0.67 (-3.27; 4.62)	1.19 (-2.69; 5.07)	2.03 (-1.94; 5.60)
Continuous (h)	0.17 (-1.05; 1.40)	1.11 (-0.10; 2.33)	<b>1.34<sup>e</sup></b> (0.11; 2.56)	<b>1.40<sup>e</sup></b> (0.20; 2.60)	<b>1.85<sup>f</sup></b> (0.60; 3.12)

Table 14 (cont.). Study 3 (Sample 2): Linear regression for the association between social jetlag and MetS components.

<b>DBP: n = 1,772</b>	<b>Crude model</b>	<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.42 (-1.63; 0.78)	0.41 (-0.76; 1.58)	0.49 (-0.69; 1.66)	0.55 (-0.61; 1.71)	0.75 (-0.43; 1.93)
≥ 2h	-1.85 (-4.77; 1.07)	-0.93 (-3.76; 1.90)	-0.76 (-3.58; 2.06)	-0.47 (-3.25; 2.31)	0.05 (-2.80; 2.90)
Continuous (h)	-0.64 (-1.52; 0.25)	0.17 (-0.70; 1.04)	0.29 (-0.58; 1.17)	0.35 (-0.52; 1.21)	0.61 (-0.29; 1.52)

Abbreviations; WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c. FBG (n = 1,895): excluded 35 participants who were under medication of hypoglycemic drug. TG and HDL-C (n = 1,783): excluded 147 participants who were under medication of dyslipidemia treatment drug.

SBP and DBP (n = 1,772): excluded 158 participants who were under medication of antihypertensive.

<sup>a</sup>Model 1: gender and age.

<sup>b</sup>Model 2 : additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3 : additionally adjusted BMI(numeric), LDL-C, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4 : additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps.

Bold values denote statistically significant results: <sup>e</sup>*p* < .05 and <sup>f</sup>*p* < .01.

Table 15. Study 3 (Sample 3): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 68</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 628</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 n = 2,619</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>127.0 ± 40.4</b>	<b>133.3 ± 41.7</b>	<b>138.4 ± 39.4</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>Gender</b>				
Men (%)	46 (67.6)	387 (61.6)	1906 (72.8)	<0.001
Women (%)	22 (32.4)	241 (38.4)	713 (27.2)	
<b>Age on the baseline AHC date [mean (years ± SD)]</b>	<b>45.4 ± 9.1</b>	<b>46.1 ± 9.2</b>	<b>47.7 ± 8.1</b>	<b>&lt;0.001</b>
<b>Smoking status</b>				
Non-smoker (%)	57 (83.8)	535 (85.2)	2274 (86.8)	0.42
Smoker (%)	11 (16.2)	93 (14.8)	345 (13.2)	
<b>Skipping breakfast</b>				
Yes (%)	19 (27.9)	110 (17.5)	366 (14.0)	0.001
No (%)	49 (72.1)	518 (82.5)	2253 (86.0)	
<b>Frequency of drinking</b>				
Every day (%)	13 (19.1)	163 (26.0)	781 (29.8)	0.03
Sometimes (%)	29 (42.6)	272 (43.3)	1144 (43.7)	
Rarely (%)	26 (38.2)	193 (30.7)	694 (26.5)	
<b>Alcohol consumption</b>				
Less than 180 ml (%)	32 (47.1)	354 (56.4)	1388 (53.0)	0.05
180-360 ml (%)	24 (35.3)	173 (27.5)	822 (31.4)	
360-540 ml (%)	6 (8.8)	69 (11.0)	317 (12.1)	
More than 540 ml (%)	6 (8.8)	32 (5.1)	92 (3.5)	
<b>Sleep satisfaction</b>				
Satisfied (%)	37 (54.4)	334 (53.2)	1818 (69.4)	<0.001
Not satisfied (%)	31 (45.6)	294 (46.8)	801 (30.6)	
<b>Body mass index (kg/m<sup>2</sup>)</b>				
< 25 (%)	61 (89.7)	556 (88.5)	2315 (88.4)	0.99
≥25 (%)	7 (10.3)	72 (11.5)	304 (11.6)	
<b>Body mass index (kg/m<sup>2</sup>)</b>	<b>22.3 ± 2.6</b>	<b>21.9 ± 2.6</b>	<b>22.2 ± 2.6</b>	<b>0.03</b>

Table 15 (cont.). Study 3 (Sample 3): Baseline characteristics and 1-year pre-MetS/MetS incidence between over 2 hours social jetlag, less than 2 hours and over 1 hour, and less than 1-hour social jetlag.

	<b>Social jetlag ≥ 2 h n = 68</b>	<b>Social jetlag ≥ 1 &amp; &lt; 2 h n = 628</b>	<b>Social jetlag ≥ 0 &amp; &lt; 1 n = 2,619</b>	<b>P value</b>
<b>Number of main sleep (mean ± SD)</b>	<b>127.0 ± 40.4</b>	<b>133.3 ± 41.7</b>	<b>138.4 ± 39.4</b>	
<b>Variables: lifestyle factors from AHC data</b>				
<b>LDL-C</b> [mean(mg/dl) ± SD]	116.4 ± 29.1	121.0 ± 30.0	121.3 ± 28.9	0.39
<b>HbA1c</b> [mean (%) ± SD]	5.4 ± 0.3	5.4 ± 0.4	5.4 ± 0.4	0.52
<b>WC</b> [mean(cm) ± SD]	79.1 ± 7.0	78.1 ± 7.0	79.1 ± 7.2	0.01
<b>FBG</b> [mean(mg/dl) ± SD]	92.8 ± 9.2	92.6 ± 11.7	93.8 ± 10.5	0.04
<b>TG</b> [mean(mg/dl) ± SD]	91.0 ± 39.3	83.2 ± 46.0	87.9 ± 51.2	0.09
<b>HDL-C</b> [mean(mg/dl) ± SD]	67.3 ± 18.8	66.4 ± 16.6	66.1 ± 16.5	0.76
<b>SBP</b> [mean(mmHg) ± SD]	118.0 ± 12.9	115.5 ± 13.8	116.2 ± 14.1	0.30
<b>DBP</b> [mean(mmHg) ± SD]	73.7 ± 11.1	72.3 ± 10.5	73.2 ± 10.5	0.12
<b>Pre-MetS/MetS incidence</b>	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	
None	62 (91.2)	592 (94.3)	2444 (93.3)	0.47
Total incidence	6 (8.8)	36 (5.7)	175 (6.7)	
Pre-Mets	5 (7.3)	29 (4.6)	130 (5.0)	
MetS	1 (1.5)	7 (1.1)	45 (1.7)	
<b>Lifestyle factors from Fitbit data</b>				
<b>TST</b> [mean (hour) ± SD]	5.5 ± 0.8	5.7 ± 0.7	5.8 ± 0.7	<0.001
<b>Sleep period</b> [mean (hour) ± SD]	6.3 ± 0.9	6.6 ± 0.8	6.7 ± 0.8	<0.001
<b>Mid-sleep time</b> [mean (clock time) ± SD (hour)]	4:15 ± 1.4	3:39 ± 1.3	3:07 ± 1.5	<0.001
<b>Number of step counts/day</b> [mean (count) ± SD]	9587.1 ± 3904.5	9781.2 ± 3524.5	9926.7 ± 3740.9	0.54

Abbreviations; MetS: metabolic syndrome, AHC: annual health check-up, SD: standard deviation, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, TST: total sleep time.

Statistical test; Fisher's exact test for categorical variables and analysis of variance for continuous variables.

Table 16. Study 3 (Sample 3): Modified Poisson regression for the association between social jetlag and Mets.

Risk ratio (95% Confidence Interval)							
Social jetlag	Total n (%)	Case of pre-Mets and Mets n (%)	Crude model	Model 1 <sup>a</sup>	Model 2 <sup>b</sup>	Model 3 <sup>c</sup>	Model 4 <sup>d</sup>
< 1h	2619 (79.0)	Pre-Mets: 130 (5.0) MetS: 45 (1.7)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	628 (18.9)	Pre-Mets: 29 (4.6) MetS: 7 (1.1)	0.99 (0.97; 1.01)	1.00 (0.98; 1.02)	1.00 (0.98; 1.02)	1.00 (0.98; 1.02)	1.00 (0.98; 1.02)
≥ 2h	68 (2.1)	Pre-Mets: 5 (7.3), MetS: 1 (1.5)	1.02 (0.96; 1.09)	1.03 (0.94; 1.02)	1.02 (0.96; 1.09)	1.02 (0.96; 1.09)	1.02 (0.96; 1.08)
Exclude less than 180 days until outcome: n = 3,305							
< 1h	2611 (79.0)	Pre-Mets: 129 (4.9) MetS: 45 (1.7)	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	627 (19.0)	Pre-Mets: 29 (4.6) MetS: 7 (1.1)	0.86 (0.61; 1.22)	0.99 (0.70; 1.41)	0.98 (0.69; 1.39)	1.22 (0.86; 1.72)	1.17 (0.83; 1.66)
≥ 2h	67 (2.0)	Pre-Mets: 5 (7.5), MetS: 1 (1.5)	1.34 (0.62; 2.92)	1.46 (0.67; 3.18)	1.42 (0.65; 3.08)	1.56 (0.72; 3.39)	1.43 (0.66; 3.12)

Abbreviations: Mets: metabolic syndrome ,BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c.

Bold values denote statistically significant results.

<sup>a</sup>Model 1: gender and age adjusted.

<sup>b</sup>Model 2: additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3: additionally adjusted BMI (numeric), LDL-C, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4: additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps. .

Table 17. Study 3 (Sample 3): Multiple linear regression for the association between social jetlag and MetS components.

<b>WC: n = 3,315</b>	<b>Crude model</b>	<b>Model 1<sup>a</sup></b>	<b>Model 2<sup>b</sup></b>	<b>Model 3<sup>c</sup></b>	<b>Model 4<sup>d</sup></b>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	<b>-1.16<sup>f</sup></b> (-1.81; -0.52)	<b>-0.66<sup>e</sup></b> (-1.29; -0.04)	<b>-0.71<sup>e</sup></b> (-1.34; -0.09)	-0.28 (-0.66; 0.11)	<b>-0.40<sup>e</sup></b> (-0.79; -0.01)
≥ 2h	-0.01 (-1.78; 1.77)	0.35 (-1.38; 2.08)	0.22 (-1.51; 1.95)	-0.08 (-1.13; 0.98)	-0.25 (-1.31; 0.81)
Continuous (h)	<b>-0.81<sup>f</sup></b> (-1.29; -0.33)	-0.32 (-0.80; 0.15)	-0.37 (-0.85; 0.10)	-0.12 (-0.41; 0.17)	-0.27 (-0.57; 0.03)
<b>FBG: n = 3,253</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	<b>-1.54<sup>f</sup></b> (-2.39; -0.69)	-0.69 (-1.51; 0.13)	-0.69 (-1.51; 0.13)	-0.64 (-1.38; 0.10)	-0.49 (-1.24; 0.26)
≥ 2h	-0.20 (-2.55; 2.15)	0.64 (-1.61; 2.90)	0.65 (-1.60; 2.90)	0.39 (-1.63; 2.42)	0.60 (-1.44; 2.63)
Continuous (h)	<b>-0.91<sup>f</sup></b> (-1.55; -0.28)	-0.12 (-0.74; 0.50)	-0.08 (-0.70; 0.54)	-0.08 (-0.64; 0.48)	0.03 (-0.54; 0.60)
<b>TG: n = 3,035</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-4.12 (-9.38; 1.13)	-1.02 (-6.22; 4.17)	-1.75 (-6.91; 3.42)	-1.88 (-6.90; 3.15)	-1.66 (-6.73; 3.40)
≥ 2h	8.07 (-6.48; 22.62)	10.57 (-3.73; 24.86)	8.99 (-5.25; 23.24)	8.32 (-5.54; 22.19)	8.51 (-5.33; 22.34)
Continuous (h)	-2.80 (-6.73; 1.15)	0.23 (-3.68; 4.15)	-0.53 (-4.44; 3.38)	-0.36 (-4.15; 3.44)	-0.78 (-4.65; 3.09)
<b>HDL-C: n = 3,035</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	0.29 (-1.25; 1.83)	-0.32 (-1.79; 1.15)	-0.25 (-1.69; 1.19)	-0.46 (-1.80; 0.87)	-0.48 (-1.81; 0.85)
≥ 2h	0.93 (-3.33; 5.18)	1.00 (-3.04; 5.04)	1.01 (-2.96; 4.97)	1.35 (-2.33; 5.02)	1.45 (-2.18; 5.09)
Continuous (h)	1.09 (-0.06; 2.24)	0.42 (-0.68; 1.53)	0.66 (-0.43; 1.75)	0.48 (-0.53; 1.49)	0.72 (-0.29; 1.74)
<b>SBP: n = 3,007</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.43 (-1.72; 0.87)	0.48 (-0.79; 1.76)	0.49 (-0.78; 1.76)	0.72 (-0.52; 1.96)	1.01 (-0.25; 2.27)
≥ 2h	1.55 (-2.02; 5.13)	2.57 (-0.93; 6.07)	2.64 (-0.84; 6.12)	2.51 (-0.90; 5.93)	3.07 (-0.37; 6.51)
Continuous (h)	-0.50 (-1.47; 0.47)	0.37 (-0.59; 1.33)	0.44 (-0.51; 1.40)	0.59 (-0.35; 1.52)	0.92 (-0.04; 1.89)

Table 17 (cont.). Study 3 (Sample 3): Linear regression for the association between social jetlag and MetS components.

DBP: n = 3,007	Crude model	Model 1 <sup>a</sup>	Model 2 <sup>b</sup>	Model 3 <sup>c</sup>	Model 4 <sup>d</sup>
<b>Social jetlag</b>					
< 1h	Reference	Reference	Reference	Reference	Reference
≥ 1 h & < 2h	-0.72 (-1.67; 0.24)	0.09 (-0.84; 1.02)	0.12 (-0.80; 1.03)	0.25 (-0.66; 1.15)	0.47 (-0.45; 1.38)
≥ 2h	1.60 (-1.04; 4.24)	2.53 (-0.02; 5.09)	<b>2.64<sup>e</sup></b> (0.11; 5.17)	<b>2.50<sup>e</sup></b> (0.01; 5.00)	<b>2.98<sup>e</sup></b> (0.47; 5.49)
Continuous (h)	-0.56 (-1.28; 0.15)	0.21 (-0.49; 0.91)	0.30 (-0.40; 0.99)	0.38 (-0.30; 1.07)	0.59 (-0.11; 1.29)

Abbreviations; WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, BMI: body mass index, LDL-C: low-density lipoprotein cholesterol, HbA1c: hemoglobin A1c.

FBG (n = 3,253): excluded 62 participants who were under medication of hypoglycemic drug.

TG and HDL-C (n = 3,035): excluded 280 participants who were under medication of dyslipidemia treatment drug.

SBP and DBP (n = 3,007): excluded 308 participants who were under medication of antihypertensive.

<sup>a</sup>Model 1: gender and age.

<sup>b</sup>Model 2 : additionally adjusted smoking, alcohol frequency, and alcohol amount.

<sup>c</sup>Model 3 : additionally adjusted BMI(numeric), LDL-C, HbA1c, and skipping breakfast.

<sup>d</sup>Model 4 : additionally adjusted average asleep time, average mid-sleep time, sleep satisfaction, and average steps.

Bold values denote statistically significant results: <sup>e</sup>*p* < .05 and <sup>f</sup>*p* < .01.

Table 18. Study 3 (Sample 1): AHC data by the population with sleep data linkage and without sleep data linkage from the JMDC database in fiscal year 2019.

Variables		With sleep linkage n = 1,329	Without sleep linkage n = 2,110,491	
		n (%)	n (%)	
<b>Gender</b>	Men	987 (74.3)	1608596 (76.2)	
	Women	342 (25.7)	501895 (23.8)	
<b>Age</b>	10s-20s	54 (4.1)	289582 (13.7)	
	30s	188 (14.1)	457224 (21.7)	
	40s	591 (44.5)	692774 (32.8)	
	50s	441 (33.2)	517588 (24.5)	
	60s-70s	55 (4.1)	153323 (7.3)	
	Minimum age (years)	23	16	
	Maximum age (years)	66	73	
<b>MetS determination</b>	MetS	119 (9.0)	225607 (10.7)	
	Pre-MetS	137 (10.3)	241665 (11.5)	
	None	1006 (75.7)	1333950 (63.2)	
	Undecidable	0 (0)	93862 (4.4)	
	Missing value	67 (5.0)	215407 (10.2)	
<b>MetS components</b>		<b>Mean ± SD</b>	<b>Mean ± SD</b>	<b>Missing value: n (%)</b>
	<b>WC (cm)</b>	81.9 ± 8.8	82.6 ± 10.3	131036 (6.2)
	<b>FBG (mg/dl)</b>	94.9 ± 12.6	95.6 ± 17.6	355454 (16.8)
	<b>TG (mg/dl)</b>	100.1 ± 62.2	111.7 ± 90.7	49793 (2.4)
	<b>HDL-C (mg/dl)</b>	63.3 ± 16.4	61.8 ± 16.2	49484 (2.3)
	<b>SBP (mmHg)</b>	117.6 ± 14.4	120.5 ± 15.6	8577 (0.4)
	<b>DBP (mmHg)</b>	74.4 ± 11.0	74.7 ± 11.8	8577 (0.4)

Abbreviations; AHC: annual health check-up, MetS: metabolic syndrome, SAS: sleep apnea syndrome, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, SD: standard deviation.

The population with sleep data linkage was applied the exclusion criteria except with pre-MetS/MetS and missing or unreasonable values on covariates, and the population without sleep data linkage from the JMDC database was applied exclusion criteria: SAS, having psychotropic medication, eating disorder, malignant neoplasm, and pregnant women or gave birth with medical treatment.



Table 19. Study 3 (Sample 2): AHC data between the population with sleep data linkage and without sleep data linkage from the JMDC database in fiscal year 2020.

Variables		With sleep linkage n = 3,122	Without sleep linkage n = 2,412,987	
		n (%)	n (%)	
<b>Gender</b>	Men	2275 (72.9)	1800430 (74.6)	
	Women	847 (27.1)	612557 (25.4)	
<b>Age</b>	10s-20s	116 (3.7)	338317 (14.0)	
	30s	409 (13.1)	508376 (21.1)	
	40s	1254 (40.2)	773683 (32.1)	
	50s	1118 (35.8)	606981 (25.2)	
	60s-70s	225 (7.2)	185630 (7.7)	
	Minimum age (years)	23	16	
	Maximum age (years)	71	73	
<b>MetS determination</b>	MetS	305 (9.8)	268670 (11.1)	
	Pre-MetS	358 (11.5)	281133 (11.7)	
	None	2319 (74.3)	1491972 (61.8)	
	Undecidable	11 (0.4)	93187 (4.0)	
	Missing value	129 (4.1)	275025 (11.4)	
<b>MetS components</b>		<b>Mean ± SD</b>	<b>Mean ± SD</b>	<b>Missing value: n (%)</b>
	<b>WC (cm)</b>	82.1 ± 9.2	82.7 ± 10.5	135398 (5.6)
	<b>FBG (mg/dl)</b>	95.7 ± 14.0	95.8 ± 18.0	428687 (17.8)
	<b>TG (mg/dl)</b>	101.4 ± 67.4	113.2 ± 91.0	51507 (2.1)
	<b>HDL-C (mg/dl)</b>	63.5 ± 16.4	62.0 ± 16.4	51264 (2.1)
	<b>SBP (mmHg)</b>	118.9 ± 14.3	121.6 ± 15.9	6374 (0.3)
	<b>DBP (mmHg)</b>	74.9 ± 11.1	75.5 ± 11.9	6374 (0.3)

Abbreviations; AHC: annual health check-up, MetS: metabolic syndrome, SAS: sleep apnea syndrome, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, SD: standard deviation.

The population with sleep data linkage was applied the exclusion criteria except with pre-MetS/MetS and missing or unreasonable values on covariates, and the population without sleep data linkage from the JMDC database was applied exclusion criteria: SAS, having psychotropic medication, eating disorder, malignant neoplasm, and pregnant women or gave birth with medical treatment.

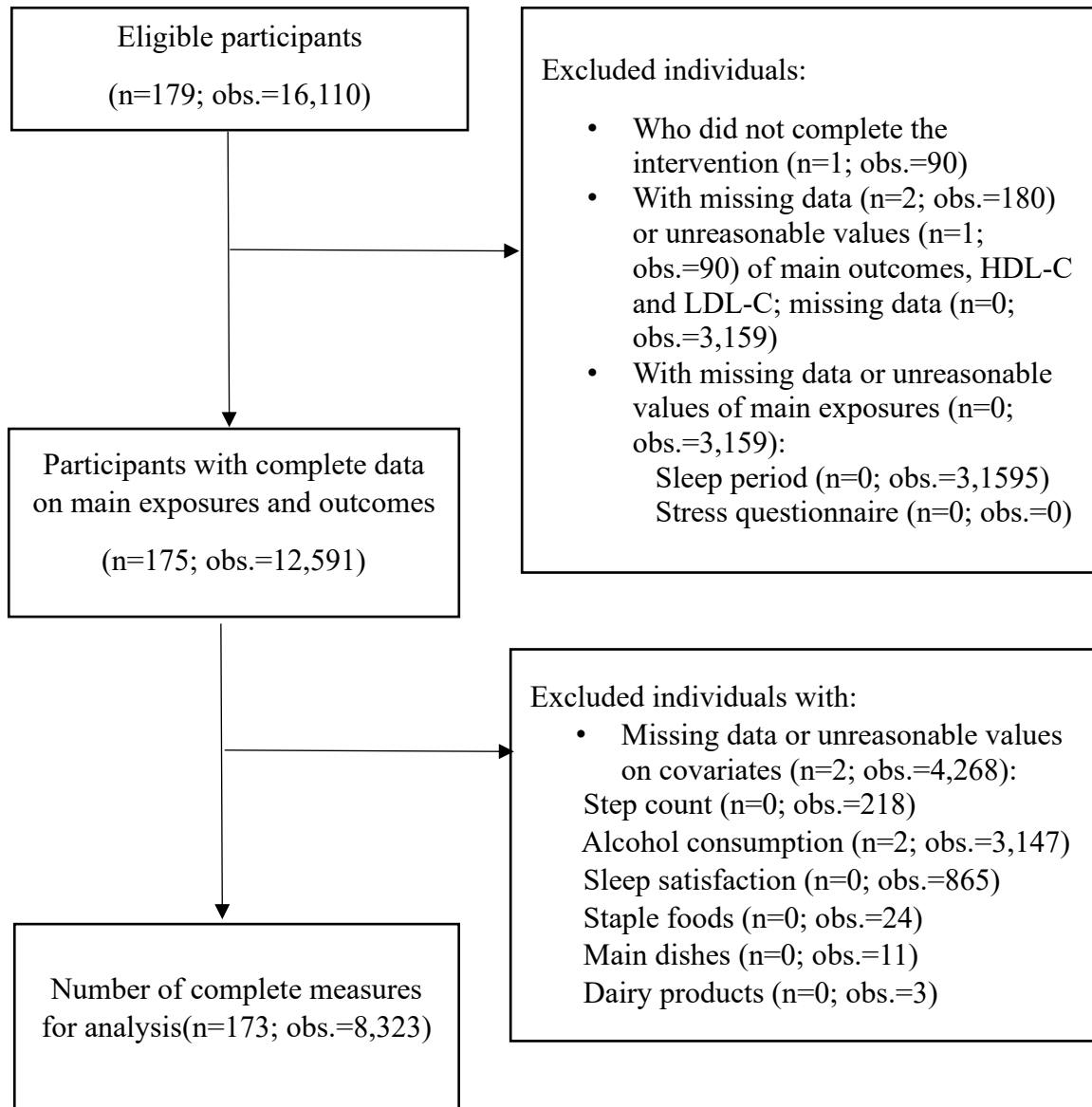
Table 20. Study 3 (Sample 3): AHC data between the population with sleep data linkage and without sleep data linkage from the JMDC database in fiscal year 2020.

Variables		With sleep linkage n = 5,325	Without sleep linkage n = 2,890,967	
		n (%)	n (%)	
<b>Gender</b>	Men	3930 (73.8)	2138668 (74.0)	
	Women	1395 (26.2)	752299 (26.0)	
<b>Age</b>	10s-20s	228 (4.3)	405352 (14.0)	
	30s	724 (13.6)	603960 (20.9)	
	40s	2070 (38.9)	898755 (31.1)	
	50s	1895 (35.6)	748541 (25.9)	
	60s-70s	405 (7.6)	234359 (8.1)	
	Minimum age (years)	19	16	
	Maximum age (years)	70	73	
<b>MetS determination</b>	MetS	475 (8.9)	319685 (11.1)	
	Pre-MetS	618 (11.6)	332426 (11.5)	
	None	3985 (74.8)	763215(61.0)	
	Undecidable	23 (0.4)	88638 (3.1)	
	Missing value	224 (4.2)	387003 (13.4)	
<b>MetS components</b>		<b>Mean ± SD</b>	<b>Mean ± SD</b>	<b>Missing value: n (%)</b>
	<b>WC (cm)</b>	81.8 ± 9.2	82.6 ± 10.6	145709 (5.0)
	<b>FBG (mg/dl)</b>	95.1 ± 14.1	95.8 ± 17.9	471499 (16.3)
	<b>TG (mg/dl)</b>	98.8 ± 81.8	109.6 ± 87.1	58309 (2.0)
	<b>HDL-C (mg/dl)</b>	63.6 ± 16.6	62.2 ± 16.4	59506 (2.1)
	<b>SBP (mmHg)</b>	118.6 ± 14.9	121.3 ± 15.9	7983 (0.3)
	<b>DBP (mmHg)</b>	74.8 ± 11.2	75.2 ± 11.8	7983 (0.3)

Abbreviations; AHC: annual health check-up, MetS: metabolic syndrome, SAS: sleep apnea syndrome, WC: waist circumference, FBG: fasting blood glucose, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, SD: standard deviation.

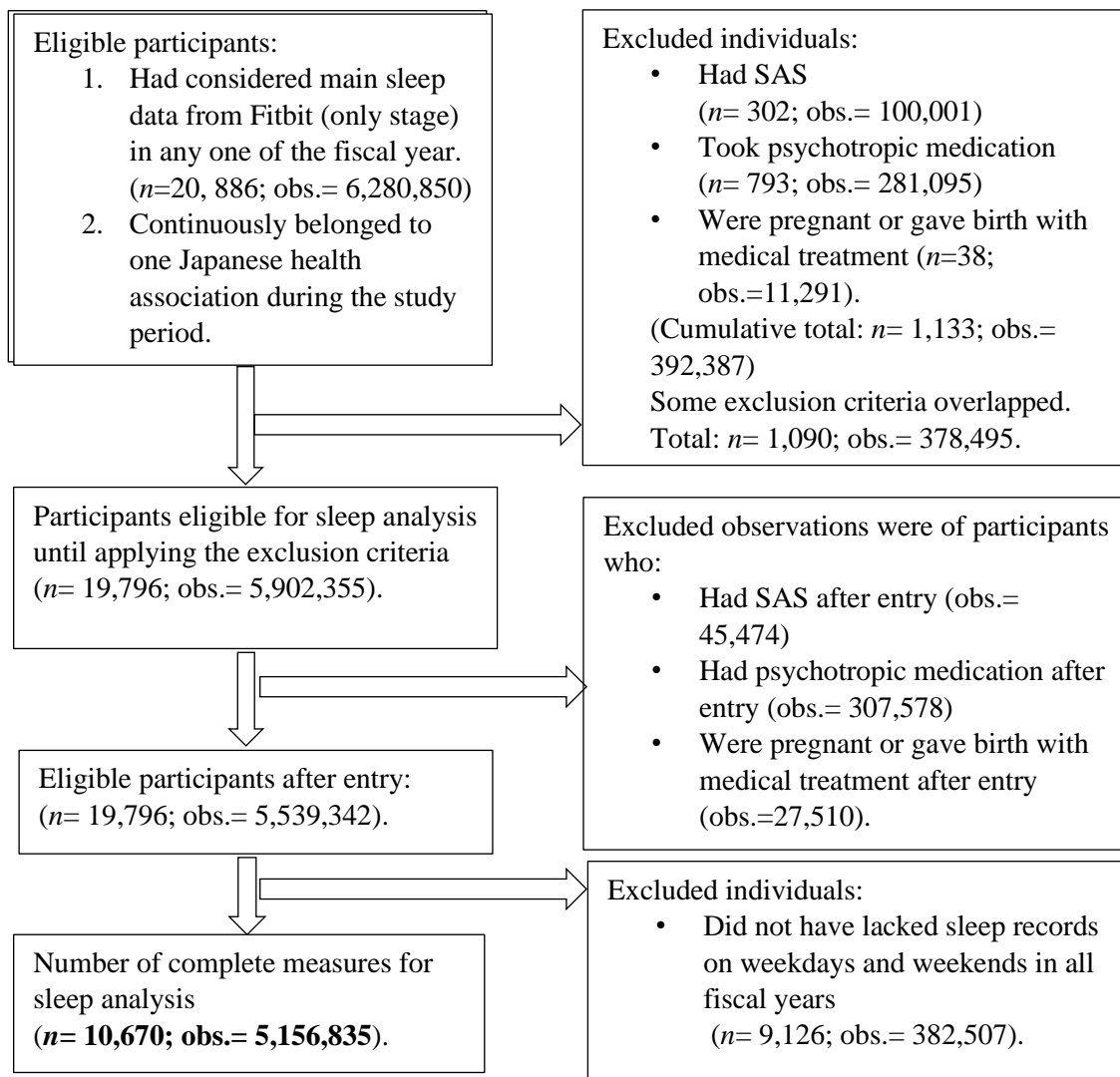
The population with sleep data linkage was applied the exclusion criteria except with pre-MetS/MetS and missing or unreasonable values on covariates, and the population without sleep data linkage from the JMDC database was applied exclusion criteria: SAS, having psychotropic medication, eating disorder, malignant neoplasm, and pregnant women or gave birth with medical treatment

Figure 1. Study 1: Flowchart detailing the inclusion and exclusion of study measures for analysis



Abbreviations; HDL-C: high-density lipoprotein cholesterol, LDL-C: low-density lipoprotein cholesterol.

Figure 2. Study 2: Flowchart of inclusion and exclusion criteria of the participants.



Abbreviations; SAS: sleep apnea syndrome.

Figure 3. Study 3: Flowchart for Sample 1 (data set fiscal year 2019).

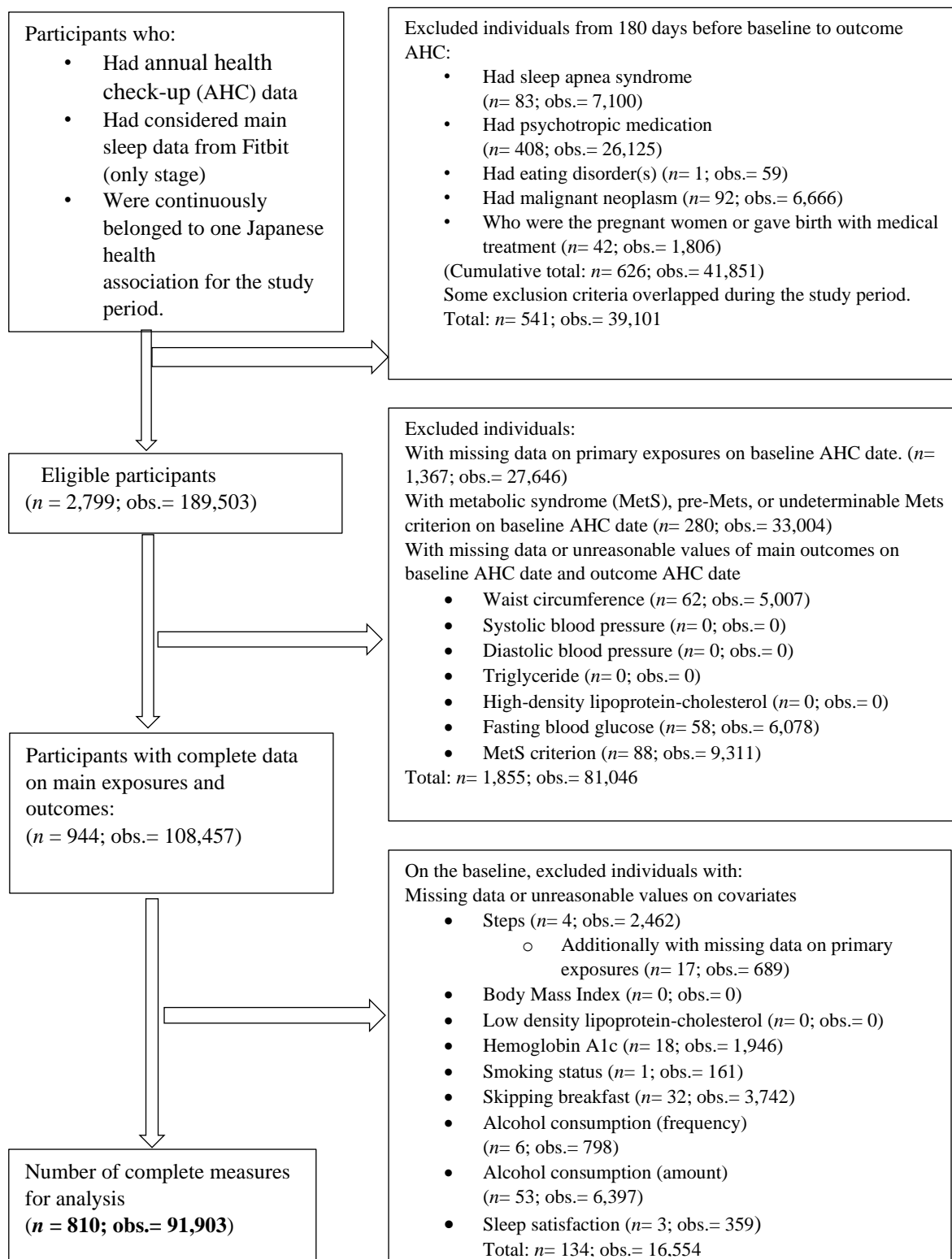


Figure 4. Study 3: Flowchart for Sample 2 (data set fiscal year 2020).

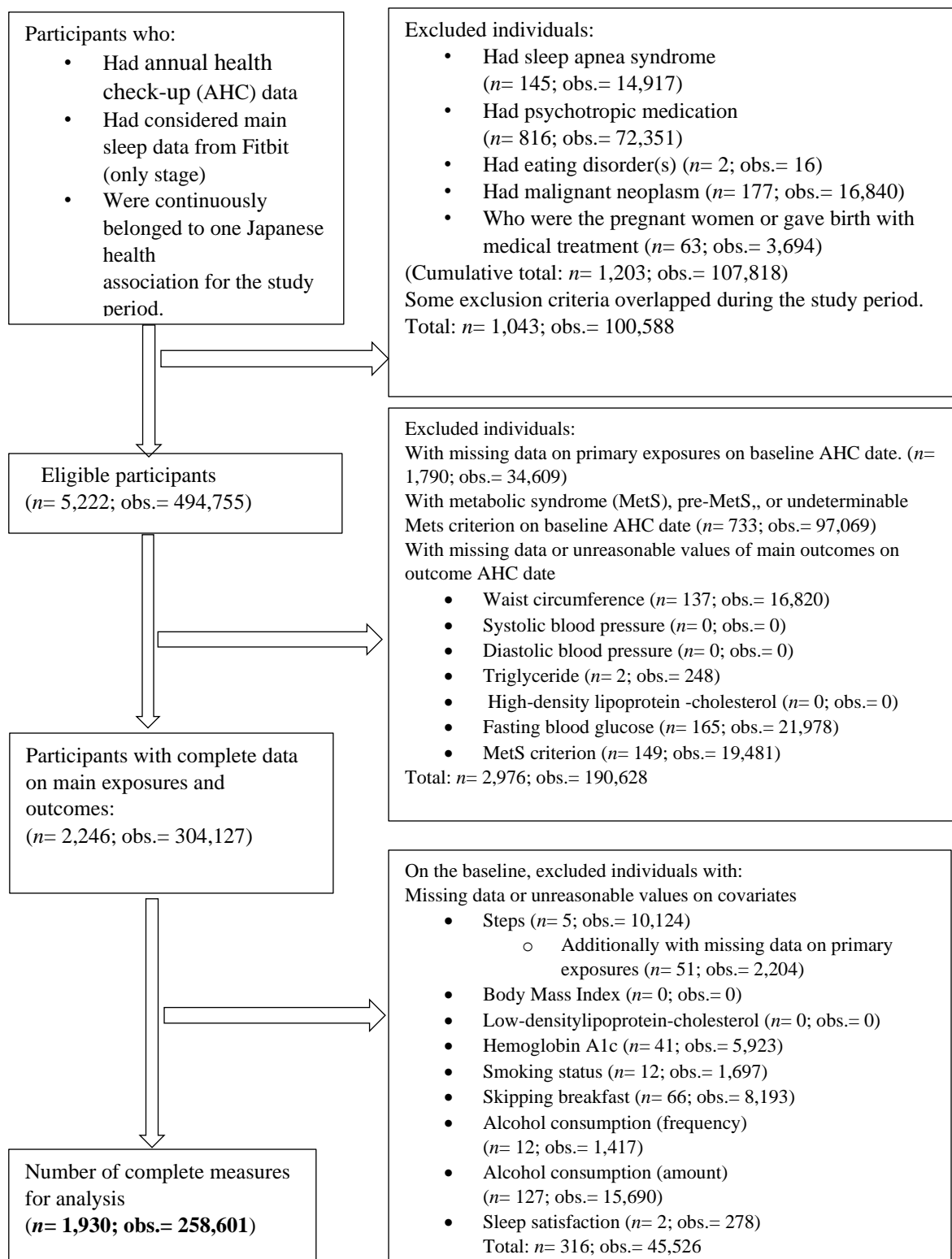


Figure 5. Study 3: Flowchart for Sample 3 (data set fiscal year 2020).

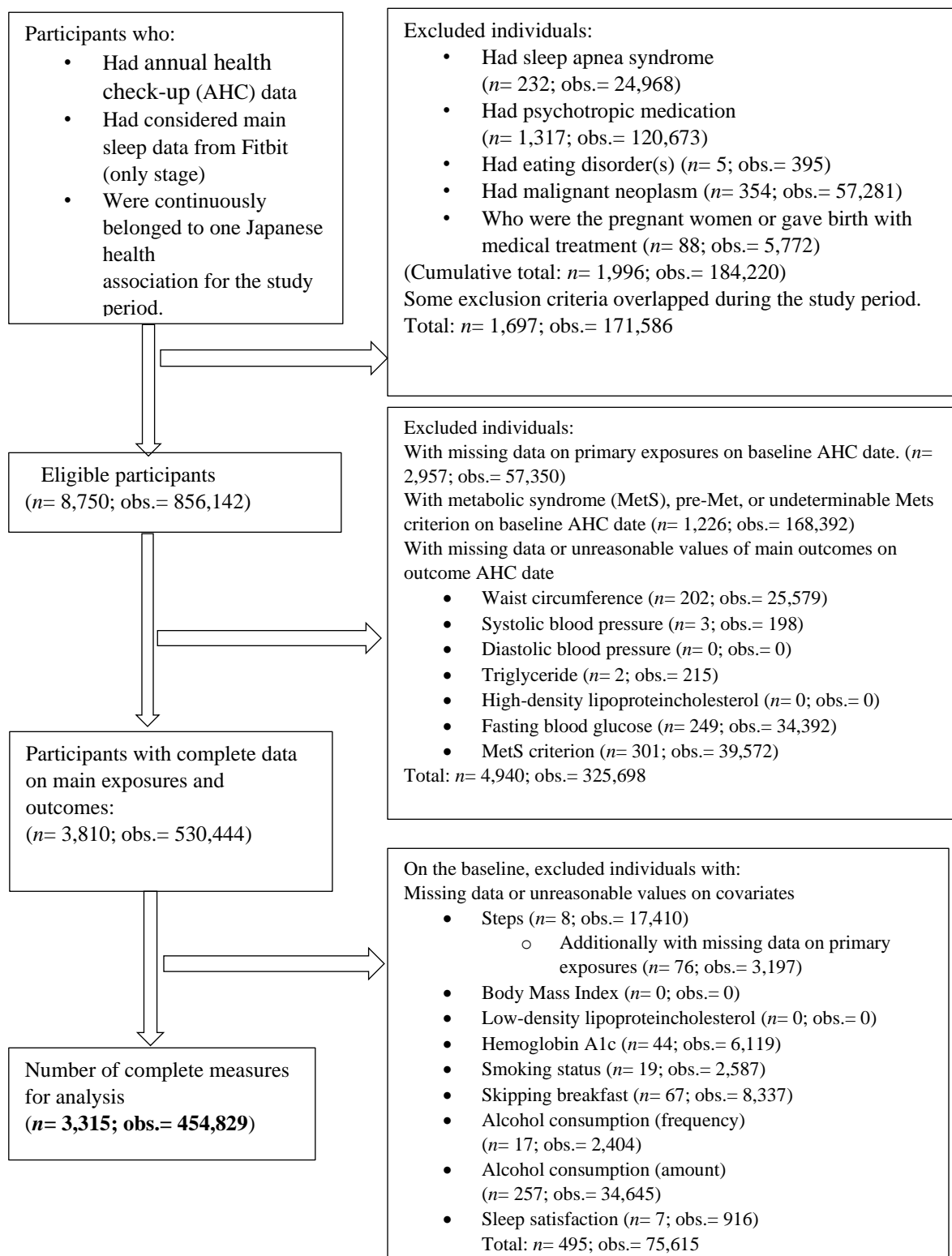
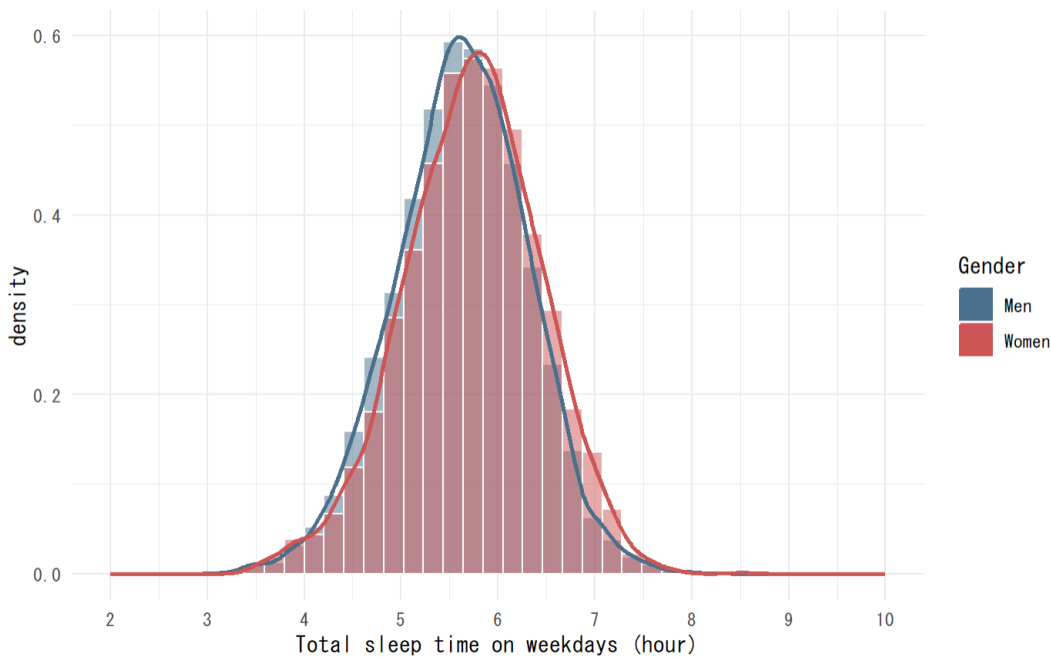


Figure 6. Study 2: Total sleep time on weekdays by gender in 3 fiscal years (2019-2021).



Unit: hour

Figure 7. Study 2: Total sleep time on weekends by gender in 3 fiscal years (2019-2021).

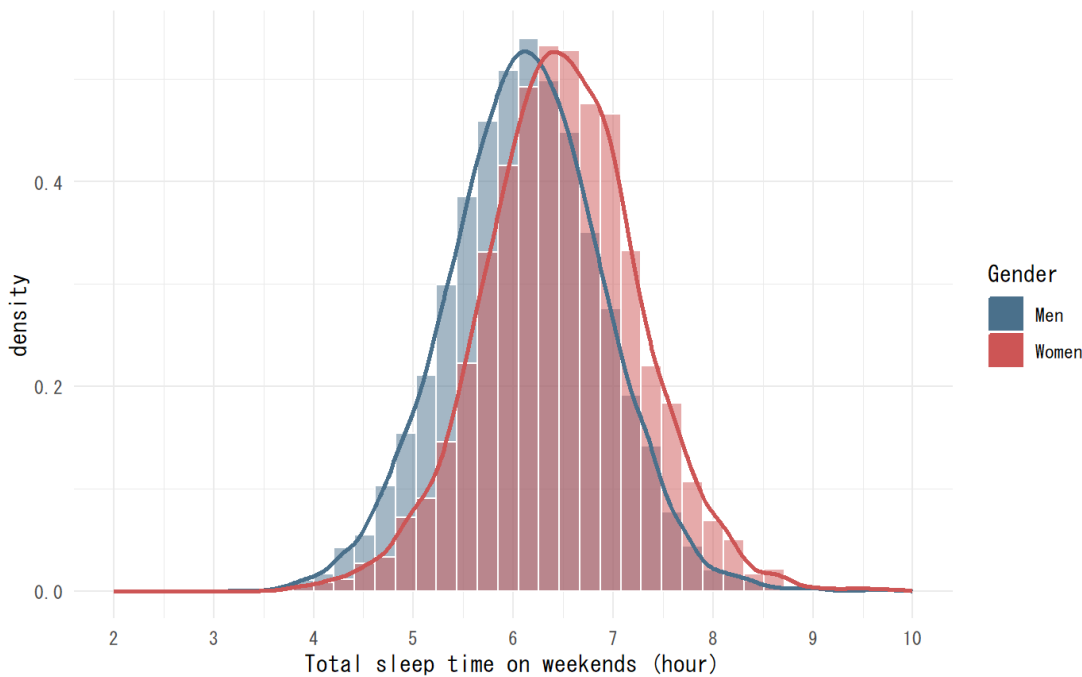
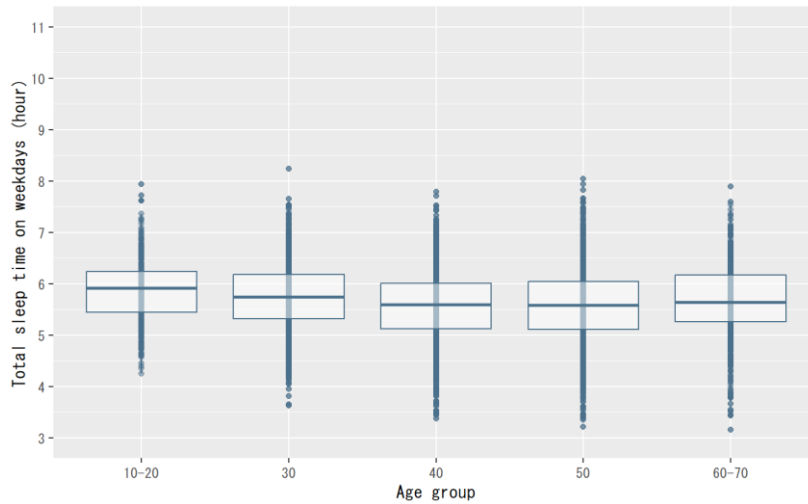




Figure 8. Study 2: Total sleep time on weekdays in men by age in 3 fiscal years (2019-2021).



The number of participants by age in men

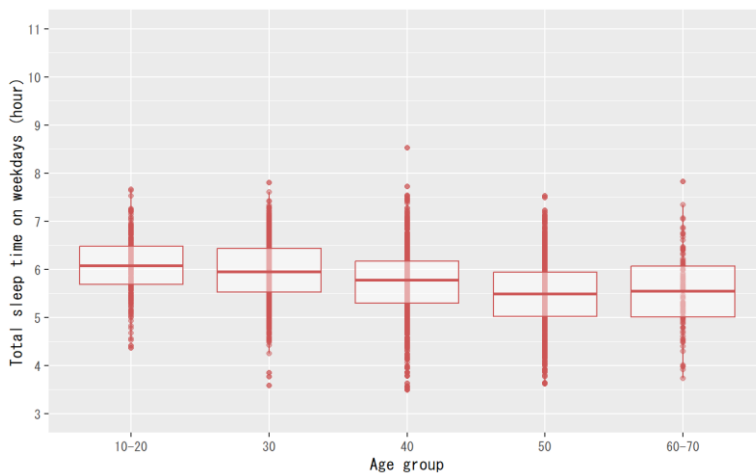
10's-20's (456), 30's (1489), 40's (2760), 50's (2504), 60's-70's (540)

Maximum age: 71

Minimum age: 18

Median: 47

Figure 9. Study 2: Total sleep time on weekdays in women by age in 3 fiscal years (2019-2021).



The number of participants by age in women

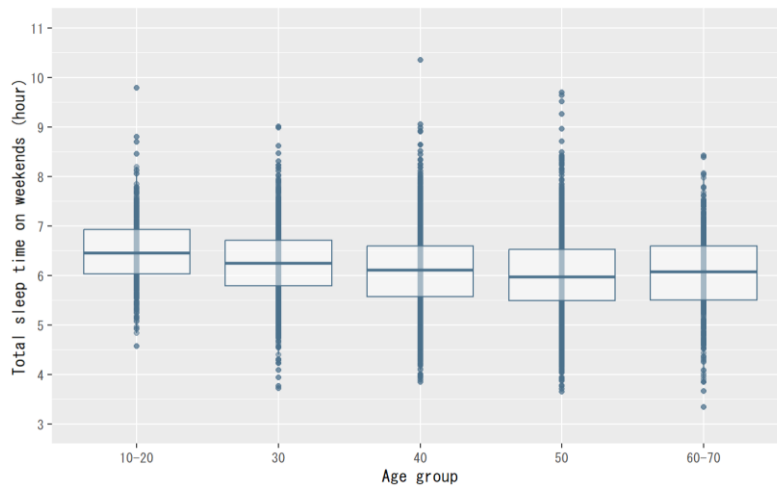
10's ~ 20's (263), 30's (586), 40's (1151), 50's (811), 60's-70's (110)

Maximum age: 73

Minimum age: 19

Median: 45

Figure 10. Study 2: Total sleep time on weekends in men by age in 3 fiscal years (2019-2021).



The number of participants by age in men

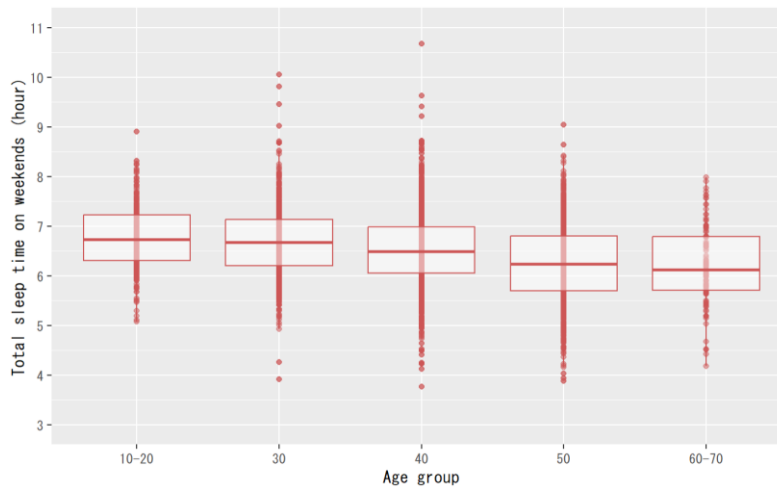
10's-20's (456), 30's (1489), 40's (2760), 50's (2504), 60's-70's (540)

Maximum age: 71

Minimum age: 18

Median: 47

Figure 11. Study 2: Total sleep time on weekends in women by age in 3 fiscal years (2019-2021).



The number of participants by age in women

10's ~ 20's (263), 30's (586), 40's (1151), 50's (811), 60's-70's (110)

Maximum age: 73

Minimum age: 19

Median: 45