Original Article

Effect of night shift on development of metabolic syndrome among health care workers

Jyotirmayee Bahinipati[1], Rajlaxmi Sarangi[1], Mona Pathak[2], Srikrushna Mohapatra[1]

Department of [1]Biochemistry and [2]Research & Developement, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India

Abstract

Circadian desynchronization, sleep deprivation, changes in eating habit, and lack of physical activity resulting in an increase in pro-inflammatory markers in night shift health care workers is associated with various risk factors for the development of metabolic syndrome. This study aimed to estimate the pro-inflammatory markers in night shift work and find its relationship with different criteria of metabolic syndrome. **Materials and Methods:** A total of 303 participants were recruited for the study. Demographic data and parameters pertaining to the development of metabolic syndrome were taken. Highly sensitive C-reactive protein (Hs CRP) as proinflammatory marker was analyzed. Fasting blood sugar (FBS), serum triglyceride (TG), and high-density lipoprotein (HDL) were estimated. Criteria for metabolic syndrome were taken according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) guidelines. **Results:** Night shift workers had higher hs CRP compared to day shift workers. TG and FBS were increased significantly ($P < 0.001$). A total of 6.5% of the night shift workers had a waist circumference greater than 40 inches. It was observed that night shift workers with higher hsCRP had significantly high waist circumference ($P < 0.001$) and FBS ($P < 0.05$). A total of 3.57% of the night shift workers were diagnosed with metabolic syndrome with three criteria positive. **Conclusion:** Night shift work is associated with an increase in pro-inflammatory markers and the development of risk factors leading to metabolic syndrome. Thus, early screening and management of risk factors among night shift health care workers may improve their health status and prevent the development of MS.

Keywords: hsCRP, metabolic syndrome, night shift, proinflammatory markers, waist circumference

Introduction

Metabolic syndrome (MS) is defined by the WHO as a pathologic condition characterized by hypertension, dyslipidemia, derangement in glucose metabolism, and abdominal obesity secondary to insulin resistance.[1] MS increases the risk of chronic illness specifically cardiovascular disease (CVD) and ischemic stroke. It is now a global epidemic affecting 12% to 37% of the Asian population and 12% to 26% of the European population. The incidence of MS even parallels the incidence of obesity and T2DM. According to CDC data of 2017, 30.2 million adults (≥ 18 yrs) i.e. 12.2% of the USA have T2 DM. The incidence increase with age to 25.2%. The prevalence of prediabetes or MS is almost three times suggesting one-third of the USA adults have MS.[2] The prevalence of MS in India has been documented to be 11% to 41% across the country with numerous socio-cultural variations.[3] Though pathogenesis of MS remains an unclear variety of contributing factors such as lifestyle, environmental and genetic factors, stress, shift work has been associated with it.

Circadian rhythm has an impact on many aspects of our physiology. The circadian clock helps to regulate sleep patterns,

Address for correspondence: Dr. Rajlaxmi Sarangi, Professor, Department of Biochemistry, KIMS, KIIT University, BBSR, Odisha, India.
E-mail: drrajlaxmisarangi@gmail.com

Received: 21-02-2021 **Revised:** 15-07-2021
Accepted: 29-08-2021 **Published:** 14-05-2022

Access this article online

Quick Response Code:

Website: www.jfmpc.com

DOI: 10.4103/jfmpc.jfmpc_375_21

How to cite this article: Bahinipati J, Sarangi R, Pathak M , Mahapatra S. Effect of night shift on developement of metabolic syndrome among health care workers. J Family Med Prim Care 2022;11:1710-5.

feeding behavior, hormone release, blood pressure, and body temperature.[4] The molecular clock plays a critical role in tissues. Clock genes exert a profound influence on metabolism through the control of gluconeogenesis, insulin sensitivity, and systemic oscillation of blood glucose.[5] Chronic misalignment between our lifestyle and rhythm dictated by our endogenous circadian clock is associated with an increased risk of various diseases including cancer, neurodegenerative diseases, metabolic disorders, and inflammation.[6] Circadian rhythm desynchronization occurs when internal oscillations are misaligned with the external environment. Shift work specifically defined as working in the night shift (6 PM to 7 AM) negatively affects the circadian rhythm causing an alteration in the secretion of hormones, melatonin, cortisol, leptin, ghrelin, etc., Alteration of these hormones affects body metabolism, reduces glucose tolerance, and increases insulin resistance.[7] Night shift work generally results in a mismatch between the light-sensitive central pacemaker in the suprachiasmatic nucleus (SCN) and energy-sensitive peripheral oscillators. At night, metabolic rate slows down, and anabolism is favored. However, during nightshift, the working body is challenged with high-energy requirements. With food intake, there is an additional challenge in digestion and assimilation.[8] Sleep displacement and altered food timing due to shifting work, disturb normal hormonal behavior involving key regulators of satiety and hunger. Circadian regulation of immune response is the integration of signals from the central clock and peripheral clocks found in immune cells and organs and sites of infection. Chronic low-grade inflammation has been suggested as a major factor for both MS and subsequent clinical outcomes. Highly-sensitive C-reactive protein (hs-CRP) is a known biomarker of acute and chronic inflammation, and various studies have correlated hsCRP with MS.[9] Circadian misalignment increases the levels of numerous inflammatory markers including hs-CRP. This may further induce the development of various components of MS and hence increases the risk of different chronic diseases.[10] Although various studies have been done, the link between shift work and MS cannot be firmly assorted. This study aims to evaluate the prevalence of metabolic syndrome and its components among night shift health care workers and find its correlation with hsCRP.

Materials and Methods

This cross-sectional study was conducted in the dept of biochemistry of a tertiary care medical college and hospital. Health care workers (doctors, nurses, technicians, and attendants) of age group 25–45 years with 169 night shift and 134 day shift health care workers were recruited for the study purpose. Individuals with type 2 DM, hypertension, CVD, or with any known inflammatory diseases were excluded from the study.

Approval from the Institutional Ethical Committee was obtained (bearing IEC No: KIIT/KIMS/38/2019) before the commencement of the study. Informed consent was taken from each participant after a proper explanation of the study's purpose. The frequency and duration of night shift work were recorded. A minimum of 2 night shifts per week or 5 per month for at least 2 years were included for the study purpose. Data were collected regarding age, family history for any component of metabolic syndrome, cardiovascular disease, intake of alcohol, and smoking. The average of three subsequent measurements of blood pressure in a relaxed state was taken. Weight in kilogram and height in meter were recorded.

Waist circumference was measured in inches at the midpoint between the lower border of the rib cage and iliac crest. Criteria for the metabolic syndrome were taken according to the updated National Cholesterol Education Program. Metabolic syndrome was identified when three criteria were present: Waist circumference >40.15 inches in men and >34.64 inches in women, serum TG >150 mg/dL, HDL cholesterol <40 mg/dL in men and <50 mg/dL in women, SBP >130 mm of Hg and DBP >85 mm of Hg, and plasma glucose >100 mg/dL.

After overnight fasting, 3 mL of the venous blood sample was collected. One mL was kept in a fluoride vial for glucose estimation and 2 mL in red top vacutainer for estimation of TG, HDL, and hs CRP. FBS was estimated by the hexokinase method. TG was done by glycero phosphate oxidase peroxidase (GPO-POD method). Serum HDL was measured by the colorimetric non-HDL precipitation method. hs CRP was estimated by particle enhanced turbidimetric assay. hs-CRP > 0.05 mg/dL was considered as elevated. All the parameters were estimated by Vitros 5600 (Ortho Clinical Diagnostic) after running of daily QC.

Statistical Analysis: All of the metabolic syndrome parameters are reported as number (%) for the day shift and night shift workers. hs CRP levels were compared using the Wilcoxon Rank Sum test among various metabolic syndrome parameters. Association of MS criteria with shift work was tested using Chi-square test. All the tests were considered significant at a 5% level of significance. SATA15.1. Stata Corp, Texas was used for analysis.

Results

A total of 302 individuals (176 female and 126 male) including doctors, nurses, technicians, and attendants participated in the study. The mean age of participants was 28.6 ± 7.8 years, which was relatively lower among night shift workers (27.89 ± 6.57 years) in comparison to day shift workers (29.5 ± 9.00 years). Among the participants, there were 57 doctors, 98 nurses, 33 technical staff, 38 students, and 51 attendants. Among the night shift workers, 45% were nurses, 18% doctors, 14% technical staff, and 22% were attendants. As 91% of the nurses were female, the female proportion was significantly higher in night shift workers (70%) in comparison to day shift workers (43%). Bodyweight (night shift: 60.1 ± 13.7 and day shift: 61.6 ± 13.2) and BMI (night shift: 23.9 ± 5.4 and day shift: 23.1 ± 5.4) were well balanced among both arms. Table 1 describes the number and percentage of individuals with parameters more than the cut-off value for

Table 1: Parameters more than the cut off value for metabolic syndrome

Parameters	Day Shift (*N*=134) *N* (%)	Night Shift (*N*=168) *N* (%)	*P*
Blood Pressure >130/80 mm of Hg	4 (3%)	8 (4.7%)	0.438
Waist Circumference >40 inch	1 (0.7%)	11 (6.5%)	0.010
TG >150 mg/dL	16 (11.9%)	41 (24.3%)	0.006
HDL <40 mg/dL	88 (65.7%)	110 (65.1%)	0.916
FBS >100 mg/dL	0 (0%)	16 (9.5%)	0.000

Footnotes: TG: Triglyceride, HDL: High density lipoprotein, FBS: Fasting blood sugar

metabolic syndrome in the study subjects. Blood pressure and HDL levels were similar among both night and day shift workers. However, WC (6.5% v/s < 1% and TG (24% v/s 12%) were higher for a significantly a greater number of individuals in the night shift in comparison to day shift workers. Higher FBS was found among 16 (9.5%) night shift workers but among day shift workers none had higher FBS. The participants having higher WC had significantly higher level of hs CRP (0.19 ± 0.22 v/s 0.64 ± 0.75 mg/dL). Similarly, individuals with higher FBS also had higher hs CRP levels [Table 2]. The presence of criteria for MS was seen among the study participants (including both day and night shift). It was observed that six individuals (3.57%) of night shift confirmed three parameters for metabolic syndrome and were diagnosed as MS. Whereas, none of the day shift individuals had MS [Figure 1]. Metabolic syndrome was found to be significantly associated with the shift of working ($P = 0.002$).

Table 2: Relationship of higher hs-CRP with parameters of MS

Parameters	Number of Participants	Hs-CRP Mean±SD	*P*
BP (mm of Hg)			0.232
<130/80	291	0.21±0.27	
>130/80	12	0.27±0.21	
Waist Cir (Inches)			0.000
Normal (<40)	290	0.19±0.22	
High (>40)	13	0.64±0.75	
TG (mg/dL)			0.09
Normal<150	246	0.20±0.22	
High (>150)	57	0.28±0.42	
HDL (mg/dL)			0.20
Normal	105	0.27±0.38	
Low	198	0.18±0.19	
FBS (mg/dL)			0.005
Normal	287	0.19±0.22	
High	16	0.54±0.70	

Footnotes: TG: Triglyceride, HDL: High-density lipoprotein, FBS: Fasting blood sugar, BP: Blood pressure, hs-CRP: highly sensitive C-reactive protein

Discussion

Repeated desynchronization and resynchronization associated with rotating night shift work may alter the circadian rhythmicity and alter accelerate or cause several chronic degenerative diseases.

In our study, 4.7% of the night-shift workers had blood pressure greater than 130/80 mm of Hg. The blood pressure was though increased in the night shift but was not significant statistically. Similarly, the study done by Sfreddo C *et al*.[11] found blood pressure was not different in day and night shift workers. But in a study done by the researcher of the University of California, over 2011 workers for 10 years found a four-fold increase in the risk of hypertension to the employees working mostly in the night shift.[12] Higher hypertension prevalence (*P* value 0.045) was found in nursing professionals doing shift work.[13] Even night shift results in uncontrolled blood pressure among those who are taking antihypertensives.[14]

Night shift work was associated with a significant increase in waist circumference in our study population. Abdominal obesity was one of the major components of metabolic syndrome and even considered as a preclinical stage of diabetes and cardiovascular disease. Body mass index is not gender-specific and cannot differentiate between the fat and muscle tissue and more importantly the fat distribution of the body hence waist circumference suggesting visceral obesity is considered as it is more strongly associated with cardiovascular risk.[15] Other studies also have demonstrated a similar increase in waist circumference compared to day shift workers. Night shift worker exhibits a higher proportion of increased waist circumference or abdominal obesity.[16] The risk of abdominal obesity steadily increases over time (1.40 (95% CI 1.23–1.58 & 1.60 (95% CI 1.36–1.87) in different age groups which was shown by a follow-up study done by Lee G J *et al*.[17] Shift work causes disruption in the circadian rhythm which could result in changes in eating and exercise habits leading to weight gain. Besides, sleep deprivation can also result in appetite-regulating hormone imbalance (leptin and ghrelin). Furthermore, they have limited opportunities for physical activity.[12]

Dyslipidemia was significantly associated with night shift workers in our study (significant increase in triglyceride and insignificant changes in HDL). Studies have shown high levels of TG more prevalent in night shift workers with no difference in serum HDL level.[18] Sleep quality and its influence in shift work play a role in the alteration of some lipid parameters[19] But some studies found no such difference for triglyceride and HDL between day and night shift work.[20] Lipid metabolism is susceptible to the effects of irregular shift work schedules and deranged sleep. Two proteins involved in circadian regulation circadian locomotor output cycles caput (CLOCK) and nocturnin play an important role in the regulation of dietary lipid absorption. CLOCK plays a role in turning off the genes involved in lipid absorption at the onset of the day and its deficiency increases lipid absorption. Its disruption triggers lipid accumulation in the liver. Nocturnin deficiency decreases lipid absorption. Night shift work disrupts the circadian rhythm, hence affecting the physiology of the lipids.[21]

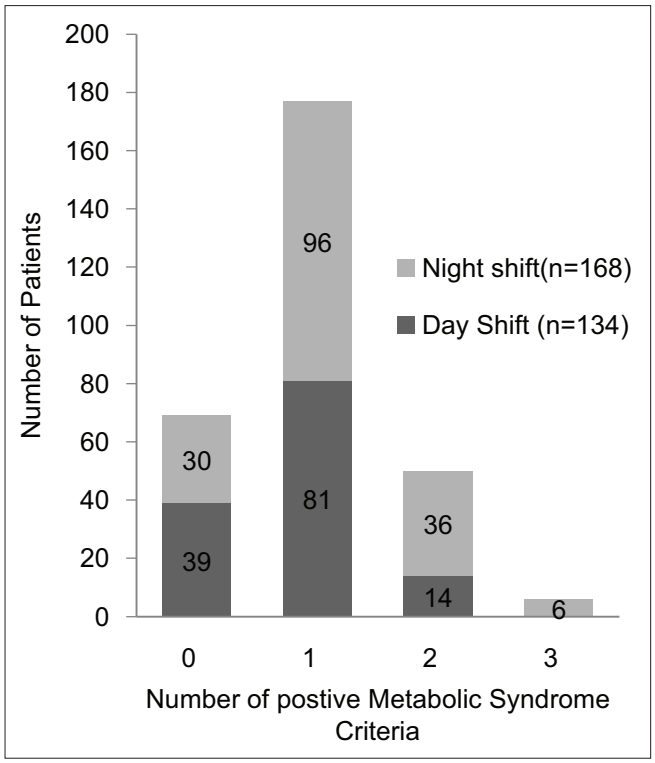

Figure 1: Positive Metabolic syndrome criteria

Shift work adversely affects the blood glucose level. In our study, 9.47% of the night shift workers had raised fasting blood sugar levels. The study has shown higher odds for type 2 diabetes mellitus in night shift work.[22] Wyse *et al.*[23] suggested a 7% increase in likelihood for type-2 diabetes mellitus in night shift workers after multivariable adjustment. A report from NHS2 had suggested that the type 2 diabetes risk is dependent on the chronotype and rotating night shift work.[24] Hence, in the night shift, there is more risk for the development of diabetes mellitus compared to the day shift.

Mean hs CRP in night shift workers was significantly increased (0.300 ± 33 mg/dL) compared to those who work in the day shift (0.10 ± 0.09 mg/dL). A cutoff value of 0.5 mg/dL was taken for higher hs CRP. Components of metabolic syndrome were seen in night shift individuals who had higher than the cutoff value for hs CRP. It was observed that waist circumference and fasting blood sugar were significantly higher among those who had high hs CRP, TG was though increased but not significant. Blood pressure and HDL were not affected by high hs CRP levels.

Systemic inflammation is associated with greater adiposity measured in the form of waist circumference and BMI. Studies have found a strong positive relationship of hs CRP both with waist circumference and BMI. Obesity results in an increased risk of many metabolic and cardiovascular complications. Santos AC found that mean CRP levels were significantly higher in the presence of central obesity (2.45 Vs 1.24 mg/dL). They suggested that an increase in the severity of metabolic syndrome is associated with an increase in CRP.[25] When the relation was analyzed on regression analysis, the correlation of hs CRP with waist circumference (r = 0.42) was strong.[26] Chronic low-grade inflammation has been suggested as an important factor for both metabolic syndrome and its corresponding clinical outcome. Diverse cross-sectional studies have also documented hs CRP as a biomarker of acute and chronic inflammation as being associated with metabolic syndrome.[27] Oxidative stress and inflammation tend to be a central component of diabetes, and it is a complication and is also associated with impaired glycemic regulation and further pathogenesis. A significant positive correlation is observed between hs CRP and FBS.[28]

As seen in shift employees, when the circadian rhythm does not fit the sleep-wake cycle, it induces opposition signaling called circadian desynchrony. This desynchronization disturbs the rhythm of the suprachiasmatic nucleus and hormonal release for which it retains time leading to sleep and metabolic disorder. Circadian desynchronization presents with numerous abnormalities in hormonal levels including an increase in cortisol, ghrelin, decrease in TSH, growth hormone, insulin, leptin, and serotonin. The decrease in insulin sensitivity in them explains the disturbance in glycemic status in shift workers. A similar effect on ghrelin results in an increase in appetite for high-energy food.

In our study, all three parameters for metabolic syndrome were seen in six (3.57%) individuals doing night shift work. Whereas, none of the individuals from the day shift had all the three parameters to be diagnosed with metabolic syndrome. A total of 78.57% of night shift health care workers were either having one or two components of metabolic syndrome. Hence, in the night shift, there is a high risk of metabolic syndrome. Studies have shown night shift workers have an increased incidence of metabolic syndrome, which raises the risk of cardiovascular disease, stroke, and type 2 diabetes mellitus.[29] An incidence of 5.7% of metabolic syndrome was seen in a total of 738 patients with a total of 9% occurring in night shift workers and 1.8% among day shift with a relative risk of 5.0 (95% CI 2.1–14.6).[30]

In a study conducted on 26,382 workers, long-term shift work was associated with metabolic syndrome without adjustment for any confounding factor.[31] In another study, the author suggested that there was no sufficient evidence showing an association between shift work and prevalent metabolic syndrome when confounders were taken into account.[32]

Limitation: Our study had certain limitations. We were not able to obtained details regarding physical activity or exercise, personal eating habits, sleep patterns, or disorders associated with sleep. Further estimation of hormonal level (cortisol, melatonin) impacting the circadian rhythm for their diurnal variations could have helped more suggesting the relevance of night shift, proinflammatory markers increasing the risk for metabolic syndrome.

Conclusion: Raised proinflammatory markers in night shift health care workers increases the risk of metabolic syndrome.

MS is associated with functional hypercortisolism. As cortisol has a role in modulating circadian rhythm via the hypothalamic-pituitary axis, regulating the cortisol level can improve sleep quality by circadian synchronization. Regular physical activity and exercise have an important role in reducing the cortisol level specifically in individuals with metabolic syndrome. Regular shift and clockwise rotation of shift duties can avoid circadian desynchronization. Early identification and primary prevention through lifestyle modifications can provide better long-term health benefits for the health care workers involved in night shift duty.

Strategy must be initiated to increase awareness among health care workers including primary physicians and health care workers regarding dietary pattern, physical activity, regular metabolic parameters screening for their health benefits as they are providing 24 h service to society.

Abbreviations: hs-CRP: highly sensitive C-reactive protein, HDL: High density lipoprotein, MS: Metabolic syndrome, NCEP ATP III: National Cholesterol Education Program Adult Treatment Panel III, CDC: Centers for disease control and prevention.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Kawabe Y, Nakamura Y, Kikuchi S, Murakami Y, Tanaka T, Takebayashi T, *et al.* Relationship between shift work and clustering of the metabolic syndrome diagnostic components. J Atheroscler Thromb 2014;21:703-11.
2. Saklayen MG. The global epidemic of the metabolic syndrome. Curr Hypertens Rep 2018;20:12.
3. Khan Y, Lalchandani A, Gupta AC, Khadanga S, Kumar S. Prevalence of metabolic syndrome crossing 40% in Northern India: Time to act fast before it runs out of proportions. J Family Med Prim Care 2018;7:118-23.
4. Reddy S, Reddy V, Sharma S. Physiology, Circadian Rhythm. Sta Pearls. 2020. Available from: https://www.ncbi.gov/books/NBK519507.
5. Gachon F, Mangold UL, Petrenko V, Dibner C. Glucose homeostasis: Regulation by peripheral circadian clocks in Rhodentsand humans. Endocrinology 2017;158:1074-84.
6. Farhud D, Aryan Z. Circadian rhythm, lifestyle and health: A narrative review. Iran J Pub Health 2018;47:1068-76.
7. Morris CJ, Yang JN, Garcia JI, Myers S, Bozzi I, Wang W, *et al.* Endogenous circadian system and circadian misalignment impact glucose tolerance *via* separate mechanisms in humans. Proc Natl Acad Sci 2015;112:E2225–34.
8. James SM, Honn KA, Gaddameedhi S, Van Dongen HPA. Shift work: Disrupted circadian rhythms and sleep-implications for health and well-being. Curr Sleep Med Rep 2017;3:104-12.
9. Chowta MN, Adhikari PM, Sinha R, Acharya SD, Gopalakrishna HN, Ramapuram JT. Highly sensitive C reactive protein in patients with metabolic syndrome and cardiovascular disease. Ann Trop Med Public Health 2012;5:98-102.
10. Morris CJ, Purvis TE, Mistretta J, Hu K, Scheer FAJL. Circadian misalignment increases C-reactive protein and blood pressure in chronic shift workers. J Biol Rhythms 2017;32:154-64.
11. Sfreddo C, Fuchs SC, Merlo AR, Fuchs FD. Shift work is not associated with high blood pressure or prevalence of hypertension. PLoS One 2010;5:e15250.
12. Lowden A, Moreno C, Holmbäck U, Lennernäs M, Tucker P. Eating and shift work-effects on habits, metabolism and performance. Scand J Work Environ Health 2010;36:150-62.
13. Nascimento JOV, Santos JD, Meira KC, Pierin AMG, Souza-Talarico JN. Shift work of nursing professionals and blood pressure, burnout and common mental disorders. Rev Esc Enferm USP 2019;53:e03443.
14. Park J, Shin SY, Kang Y, Rhie J. Effect of night shift work on the control of hypertension and diabetes in workers taking medication. Ann Occup Environ Med 2019;31:e27.
15. Czeczelewski M, Czeczelewski J, Czeczelewska E, Kondracink AG. Association of body composition indexes with cardio-metabolic risk factors. Obesity Med 2020;17:100171. https://doi.org/10.1016/j.obmed.2019.100171.
16. Mohebbi I, Shateri K, Seyedmohammadzad M. The relationship between working schedule patterns and the markers of the metabolic syndrome: Comparison of shift workers with day workers. Int J Occup Med Environ Health 2012;25:383–91.
17. Lee GJ, Kim K, Kim SY, Kim JH, Suh C, Son BC, *et al.* Effects of shift work on abdominal obesity among 20-39-year-old female nurses: A 5-year retrospective longitudinal study. Ann Occup Environ Med 2016;28:69.
18. Gadallah M, Hakim SA, Mohsen A, Eldin WS. Association of rotating night shift with lipid profile among nurses in an Egyptian tertiary university hospital. Eastern Medi Health J 2017;23:295-302.
19. Charles LE, Gu JK, Tinney-Zara CA, Fekedulegn D, Ma CC, Baughman P, *et al.* Separate and joint associations of shift work and sleep quality with lipids. Saf Health Work 2016;7:111-9.
20. Akbari H, Mirzaei R, Nasrabadi T, Gholami-Fesharaki M. Evaluation of the effect of shift work on serum cholesterol and triglyceride levels. Iran Red Crescent Med J 2015;17:e18723.
21. Hussain MM, Pan X. Circadian regulators of intestinal lipid absorption. J Lipid Res 2015;56:761–70.
22. Vetter C, Dashti HS, Lane JM, Anderson SG, Schernhammer ES, Rutter MK, *et al.* Night shift work, genetic risk, and type 2 diabetes in the UK Biobank. Diabetes Care 2018;41:762-9.

23. Wyse CA, Celis Morales CA, Graham N, Fan Y, Ward J, Curtis AM, *et al.* Adverse metabolic and mental health outcomes associated with shift work in a population-based study of 277,168 workers in UK Biobank. Ann Med 2017;49:411–20.
24. Vetter C, Devore EE, Ramin CA, Speizer FE, Willett WC, Schernhammer ES. Mismatch of sleep and work timing and risk of type 2 diabetes. Diabetes Care 2015;38:1707-13.
25. Santos AC, Lopes C, Guimarães JT, Barros H. Central obesity as a major determinant of increased high-sensitivity C-reactive protein in metabolic syndrome. Int J Obes 2005;29:1452-6.
26. Sadanand CD, Anitha J, Raveesh PM. Relation between high sensitivity C reactive protein to obesity among Indians. Int J Med Sci Public Health 2015;4:1523-6.
27. Song Y, Yang SK, Kim J, Lee DC. Association between C-reactive protein and metabolic syndrome in Korean adults. Korean J Fam Med 2019;40:116–23.
28. Gohel MG, Chacko AN. Serum GGT activity and hsCRP level in patients with type 2 diabetes mellitus with good and poor glycemic control: An evidence linking oxidative stress, inflammation and glycemic control. J Diabetes Metab Disord 2013;12:56.
29. Proper KI, van de Langenberg D, Rodenburg W, Vermeulen RCH, van der Beek AJ, van Steeg H, *et al.* The relationship between shift work and metabolic risk factors: A systematic review of longitudinal studies. Am J Prev Med 2016;50:e147-57.
30. Pietroiusti A, Neri A, Somma G. Incidence of metabolic syndrome among night-shift healthcare workers. Occup Environ Med 2010;67:54-7.
31. Guo Y, Rong Y, Huang X, Lai H, Luo X, Zhang Z, *et al.* Shift work and the relationship with metabolic syndrome in Chinese aged workers. PLoS One 2015;10:e0120632.
32. Canuto R, Garcez AS, Olinto MT. Metabolic syndrome and shift work: A systematic review. Sleep Med Rev 2013;17:425-31.