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Sleep Quality of Industrial Workers with Rotating Shifts based on Occupational Fatigue: Structural Equation Modeling

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Abstract

Background: Shiftwork among industrial workers can lead to poor sleep quality, which in turn is related to occupational fatigue. This study aimed to predict the sleep quality of industrial workers with rotating shifts based on occupational fatigue using structural equation modeling.

Material and Methods: This descriptive study was conducted among 208 production line workers in a food industry of Alborz province, Iran, in the year 2022. Participants were selected by the census method. Data were collected using a demographic questionnaire, the Pittsburgh Sleep Quality Questionnaire (PSQI), and occupational recovery (OFER-15). Structural equation modeling (SEM) was used to investigate the association between the latent variables of occupation fatigue and sleep quality.

Results: About 74% of workers in all three subscales (chronic, acute, and recovery) reported moderate or high fatigue. In seven subscales related to sleep quality, approximately 22.6-32.2% of workers in the subscales of subjective sleep quality, sleep latency, sleep duration, and daytime dysfunction reported poor or very poor quality. The results indicated a significant and negative association between occupational fatigue and the sleep quality of workers. The model presented in this study indicated that occupational fatigue could predict 22% of sleep quality among industrial workers ($R2=0.22$, $\beta=-0.47$, t-value=-4.37).

Conclusions: According to the results of structural association between latent variables, decreasing occupational fatigue could improve sleep quality among one-fifth of industrial workers. Therefore, identifying effective factors and corrective strategies for removing occupational fatigue plays an important role in promoting the sleep quality of rotating shift workers.

Keywords: Fatigue, Food Industry, Occupational, Shift Work, Sleep, Workers

Introduction

The development of manufacturing sectors in industries, the cost-effectiveness of using machines, and the need for greater production have increased the number of shift workers[1, 2]. Studies have shown that about 15-20% of people in American and European countries work shifts [3]. The amount and quality of sleep among shift workers can be affected by staying awake outside of regular sleep hours [4-6].

Long working hours and short sleep can lead to poor sleep quality, which can cause increased work-related errors, injuries, accidents, and absenteeism, thereby reducing workers' cognitive performance and productivity [6, 7]. The cost of insomnia in the United States is estimated at $14 billion and $28 billion annually for direct and indirect treatment, respectively [8].

In addition to sleep deprivation, shift work leads to fatigue, irritability, anxiety, inattention, and failure of work activities [9, 10]. Fatigue among shift workers is caused by abnormal working hours, irregular sleep-wake cycles, overtime, disruption of the circadian rhythm, sleep disorders, and unhealthy lifestyle [11, 12]. A meta-analysis of shift-related fatigue research estimated that 90% of shift workers reported fatigue and drowsiness at work [12, 13] The effects of fatigue on workers' health can lead to reduced efficiency, productivity, and quality of work, an increase in the rate of work accidents and human error, and thus the reduced ability of the worker [11-15]. The workforce of developed countries has a reported rate of work-related fatigue of about 10-50% [16].

In the United States, the consequences of short- and long-term fatigue costs employers an estimated $136 billion annually [13]. Fatigue can also reduce reaction time, increase the probability of accidents and injuries, lead to musculoskeletal disorders, and affect physical and mental health. Workers' fatigue is estimated to result in economic losses of $18 billion annually [14-17].

Rajaratnam et al. stated that sleepiness and fatigue may also have other consequences, including decreased efficiency, increased work-related accidents due to decreased attention, concentration, and increased absenteeism [18]. Choobineh et al. concluded that fatigue and drowsiness are considered important risk factors that have negative effects on the health, safety, and productivity of employees [11]. Havlioglu et al. determined that planned training to reduce workers' fatigue and increase their sleep quality reduces health-related risk factors for workers, therefore contributing significantly to the prevention of occupational accidents [19].

Structural equation modeling (SEM) is a statistical technique that allows the analysis of multiple constructs, variables, and factors simultaneously. It has been used in numerous studies related to human factors and ergonomics [20].

Because fatigue is an important issue of occupational health and safety at work and is a consequence faced by people with sleep disorders, it seems necessary to study its role in reducing sleep quality [9, 11, 14, 16]. Therefore, the current study aimed to predict the sleep quality of industrial workers with rotating shifts based on occupational fatigue using structural equation modeling.

Materials and Methods

The present cross-sectional descriptive study is registered with ethics code IR.QUMS.REC.1400.443 at Qazvin University of Medical Sciences and was conducted in the year 2022. Among 250 rotating shift workers in a food industry in Alborz province, Iran, 212 were willing to participate in the research and were selected by the census method; four people did not meet the inclusion criteria, leaving 208 people remaining. Finally, the data from 208 participants were used to implement SEM. All workers provided a written consent form.

Then they completed the demographic information questionnaire, which collected data such as age, gender, height, weight, marital status, and level of education. In the next step, participants were selected based on the inclusion criteria which, based on previous studies, comprised age>18 years [6, 8, 21], work experience >1 month [6], being a shift and rotation worker [22], and working full time [6, 21]. Workers with a history of confirmed physical or mental illness [23] or taking medication for a mental illness [24] as assessed by the demographic questionnaire were excluded. Eventually, the remaining workers completed the Pittsburgh Sleep Quality (PSQI) and the Occupational Fatigue Exhaustion Recovery (OFER-15) questionnaires.

The PSQI questionnaire was used to determine sleep quality; its high validity and reliability have been assessed and confirmed by many studies. This questionnaire is reported to differentiate bad sleep quality from good sleep quality (0.36). Each of the seven scales on this questionnaire has an internal consistency coefficient and reliability (Cronbach's alpha) of about 0.83 and 0.36, respectively [25]. The seven subscales are scored between 0 and 3. Subscales comprise (1) Subjective sleep quality (range of very good to very poor); (2) Sleep latency (Less than or equal to 15 min to more than 60 min); (3) Sleep duration (more than or equal to 7 hours to less than 5 h); (4) Sleep efficiency (more than or equal to 85% to less than 65% hours of sleep per hours in bed); (5) Sleep disturbances (not during the past month to more than or equal to 3 times per week); (6) Use of sleeping medications (none to more than or equal to 3 times per week); and (7) daytime dysfunction (not a problem to a very big problem). Scores and categories of the PSQI subscales are provided in Table 1. The total number of questions is 18, and the final score of the questionnaire ranges from 0 to 21. A final score greater than 5 indicates that the person's sleep quality is poor and has severe problems in at least 2 subscales or moderate problems in more than 3 subscales.

Table 1. Scores and categories of PSQI subscales

Subscales	Items	Scores and category			
Subjective sleep quality	Score item 18	0	1-2	3-4	5-6
		Very good	Fair	Relatively bad	Very bad
Sleep latency	Sum scores of items 2 and 5	0	1-2	3-4	5-6
		Very good	Fair	Relatively bad	Very bad
Sleep duration	Score item 4	0	1	2	3
		Very good	Fair	Relatively bad	Very bad
Habitual sleep efficiency	$\frac{Item\ 4}{The\ distance\ between\ items\ 1\ and\ 3\ (hour)} \times 100$	>85%	75-4%	65-74%	<65%
		Very good	Fair	Relatively bad	Very bad
Sleep disturbance	Sum scores of items 6 and 15	0	1-9	10-18	19-27
		Very good	Fair	Relatively bad	Very bad
Use of sleeping medications	Score item 15	0	1	2	3
		Very good	Fair	Relatively bad	Very bad
Daytime dysfunction	Sum scores of items 16 and 17	0	1-2	3-4	5-6
		Very good	Fair	Relatively bad	Very bad

The OFER-15 questionnaire was used to measure occupational fatigue. Cronbach's alpha coefficient for the internal reliability of the questionnaire is widely reported as 0.80 to 0.85 [26, 27]. Moreover, Feng et al. confirmed the construct validity of the three factors mentioned in this questionnaire [28]. This questionnaire comprises 15 questions and measures their subscales: (1) acute fatigue; (2) chronic work-related fatigue; and (3) inter-shift recovery. Items are scored on a 7-point Likert scale: (1=completely disagree, 2=very disagree, 3=neither disagree nor agree, 5=agree, 6=very agree, 7=completely agree). According to the OFER-15 user guide, the average score of each dimension of fatigue based on quarters was classified into three levels: low (score less than 23.33), medium (score between 23.33 and 60), and high (mean score more than 60) [29].

SEM was used to explore causal relationships between the latent variables of occupational fatigue and sleep quality, which were explained by observed variables. In the model used in the present study, occupational fatigue was considered an independent and exogenous variable, and sleep quality was a dependent and endogenous variable. Acceptable values of the goodness-of-fit indices are briefly presented in Table 5 of the results section [30-32]. Statistical analyses were done using LISREL 8.80 [31]. With the SEM method, relationships between variables are examined through the path coefficients and the significance level through the T-value > ±1.96.

Results

The normality assumption of quantitative variables was investigated using the Kolmogorov-Smirnov test, and based on p>0.05, it was found to be normal. The results indicate that participant mean age was 34.09 +7.43 years, all participants were male, and 149 (71.6%) of them were married. Other demographic and occupational characteristics of the subjects are presented in Table 2.

Table 2. Demographic information of study participants (n=208)

Quantitative Information		Qualitative Information			
Variable	**Mean ± SD**	**Variable**	**Classification**	**Frequency**	**Percentage**
Age (year)	34.0 ± 7.4	Marital status	Single	59	28.4
			Married	149	71.6
Height	175.2±7.3	Level of education	Middle school	49	23.6
			Diploma	122	58.7
Weight (kg)	76.4± 12.4		Associate degree	26	12.5
			Bachelor's degree or higher	11	5.3

In all three subscales of fatigue (chronic fatigue, acute fatigue, recovery between shifts), 54 (26%) of participants reported low fatigue, and 154 (74%) reported moderate to high fatigue (Table 3).

Table 3. Results of subscales of occupational fatigue among shift workers (n=208)

Sub-scales of fatigue	Mean ± SD	Category	Frequency	Percentage (%)
Chronic fatigue	12.99 ± 6.8	Low	53	25.5
		Moderate	61	29.3
		High	94	45.2
Acute fatigue	20.89 ± 8.20	Low	54	26.0
		Moderate	58	27.9
		High	96	46.1
Recovery between shifts	16.23 ± 5.70	Low	54	26.0
		Moderate	70	33.7
		High	84	40.3

Among the 208 participants, 120 (57.7%) had good sleep quality and 88 (42.3%) had poor sleep quality. In seven subscales related to sleep quality, 46 (22.1%) of participants reported poor quality and 21 (10.1%) reported very poor quality of subjective sleep. Furthermore, 208 (100%) participants reported good and very good quality of habitual sleep efficiency and sleep disturbance (Table 3). Information related to the other subscales of sleep quality is provided in Table 3. It should be noted that none of the participants had taken sleeping medication, so the results are not presented in Table 4.

Table 4. Results of six subscales of sleep quality among shift workers (n=208)

Variable	Mean ± SD	Category	Frequency	Percentage (%)
Subjective sleep quality	1.27± 0.84	Very good	32	15.4
		Fair	109	52.4
		Relatively bad	46	22.1
		Very bad	21	10.1
Sleep latency	1.01± 0.69	Very good	48	23.1
		Fair	110	52.9
		Relatively bad	50	24.0
		Very bad	-	-
Sleep duration	0.82± 0.77	Very good	84	40.4
		Fair	77	37.0
		Relatively bad	47	22.6
		Very bad	-	-
Habitual sleep efficiency	0.13± 0.34	Very good	181	87.0
		Fair	27	13.0
		Relatively bad	-	-
		Very bad	-	-
Sleep disturbance	1.17± 0.37	Very good	173	83.2
		Fair	35	16.8
		Relatively bad	-	-
		Very bad	-	-
Daytime dysfunction	0.9± 0.83	Very good	75	36.1
		Fair	86	41.3
		Relatively bad	39	18.8
		Very bad	8	3.8
Total PSQI score	5.29± 2.41	Good	120	57.7
		Poor	88	42.3

The relationship between occupational fatigue and sleep quality was explored using SEM analysis.
The results indicated a significant and negative relationship between occupational fatigue and sleep quality (β=-0.47, t-value=-4.37).
The influence of occupational fatigue (exogenous variables) on sleep quality (endogenous variables) with standard factor loads (the numbers outside the parentheses between the latent and manifest variable and the endogenous and exogenous latent variable), errors (numbers outside of manifest variable parentheses), and t-value (numbers inside the parentheses) has been shown in Figure 1. The t-values (greater than 1.96) showed that all factor loadings were significant at a 95% confidence interval (CI). Moreover, the evaluated fit indices for the final model suggest acceptable goodness-of-fit for the data (Table 5). Findings showed that the quality of sleep decreases with increasing occupational fatigue in shift workers.

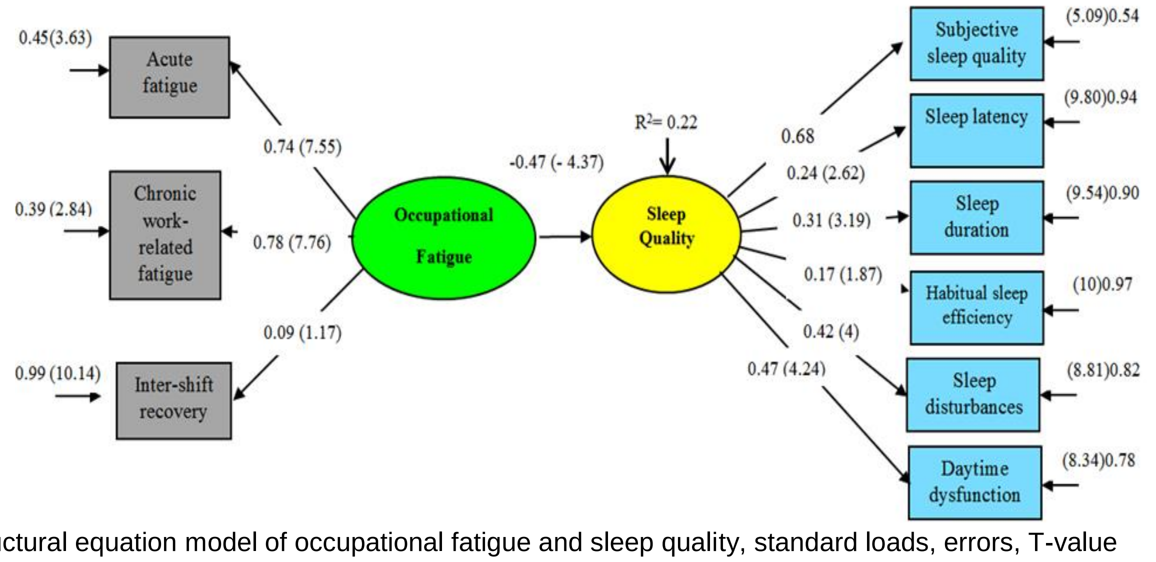

Fig. 1. Structural equation model of occupational fatigue and sleep quality, standard loads, errors, T-value

Chi-Square=31.84, df=26, *p*-value=0.19855≅0.2, RMSEA=0.033

Table 5 shows the acceptable threshold of model evaluator goodness-of-fit indices (NCP, non-centrality parameter; RMSEA, root mean square error of approximation; AIC, Akaike information criterion; NFI, normed fit index; NNFI, non-normed fit index; CFI, comparative fit index; SRMR, standardized root mean square residual; GFI, goodness-of-fit index; AGFI, adjusted goodness-of-fit index; PGFI, parsimony goodness-of-fit index) [30, 31] along with the results obtained from the output of Lisrel software related to the model of this study.

Table 5. Thresholds of goodness-of-fit indices and values obtained for structural equation model [31, 32]

Chi-square test ($\chi 2$) P > 0.05	$\chi 2$/df <2 or <3 Or 2:1 or 5:1 ratio	NCP close to 0	RMSEA ≤0.05: good fit; <0.08: reasonable fit	Model AIC < Saturated AIC and independence AIC	NFI >0.90	NNFI>0.90
p =0.20	1.22	5.84	0.033	69.84<90.00 and 295.68	0.87	0.96

CFI>0.90 Preferably >0.95	SRMR<0.08 Preferably <0.05	GFI >0.9 or >0.8	AGFI >0.9 or >0.8	PGFI >0.50	Measurement model assessment Standardized path coefficients > 0.7	Structural model assessment R2 more than 0.3
0.97	0.055	0.97	0.94	0.56	0.09-0.78	0.22

Discussion

In addition to lack of sleep, shift work can lead to fatigue among shift workers in industry. Therefore, this study aimed to predict of sleep quality of industrial workers with rotating shifts based on occupational fatigue using structural equation modeling.

The current results indicate that in each of the three scales related to fatigue (acute, chronic, and recovery between shifts), 154 (74%) participants reported moderate or high occupational fatigue; the mean score in the subscale of acute fatigue (20.8±8.2) was greater (Table 3). This result is in line with those of Choobineh et al., who reported the highest score of acute fatigue based on P-OFER-15 among 501 employees in the petrochemical industry [11]. Furthermore, Barker et al. and Chen et al. used the OFER-15 questionnaire in their studies and reported the highest mean scores as belonging to the acute fatigue subscale (65.55% and 65.6%), respectively, which is consistent with the present study [17, 33, 34].

Daniel et al. studied 100 emergency medical service shift workers [25], and another study evaluated 83 air physicians [25]; both reported the highest score in the subscale of recovery between shifts, which contradicts the present study. This result may be explained by the differences in jobs and societies, and working conditions [35, 36].

The high prevalence of fatigue in all three subscales found among shift workers in the present study may be because of insufficient rest and, as a result, a lack of energy to spend on family, friends, entertainment, and other activities. Moreover, a lack of time and insufficient rest between shifts can be reasons for not relieving work fatigue, leaving the worker with insufficient freshness and well-being at the beginning of the next shift. In addition, excessive expectations in the workplace, lack of rest and inadequate interwork breaks, and complete depletion of

energy in the workplace are other causes of fatigue among workers [29].
To reduce occupational fatigue among shift workers, items such as: considering a regular schedule for adequate rest between work shifts, spending enough time on family and other activities, clarity of role at work to avoid expectations, and consideration of interwork breaks can play effective roles in recovering workers' energy.
In the present study, 120 (57.7%) participants reported good sleep quality and 88 (42.3%) reported poor sleep quality (Table 4). In a study by Hwanjin et al., 66% and 34% of workers reported good and poor sleep quality, respectively [37]. Wanpen found that 33.7% of industrial workers reported poor sleep quality. Both reports of a lower percentage of poor sleep quality are consistent with the results of the present study [6].
In a study by Stina et al., 78% of shift workers reported poor sleep quality, which contradicts the results of the present study. The reason for this discrepancy can be differences in industries, age groups, tasks, expectations, working conditions, and rotation schedules [38].
In the current study, a higher mean PSQI final score of 5.29± 2.41 (Table 4) indicated workers' problems in some subscales, such as subjective sleep quality and sleep latency. In the seven subscales related to sleep quality, approximately 22.6-32.2% (Table 4) of workers in the subscales of subjective sleep quality, sleep latency, sleep duration, and daytime dysfunction were of poor and very poor quality. Items mentioned can be explained by going to bed late, long time between lying down and falling asleep, waking up for various reasons during the night, low deep sleep during the night, and overall poor sleep quality [26]. Training workers and providing suggestions to them such as getting to bed early for a good night's sleep, not drinking pre-bedding drinks, and sleeping hygiene can all contribute to deep sleep and, consequently, sleep quality.
Modeling occupational fatigue on the sleep quality of shift workers, this study revealed a negative and significant correlation (β =-0.47, t-value=-4.37 in Figure 1) between two latent variables. Choobineh et al., however, reported a positive and significant relationship between drowsiness and fatigue. Hence, fatigue dimension scores were significantly higher among people with sleep disorders compared to people without sleep disorders [11]. Eldevik et al. showed a positive relationship between shift work, insomnia, and fatigue, which is consistent with the results of the present study [12, 39].
A significant correlation between occupational fatigue and sleep quality in the present study showed that occupational fatigue has a negative effect on sleep quality and leads to reduced sleep quality among shift workers [11]. As studies have shown, significant positive relationships were found between sleepiness and fatigue, and a lack of sleep and insufficient rest can also influence occupational fatigue [11]. According to relevant studies, occupational fatigue and rotational shifts affect sleep [6]. Therefore, work schedules, such as shift work and long working hours without proper rest intervals, may lead to sleep problems and gradually lead to the accumulation of physical and mental fatigue in workers [11].
Studies have shown that occupational fatigue is associated with various factors such as education level, job position, work experience, emotional factors, work environment conditions (work intensity, work climate, light, noise, etc.), and individual factors [16]. Moreover, work factors such as lack of planning for work activities, work shifts, duration of work, and repetitive tasks are effective [11, 14]. In shift workers, fatigue is caused by abnormal working hours, because workers are required to work contrary to the normal cycle of sleep and wakefulness [40]. Kneginja et al. showed that the main causes of shift-related fatigue were reported as circadian rhythm disturbances, irregular sleep-wake interruptions, and sleep loss along with other contributing factors such as lifestyle, anxiety, or mood disorders [12, 41]. In Anjali Rameshbabu's study, lack of sleep, work stress, and shift schedule were the three main causes of fatigue reported by more than 50% of respondents [13].
According to the obtained model in the current study, 22% (Fig. 1) of the sleep quality of shift workers can be predicted by occupational fatigue [17]. Therefore, considering the effective role of occupational fatigue on the sleep quality of shift workers, the following solutions and measures are suggested: design a workplace light similar to daylight in night shifts to reduce fatigue and drowsiness, provide short breaks during work shifts to recover energy, make changes in shift rotation, give workers special nutritional instructions, get feedback from workers to solve their problems, create workplace entertainment for workers during breaks and lunches, and contract with sports clubs for workers to use outside of shift work [12, 42]. To improve the quality of their sleep, shift workers can keep their bedroom at a suitable temperature and dark, use blindfolds if necessary, keep their bedroom quiet, rest immediately after the night shift, and use earplugs if needed. Taking the

above-mentioned corrective measures will result in improved quality of sleep among one-fifth of the workforce by reducing occupational fatigue.

One of the strengths of this study is the identification of the impact of occupational fatigue on the quality of sleep of rotating shift workers in industry, which to date has been insufficiently studied in Iran. One of the limitations of this research is the lack of employment of women in the studied industry. As a result, the relationship between PSQI and OFER-15 was not investigated. It is suggested that this research be carried out in a statistical population of female shift workers.

Conclusion

About two-thirds of workers reported moderate or high occupational fatigue, and one-fifth to one-third of workers reported poor or very poor sleep quality in the subscales of subjective sleep quality, sleep latency, sleep duration, and daytime dysfunction. The final PSQI score also indicates problems in some sleep quality subscales, as 42.3% of workers reported poor sleep quality. In addition, the relationship between occupational fatigue and sleep quality showed that there is a negative and significant relationship between these two latent variables, such that occupational fatigue can predict 22% of sleep quality among workers. Providing appropriate solutions based on interwork breaks, work shift, and rest schedules, and providing adequate time between work shifts for entertainment and being with family play important roles in recovering energy and reducing occupational fatigue, thereby increasing the quality of workers' sleep.

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