Diabetes/Lipids/Obesity
Original Article

Comparative Analysis of Metabolic and Endocrine Parameters in Night Shift versus Day Shift Workers: Insights from an Observational Study

Vijay S. R. Danda, Mujeeb M. A. Afzal, Vivek Kyatham, Chandrashekar Bhandiwad
Department of Endocrinology, Gandhi Medical College, Secunderabad, Telangana, India

Abstract

Introduction: Night shift work has been associated with obesity, cardiovascular diseases, and certain cancers. The primary objective of this study was to assess the differences in metabolic and endocrine profiles between night shift and day shift workers in a South Indian cohort. **Methods:** This cross-sectional study included 45 night shift workers (NSWs) and 45 day shift workers (DSWs). Metabolic parameters measured were HOMA IR, HDL-C, triglycerides, adiponectin, free fatty acids, and BMI. Hormonal parameters measured were total T3, total T4, TSH, 8 am cortisol, LH, FSH, testosterone, oestradiol, growth hormone, IGF-1, and 25 (OH) vitamin D_3. **Results:** NSWs were younger (28.6 ± 5.7 years vs. 31.1 ± 7.2 years; $P = 0.022$) with a lower mean BMI (24.2 ± 5 kg/m^2 vs. 25.2 ± 5.7 kg/m^2; $P = 0.33$) and higher mean HOMA IR (6.3 ± 5.4 vs. 5.2 ± 4.4; $P = 0.26$). 77% (n = 35) of NSW had HOMA-IR ≥ 2.5 in comparison to 62% (n = 28) of DSW ($P = 0.031$). NSW had higher median triglycerides (195[90] mg/dl vs. 180[44] mg/dl; $P = 0.045$) and lower mean HDL-C levels (35 ± 2.7 mg/dl vs. 40 ± 3 mg/dl; $P < 0.001$). NSW males had lower mean LH levels (2.8 ± 1.4 mIU/ml vs. 5.6 ± 3 mIU/ml; $P = <0.001$) and testosterone levels (373.6 ± 146 ng/dl vs. 400 ± 140 ng/dl; $P = 0.5$). The mean oestradiol levels were elevated in female NSW (181 ± 84 pg/ml vs. 100 ± 62 pg/ml; $P = 0.006$). 25(OH) vitamin D_3 levels were significantly low in the NSW (10.4 ± 4.8 ng/ml vs. 13.7 ± 4.5 ng/ml; $P = 0.032$). **Conclusion:** The present study shows night shift work is associated with increased risk of insulin resistance, hypertriglyceridemia, low HDL-C, low LH and testosterone in males, high oestradiol among females, and vitamin D deficiency.

Keywords: Endocrine, metabolic, night shift work

Introduction

The concept of shift work can be traced back to ancient societies, where workers were organised into shifts for maintaining security. With the advent of industrial revolution, night shift work became more prominent for maximising production. Karl Marx in his '*Das Kapital*' critiqued the extension of the working day into the night which prioritises profit over workers' well-being.[1] Shift work has become a prevalent feature in various industries, including healthcare, manufacturing, and transportation. The International Labour Organization (ILO) defines shift work as "a method of organization of working time in which workers succeed one another at the workplace so that the establishment can operate longer than the hours of work of individual workers".[2] Approximately 19% to 26% workers engage in some form of shift work, which often includes night shifts.[3,4] Human beings are biologically wired to follow a circadian rhythm that regulates sleep–wake cycles and various metabolic processes. Night shift work disrupts these natural rhythms, leading to potential adverse health outcomes such as obesity, cardiovascular diseases, and certain cancers.[5-7] A recent umbrella review found highly suggestive evidence for association between shift work and myocardial infarction and diabetes.[8] Night shift work is considered to be probably carcinogenic (Group 2A).[9] There is very little to no research on night shift work in India given the

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Address for correspondence: Dr. Vijay S. R. Danda, Department of Endocrinology, 3rd Floor, Gandhi Medical College and Hospital, Musheerabad, Secunderabad - 500 003, Telangana, India.
E-mail: drdvsreddyendo@yahoo.com

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increasing prevalence of night shift work and its adverse health consequences. The primary objective of this study is to assess the differences in endocrine and metabolic profiles between night shift and day shift workers in a South Indian cohort.

Material and Methods

This was a cross-sectional study done between March 2020 and March 2022 for a period of 24 months. Volunteers from a multinational company in South India were recruited for the study. All adult healthy volunteers with a minimum of 3 months of night shift work were included in the study. Night shift work was defined as work in the night of more than 6–8 hours crossing mid night for more than or equal to 5 days a week work. Healthy volunteers with day shift work were taken as the comparator group. Subjects with chronic illness, subjects on antifungal medications, subjects on antipsychotics, those with a history of taking vitamin D supplementation in the last 6 months, and those with onset of diabetes before the night shift work were excluded. A total of 90 subjects with 45 night shift workers (NSWs) and 45 day shift workers (DSWs) were considered for this pilot project. A thorough history on any chronic illness, diabetes, hypertension, duration of present shift work, drug usage including tobacco use in any form (current user), and alcohol use (defined as any intake in the last month) was taken. Height, weight, and waist circumference were measured to the nearest cm. BMI was calculated as kg/m^2. All participants were sampled after ≥8 hours overnight fast on non-working days. They were instructed to avoid tea/coffee/snacks after 10 PM. The blood sample was collected between 7 AM and 8 AM. Serum was separated and stored in -80°C for analysis at a later date. At the same time, 1 ml sodium fluoride blood samples were analysed for fasting blood glucose immediately. All the stored serum samples were analysed within 1 month. Each sample was assayed for fasting plasma glucose (FPG) concentration based on a glucose oxidase-peroxidase method using Erba Glucose reagents supplied by Erba Chem Ltd on Erba Chem 5 chemistry Semi auto-analyser. The intra- and inter-assay coefficients of variation (CVs) were 0.9% to 1.3% and <1.8%, respectively. Serum insulin was measured using the ELISA method using Insulin ELISA Kit (Calbiotech Inc) with intra- and inter-assay CVs of 3.7% to 4.2% and 5.5% to 6.74, respectively. HOMA-IR was calculated based on the formula: fasting plasma insulin (mIU/L) × fasting plasma glucose (mg/dl)/405.[10] HbA1c measurements were performed using high-performance liquid chromatography (Bio-Rad, D10). Serum triglycerides were measured using the glycerol phosphate method using Erba triglyceride reagent on Erba Chem 5 chemistry Semi auto-analyser. Serum HDL was measured using the enzymatic colorimetric method using Erba HDL cholesterol direct kit reagent on Erba Chem 5 chemistry Semi auto-analyser. Serum free fatty acids (FFAs) were measured utilising the human FFA ELISA kit (BT LAB – Bioassay technology Laboratory, Zhejiang, China), which is a sandwich ELISA kit with a sensitivity of 10.47 nmol/ml. The intra-assay and inter-assay CVs were <8% and <10%, respectively. Serum adiponectin was measured using the adiponectin ELISA kit (DBC – Diagnostics Biochem Canada Inc), which is a two-step sandwich EIA. The intra-assay and inter-assay precisions were 4.6–5.5% and 6.6–8.4%, respectively. Serum T3, T4, and TSH were measured using the CLIA method using Seimens advia centaur kits on Seimens advia centaur auto analyser. Serum LH and Testosterone were measured using the CLIA method using Seimens advia centaur kits on Seimens advia centaur auto analyser. Serum FSH and Estradiol were measured using the ELISA method using FSH ELISA kit by Calbiotech Inc. Serum 25 (OH) Vitamin D_3 levels were measured using the CLIA method using Seimens advia centaur kits on Seimens advia centaur auto analyser. Human growth hormone (GH) was measured using the hGH ELISA kit (Calbiotech Inc) based on the solid-phase sandwich hGH method. The intra-assay and inter-assay CVs were 4.90–7.67% and 4.53–8.59%, respectively. Serum IGF1 was measured by using DRG IGF1 600 ELISA kit (DRG instruments GmbH, Germany), which is a solid-phase enzyme immunoassay with an intra-assay variability of 6.39% to 7.39% and an inter-assay variability of 10.34% to 14.84%. NCEP ATP lll criteria (modified in 2005) were used for defining metabolic syndrome.[11]

Statistical analysis

Data were entered using Microsoft Excel and analysed by using SPSS V25. Continuous variables were tested for normality using the Shapiro–Wilk test. Variables with normal distribution were expressed as mean ± SD and compared using independent *t*-test. Non-normally distributed variables were expressed as median [IQR] and compared using Mann–Whitney U test. For categorical variables, proportions were compared using the Chi-square test. The *P* value for significance is set at 0.05.

Ethical aspects

Approval from the Institutional Ethics Committee of Gandhi Medical College, Secunderabad, Telangana (approval no: IEC/GMC/2020/02/08; approval date: 9th March, 2020), was taken before the conduct of the study. Written informed consent was obtained for participation in the study and use of the patient data for research and educational purposes. The study procedures followed were by the ethical standards of the responsible committee and with the Helsinki Declaration of 1964, as revised in 2013.

Results

Table 1 depicts the comparison of metabolic and endocrine parameters between night and day shift workers. A total of 90 participants were included, comprising 45 NSW and 45 DSW. Each group included 30 males and 15 females. The groups were comparable in gender distribution but not in age, with NSW tending to be slightly younger.

Metabolic profile

NSW exhibited lower mean BMI and waist circumference compared to DSW, though not statistically significant. This may be because of the over-representation of obese class l subjects in DSW. Despite this, NSW had higher median

fasting triglyceride levels and lower mean HDL-C. Fasting plasma glucose levels were similar between the groups. The mean HOMA-IR values were elevated in NSW. 77% (n = 35) of NSW had HOMA-IR ≥2.5 in comparison to 62% (n = 28) among DSW (P = 0.0313) [Figure 1]. In the bivariate analysis of HOMA-IR, there was no difference among the groups. A violin plot was used to visualise the distribution of HOMA-IR. It combines a density plot with a box overlay to provide comprehensive view of the data. The distribution of HOMA-IR values is wider in the night shift group, which indicates greater variability. The median HOMA-IR is higher in comparison with the day shift group. The density plot shows a longer tail on the higher end suggesting more individuals with elevated HOMA-IR values in the night shift group [Figure 2]. Metabolic syndrome was more prevalent in the DSW.

Table 1: Comparison of metabolic and endocrine parameters between night shift and day shift workers

Variable	Night shift (n=45)	Day shift (n=45)	P
Age (years)	28.6±5.7	31.1±7.2	0.022
Gender (n (%))			
Males	30 (67%)	30 (67%)	------
Females	15 (33%)	15 (33%)	
Tobacco use (n (%))*	3 (7%)	2 (4%)	------
Alcohol use (n (%))	7 (15%)	5 (11%)	------
BMI (kg/m^2)	24.2±5	25.2±5.7	0.33
BMI categories (n (%))			------
Underweight (<17.5 Kg/m^2)	2 (5%)	None	---
Normal weight (17.5-22.9 Kg/m^2)	14 (31%)	12 (27%)	
Overweight (23-27.4 Kg/m^2)	14 (31%)	14 (31%)	
Obesity class l (27.5-32.4 Kg/m^2)	13 (29%)	17 (38%)	
Obesity class ll (32.5-37.4 Kg/m^2)	1 (2%)	1 (2%)	
Extreme obesity (≥37.5 Kg/m^2)	1 (2%)	1 (2%)	
Waist circumference (cm)			
Males	88.6±1.6	90.3±1	0.07
Females	82.4±2.9	86.7±2.8	0.24
Waist hip ratio			
Males	0.91±0.01	0.91±0.02	0.37
Females	0.88±0.01	0.85±0.09	0.07
SBP (mmHg)	114±11	115±11	0.71
DBP (mmHg)	71±7	70±7	0.67
FPG (mg/dl)	95.4±15	95.7±11	0.43
Insulin (miu/ml)	26.2±20	27±17	0.17
HOMA-IR	6.3±5.4	5.2±4.4	0.26
HBA1c (%)	5.70±0.4	5.77±0.4	0.8
Triglycerides (mg/dl)[ǂ]	195[90]	180[44]	0.045
HDL-C (mg/dl)	35±2.7	40±3	<0.001
Metabolic Syndrome (n (%))	18 (40%)	21 (46%)	------
FFA (nmol/ml)[ǂ]	532[312]	565[168]	0.6
Adiponectin (mcg/ml)	30.8±24	18±19	0.07
Total T3 (ng/ml)	1.1±0.2	1±0.2	0.24
Total T4 (mcg/dl)	6.5±2	7.7±2	<0.001
TSH (mIU/ml)[ǂ]	2[1.9]	2[1.2]	0.17
8 am cortisol (mcg/dl)	9.5±5.3	10.8±5.6	0.24
LH (mIU/ml)			
Males	2.8±1.4	5.6±3µ	<0.001
Females	4.6±3.5	7.5±5.5	0.1
FSH (mIU/ml)			
Males	3.5±2	4.3±2.2	0.1
Females	7±2.5	5.7±3.8	0.3
Estradiol (pg/ml)			
Females	181±84	100±62	0.006
Males	26.3±13.7	20.4±10.8	0.07
Testosterone (ng/dl)			
Males	373.6±146	400±140	0.5
Females	14±5.3	15±6	0.6
Growth hormone (ng/ml)[ǂ]	7.6[5.8]	10.2[4.3]	0.3
IGF1 (ng/ml)	274±32	276±40	0.6
25 (OH)vitamin D3 (ng/ml)	10.4±4.8	13.7±4.5	0.032

[ǂ]Non-normally distributed variables expressed as median [IQR]; rest all expressed as mean±SD. *All were cigarette smokers

Hormonal profile

NSW had lower mean total T4 levels in comparison to DSW. 22% (n = 10) of NSW had subclinical hypothyroidism in comparison to 11% (n = 5) in DSW, respectively (P = 0.02) [Figure 3]. NSW females showed higher mean oestradiol levels compared to DSW females. Lower mean testosterone levels were observed in NSW males, though not significant. NSW males had significantly lower mean LH levels. The median growth hormone levels were reduced in NSW, consistent with impaired nocturnal secretion.

Adipokines and vitamin D

Median serum FFA levels were non-significantly higher in DSW. Mean serum adiponectin levels were higher in NSW contrary to the expectation. 25 (OH) Vitamin D 3 levels were low in both the groups but significantly lower in NSW.

Correlation analysis

Among NSW, HOMA-IR had positive correlations with TSH and adiponectin levels [Table 2]. Among DSW, HOMA-IR positively correlated with waist circumference and estradiol levels and negatively correlated with serum testosterone and 25(OH) Vitamin D3 levels.

Discussion

This study demonstrates that night-shift work is associated with adverse metabolic and hormonal alterations in a South Indian cohort. A striking finding was that NSW had lower BMI and waist circumference compared with day-shift workers but still displayed higher insulin resistance, dyslipidaemia, and altered endocrine parameters. This paradox suggests that

Figure 1: Comparison of HOMA-IR of ≥ 2.5 vs. <2.5 among the groups

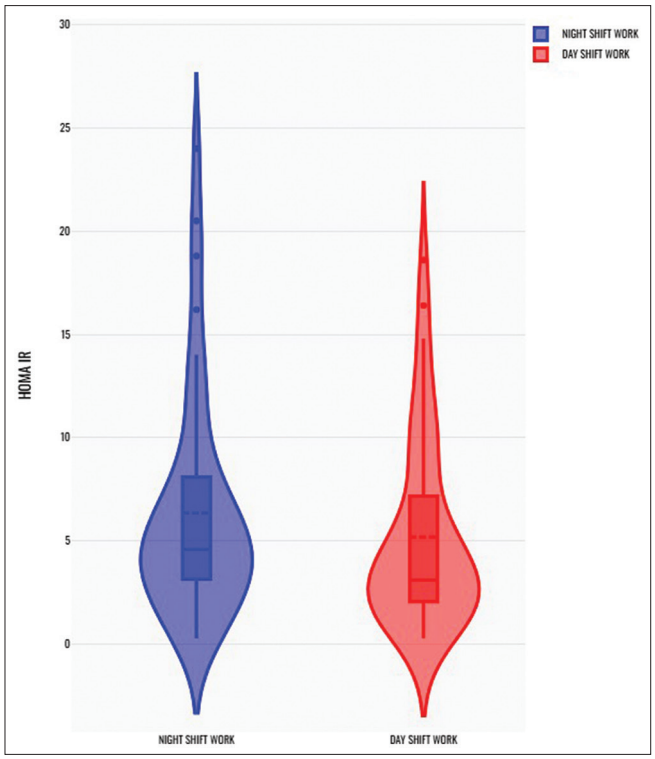

Figure 2: Violin plot with box overlay showing the distribution of HOMA-IR among night shift and day shift workers

Table 2: Correlation of metabolic and endocrine parameters with HOMA-IR among night shift and day shift workers

Variables	Correlation with HOMA-IR			
	Night shift work		Day shift work	
	r	*P*	*r*	*P*
Age	-0.024	0.877	0.276	0.066
BMI	-0.005	0.974	0.292	0.052
Waist circumference	0.278	0.064	0.431	0.003
T3	-0.099	0.519	0.202	0.183
T4	-0.163	0.285	-0.019	0.902
TSH	0.328	0.028	-0.148	0.333
LH	-0.174	0.254	-0.069	0.654
Cortisol	-0.027	0.860	-0.082	0.593
Testosterone	-0.289	0.054	-.516	<0.001
25 (OH)vitamin D_3	-0.076	0.621	-.387	0.009
FSH	-0.016	0.919	-0.183	0.228
Estradiol	0.159	0.297	0.393	0.008
Triglyceride	0.240	0.112	-0.021	0.890
HDL-C	-0.080	0.600	0.228	0.132
FFA	0.185	0.337	-0.003	0.991
Adiponectin	0.395	0.034	-0.350	0.184
GH	0.282	0.138	-0.021	0.940
IGF1	0.232	0.227	-0.415	0.110

circadian disruption exerts metabolic effects independent of overall adiposity. Our findings align partially with previous literature showing increased metabolic risk in night-shift

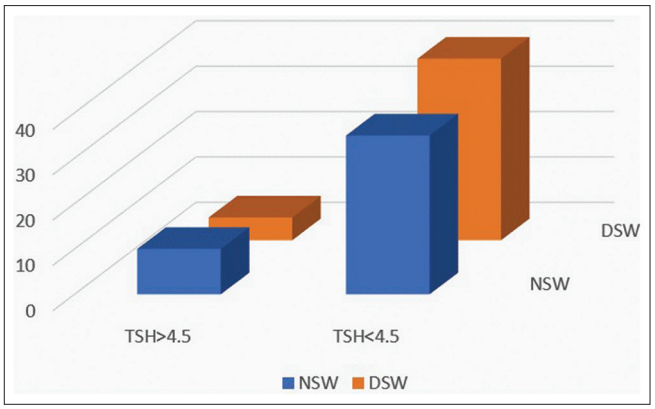

Figure 3: Comparison of subclinical hypothyroidism among the groups

workers. However, most studies report higher obesity indices in shift workers,[12] whereas our study population consisting of younger and more physically active night-shift employees likely explains the lower BMI and waist circumference compared to the predominantly sedentary day-shift controls. There were a higher number of subjects with insulin resistance (HOMA-IR ≥ 2.5) in the NSW group despite the lower BMI and waist circumference. This highlights the potential role of circadian misalignment and sleep disruption in driving insulin resistance. The prevalence of metabolic syndrome in our study was similar to a population-based cohort study in Switzerland which was around 40%.[13] Higher risk of metabolic syndrome among NSW may be related to sleep duration and quality, meal timing, and circadian desynchronisation.[14-16] Elevated triglycerides and low HDL-C levels were observed in the NSW group. Prior studies have conclusively demonstrated the association of night shift work with high triglycerides and low HDL-C explaining the increased cardiovascular risk.[17]

Few studies have assessed detailed endocrine parameters in the Indian context, where genetic susceptibility and lifestyle factors may amplify risk. The inclusion of adiponectin, FFA, GH, and IGF-1 provides novel insights into potential mechanisms. Serum FFA levels were elevated in DSW. Previous studies have demonstrated diurnal variation of FFA which is primarily influenced by feeding.[18] Late night snacking/feeding in the NSW group may have contributed to lower FFA. Also, a recent study showed an association between night shift work and unfavourable fatty acid profiles.[19] The serum adiponectin levels were higher in the night shift group without reaching statistical significance. A small study previously showed that serum adiponectin levels are lower among NSW.[20] A younger age group and lower BMI in NSW may explain the discrepancy. Acute sleep deprivation leading to higher adiponectin levels to counteract increasing insulin resistance may also be a plausible explanation.[21]

Our study showed that there is no difference in the TSH levels among the groups. A systematic review showed that night shift work may be associated with higher TSH, though within normal range. However, a definite association could not be established because of heterogeneity among the

populations studied.[22] Sleep deprivation and nocturnal eating may contribute to increasing TSH among night shift workers.[23,24] In this study, we found the number of subjects with subclinical hypothyroidism was significantly more among NSW compared to DSW. In a study by Moon *et al.,* NSW had 1.4 times higher risk of developing subclinical hypothyroidism.[25] Although the mean T3 levels were not significantly different among the groups, the mean T4 level was lower among the NSW. This finding is in contrast to a cross-sectional study by Korompeli *et al.*, who found T3 was significantly lower and T4 significantly higher among night shift workers.[26] Higher prevalence of subclinical hypothyroidism in NSW group may explain the lower T4 levels. DSW group who were more obese may have higher thyroxine binding globulin giving a probable reason for higher total T4.

One of the factors that could play a role in the development of the metabolic syndrome in shift workers is the stress hormone cortisol. Cortisol is secreted in a circadian rhythm with high levels in the early morning and low levels in the evening and night. Elevated cortisol levels and BMI may contribute to the increased cardiovascular risk found in shift workers. Eight AM cortisol levels were lower in NSW group as expected. A Brazilian study showed that though circadian rhythm was normal among day shift and night shift workers, it was attenuated among NSW.[27]

The GH levels were reduced in NSW, consistent with impaired nocturnal secretion. In this study, NSW males had lower LH and testosterone compared to DSW. Bracci *et al.* also found low testosterone levels in male shift workers[28] and explain the higher risk of erectile dysfunction.[29] Circadian misalignment impairs hypothalamic-pituitary signalling, reduces growth hormone secretion, alters gonadal hormone regulation, and disrupts adipokine release, providing biological plausibility for our findings. The mean oestradiol levels were significantly elevated in female NSW. Menstrual cycle variation could have contributed as we did not restrict sampling to the follicular phase. Also, the role of estradiol in fat distribution is widely known[30] and may have contributed to lesser visceral adiposity in the NSW group in our study.

Reduced vitamin D levels in NSW are plausibly attributable to diminished sunlight exposure, reinforcing the occupational contribution to metabolic risk. Among NSW, HOMA-IR demonstrated positive correlations with TSH and adiponectin levels. The positive link with TSH may reflect subtle thyroidal adaptations in response to circadian misalignment as previous studies have reported altered hypothalamic–pituitary–thyroid axis regulation in night-shift populations. The unexpected positive correlation with adiponectin could suggest a compensatory adipokine response aimed at mitigating insulin resistance as adiponectin is typically insulin-sensitising. In contrast, among DSW, HOMA-IR positively correlated with waist circumference and estradiol levels and negatively correlated with testosterone and vitamin D. Together, these divergent patterns highlight that while circadian disruption in NSW alters classical endocrine–metabolic relationships, conventional risk factors such as central obesity, sex steroid imbalance, and vitamin D deficiency remain dominant drivers of insulin resistance in DSW.

The novelty of our findings lies in demonstrating that even with lower BMI and waist circumference, night-shift workers have significant metabolic and endocrine derangements. This underscores that body weight alone may underestimate cardiometabolic risk in this group. Screening and intervention strategies for shift workers must therefore go beyond anthropometric measures and address circadian and hormonal pathways.

Strengths of this study include a detailed endocrine and metabolic assessment and focus on South Indian shift workers, an under-studied group. Limitations include a small sample size, cross-sectional design, lack of strict age-matching, and inability to fully control for menstrual cycle phase or residual confounders such as diet, sleep, and physical activity.

Conclusion

In conclusion, night-shift work in this cohort was associated with increased insulin resistance, dyslipidaemia, and alterations in adiponectin, testosterone, estradiol, GH/IGF-1 axis, and vitamin D, despite lower BMI and waist circumference. This paradox highlights the independent contribution of circadian disruption to metabolic risk and calls for targeted occupational health strategies.

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Author contribution

VSRD: Study idea, protocol development, data collection, and manuscript writing and will act as guarantor for the study; MAMA: Developing protocol, data collection, analysis, and manuscript writing; VK: Developing protocol, data analysis and manuscript writing; CB: Developing protocol and manuscript writing VSRD, MAMA, VK and CB: Critical appraisal and revision of manuscript. All authors approved the final version of the manuscript.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence

Artificial intelligence was not used in any form for analysis or writing of this research article

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. Jones G. In retrospect: Das Kapital. Nature 2017;547:401-2.
2. International Labour Organization. C171-Night Work Convention No. 171 (C171). Geneva, Switzerland: International Labour Organization; 1990. Available from: https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0:NO:P12100_INSTRUMENT_ID:312316.
3. Parent-Thirion A, Biletta I, Cabrita J, Vargas O, Vermeylen G, Wilczynska A, *et al*. Sixth European Working Conditions Survey – Overview Report (2017 Update). Luxembourg: Publications Office of the European Union; 2017. doi: 10.2806/724968.
4. Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH). Worker Health Charts: Unadjusted prevalence of work organization characteristics among workers, National Health Interview Survey (NHIS), 2015. Cincinnati (OH): U.S. Department of Health and Human Services; 2015. Available from: https://www.cdc.gov/niosh-whc/charts/ohs-workorg/work. [Last accessed on 2025 Dec 06].
5. Liu Q, Shi J, Duan P, Liu B, Li T, Wang C, *et al*. Is shift work associated with a higher risk of overweight or obesity? A systematic review of observational studies with meta-analysis. Int J Epidemiol 2018;47:1956-71.
6. Wang D, Ruan W, Chen Z, Peng Y, Li W. Shift work and risk of cardiovascular disease morbidity and mortality: A dose-response meta-analysis of cohort studies. Eur J Prev Cardiol 2018;25:1293-302.
7. Liu W, Zhou Z, Dong D, Sun L, Zhang G. Sex differences in the association between night shift work and the risk of cancers: A meta-analysis of 57 articles. Dis Markers 2018;2018:7925219.
8. Wu QJ, Sun H, Wen ZY, Zhang M, Wang HY, He XH, *et al*. Shift work and health outcomes: An umbrella review of systematic reviews and meta-analyses of epidemiological studies. J Clin Sleep Med 2022;18:653-62.
9. IARC. Night shift work. IARC Monogr Identif Carcinog Hazards Hum 2020;124:1-371.
10. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: Insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
11. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, *et al*. Diagnosis and management of the metabolic syndrome: An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005;17:2735-52.
12. Streng AA, Loef B, Dollé MET, van der Horst GTJ, Chaves I, Proper KI, *et al*. Night shift work characteristics are associated with several elevated metabolic risk factors and immune cell counts in a cross-sectional study. Sci Rep 2022;12:2022.
13. Bayon V, Berger M, Solelhac G, Haba-Rubio J, Marques-Vidal P, Strippoli MP, *et al*. Impact of night and shift work on metabolic syndrome and its components: A cross-sectional study in an active middle-to-older-aged population-based sample. BMJ Open 2022;12:e053591.
14. Xi B, He D, Zhang M, Xue J, Zhou D. Short sleep duration predicts risk of metabolic syndrome: A systematic review and meta-analysis. Sleep Med Rev 2014;18:293-7.
15. Stamatakis KA, Punjabi NM. Effects of sleep fragmentation on glucose metabolism in normal subjects. Chest 2010;137:95-101.
16. Molzof HE, Wirth MD, Burch JB, Shivappa N, Hebert JR, Johnson RL, *et al*. The impact of meal timing on cardiometabolic syndrome indicators in shift workers. Chronobiol Int 2017;34:337-48.
17. Dutheil F, Baker JS, Mermillod M, De Cesare M, Vidal A, Moustafa F, *et al*. Shift work, and particularly permanent night shifts, promote dyslipidaemia: A systematic review and meta-analysis. Atherosclerosis 2020;313:156-69.
18. Barter PJ, Carroll KF, Nestel PJ. Diurnal fluctuations in triglyceride, free fatty acids, and insulin during sucrose consumption and insulin infusion in man. J Clin Invest 1971;50:583-91.
19. van de Langenberg D, Dollé MET, van Kerkhof LWM, Vermeulen RCH, Vlaanderen JJ. Effects of nightshift work on blood metabolites in female nurses and paramedic staff: A cross-sectional study. Ann Work Expo Health 2023;67:694-705.
20. Crispim CA, Padilha HG, Zimberg IZ, Waterhouse J, Dattilo M, Tufik S, *et al*. Adipokine levels are altered by shiftwork: A preliminary study. Chronobiol Int 2012;29:587-94.
21. van Egmond LT, Meth EMS, Engström J, Ilemosoglou M, Keller JA, Vogel H, *et al*. Effects of acute sleep loss on leptin, ghrelin, and adiponectin in adults with healthy weight and obesity: A laboratory study. Obesity (Silver Spring) 2023;31:635-41.
22. Leso V, Vetrani I, Sicignano A, Romano R, Iavicoli I. The impact of shift-work and night shift-work on thyroid: A systematic review. Int J Environ Res Public Health 2020;17:1527.
23. Parker DC, Rossman LG, Pekary AE, Hershman JM. Effect of 64-hour sleep deprivation on the circadian waveform of thyrotropin (TSH): further evidence of sleep-related inhibition of TSH release. J Clin Endocrinol Metab 1987;64:157-61.
24. Holmbäck U, Forslund A, Lowden A, Forslund J, Akerstedt T, Lennernäs M, *et al*. Endocrine responses to nocturnal eating--possible implications for night work. Eur J Nutr 2003;42:75-83.
25. Moon SH, Lee BJ, Kim SJ, Kim HC. Relationship between thyroid stimulating hormone and night shift work. Ann Occup Environ Med 2016;28:53.
26. Korompeli A, Sourtzi P, Tzavara C, Velonakis E. Rotating shift-related changes in hormone levels in intensive care unit nurses. J Adv Nurs 2009;65:1274-82.
27. Brum MCB, Senger MB, Schnorr CC, Ehlert LR, Rodrigues TDC. Effect of night-shift work on cortisol circadian rhythm and melatonin levels. Sleep Sci 2022;15:143-8.
28. Bracci M, Zingaretti L, Martelli M, Lazzarini R, Salvio G, Amati M, *et al*. Alterations in pregnenolone and testosterone levels in male shift workers. Int J Environ Res Public Health 2023;20:3195.
29. Rodriguez KM, Kohn TP, Kohn JR, Sigalos JT, Kirby EW, Pickett SM, *et al*. Shift work sleep disorder and night shift work significantly impair erectile function. J Sex Med 2020;17:1687-93.
30. Steiner BM, Berry DC. The regulation of adipose tissue health by estrogens. Front Endocrinol (Lausanne) 2022;13:889923.