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Chronobiological Risk Factors for Metabolic Syndrome in Shift Workers: Basis for Occupational Health Intervention

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Abstract
Introduction: *Shift work is recognized as an important occupational health concern because it may disrupt circadian rhythms, sleep quality, and workers' physiological conditions. Irregular working schedules that are inconsistent with the body's biological timing may contribute to fatigue and changes in health-related behaviors.* ***Objective:*** *This study aimed to explore the impact of shift work systems on sleep patterns, fatigue, and health-related behaviors among workers.* ***Method:*** *This study employed a descriptive exploratory design involving 11 respondents. Data were collected using a structured questionnaire covering work characteristics, sleep patterns, fatigue symptoms, dietary changes, physical activity, and health conditions. Descriptive analysis was conducted to identify patterns of occupational health problems associated with shift work.* ***Result and Discussion****: A total of 45,5% of respondents worked under rotating shift schedules. Most respondents experienced irregular sleep patterns (63,6%), difficulties adapting to work schedule changes (54,5%), and increased fatigue after work (63,6%). Furthermore, 45,5% reported decreased concentration during work, while 54,5% experienced changes in meal timing due to shift schedules.* ***Conclusions:*** *Shift work is potentially associated with sleep disturbances, increased fatigue, and changes in health-related behaviors through circadian rhythm disruption mechanisms. Effective shift management, sleep hygiene strategies, and regular health monitoring are needed to support workers' well-being.*

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Introduction

The evolution of modern industry has altered work patterns, leading to an increased demand for shift-based work systems. Various sectors such as manufacturing, healthcare, transportation, energy, and general industry operate on a 24-hour basis. Shift work patterns are highly beneficial for companies seeking to maintain continuous operations; however, this system can have biological and physiological effects on individuals. One health-related consequence is an increased risk of metabolic syndrome a cluster of metabolic disorders comprising abdominal obesity, elevated blood pressure, insulin resistance, hyperglycemia, and lipid profile abnormalities which significantly raises the risk of cardiovascular disease and type 2 diabetes mellitus (Alice and Schettini, 2023). Metabolic syndrome in shift workers is influenced not only by lifestyle factors such as low physical activity and unhealthy diets but is also closely linked to disruptions in the body's biological timing system. Epidemiological evidence indicates that shift workers face a higher risk of metabolic disorders compared to those on standard daytime schedules. Recent meta-analyses show that shift workers have an increased likelihood of developing metabolic syndrome compared to non-shift workers; this risk is particularly pronounced among those on rotating shift systems, which entail repeated changes to work and sleep schedules (Masoud et al., 2021).

A primary mechanism ealixplaining the link between shift work and metabolic disorders is circadian rhythm disruption. Circadian rhythms are biological regulatory systems operating on an approximately 24-hour cycle that coordinate various bodily functions, including the sleep-wake cycle, hormone secretion, energy metabolism, glucose regulation, and cardiovascular function. For night-shift workers, nighttime light exposure, activity during times when the body should be resting, and daytime sleep create a mismatch between the internal biological clock and the external environment a condition known as circadian misalignment (Burooj, 2024). Circadian rhythm disruption can affect metabolism through alterations in hormonal regulation and organ function. Shifts in sleep timing and exposure to light at night can reduce melatonin secretion, disrupt cortisol patterns, and decrease insulin sensitivity. Recent systematic reviews indicate that shift work is associated with impaired glucose control, altered insulin function, disrupted cortisol release, changes in cholesterol levels, and altered melatonin secretion; collectively, these factors can contribute to the development of metabolic syndrome (Alice and Schettini, 2023).

Beyond circadian rhythm disruption, the activity–rest rhythm is a crucial factor influencing the metabolic health of shift workers. Shift workers frequently experience irregular sleep timing, shorter sleep duration, sleep fragmentation, and high variability in daily activity. Imbalances between activity and rest periods can disrupt the body's physiological recovery processes and alter energy regulation. Chronic sleep disturbances are linked to increased systemic inflammation, impaired glucose metabolism, elevated blood pressure, and changes in body composition all key components of metabolic syndrome (Arpita et al., 2022). Another factor gaining increasing attention in studies of shift worker metabolism is meal timing regularity. Under normal conditions, meal timing acts as a zeitgeber (time cue) for peripheral biological clocks located in liver, pancreatic, and adipose tissues. However, shift workers often experience irregular eating patterns, skip main meals, or consume food at night when the body's metabolic capacity is lower. This condition can create a mismatch between the timing of energy intake and the body's

metabolic readiness, thereby increasing the risk of metabolic disorders (Rogers, Coates, and Banks, 2021).

The concept of chrononutrition posits that health is influenced not only by the type and quantity of food consumed but also by the timing of consumption. Recent research indicates that eating at biologically inappropriate times specifically late-night eating or maintaining inconsistent meal intervals is associated with an increased risk of obesity, impaired insulin sensitivity, and cardiometabolic diseases. Among shift workers, altered meal schedules serve as a factor that exacerbates circadian misalignment, as meal timing interacts directly with peripheral biological clock systems (Rogers, Coates, and Banks, 2021). While the relationship between shift work and the risk of metabolic syndrome has been extensively studied, most prior research has assessed risk factors such as shift work duration, sleep quality, or dietary patterns in isolation. There is limited research integrating circadian rhythm disruption, activity-rest rhythms, and meal timing regularity as interacting determinants of metabolic syndrome risk. Yet, these three factors share complex physiological interconnections in the regulation of energy balance, hormonal function, and glucose and lipid metabolism.

Therefore, it is crucial to investigate the roles of circadian rhythm disruption, activity-rest rhythms, and meal timing regularity regarding metabolic syndrome risk among shift workers. Findings from this research are expected to provide a more comprehensive understanding of work-related metabolic risk factors and serve as a foundation for developing prevention strategies—including occupational health promotion, the design of more ergonomic shift schedules, sleep management, and dietary interventions based on chronobiological principles.

Method

This study employed a quantitative descriptive approach with a cross-sectional design to describe work schedules, circadian rhythm-related conditions, sleep patterns, eating behavior, physical activity, and occupational health among workers. The study involved 11 respondents with different work arrangements, including rotating shifts, morning shifts, and non-shift work. Data were collected using a structured questionnaire covering demographic and occupational characteristics, including age, sex, length of employment, work system, average working hours, height, weight, and physical activity. The questionnaire also assessed respondents' perceptions of shift-work adaptation and circadian rhythm, including irregular sleep schedules, fatigue after night shifts, changes in energy levels, productivity during night work, sleep–wake regularity, and perceived disruption of the biological clock. Sleep-related variables included difficulty sleeping, sleepiness during work, difficulty initiating sleep, frequent awakening, early awakening, excessive daytime sleepiness, and decreased concentration. Eating-related variables included regularity of meal timing, changes in meal schedules due to work, night-time eating, skipping meals, adjustment of eating time to sleep schedules, eating before sleep, and consumption of high-calorie foods during night shifts. Respondents were also asked about a history of hypertension, hypercholesterolemia, diabetes mellitus, and overweight or obesity, as well as physical fatigue, concentration problems, work errors related to sleepiness, and workplace support for shift-worker health.

Body mass index (BMI) was calculated by dividing body weight in kilograms by the square of height in meters (kg/m²) and was categorized as underweight, normal weight, overweight, or obesity. Prior to analysis, the data were checked and standardized to ensure consistency in numerical and categorical responses. Data were analyzed descriptively using frequencies, percentages, means, and standard deviations. Continuous variables, such as age and BMI, were presented as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. For descriptive interpretation, five-point Likert-scale responses were grouped into three categories: agree, neutral, and disagree, while frequency-based responses were categorized as frequent, occasional, and rare/never. Considering the relatively small sample size, no inferential statistical analysis was performed; therefore, the findings were interpreted descriptively and were not intended to establish causal relationships or statistically significant differences between work-schedule groups.

Result and Discussion

1. Result

A total of 11 respondents were included in the analysis. Descriptive analysis was conducted using frequencies, percentages, means, and standard deviations. For presentation purposes, Likert responses were grouped into three categories: agree (agree and strongly agree), neutral, and disagree (disagree and strongly disagree). Frequency responses were also grouped into frequent (often/always), occasional (sometimes), and rare/never (rarely/never).

Characteristics of Respondents, the respondents had a mean age of 34.64 ± 4.41 years, with an age range of 27–40 years. Most respondents were female (90.9%). In terms of work system, rotating-shift workers constituted the largest group (45.5%), followed by morning-shift workers (36.4%) and non-shift workers (18.2%). More than half of the respondents worked less than eight hours per day.

Table 1
Characteristics of Respondents

Characteristis	n(%)	mean	SD
age		34.64	4.41
sex:			
- Female	90.9		
- male	9.1		
Length of employment:			
- < 1 year	18.2	-	
- 1-5 years	27.3		
- 6-10 years	27.3		
- > 10 years	27.3		
work System:			
- Rotating shift	45.5		
- Morning shift	36.4		
- Non shift	18.2		
Average Working Hours:			
- < 8 hours	54.5		
- 8 hours	36.4		
- > 8 hours	9.1		
BMI:			
- Underweight	9.1		
- Normal	54.5		

- Overweight	18.2
- obesity	18.2
Physical Activity:	
- inactive	9.1
- light	36.4
- light moderate	9.1
- moderate	36.4
- heavy	9.1

The mean BMI was 25.10 kg/m². Although more than half of the respondents were within the normal BMI category, four respondents (36.4%) were categorized as overweight or obese. This finding indicates the presence of potential cardiometabolic risk factors in a proportion of the study population.

Circadian Rhythm and Adaptation to Work Schedule, respondents demonstrated varying responses regarding adaptation to work schedules. The most prominent finding was fatigue after working a night shift, which was reported by 63.6% of respondents. More than half also agreed that changes in work schedules affected their energy levels (54.5%). Nearly half reported reduced productivity when working at night (45.5%).

Table 2
Perceptions of Work Schedule and Circadian Rhythm

Statement	agree (%)	netral (%)	disagree (%)
Difficulty adjusting to shift schedules	9.1	18.2	72.7
Shift work makes sleep schedules irregular	27.3	9.1	63.6
Feeling tired after working a night shift	63.6	9.1	27.3
Rotating shifts make physical adaptation difficult	18.2	36.4	45.4
Productivity decreases when working at night	45.5	18.2	36.4
Having a regular sleep–wake pattern	54.5	18.2	27.3
Feeling more active at certain times of day	72.7	18.2	9.1
Schedule changes affect body energy	54.5	18.2	27.3
Difficulty sleeping at a different time than usual	36.4	27.3	36.4
Biological clock is disturbed by work	27.3	9.1	63.6

Interestingly, although 63.6% of respondents experienced fatigue after night shifts and 54.5% perceived changes in their energy levels, only 27.3% explicitly perceived their biological clock as being disturbed. This suggests that physiological or functional effects may be experienced by workers without necessarily being recognized as circadian rhythm disruption.

Sleep-Related Symptoms, Sleep-related disturbances were generally intermittent rather than severe. Difficulty sleeping was experienced frequently by 9.1% and occasionally by 27.3% of respondents. Meanwhile, 54.6% reported being sleepy at work either frequently or occasionally.

Table 3
Sleep-Related Symptoms Among Respondents

Sleep related Indicator	n%
Difficulty sleeping:	
- Frequent	9.1
- Occasional	27.3
- Rare/never	63.3
Sleepiness while Working	
- Frequent	9.1
- Occasional	45.5
- Rare/never	45.5
- Difficulty initiating sleep	36.4
- Frequent awakening during sleep	18.2
- Waking too early	9.1
- Excessive daytime sleepiness	9.1
- Self reported decline in cocentration	0

The most frequently identified specific sleep symptom was difficulty initiating sleep, reported by 36.4% of respondents. In contrast, frequent awakening during sleep, early awakening, and excessive daytime sleepiness were relatively uncommon. These findings indicate that sleep disturbances in this sample were characterized more by intermittent sleepiness and problems initiating sleep than by severe or persistent sleep disruption.

Eating Patterns and Metabolic Health, Changes in eating behavior were also observed. Most respondents reported that their work schedule occasionally changed their meal timing (81.8%). More than half occasionally ate at night while working, skipped meals because of work, adjusted eating time according to their sleep schedule, or ate within two hours before sleep.

Table 4
Eating Patterns and Metabolic Health

Indicator	Frequent n (%)	Occasional n (%)	Rare/Never n (%)
Eating at the same time every day	36.4	45.5	18.2
Work schedule changes meal timing	9.1	81.8	9.1
Eating at night while working	27.3	54.4	18.2
Skipping meals because of work	9.1	63.6	27.3
Adjusting meals according to sleep schedule	27.3	54.5	18.2
Eating within two hours before sleep	9.1	54.5	36.4
Consuming high-calorie foods during night shifts	9.1	45.5	45.5

Despite these variations, the main meal times remained relatively conventional. Ten respondents (90.9%) usually ate breakfast between 07:00 and 10:00, while nine respondents (81.8%) ate dinner between 18:00 and 21:00. Regarding metabolic history, none of the respondents reported hypertension or diabetes. Two respondents (18.2%) reported a history of high cholesterol, and two respondents (18.2%) reported a history of obesity or overweight. However, anthropometric measurements showed that four respondents (36.4%) were currently categorized as overweight or obese based on BMI.

Perceived Health, Fatigue, and Workplace Support, most respondents perceived themselves as being in good health during their employment. A total of 81.8% reported feeling healthy frequently or always. Nevertheless, physical fatigue and reduced concentration were still reported intermittently.

Table 5
Occupational Health and Workplace Support (n = 11)

Indicator	Frequent n (%)	Occasional n (%)	Rare/Never n (%)
Feeling healthy while working	81.8	18.2	0
Physical fatigue due to work	9.1	36.4	54.5
Reduced concentration while working	0	36.4	63.6
Work errors caused by sleepiness	0	27.3	72.7
Workplace support for shift-worker health	45.5	45.5	9.1

Although most respondents perceived themselves as healthy, 36.4% occasionally experienced physical fatigue, and the same proportion occasionally experienced reduced concentration at work. Furthermore, 27.3% reported occasionally making work-related errors due to sleepiness. Workplace support was reported frequently or always by 45.5% of respondents, while another 45.5% perceived such support only occasionally.

2. Discussion

The present study shows that the effects associated with shift-based work in this small sample were manifested primarily through fatigue, variations in energy levels, sleepiness during work, and changes in meal timing rather than through severe sleep disturbances or diagnosed metabolic disease. This pattern is particularly relevant because 81,8% of respondents worked either rotating or morning shifts, indicating substantial exposure to structured work schedules that may influence the body's circadian rhythm. The circadian rhythm is the body's internal biological clock, influenced by patterns of sleep, work, eating, and exposure to light. For shift workers, this rhythm is altered because they are required to be active at unconventional times. The National Institute for Occupational Safety and Health (NIOSH) notes that night or shift work often coupled with insufficient sleep can lead to a disruption of the circadian rhythm. Research indicates that some workers experience such disruptions, manifesting in various complaints that often go unnoticed by the workers themselves, or are perceived as merely a normal part of their routine.

One of the strongest findings was that 63,6% of respondents reported feeling tired after night shifts, while 54,5% perceived that changes in work schedules affected their energy levels. Nearly half also perceived reduced productivity when working at night. These findings are biologically plausible because changes in work and sleep timing can create misalignment between behavioral demands and the endogenous circadian system. Circadian disruption can affect sleep–wake regulation, alertness, metabolic function, and performance. Reviews of shift-work research consistently identify sleep disruption and fatigue as important consequences of work schedules that overlap with normal biological sleep periods. However, only 27.3% of respondents explicitly stated that their biological clock was disturbed. At the same time, more than half reported maintaining regular sleep–wake patterns. This apparently contradictory finding may reflect individual differences in tolerance and adaptation to shift work. It may also indicate that respondents recognize symptoms such as fatigue or changes in energy but do not interpret these symptoms as

circadian disruption. Consequently, assessment of shift-work effects should not rely solely on workers' perception of whether their biological clock is disturbed.

Sleep symptoms showed a similar pattern. More than half of respondents experienced sleepiness while working at least occasionally, while 36.4% reported difficulty initiating sleep. In contrast, only a small proportion reported excessive daytime sleepiness, early awakening, or frequent nighttime awakening. Therefore, the present data do not indicate uniformly severe sleep problems but rather suggest intermittent sleep-related disturbances. The finding remains important because fatigue and sleepiness may impair vigilance and cognitive performance even when workers do not meet criteria for clinically significant sleep disorders. Shift-work literature has similarly identified sleep quality, sleepiness, fatigue, and alertness as major occupational health concerns. Another important finding concerns meal timing. Although most respondents maintained relatively conventional breakfast and dinner times, work schedules affected the timing of meals at least occasionally in 81.8% of respondents. Night-time eating, meal skipping, and eating close to sleep were also commonly reported on an occasional basis. This result indicates that the effect of shift schedules may not completely replace conventional meal patterns but may introduce variability and additional eating occasions around work periods.

This pattern is consistent with current evidence on dietary behavior among shift workers. Shift work has been associated with more irregular meal patterns, night-time eating and altered meal timing. Meal timing is relevant because feeding schedules act as time cues for peripheral circadian clocks, and eating at biologically inappropriate times may contribute to circadian misalignment and impaired metabolic regulation. Alyami et al. (2025) also noted substantial heterogeneity in dietary behaviors among shift workers and emphasized the importance of assessing the timing of food intake rather than dietary composition alone. The anthropometric findings provide additional context. Although only 18.2% reported a previous history of overweight or obesity, BMI calculations showed that 36.4% were currently either overweight or obese. The difference between self-reported history and measured BMI category suggests that self-reported health history may underestimate current weight-related risk. Nevertheless, these findings should not be interpreted as evidence that shift work caused increased BMI because the present data are cross-sectional, involve a very small sample, and do not control for dietary intake, physical activity, duration of shift exposure, age, or other potential confounders. Previous evidence indicates that circadian disruption, irregular sleep, shift work, and late meal timing may be associated with adverse cardiometabolic outcomes, but observational associations do not establish causality (Knutson, 2024).

Despite the presence of several shift-related symptoms, 81.8% of respondents frequently or consistently perceived themselves as healthy. Severe occupational effects were also relatively uncommon; no respondent reported frequent concentration decline or frequent work errors caused by sleepiness. Nevertheless, occasional concentration decline was reported by 36.4%, and occasional work errors caused by sleepiness were reported by 27.3%. These findings are important from an occupational-safety perspective because even intermittent fatigue and sleepiness may become relevant when work requires sustained attention, rapid decision-making, or safety-sensitive activities. Workplace support may represent an important contextual factor. Almost half of respondents reported frequent or consistent workplace support for shift-worker health, although an equally large proportion perceived support only occasionally. Appropriate organizational

strategies, including better scheduling, sufficient recovery time, sleep-health education, fatigue management, and attention to meal opportunities, are commonly recommended to reduce the health and performance consequences associated with shift work. Systematic reviews suggest that interventions involving optimized scheduling, naps, sleep education, light exposure management, and other organizational approaches can improve several sleep- and fatigue-related outcomes, although the strength of evidence varies across interventions. Overall, the findings suggest that the respondents were generally able to maintain their perceived health despite shift-related demands. Nevertheless, fatigue after night work, changes in energy levels, intermittent work-related sleepiness, altered meal timing, and the presence of overweight or obesity in more than one-third of respondents indicate areas that require attention. Workplace health programs should therefore not focus only on diagnosed disease but also on early behavioral and functional indicators such as fatigue, sleep quality, meal timing, physical activity, and recovery between shifts.

Interventions that can be implemented as workplace programs include the early detection and risk stratification of metabolic syndrome. Such interventions may take the form of periodic screening for metabolic risk factors among healthcare workers. These screenings can include anthropometric measurements, body mass index (BMI) assessment, blood pressure monitoring, blood glucose and lipid profile testing, as well as evaluations of sleep history and shift patterns. This approach serves as a primary preventive measure within the workplace (Samsiana et al., 2025).

Metabolic syndrome-related issues can be addressed through shifts in individual perspectives and behaviors specifically concerning sleep and circadian rhythms, workplace nutrition, physical activity, medical management, and organizational work interventions. Improvements in sleep quality and nutrition can be achieved through measures such as adjusting shift schedules and break times, avoiding overly rapid shift rotations, providing education on sleep hygiene, offering healthy food options during night shifts, limiting the consumption of high-sugar or high-fat foods, and whenever possible avoiding large meals in the middle of the night (Galván et al., 2025; Nurkhotimah, Mahmud, and Syaiful, 2025). The findings must be interpreted cautiously. The sample consisted of only 11 respondents and included heterogeneous work arrangements, including rotating shifts, morning shifts, and non-shift work. The use of self-reported questionnaires may introduce recall and response bias, while several indicators were assessed using different response formats. Consequently, the present results should be regarded as descriptive preliminary findings rather than evidence of causal relationships or statistically significant differences between work systems. Future studies should involve larger samples, clearly defined shift categories, validated sleep and circadian instruments, objective anthropometric or metabolic measurements, and inferential analyses comparing shift and non-shift workers.

Conclusion

This study indicates that shift work particularly rotating shift work is associated with sleep disturbances, increased fatigue, and changes in health-related behaviors among workers. Irregular work schedules can disrupt circadian rhythms, diminish sleep quality and duration, and impair concentration and alertness while on the job. Such conditions may also lead to irregular eating patterns, higher consumption of calorie-dense foods, and reduced physical activity, which in turn may increase the risk of metabolic disorders. Key risk factors to consider include abdominal obesity, elevated blood pressure, impaired

glucose regulation, high triglyceride levels, and low HDL cholesterol all of which are core components of metabolic syndrome. Consequently, an integrated occupational health intervention model is required. This should encompass more ergonomic scheduling and shift rotation, the provision of adequate rest and recovery periods, education on sleep and fatigue management, the promotion of healthy eating and physical activity, and regular monitoring of metabolic risk factors. Furthermore, periodic screening of body mass index, waist circumference, blood pressure, blood glucose, triglycerides, and HDL levels can serve as a basis for risk stratification and targeted follow-up for workers. Such a preventive approach is expected to reduce the risk of health issues while maintaining worker safety and productivity. Longitudinal studies with larger sample sizes are necessary to confirm these associations and the long-term impact of shift work on metabolic health.

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