Association between night work and dyslipidemia in South Korean men and women: a cross-sectional study

Jae Hong Joo 1,2, Doo Woong Lee 1,2, Dong-Woo Choi 1,2 and Eun-Cheol Park 2,3*

Abstract

Background: Previous studies have reported that an irregular work schedule, particularly nighttime work, is associated with an altered lipid profile. Additionally, a mismatch in circadian rhythm can affect sleeping and eating habits, leading to poor health. This study aimed to examine the association between night work and dyslipidemia among South Korean adults aged ≥30 years.

Methods: For this study, the data of 5813 participants in the 2013–2016 Korea National Health and Nutrition Examination Survey were analyzed. Diagnoses of dyslipidemia were based on blood sampling tests of total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL) cholesterol, and triglyceride levels. Night work was defined as that conducted during evening (6 P.M.–12 A.M.) and overnight hours (12 A.M.–8 A.M.). The association between night work hours and dyslipidemia in South Korean men and women was investigated using a logistic regression analysis.

Results: After adjusting for sociodemographic, economic, health-related, and nutritional factors, an association of night work with dyslipidemia was observed in male participants (odds ratio = 1.53, 95% confidence interval: 1.05–2.24). In subset analyses of male participants, night workers who skipped meals were more likely to have dyslipidemia than their day-working counterparts. Among men who slept < 7 h, night workers had a higher probability of dyslipidemia than day workers. In contrast, no statistically significant association between night work and dyslipidemia was observed in female participants, although the probability of dyslipidemia appeared to increase with advancing age. Furthermore, when women with dyslipidemia were subdivided by occupational categories, night workers in white collar positions were more likely to have dyslipidemia than their day-working counterparts.

Conclusion: Our study observed an association of night work with dyslipidemia, particularly in men. Although these findings may support interventions for South Korean night workers, further studies are needed for validation.

Keywords: Dyslipidemia, Night work, Eating habit, Sleep duration, White-collar
Background
The concept of shift work arose from industrial growth and the increase of 24-h workplaces, which required continuous staffing and irregular work schedules [1, 2]. In South Korea, the prevalence of night and shift work is highest in the field of manufacturing, followed by wholesale and retail businesses [3]. Although no consensus has been reached regarding the definition of shift work, this term is often used in reference to work hours outside of the conventional daytime period.

The major difficulties associated with shift work mainly involve work conducted during evening or overnight hours, due to its effects on circadian rhythm. Changes in circadian rhythms can disrupt homeostasis and lead to the desynchronization of enzymatic activity and metabolic function [4]. For example, evidence suggests a correlation between an altered distribution of food intake due to a mismatch in circadian rhythm (e.g., nighttime food ingestion) and increased cholesterol levels [5]. Circadian rhythm disturbances have also been identified as a significant factor related to cardiovascular disease (CVD). For example, an inability of the circadian rhythm governing oxygen supply to adapt promptly to the changing demands of night work will likely lead to myocardial infarction [4]. Furthermore, night workers are more likely to experience fatigue due to a lack of sleep [6]. Although this relationship is poorly understood, sleep deprivation has been identified as a potential risk factor for CVD [7].

CVD is the cause of substantial societal burdens worldwide and is the leading cause of death in South Korea, where the CVD-associated mortality rate has been increasing gradually in recent years. In 2017, diseases of the circulatory system accounted for 21.5% of all deaths in South Korea, second only to neoplasms (28.1%) [8]. The prevalence of dyslipidemia, a major risk factor for CVD [9], is also increasing in South Korea [10], with reported rates ranging from 30 to 60% [10]. Although age, hypertension, and obesity are commonly known risk factors for dyslipidemia, these factors are better controlled and moderated today than in previous periods [11]. Therefore, the increased prevalence of dyslipidemia in South Korea is likely attributable to lifestyle factors.

Previous studies have reported associations between irregular work schedules, particularly night work, and altered lipid profiles [12, 13]. Therefore, preventive measures are needed to mitigate lipid disorders and ensure the well-being of workers during non-standard working hours. Night work appears to serve as barrier to a healthy lifestyle and a threat to well-being, as a circadian rhythm mismatch can disrupt adequate sleeping and eating habits, leading to poor health [14]. We hypothesize that in night workers, insufficient amounts of sleep and irregular eating habits may contribute to the onset of dyslipidemia. In this study, therefore, we aimed to investigate and elucidate the association of dyslipidemia with night work.

Methods
Study participants
We collected data from the 2013 to 2016 Korea National Health and Nutrition Examination Survey (KNHANES), which was conducted by the Korea Centers for Disease Control and Prevention (KCDCP). The KNHANES is a self-reported, nationally representative survey of South Koreans of all ages and is designed to gather annual national data on sociodemographic, economic, and health-related conditions and behaviors. Since 2007, the collected data have been subjected to an annual review and approval by the KCDCP Research Ethics Review Committee. The KNHANES 2013–2016 included 31,908 participants. We excluded 25,285 of these participants for various reasons (Fig. 1). First, participants with a previous clinical diagnosis of dyslipidemia were excluded, as this may have influence the reliability of the outcome (n = 3328). Second, in this study, dyslipidemia was diagnosed via a blood samples collected during the KNHANES. Therefore, people younger than 30 years were excluded because they did not undergo blood testing as part of the survey (n = 9656). Third, our study aimed to examine specific relationships with dyslipidemia. As dyslipidemia and metabolic syndrome share a few diagnostic components, including high-density lipoprotein (HDL) cholesterol and triglycerides levels, participants who met the modified National Cholesterol Education Program Expert Panel Adult Treatment Panel III (NCEP-ATP III) diagnostic criteria for metabolic syndrome with a lower waist circumference were excluded to increase the validity of our study (n = 4163) [15, 16]. Fourth, people deemed ineligible because they were unemployed or were not representative of covariates considered in the study (failure to answer the questionnaires or lack of applicability) were also excluded (n = 8138). Finally, the analyzed sample comprised 5813 participants (men: 2821 and women: 2992).

Variables
Dyslipidemia, the dependent variable in this study, was diagnosed based on the levels of total, high-density lipoprotein (HDL), low-density lipoprotein (LDL) cholesterol, and triglycerides in blood samples collected after 9–12 h of fasting. According to the 2015 Korean Guidelines for the Management of Dyslipidemia, one of the following four criteria was required: (a) total cholesterol ≥240 mg/dL, (b) HDL cholesterol ≤40 mg/dL, (c) LDL cholesterol ≥160 mg/dL, or (d) triglycerides ≥200 mg/dL [11].
The main independent variable was the work pattern, which included three categories: day, night, and other shifts. The day shift was defined as between 6 A.M. and 6 P.M., while the night shift merged both evening (6 P.M.–12 A.M.) and overnight work (12 A.M.–8 A.M.). Other shifts included various types of working patterns, such as alternating shifts (e.g., day-night-day), 24-h shifts (a full 24-h shift followed by a day(s) off), and split shifts (≥2 shifts within a day).

Socio-demographic, economic, health-related, and nutritional factors were also assessed. Socio-demographic factors included age (30–39, 40–49, 50–59, and ≥60 years), region (metropolitan or rural), educational level (high school or less or college and/or beyond), and marital status (married or unmarried). Economic factors included the household income (low, mid-low, mid-high, or high) and occupational category (white-, pink-, or blue-collar employment). Health-related factors included eating habits (regular consumption of breakfast, lunch, and dinner or skipping meals), physical activity/week (active: ≥150 min of moderate activity, ≥ 75 min of vigorous activity, or a mixture of both for ≥150 min; inactive: < 150 min of moderate activity, < 75 min of vigorous activity, or a mixture of both for < 150 min), sleep duration (0–6 or ≥7 h per night), smoking status (current smoker, ex-smoker, or non-smoker), alcohol consumption status (≥2 times/month or never), body mass index (BMI) defined obesity status (in reference to the Korean guidelines for overweight and obesity; underweight/normal: < 23, overweight: 23–24.9, and obese: ≥25) [17], hypertension (in reference to the Korean guideline for normal BP, < 120/80 mmHg; normal: 90–199 mmHg systolic or 60–79 mmHg diastolic; prehypertension: 120–139 mmHg systolic or 80–89 mmHg diastolic; hypertension: ≥140 mmHg systolic or ≥90 mmHg diastolic) [18], and menopausal status (yes or no). Nutritional factors included macronutrient intake (total kcal, protein, fat, and carbohydrate). For the continuous variables (macronutrient intakes), the OR was calculated for every 100-kcal increase in calorie intake and every 10-g increase in protein, fat, and carbohydrate intake.
Statistical analysis
All statistical analyses were performed using SAS version 9.4 (SAS Inc., Cary, NC, USA). The chi-square (χ²) test was used to evaluate the general characteristics of the study population. For continuous variables (macro-nutrient intake), a t-test was used to calculate the means and standard deviations. A multiple logistic regression analysis was used to calculate the odds ratios (ORs) with 95% confidence intervals (CIs) in three different models. Model 1 yielded a crude OR, model 2 was adjusted for socio-demographic and economic factors, and model 3 was adjusted for all socio-demographic, economic, health-related, and nutritional factors. Multiple logistic regression analyses of subgroups were also performed to examine the association between night work and dyslipidemia according to occupational category, eating habits, and sleep duration. A general linear model analysis was also used to calculate the mean levels of the four diagnostic determinants (total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides), and the distributions and percentages of each were calculated. The stratified, clustering, and weight variables developed by the KNHANES were applied to all analyses to improve the representativeness of the sample and account for the limited proportion of participants retained in the final analysis [19]. The significance level was set at p value < 0.05.

Results
Table 1 summarizes the general characteristics of the study population, which included 2821 men and 2992 women. A total of 816 (28.9%) men and 469 (15.7%) women had dyslipidemia. Of the 196 male participants who reported working at night, 76 (38.8%) had dyslipidemia, and the prevalence of dyslipidemia was greater among these night workers compared to those who worked at other times (day: 684/2404, 28.5%; other shifts: 56/221, 25.3%). A similar trend was observed among the female participants, as 70 of the 379 women (18.5%) who reported working at night had dyslipidemia, compared to their day working counterparts (day: 382/2512, 15.2%; other shifts: 17/101, 16.8%).

Table 2 summarizes the results from the multiple logistic analysis of the association between night work and dyslipidemia. In all three models, the association between night work and dyslipidemia remained statistically significant in male participants (model 1: OR = 1.58, 95% CI: 1.12–2.21; model 2: OR = 1.61, 95% CI: 1.13–2.29; model 3: OR = 1.53, 95% CI: 1.05–2.24). By contrast, however, no statistically significant association of night work with dyslipidemia was observed in female participants. However, women aged 50 years or older were more likely to have dyslipidemia, compared to their younger counterparts (50–59 years: OR = 1.61, 95% CI: 1.04–2.50; ≥60 years: OR = 1.66, 95% CI: 0.92–3.01).

Table 3 summarizes the results from subgroup analyses stratified by occupational categories, eating habits, and sleep duration. Male night workers who reported skipping meals were more likely to have dyslipidemia, compared to their day working counterparts (OR = 1.63, 95% CI: 1.00–2.67). Similarly, male night workers who slept for 0–6 h were more likely to have dyslipidemia, compared to their day working counterparts. Among female participants, a strong significant association was observed between the occupational category and dyslipidemia, as female night workers with white collar jobs had a nearly three-fold risk of dyslipidemia, compared to their day working counterparts (OR = 2.95, 95% CI: 1.68–5.16).

Table 4 individually summarizes the mean values of the four dyslipidemia diagnostic parameters: (a) total cholesterol, (b) HDL cholesterol, LDL, (c) cholesterol, and (d) triglycerides, as well as the related distributions and percentages of the study sample. Among male subjects, night workers were generally more likely to present with dyslipidemia, compared to their counterparts with other work shift patterns, with 8.2, 16.3, 3.6, and 15.3% meeting the respective criteria of ≥240 mg/dL total cholesterol, ≥40 mg/dL HDL cholesterol, ≥160 mg/dL LDL cholesterol, and ≥200 mg/dL triglycerides.

Discussion
After controlling for socio-demographic, economic, health-related, and nutritional factors, we found that night work increased the risk of dyslipidemia in the male participants. Physiological activities, such as eating patterns, lipid/carbohydrate/glucose metabolism, and sleep, all operate on day/night rhythms [20] that are controlled by the circadian biological clock [20]. Accordingly, work schedules that extend beyond the standard 9 A.M.–5 P.M. period impair the circadian rhythm [21]. Night work-related disruptions of the biological clock are likely to result in obesity, impaired insulin secretion, and aberrant glucose homeostasis [20, 22]. Notably, overlap has been observed between the mechanisms associated with insulin resistance and atherosclerosis (a consequence of dyslipidemia), including elevated levels of glucose and free acids that cause oxidant stress, the activation of pro-inflammatory pathways, low levels of HDL, and high levels of triglycerides [23, 24]. The circadian clock is a key regulator of lipid metabolism and therefore, the lipid profile [25, 26], and periodic disruption of circadian rhythm negatively affects lipid metabolism [26, 27]. Accordingly, night work is more strongly associated with dyslipidemia, compared to day or other shift work.

Meal skipping is a common practice in modern society. Commonly, constant changes in the daily routines of night workers lead to irregular meal times. In our subgroup analysis, we observed a significant positive
| Variables                      | Dyslipidemia |                  |                  |                  |                  |                  |                  |
|--------------------------------|--------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                               | Male         | Total            | Yes              | No               | Female           | Total            | Yes              | No               |
|                               |              | N                | %                | N                | %                | N                | %                | N                | %                |
| Work pattern                   |              |                  |                  |                  |                  |                  |                  |                  |                  |
| Day                            | 2404         | 85.2             | 684              | 28.5             | 1720             | 71.5             | 2512             | 84.0             | 382              | 15.2             | 2130             | 84.8             | 0.004            | 0.252 |
| Night                          | 196          | 69.9             | 76               | 38.8             | 120              | 61.2             | 379              | 12.7             | 70               | 18.5             | 309              | 81.5             | <.0001           | <.0001 |
| Other shifts                   | 221          | 7.8              | 56               | 25.3             | 165              | 74.7             | 101              | 3.4              | 17               | 16.8             | 84               | 83.2             | 0.11             | .011 |
| Age(years)                     |              |                  |                  |                  |                  |                  |                  |                  |                  |
| 30–39                          | 741          | 26.3             | 210              | 28.3             | 531              | 71.7             | 830              | 27.7             | 85               | 102              | 745              | 89.8             | 0.011            | <.0001 |
| 40–49                          | 738          | 26.2             | 236              | 32.0             | 502              | 68.0             | 997              | 33.3             | 119              | 11.9             | 878              | 88.1             | 0.348            | <.0001 |
| 50–59                          | 634          | 22.5             | 196              | 30.9             | 438              | 69.1             | 742              | 24.8             | 163              | 22.0             | 579              | 78.0             | 0.014            | 0.014 |
| ≥ 60                           | 708          | 25.1             | 174              | 24.6             | 534              | 75.4             | 423              | 14.1             | 102              | 24.1             | 321              | 75.9             | 0.586            | 0.314 |
| Region                         |              |                  |                  |                  |                  |                  |                  |                  |                  |
| Metropolitan                   | 1696         | 60.1             | 497              | 29.3             | 1199             | 70.7             | 1861             | 62.2             | 282              | 15.2             | 1579             | 84.8             | 0.586            | 0.314 |
| Rural                          | 1125         | 39.9             | 319              | 28.4             | 806              | 71.6             | 1131             | 37.8             | 187              | 16.5             | 944              | 83.5             | <.0001           | <.0001 |
| Educational level              |              |                  |                  |                  |                  |                  |                  |                  |                  |
| ≤ Highschool                   | 1541         | 54.6             | 457              | 29.7             | 1084             | 70.3             | 1812             | 60.6             | 343              | 18.9             | 1469             | 81.1             | 0.348            | <.0001 |
| ≥ College                      | 1280         | 45.4             | 359              | 28.0             | 921              | 72.0             | 1180             | 39.4             | 126              | 10.7             | 1054             | 89.3             | 0.156            | <.0001 |
| Occupational categories²       |              |                  |                  |                  |                  |                  |                  |                  |                  |
| White                          | 1085         | 38.5             | 336              | 31.0             | 749              | 69.0             | 1275             | 42.6             | 144              | 11.3             | 1131             | 88.7             | 0.156            | <.0001 |
| Pink                           | 355          | 12.6             | 101              | 28.5             | 254              | 71.5             | 859              | 28.7             | 157              | 18.3             | 702              | 81.7             | <.0001           | <.0001 |
| Blue                           | 1381         | 49.0             | 379              | 27.4             | 1002             | 72.6             | 858              | 28.7             | 168              | 19.6             | 690              | 80.4             | 0.179            | <.0001 |
| Household income               |              |                  |                  |                  |                  |                  |                  |                  |                  |
| Low                            | 272          | 9.6              | 79               | 29.0             | 193              | 71.0             | 295              | 9.9              | 75               | 25.4             | 220              | 74.6             | 0.179            | <.0001 |
| Mid-low                        | 679          | 24.1             | 184              | 27.1             | 495              | 72.9             | 701              | 23.4             | 115              | 16.4             | 586              | 83.6             | <.0001           | <.0001 |
| Mid-high                       | 910          | 32.3             | 251              | 27.6             | 659              | 72.4             | 908              | 30.3             | 121              | 13.3             | 787              | 86.7             | 0.014            | 0.014 |
| High                           | 960          | 34.0             | 302              | 31.5             | 658              | 68.5             | 1088             | 36.4             | 158              | 14.5             | 930              | 85.5             | 0.898            | 0.087 |
| Marital status                 |              |                  |                  |                  |                  |                  |                  |                  |                  |
| Living w/ spouse               | 2465         | 87.4             | 712              | 28.9             | 1753             | 71.1             | 2384             | 79.7             | 360              | 15.1             | 2024             | 84.9             | 0.898            | 0.087 |
| Living w/o spouse              | 356          | 12.6             | 104              | 29.2             | 252              | 70.8             | 608              | 20.3             | 109              | 17.9             | 499              | 82.1             | 0.014            | 0.564 |
| Eating habit(daily)            |              |                  |                  |                  |                  |                  |                  |                  |                  |
| Regularly eat breakfast, lunch, and dinner | 1772 | 62.8 | 484 | 27.3 | 1288 | 72.7 | 1625 | 54.3 | 249 | 15.3 | 1376 | 84.7 | 0.014 | 0.564 |
| Skip meal(s)                   | 1049         | 37.2             | 332              | 31.6             | 717              | 68.4             | 1367             | 45.7             | 220              | 16.1             | 1147             | 83.9             |
| Variables                | Male |       | Female |       |
|--------------------------|------|-------|--------|-------|
|                          | TOTAL | Yes   | No     | P-value | TOTAL | Yes | No | P-value |
|                          | N %   | N %   | N %    |         | N %   | N % | N % |         |
| Physical activity        | 0.356 | 0.145 |        |         | 0.145 |     |     |         |
| Active                   | 1549  | 54.9  | 437 28.2 | 1112 71.8 | 1528 51.1 | 254 166 | 1274 83.4 |
| Inactive                 | 1272  | 45.1  | 379 29.8 | 893 70.2 | 1464 48.9 | 215 147 | 1249 85.3 |
| Sleep duration(hours)    | 0.077 | 0.833 |        |         |        |     |     |         |
| 0~6                      | 1460  | 51.8  | 401 27.5 | 1059 72.5 | 1570 52.5 | 244 15.5 | 1326 84.5 |
| ≥ 7                      | 1361  | 48.2  | 415 30.5 | 946 69.5 | 1422 47.5 | 225 15.8 | 1197 84.2 |
| Smoking status           | <.0001 | 0.346 |        |         |        |     |     |         |
| Current smoker           | 1046  | 37.1  | 352 33.7 | 694 66.3 | 135  4.5  | 17  126 | 118  87.4 |
| Ex-smoker                | 1149  | 40.7  | 310 27.0 | 839 73.0 | 131  4.4  | 25  19.1 | 106  80.9 |
| Non-smoker               | 626   | 22.2  | 154 24.6 | 472 75.4 | 2726 91.1 | 427 15.7 | 2299 84.3 |
| Drinking status          | 0.097 | 0.001 |        |         |        |     |     |         |
| ≥ 2 times / month        | 2063  | 73.1  | 579 28.1 | 1484 71.9 | 1420 47.5 | 189 13.3 | 1231 86.7 |
| Never                    | 758   | 26.9  | 237 31.3 | 521 68.7 | 1572 52.5 | 280 17.8 | 1292 82.2 |
| BMI                      | <.0001 | < 0.0001 |        |         | < 0.0001 |       |     |         |
| Obese(≥25)               | 809   | 28.7  | 257 31.8 | 552 68.2 | 564 18.9 | 129 22.9 | 435  77.1 |
| Overweight(23~24.9)      | 855   | 30.3  | 291 34.0 | 564 66.0 | 667 22.3 | 138 20.7 | 529  79.3 |
| Normal+underweight(< 23) | 1157  | 41.0  | 268 23.2 | 889 76.8 | 1761 58.9 | 202 11.5 | 1559 88.5 |
| Hypertension             | 0.102 | 0.001 |        |         | < 0.0001 |       |     |         |
| Hypertension             | 627   | 22.2  | 160 25.5 | 467 74.5 | 375 12.5 | 82  21.9 | 293  78.1 |
| Pre-hypertension         | 897   | 31.8  | 269 30.0 | 628 70.0 | 601 20.1 | 111 18.5 | 490  81.5 |
| Normal                   | 1297  | 46.0  | 387 29.8 | 910 70.2 | 2016 67.4 | 276 13.7 | 1740 86.3 |
| Diabetes                 | 0.006 | 0.102 |        |         |        |     |     |         |
| Diabetes mellitus        | 176   | 6.2   | 49 27.8 | 127 72.2 | 78  26.2 | 19  24.4 | 59  75.6 |
| Impaired fasting glucose | 641   | 22.7  | 154 24.0 | 487 76.0 | 400 13.4 | 62  15.5 | 338  84.5 |
| Normal                   | 2004  | 71.0  | 613 30.6 | 1391 69.4 | 2514 84.0 | 388 15.4 | 2126 84.6 |
| Menopause                | < 0.0001 |       |        |         |        |     |     |         |
| Yes                      | 834   | 27.9  | 193 23.1 | 641 76.9 |        |     |     |         |
| No                       | 2158  | 72.1  | 276 12.8 | 1882 87.2 |        |     |     |         |
| Year                     | 0.604 | 0.014 |        |         |        |     |     |         |
| 2013                     | 747   | 26.5  | 216 28.9 | 531 71.1 | 764 25.5 | 119 15.6 | 645  84.4 |
| Variables       | Dyslipidemia | Male                  | Female                  | P-value |
|-----------------|--------------|-----------------------|-------------------------|---------|
|                 | TOTAL        | Yes                   | No                      |         |
|                 | N  | %     | N  | %     | N  | %     | N  | %     |         |
| 2014            | 704 | 25.0  | 200 | 28.4  | 504 | 71.6  | 722 | 24.1  | 90     | 125   | 632   | 87.5  |
| 2015            | 668 | 23.7  | 206 | 30.8  | 462 | 69.2  | 689 | 23.0  | 129    | 18.7  | 560   | 81.3  |
| 2016            | 702 | 24.9  | 194 | 27.6  | 508 | 72.4  | 817 | 27.3  | 131    | 16.0  | 686   | 84.0  |
| Calorie intake(Kcal) | 2468.3 ±1007.7 | 2466.7 ±1106.9 | 2468.9 ±964.3 | 0.958  |
| Protein intake(g) | 86.3 ±60.3   | 88.3 ±87.4            | 85.5 ±44.8            | 0.259  |
| Fat intake(g)    | 53.1 ±40.6   | 52.8 ±46.5            | 53.2 ±37.9            | 0.010  |
| Carbohydrate intake(g) | 361.9 ±132.9 | 358.9 ±128.3          | 363.2 ±134.8          | 0.439  |
| Total            | 2821 | 100.0 | 816 | 28.9  | 2005 | 71.1  | 2992 | 100.0 | 469    | 15.7  | 2523  | 84.3  |

BMI: body mass index
*Three groups based on International Standard Classification Occupations codes

Obesity status defined by BMI based on 2014 Clinical Practice Guidelines for Overweight and Obesity in Korea

Mean and Standard deviation (SD) of the continuous independent variables in this study
| Variables                  | Dyslipidemia |           |           |           |           |           |           |           |           |
|---------------------------|--------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                           | Model 1      | Model 2   | Model 3   |           |           |           |           |           |           |
|                           | Male         | Female    | Male       | Female    | Male       | Female    | Male       | Female    |
|                           | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Work pattern              |              |           |           |           |           |           |           |           |           |
| Day                       | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Night                     | 1.58 (1.12 – 2.21)* | 1.16 (0.82 – 1.64) | 1.61 (1.13 – 2.29)* | 1.19 (0.82 – 1.72) | 1.53 (1.05 – 2.24)* | 1.12 (0.76 – 1.66) |
| Other shifts              | 0.78 (0.55 – 1.11) | 0.90 (0.50 – 1.62) | 0.84 (0.58 – 1.21) | 0.95 (0.53 – 1.72) | 0.84 (0.58 – 1.21) | 0.94 (0.50 – 1.74) |
| Age(years)                |              |           |           |           |           |           |           |           |           |
| 30–39                     | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| 40–49                     | 1.20 (0.93 – 1.56) | 1.22 (0.85 – 1.74) | 1.34 (1.03 – 1.75)* | 1.19 (0.82 – 1.73) |
| 50–59                     | 1.07 (0.80 – 1.42) | 1.98 (1.39 – 2.81)* | 1.31 (0.96 – 1.77) | 1.61 (1.04 – 2.50)* |
| ≥ 60                      | 0.82 (0.60 – 1.13) | 2.02 (1.29 – 3.16)* | 1.13 (0.79 – 1.62) | 1.66 (0.92 – 3.01) |
| Region                    |              |           |           |           |           |           |           |           |           |
| Metropolitan              | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Rural                     | 1.00 (0.83 – 1.22) | 1.07 (0.83 – 1.37) | 1.03 (0.84 – 1.26) | 1.08 (0.83 – 1.39) |
| Educational level         |              |           |           |           |           |           |           |           |           |
| ≤ Highschool              | 1.39 (1.09 – 1.77)* | 1.19 (0.82 – 1.73) | 1.34 (1.04 – 1.71)* | 1.15 (0.78 – 1.69) |
| ≥ College                 | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Occupational categories³ |              |           |           |           |           |           |           |           |           |
| White                     | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Pink                      | 0.73 (0.53 – 1.01) | 1.29 (0.88 – 1.90) | 0.68 (0.49 – 0.96) | 1.24 (0.84 – 1.83) |
| Blue                      | 0.78 (0.60 – 1.03) | 1.33 (0.89 – 1.99) | 0.76 (0.58 – 1.01) | 1.27 (0.83 – 1.95) |
| Household income          |              |           |           |           |           |           |           |           |           |
| Low                       | 0.93 (0.64 – 1.37) | 1.35 (0.86 – 2.12) | 0.98 (0.63 – 1.38) | 1.33 (0.82 – 2.14) |
| Mid-low                   | 0.75 (0.57 – 0.98) | 0.90 (0.66 – 1.24) | 0.72 (0.55 – 0.95) | 0.87 (0.63 – 1.21) |
| Mid-high                  | 0.82 (0.65 – 1.04) | 0.79 (0.59 – 1.06) | 0.81 (0.64 – 1.03) | 0.76 (0.57 – 1.03) |
| High                      | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Marital status            |              |           |           |           |           |           |           |           |           |
| Living w/ spouse          | 1.00         | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      | 1.00      |
| Living w/o spouse         | 1.05 (0.79 – 1.40) | 1.19 (0.90 – 1.56) | 1.05 (0.79 – 1.41) | 1.14 (0.87 – 1.51) |
| Eating habit(daily)       |              |           |           |           |           |           |           |           |           |
| Regularly eat breakfast, lunch, and dinner | 1.00 | 1.00 | 1.00 | 1.00 | 1.19 (0.96 – 1.47) | 1.42 (1.09 – 1.85)* |
| Variables                  | Dyslipidemia | Model 1 | Male | Female | Model 2 | Male | Female | Model 3 | Male | Female |
|----------------------------|--------------|---------|------|--------|---------|------|--------|---------|------|--------|
|                            |              | OR      | 95% CI |        | OR      | 95% CI |        | OR      | 95% CI |        |
| Physical activity          |              |         |       |        |         |       |        |         |       |        |
| Active                     |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Inactive                   |              | 0.99(0.82–1.20) | 0.82(0.65–1.03) | | | | | | |
| Sleep duration(hours)      |              |         |       |        |         |       |        |         |       |        |
| 0–6                        |              | 0.84(0.69–1.02) | 0.83(0.66–1.05) | | | | |         |         |
| ≥7                         | 1.00         |         |       | 1.00   |         |       |        |         |       |        |
| Smoking status             |              |         |       |        |         |       |        |         |       |        |
| Current smoker             |              | 1.70 (1.29–2.24)* | 0.87 (0.45–1.67) | | | | | |         |
| Ex-smoker                  |              | 1.24 (0.95–1.61) | 1.55 (0.95–2.54) | | | | | |         |
| Non-smoker                 |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Drinking status            |              |         |       |        |         |       |        |         |       |        |
| ≥2 times / month           |              | 0.82 (0.66–1.01) | 0.79 (0.62–1.00) | | | | |         |         |
| Never                      | 1.00         |         |       | 1.00   |         |       |        |         |       |        |
| BMIb                       |              |         |       |        |         |       |        |         |       |        |
| Obese(≥25)                 |              | 1.74 (1.36–2.23)* | 1.92 (1.43–2.58)* | | | | |         |         |
| Overweight(23–24.9)        |              | 1.86 (1.48–2.33)* | 1.67 (1.24–2.26)* | | | | |         |         |
| Normal+underweight(< 23)  |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Hypertension               |              |         |       |        |         |       |        |         |       |        |
| Hypertension               |              | 0.79 (0.60–1.03) | 1.00 (0.68–1.45) | | | | | |         |
| Pre-hypertension           |              | 0.91 (0.74–1.12) | 1.08 (0.79–1.48) | | | | | |         |
| Normal                     |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Diabetes                   |              |         |       |        |         |       |        |         |       |        |
| Diabetes mellitus          |              | 0.98 (0.59–1.44) | 1.39 (0.73–2.66) | | | | | |         |
| Impaired fasting glucose   |              | 0.65 (0.51–0.83) | 0.80 (0.57–1.15) | | | | | |         |
| Normal                     |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Menopause                  |              |         |       |        |         |       |        |         |       |        |
| Yes                        |              | 1.43 (0.99–2.08) | | | | | | | |         |
| No                         |              | 1.00    |       | 1.00   |         |       |        |         |       |        |
| Year                       |              | 1.04 (0.79–1.37) | 1.06 (0.71–1.59) | | | | | |         |

(Continued)
Table 2 Odds ratio for dyslipidemia (Continued)

| Variables                          | Dyslipidemia | Model 2 | Model 3 |
|------------------------------------|--------------|---------|---------|
|                                    | Male         | Female  | Male    | Female  | Male    | Female  |
|                                    | OR 95% CI    | OR 95% CI| OR 95% CI| OR 95% CI| OR 95% CI| OR 95% CI|
| 2014                               | 1.01 (0.77 - 1.33) | 0.65 (0.45 - 0.94) |
| 2015                               | 1.15 (0.86 - 1.54) | 1.09 (0.78 - 1.53) |
| 2016                               | 1.00         | 1.00    |         |         |
| Calorie intake (Kcal)              | 1.00 (0.98 - 1.03) | 1.03 (0.94 - 1.12) |
| Protein intake (g)                 | 1.03 (0.99 - 1.05) | 1.00 (0.94 - 1.07) |
| Fat intake (g)                     | 0.96 (0.92 - 1.00) | 0.89 (0.82 - 0.98) |
| Carbohydrate intake (g)            | 1.00 (0.99 - 1.01) | 1.00 (0.97 - 1.04) |

Model 1: unadjusted; Model 2: adjusted for age, region, educational level, occupational categories, household income, marital status; Model 3: adjusted for age, region, educational level, occupational categories, household income, marital status, eating habit, physical activity, sleep duration, smoking status, drinking status, BMI, hypertension, diabetes, menopause, micronutrients, and year.

BMI: body mass index

*Three groups based on International Standard Classification Occupations codes

*Obesity status defined by BMI based on 2014 Clinical Practice Guidelines for Overweight and Obesity in Korea

*Per 100 (Kcal) increase

*Per 10 (g) increase

*P < 0.05
association of night work with dyslipidemia among male participants who reported skipping meals. Several previous studies reported that these workers tend to skip meals and snack more frequently during the night shift [28–30]. Additionally, compared with regular eaters, meal skippers have higher average values of mean weight, BMI, and triglycerides, which have all been identified as risk factors for dyslipidemia [31].

Sleep deprivation negatively affects metabolism and impairs the homeostatic control of energy intake (i.e., protein, fat, and carbohydrate) [28, 32], while also promoting the development of an atherogenic lipid profile [33]. These effects explain the significant association between sleep duration and dyslipidemia in this study. Specifically, night workers who slept for < 7 h per night faced a higher risk of dyslipidemia, compared to their counterparts who reported more sleep. The National Sleep Foundation recommends that adults sleep for 7 h per night [34]. According to previous studies, permanent night workers receive less sleep than day workers [35, 36]. Night workers who sleep during the day will inevitably be exposed to light, which hinders the duration and quality of sleep [37]. Specifically, light is the main environmental regulator of circadian rhythm. As the human brain tends to wake when the environment transitions from darkness to light [38], night workers find it difficult to sleep during the day.

Previous studies have reported higher rates of physical inactivity and obesity among white-collar workers, particularly female workers, than those in other occupations [39, 40]. Furthermore, physical inactivity during working hours negatively affects the health of white-collar workers [41]. Both obesity and physical inactivity have been recognized as risk factors for dyslipidemia. These findings seem relevant to our findings, as our subgroup analysis showed a significant association between night work and dyslipidemia among female white-collar workers. Notably, age also correlated directly with the prevalence of dyslipidemia in women, particularly among menopausal women older than 50 years of age. This may be attributable to lipoprotein changes associated with

| Variables | Dyslipidemia | Day | Night | Other shifts | OR† | 95% CI | OR† | 95% CI |
|-----------|-------------|-----|-------|-------------|-----|--------|-----|--------|
|           |             | OR† | OR†   | 95% CI      |     |        |     |        |
|           |             |     |       |             |     |        |     |        |
| Male      |             |     |       |             |     |        |     |        |
| Occupational categories b | | | | | | | | |
| White     | 1.00        | 1.75(0.95–3.24) | 1.56(0.60–4.04) | | | | |
| Pink      | 1.00        | 1.14(0.50–2.61) | 0.86(0.39–1.89) | | | | |
| Blue      | 1.00        | 1.70(0.99–2.94) | 0.72(0.44–1.18) | | | | |
| Eating habit (daily) | | | | | | | | |
| Regularly eat breakfast, lunch, and dinner | 1.00 | 1.56(0.85–2.86) | 0.72(0.44–1.16) | | | | |
| Skip meal(s) | 1.00 | 1.63(1.00–2.67)* | 1.16(0.64–2.10) | | | | |
| Sleep duration (hours) | | | | | | | | |
| 0–6   | 1.00 | 1.75(1.04–2.93)* | 0.91(0.54–1.54) | | | | |
| ≥ 7 ≥ 7 | 1.00 | 1.34(0.78–2.31) | 0.79(0.46–1.36) | | | | |
| Female   |             |     |       |             |     |        |     |        |
| Occupational categories b | | | | | | | | |
| White     | 1.00        | 2.95(1.68–5.16)* | 0.23(0.03–1.76) | | | | |
| Pink      | 1.00        | 0.85(0.49–1.45) | 1.65(0.67–4.09) | | | | |
| Blue      | 1.00        | 0.48(0.20–1.14) | 1.06(0.37–2.99) | | | | |
| Eating habit (daily) | | | | | | | | |
| Regularly eat breakfast, lunch, and dinner | 1.00 | 1.76(0.99–3.01) | 0.68(0.21–2.18) | | | | |
| Skip meal(s) | 1.00 | 0.80(0.49–1.30) | 1.01(0.46–2.22) | | | | |
| Sleep duration (hours) | | | | | | | | |
| 0–6   | 1.00 | 1.28(0.77–2.12) | 1.00(0.50–2.04) | | | | |
| ≥ 7 ≥ 7 | 1.00 | 1.03(0.60–1.75) | 0.88(0.28–2.74) | | | | |

†OR adjusted for all sociodemographic, economic, health-related, and nutritional factors considered in the study
bThree groups based on International Standard Classification Occupations codes
P < 0.05
menopause [42], which include increased levels of total and LDL cholesterol [42, 43].

This study had several limitations. First, the cross-sectional design rendered us unable to determine a causal relationship between night work and dyslipidemia. Second, the durations of day, night, and other shift work could not be determined because of limitations of the KNHANES questionnaire. Finally, the key covariates considered in this study, including the sleep duration and eating habits, were self-reported and may have been subject to recall bias. Despite these limitations, this study also featured strengths. This study involved a large, well-validated dataset collected from a nationally representative sample of the South Korean population.

### Table 4 Mean values of total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides

| Variable           | Dyslipidemia |                |                | Male (n = 2821) |                |                |
|--------------------|--------------|----------------|----------------|------------------|----------------|----------------|
|                    | Yesa         | Noa            |                | Mean ± SD  | P-value | Mean ± SD  | P-value |
| Total N %          | Total        | Day            | Night          | Other shifts    |                  |                  |
| Total cholesterol  | ≥240 ≥240 ≥240 | 0.044          | < 240 < 240 < 240 | 0.475 |
| Day                | 2404 170 7.1 | 254.852941 ± 14.6  | 2234 92.9 185.707623 ± 27.5 |
| Night              | 196 16 8.2 | 247.125 ± 5.4  | 180 91.8 183.117978 ± 29.3 |
| Other shifts       | 221 10 4.5 | 247.9 ± 12.4  | 211 95.5 185.149038 ± 26.8 |
| HDL cholesterol    | ≥40 ≤40 ≤40 | 0.532          | > 40 > 40 > 40 | 0.455 |
| Day                | 2404 346 14.4 | 34.8849827 ± 3.5 | 2058 85.6 52.1910633 ± 9.8 |
| Night              | 196 32 16.3 | 35.6163125 ± 3.5 | 164 83.7 51.7899506 ± 9.9 |
| Other shifts       | 221 31 14.0 | 34.9723226 ± 3.4 | 190 86.0 51.3105455 ± 9.0 |
| LDL cholesterol    | ≥160 ≥160 ≥160 | 0.049          | < 160 < 160 < 160 | 0.904 |
| Day                | 2404 71 3.0 | 175.915493 ± 14.4 | 2333 97.0 112.69986 ± 24.7 |
| Night              | 196 7 3.6 | 168.428571 ± 8.6 | 189 96.4 114.042254 ± 27.0 |
| Other shifts       | 221 5 2.3 | 162 ± 3.9  | 216 97.7 112.460317 ± 22.8 |
| Triglycerides      | ≥200 ≥200 ≥200 | 0.552          | < 200 < 200 < 200 | 0.765 |
| Day                | 2404 285 11.9 | 296.74386 ± 142.1 | 2119 88.1 104.792435 ± 38.6 |
| Night              | 196 30 15.3 | 310.73333 ± 167.1 | 166 84.7 106.871951 ± 37.8 |
| Other shifts       | 221 21 9.5 | 267.47619 ± 72.4 | 200 90.5 105.822335 ± 39.6 |

*Cut-offs according to the 2015 Korean Guidelines for the Management of Dyslipidemia*
Therefore, the findings will likely support the development of interventions and health policies aimed at the increasing problem of dyslipidemia in this population. The study thus makes a relevant contribution to the fields of cardiovascular medicine and epidemiology. Additionally, the KNHANES questionnaires are updated annually to incorporate changes in the real-life health circumstances of South Koreans. Therefore, KNHANES data have been used widely in health-related studies and have provided meaningful insights to inform health policy development in South Korea.

Conclusions
The findings of previous studies suggest an association of an irregular work schedule, particularly nighttime work, with an altered lipid profile. Accordingly, in this study, we examine the association between night work and dyslipidemia in a nationally representative sample of South Korean adults aged ≥30 years who participated in the KNHANES 2013–2016. In the overall analysis, we found a significant association of night work with dyslipidemia only among male workers. Additionally, subgroup analyses of male workers who reported skipping meals or receiving < 7 h of sleep per night revealed associations of night work with dyslipidemia. Among female participants, a subgroup analysis of white-collar workers found that those who worked at night faced higher risk of dyslipidemia, compared to their day working counterparts.

However, our study was unable to determine a causal relationship between the onset of dyslipidemia and night work, and further investigations are needed to validate the findings of our study. Given the increasing prevalence of dyslipidemia in South Korea and the association of this condition with cardiovascular disease, we also suggest the development of future interventions intended to alleviate dyslipidemia among night workers and ease the burden of CVD in South Korea.

Abbreviations
CVD: Cardiovascular disease; HDL: High-density lipoprotein; KNHANES: Korea National Health and Nutrition Examination Survey; LDL: Low-density lipoprotein

Acknowledgements
KNHANES is an ongoing surveillance system that assesses the health and nutritional status of residents of the Republic of Korea, monitors trends in health risk factors and the prevalence of major chronic diseases, and provides data for the development and evaluation of national health policies and programs.

Funding
No funding was received for this study.

Availability of data and materials
All data generated or analyzed in this study are included in this article.

Authors’ contributions
JHJ. and ECP. designed the study, collected the data, performed the statistical analysis, and wrote the manuscript. DWL. and DWC. contributed to the discussion and reviewed and edited the manuscript. ECP. is the guarantor of this work and as such, had full access to all of the data. ECP. assumes responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate
This study analyzed existing data and therefore did not require approval from an ethics review board. This study used data from the Korea National Health and Nutrition Examination Survey (KNHANES), which has been subject to an annual review and approval by the KCDC Research Ethics Review Committee since 2007.

Consent for publication
Not applicable.

Competing interests
The authors declare no conflicts of interest.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
1Department of Public Health, Graduate School, Yonsei University, Seoul, Republic of Korea. 2Institute of Health Services Research, Yonsei University, Seoul, Republic of Korea. 3Department of Preventive Medicine, Yonsei University College of Medicine, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea.

Received: 29 October 2018 Accepted: 18 March 2019
Published online: 28 March 2019

References
1. Kang EK, Kang GH, Uhm JY, et al. Association between shift work and microalbuminuria. Ann Occup Environ Med. 2017;29(6):43–51.
2. Costa G. Shift work and occupational medicine: an overview. Occup Med. 2003;53(2):83–8.
3. Statistics Korea. Korean working conditions survey. Daejeon; 2016. http://kosis.kr/statHtml/statHtml.do?orgId=380&tblId=DT_380002_E007&connPath=
4. Bøggild H, Knutsson A. Shift work, risk factors and cardiovascular disease. Scand J Work Environ Health. 1999;25(2):85–99.
5. Lennernäs M, Åkerstedt T, Hambræus L. Nocturnal eating and serum cholesterol of three-shift workers. Scand J Work Environ Health. 1994;20(6): 401–6.
6. Åkerstedt T. Sleepiness as a consequence of shift work. Sleep. 1988; 11(1):17–34.
7. Rosch PJ. [Editorial] Stress and sleep: some startling and sobering statistics. Stress Medicine. 1996;12(4):207–10.
8. Statistics Korea. Deaths and death rates by cause (236 item), sex, and age (by five-year age group). Daejeon; 2017. http://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1843&conn_path=
9. Muzunuru K. Atherosclerotic dyslipidemia: cardiovascular risk and dietary intervention. Lipids. 2010;45(10):907–14.
10. Kim HC. Epidemiology of dyslipidemia in Korea. J Korean Med Assoc. 2016; 59(5):352–7.
11. Committee for the Korean Guidelines for the Management of Dyslipidemia. 2015 Korean guidelines for the Management of Dyslipidemia: executive summary (English translation). Korean Circ J. 2016;46(3):275–306.
12. Ghiasvand M, Heshmat R, Golpira R, et al. Shift working and risk of lipid disorders: a cross-sectional study. Lipids Health Dis. 2006;5:9–9.
13. Antunes L, Levandovski R, Dantas G, Caumo W, Hidalgo M. Obesity and shift work: chronobiological aspects. Nutr Res Rev. 2010;23(3):155–68.
14. Costa G. The impact of shift and night work on health. Appl Ergon. 1996; 27(1):9–16.
15. Hong AR, Lim S. Clinical characteristics of metabolic syndrome in Korea, and its comparison with other Asian countries. J Diabetes Investig. 2015;6(3): 508–15.
16. Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP). Expert panel on detection, evaluation, and
17. Kim MK, Lee WY, Kang JH, et al. 2014 clinical practice guidelines for overweight and obesity in Korea. Endocr Metab (Seoul). 2014;29(4):79–84.

18. Lee H-Y, Park JB. The Korean Society of Hypertension Guidelines for the Management of Hypertension in 2013: its essentials and key points. Pulse (Basel). 2015;3(1):21–8.

19. Kweon S, Kim Y, Jang M, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol. 2014;43(1):69–77.

20. S-q S, Ansari TS, McGuinness Owen P, Wasserman David H, Johnson Carl H. Circadian disruption leads to insulin resistance and obesity. Curr Biol. 2013;23(5):372–81.

21. Bovin DB, Boudreau P. Impacts of shift work on sleep and circadian rhythms. Pathol Biol (Paris). 2014;62(5):292–301.

22. Bass J, Takahashi JS. Circadian integration of metabolism and energetic. Science. 2010;330(6009):1349–54.

23. Bloomgarden ZT. Insulin resistance, dyslipidemia, and cardiovascular disease. Diabetes Care. 2007;30(8):2164.

24. Sironi AM, Gastaldelli A, Mari A, et al. Visceral fat in hypertension: influence on insulin resistance and β-cell function. Hypertension. 2004;44(2):127–33.

25. Schlegel G, Dorow E. Diurnal patterns of triglycerides, free fatty acids, blood sugar, and insulin during carbohydrate-induction in man and their modification by nocturnal suppression of lipolysis. J Clin Invest. 1973;52(3):32–40.

26. Schlegel G, Dorow E. Diurnal patterns of triglycerides, free fatty acids, blood sugar, and insulin during carbohydrate-induction in man and their modification by nocturnal suppression of lipolysis. J Clin Invest. 1973;52(3):32–40.

27. Hoogerwerf WA. Role of clock genes in gastrointestinal motility. Am J Physiol Gastrointest Liver Physiol. 2010;299(3):G549–55.

28. Lowden A, Moreno C, Holmback U, Lennernas M, Tucker P. Eating and shift work - effects on habits, metabolism and performance. Scand J Work Environ Health. 2010;36(2):150–62.

29. Reinberg A, Migraine C, Apfelbaum M, et al. Circadian and ultradian rhythms in the feeding behaviour and nutrient intakes of oil refinery operators with shift-work every 3–4 days. Diabete Metab. 1979;5(1):33–41.

30. de Assis MA, Kupek E, Nahas MV, Bellisle F. Food intake and circadian rhythms in shift workers with a high workload. Appetite. 2003;40(2):175–83.

31. Sierra-Johnson J, Undén A-L, Linestrand M, et al. Eating meals irregularly: a novel environmental risk factor for the metabolic syndrome. Obesity. 2008;16(6):102–7.

32. Wilkinson R. How fast should the night shift rotate? Ergonomics. 1993;35:1425–6.

33. de Assis MA, Kupek E, Nahas MV, Bellisle F. Food intake and circadian rhythms in shift workers with a high workload. Appetite. 2003;40(2):175–83.

34. Wilkinson R. How fast should the night shift rotate? Ergonomics. 1993;35:1425–6.

35. Akerstedt T. Shift work and disturbed sleep/wakefulness. Occup Med. 2003;53(2):89–94.

36. Akerstedt T. Shift work and disturbed sleep/wakefulness. Occup Med. 2003;53(2):89–94.

37. Akerstedt T. Work hours, sleepiness and the underlying mechanisms. J Sleep Res. 1995;4(5):15–22.

38. Dumont M, Beaulieu C. Light exposure in the natural environment: relevance to mood and sleep disorders. Sleep Med. 2007;8(6):557–65.

39. Vangelova K. Cardiovascular risk factors in white collar workers under shift work. Acta Med Bulg. 2017;44(2):5–9.

40. Vangelova K. Cardiovascular risk factors in white collar workers under shift work. Acta Med Bulg. 2017;44(2):5–9.

41. Vangelova K. Cardiovascular risk factors in white collar workers under shift work. Acta Med Bulg. 2017;44(2):5–9.

42. Vangelova K. Cardiovascular risk factors in white collar workers under shift work. Acta Med Bulg. 2017;44(2):5–9.

43. Vangelova K. Cardiovascular risk factors in white collar workers under shift work. Acta Med Bulg. 2017;44(2):5–9.