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Analysis of Factors Influencing Work Fatigue of Online Workers in Manufacturing Enterprises and Research on Countermeasures

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Abstract: With the rapid development of the manufacturing industry, work safety issues in the manufacturing industry have also begun to enter people's vision, and job fatigue is one of the important influencing factors. To explore the influencing factors of occupational fatigue among online workers in manufacturing enterprises, subjective questionnaire surveys and field observations were used to collect research sample data. SPSS 26.0 software was used to analyze the validity of the obtained sample data, and five influencing factors were extracted: operators, the work itself, the work environment, work equipment, and enterprise management. A structural equation model of the influencing factors of occupational fatigue among online workers in manufacturing enterprises was constructed, and AMOS 24.0 software was used for factor analysis. The research results show that the degree of impact on job fatigue of online workers in the manufacturing industry is in the following order: work environment (B)>work equipment (F)>enterprise management (M)>work itself (O)>work personnel (D). Finally, propose targeted policy recommendations based on the degree of impact.

Keywords: Manufacturing homework fatigue; Influencing factors; Structural equation model

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1. Introduction

The manufacturing industry is the main body of the national economy, the tool of the country, and the foundation of the country. With the continuous improvement of production technology and equipment level, China's manufacturing industry is going all out to automation, mechanization, and intelligent development. The "Made in China 2025" pointed out that "people-oriented" is the foundation of China's construction of manufacturing power, only to improve the status of "people" in the production system, give full play to the function of "people", and use "people" to manipulate the machine, can ensure the long-term healthy and stable development of manufacturing. However, the process of development is gradual, as in the actual production activities, there is still a lot of manual work, which increases the work intensity of workers in the manufacturing industry, and the fatigue phenomenon of workers will rise, which will not only cause a decline in production efficiency but also increase the incidence of production accidents. Therefore, analyzing the work fatigue of workers in manufacturing enterprises and exploring the driving strength of different influencing factors on the work fatigue of online workers in the manufacturing industry has certain practical significance for solving the actual work fatigue problem in the manufacturing industry.

By combing the frontier trends in this field, it is found that the current research mainly focuses on the evaluation of work fatigue, the influencing factors of work fatigue, and the improvement of work fatigue. Since the late 1800s, scholars have used the erasure test to measure attention and fatigue in subjects, Work efficiency began to be used as an evaluation index of cancellation test to laterally characterize fatigue degree [1]. Subsequently, human physiological characteristics began to be included in the fatigue evaluation index system [2]. With the continuous deepening of research and the continuous development of science and technology, high-tech equipment began to be put into the field of fatigue evaluation. In the automotive field, computer vision systems began to be applied to analyze the fatigue degree of drivers, and the application of this technology provided a new perspective for the improvement of fatigue evaluation methods [3]. With the rapid development of the industry worldwide, some scholars began to focus their research perspectives on workers, self-diagnosis questionnaires, multidimensional fatigue scales (MFI-20) [4]; Modified fatigue scale (FAI) [5]; and Body and Brain Fatigue Evaluation Scale [6], a series of fatigue evaluation scales have been widely used, and later some scholars have based on the physical characteristics of workers [7]. For example, biochemical indicators such as eye movement frequency and blood pressure are combined with the Perclos method to obtain the fatigue state of the subjects, which can effectively avoid the interference of human subjective factors and provide a scientific basis for the physiological fatigue caused by research work.

It is generally believed that the influencing factors of job fatigue can be divided into two parts: physiological factors and psychological factors, both of which can affect job fatigue. Some scholars have pointed out in their research that the physiological conditions of the workers as the restricting factor, there is a significant positive correlation between working time, working intensity, and job fatigue, indicating that there is a certain relationship between physiological factors and job fatigue [8]. Later, when studying the order-picking operation, it was found that human psychological factors had a great impact on the efficiency of the picking operation, and mental fatigue seemed to have a negative impact on the operation effect [9]. With the deepening of research, scholars began to study the influencing factors of job fatigue from different perspectives. Some scholars proposed that job fatigue is the result of the influence of both managers and operators [9]. Subsequently, through the research on diver fatigue, the relationship between individual fatigue and team management was also found [11]. Other scholars have also conducted a large number of studies on the job fatigue of migrant workers, university teachers, and brain-based practitioners [12–14].

The work fatigue improvement is based on the theory of human factor engineering, and the improvement plan is implemented to improve work efficiency. Some scholars focus on objective mathematical models or theoretical methods for improving job fatigue, such as fatigue risk management systems (FRMS), quantile and linear regression models, mixed integer linear programming (MILP), and so on [15–17]. The appearance of these mathematical models provides a reference for solving the fatigue problem existing in the actual situation. Some scholars study fatigue improvement from a realistic perspective, exploring the root causes of fatigue from the aspects of operators, environment, equipment, etc. Some scholars analyze the workshop environment of small and medium-sized enterprises, point out that there are widespread problems such as poor lighting and serious noise pollution in enterprises, and put forward targeted suggestions for improvement [18]. Based on the ergonomic theory, some scholars have revealed the main causes of fatigue among current VDT workers, and proposed design opportunities and future development of ways to alleviate such human fatigue from the perspective of industrial design [19].

To sum up, although there are many researches on the influencing factors of job fatigue, most of them focus on the fields of transportation, sports, medicine, etc. There is little research on the influencing factors of job fatigue of online workers in the manufacturing industry, and the research on the influencing factors of job fatigue is not systematic. The different labor operations and workers' conditions of different enterprises should be considered in the research. In practice, it is necessary to analyze the actual situation. Given this, this paper adopts a questionnaire survey to collect the actual data of enterprises and uses the SEM structural equation model to explore the weight of various influencing factors on job fatigue, to put forward targeted policy suggestions.

2. Research methods and indicators

2.1. SEM structural equation model

The structural equation model (SEM) is a method commonly used in social science research to analyze causality (observed variables versus potential variables, and between potential variables). Work fatigue is affected by many factors at the same time, and its evaluation indicators are difficult to quantify. Moreover, due to the large sample size collected by the questionnaire, errors in data processing, and correlation among variables, the general processing model cannot be applied well, but the structural equation model can solve these problems well.

2.2. Indicator specification

SEM structural equation model includes two parts: measurement model and structure model. The corresponding expression of the SEM structural equation model is shown in **Table 1**.

Table 1. Corresponding expression of SEM

Model	Equation	Expression
Measurement model	Measurement equation	$X = \Lambda_x \xi + \delta$ $Y = \Lambda_y \eta + \varepsilon$
Structural model	Structural equation	$\eta = B\eta + \Gamma\xi + \zeta$

The meanings of symbols in SEM expressions are shown in **Table 2**.

Table 2. Meaning of symbols of SEM

Symbol	Meaning	Symbol	Meaning
X	A vector composed of exogenous observed variables	δ	The error term of the exogenous observed variable
Y	A vector of endogenous observed variables		A vector of endogenous latent variables
B	Relationships between potential variables		Residual term of endogenous observed variable
	The relationship between exogenous observed variables and exogenous latent variables		Path coefficient, the influence of exogenous latent variables on endogenous latent variables
	The relationship between endogenous observed variables and endogenous latent variables		The unexplained part of a structural equation - the residual term
	A vector set of exogenous latent variables		

3. Influencing factors of operation fatigue in manufacturing enterprises

3.1. To determine the influencing factors of work fatigue of online workers in manufacturing enterprises

Work fatigue is never caused by a single factor, and there are many influencing factors, but it is roughly concentrated in the four main aspects of "people, things, rings, and pipes", which can be summarized as internal factors and external factors. The internal factors are the situation of the operators themselves, and the external factors mainly include the nature of the operations, the operating environment, the operating equipment, and the enterprise management. These two factors are not independent of each other, and it is usually the interaction between them that leads to the production of work fatigue. Based on previous studies on factors affecting job fatigue by scholars, combined with the actual operation characteristics of manufacturing enterprises, 22 influencing factors were finally selected from five aspects: operator, operation itself, operation environment, operation equipment, and enterprise management.

3.2. Preparation of questionnaire and collection

According to the 22 influencing factors identified, a five-level Likert scoring method was used to compile a questionnaire, and each employee scored the influencing factors of job fatigue according to their actual situation. The questionnaire consists of two parts, the first part is the basic information of the respondents, including gender, age, monthly salary, etc. The second part is the influence factors of online workers' fatigue in 22 selected manufacturing enterprises, and the impact degree according to the subjective feelings of the respondents. The questionnaire distinguishes the impact degree as great, large, general, little, or even basically no impact, and according to 5 points, 4 points... 1 point to score. A random sampling method was adopted to select 210 employees from three local manufacturing enterprises for a questionnaire survey. 210 questionnaires were issued, 208 questionnaires were recovered, and 205 valid questionnaires were obtained after eliminating invalid questionnaires.

3.3. Sample data analysis

In this study, the main data were collected in the form of a scale, and the next analysis could only be carried out after the validity of the data obtained from the questionnaire had been tested.

Cronbach's α is often used to check the validity of data, In the 0–1 range, the greater the alpha value, the higher the internal consistency of the data. In this paper, the reliability test results obtained by SPSS 26.0 software are shown in **Table 3**. It can be seen that the reliability coefficients of each influencing factor are within the range of 0.8–1. Therefore, the reliability of the data used in this study meets the requirements and can be analyzed in the next step.

Table 3. Impact factor reliability analysis

Variable	Cronbach's α	Number of terms
Operator	0.818	4
Job	0.853	5
Environment	0.831	4
Equipment	0.839	4
Enterprise management	0.857	5
Factor of influence	0.963	22

4. SEM empirical analysis and evaluation

4.1. SEM construct

To facilitate the construction of the model, each observed variable and potential variable are represented by a letter. The variables represented by each letter are shown in **Table 4**.

Table 4. The letters represent the variables in the table

Latent variable	Alphabetic representation	Observed variable	Alphabetic representation	Latent variable	Alphabetic representation	Observed variable	Alphabetic representation
Operator	D	Physical condition	D1	Environment	B	Temperature and humidity	B3
		Working pressure	D2			Noise	B4
		Job skills	D3	Equipment	F	Reliability of equipment	F1
		Job satisfaction	D4			Operability of equipment	F2
Job	O	Operation time	O1			Coordination of equipment	F3
		Operating speed	O2			Update frequency of equipment	F4
		Job intensity	O3	Enterprise management	M	Reward and punishment system	M1
		Task difficulty	O4			Salary and welfare	M2
		Job accuracy	O5			Extra shift system	M3
Environment	B	Lighting condition	B1			Position arrangement	M4
		Dust	B2			Interpersonal relationship	M5

In this paper, AMOS 24.0 software will be used to build the structural equation model. Five variables such as the operator, the operation itself, operation environment, operation equipment, and enterprise management will be taken as five potential variables, and 22 variables such as physical condition, operation time, lighting conditions, and reliability of machinery and equipment will be taken as observed variables. e1, e2, e3... e22 is the error term of each observed variable, and all path coefficients are set to 1 by default, so the resulting model is shown in **Figure 1**.

4.2. SEM parameter estimation and fitting

After the construction of the SEM model, it is necessary to carry out a fitting evaluation. The next step can only be carried out after it is determined that the model is fully compatible with the data. After fitting, the SEM model is shown in **Figure 2**.

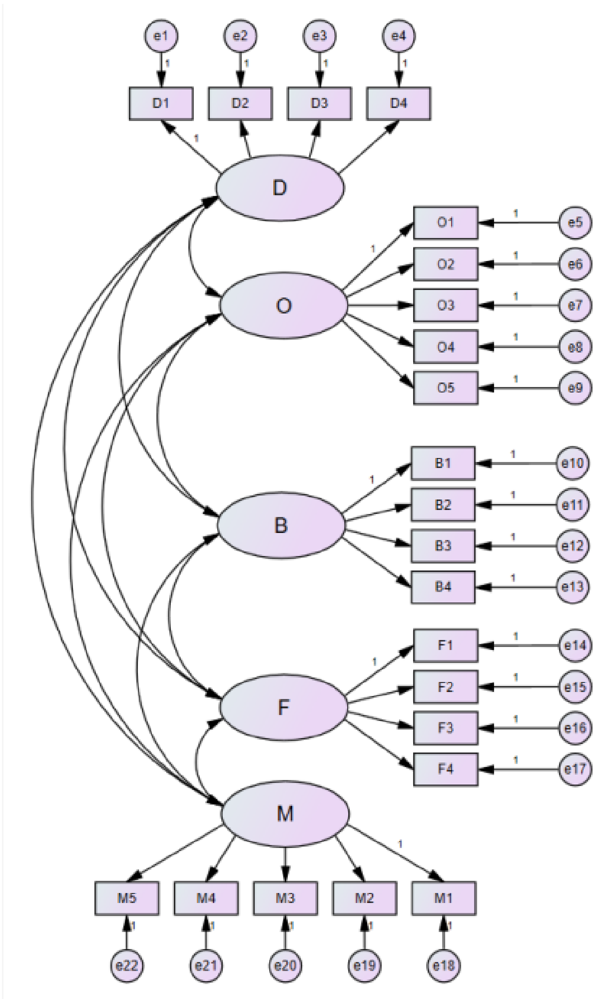

Figure 1. SEM model of influencing factors of job fatigue

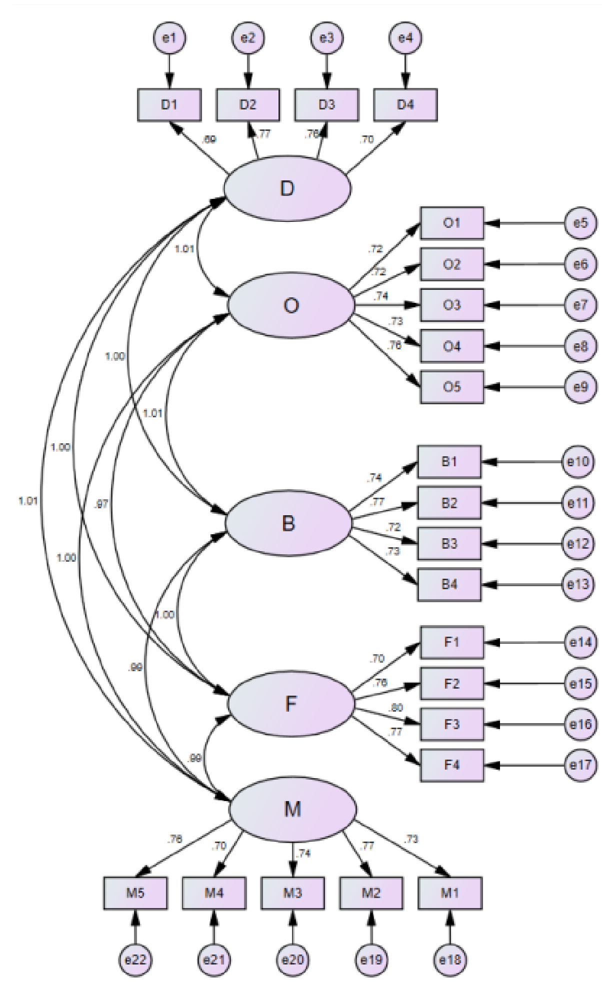

Figure 2. The SEM model was fitted

After fitting the model, its fit degree should be tested. Considering the stability of the fit degree evaluation indexes, this paper selected CMIN/DF, RMSEA, IFI, TLI, and CFI to evaluate the goodness of fit of the model. The test results of model fitness after fitting are shown in **Table 5**.

Table 5. Model fit test

Index	Reference standard	Measured result
CMIN/DF	1–3 is excellent, 3–5 is good	1.13
RMSEA	<0.05 is excellent, <0.08 is good	0.025
IFI	>0.9 is excellent, >0.8 is good	0.991
TLI	>0.9 is excellent, >0.8 is good	0.99
CFI	>0.9 is excellent, >0.8 is good	0.991

According to the model adaptation test results in **Table 5**, CMIN/DF=1.13 and RMSEA=0.025 are both representative indicators in the excellent range. In addition, the test results of IFI, TLI, and CFI were all above 0.9. These results indicate that the fitted structural equation model is a good fit and can be used for further analysis.

4.3. SEM confirmatory factor analysis

4.3.1. Scale convergence validity and combination reliability test

Under the premise that the SEM model has a good fit, the convergence validity (AVE) and combination reliability (CR) of each dimension of the scale need to be further tested. Only when AVE≥0.5 and CR≥0.7 can it be shown that the fitted model has good convergence validity and combination reliability, and the fitting results are authentic. The specific results are shown in **Table 6**.

Table 6. Convergence validity and combination reliability test for each dimension

First-order factor	Second-order factor	Factor loading	AVE	CR	First-order factor	Second-order factor	Factor loading	AVE	CR
D	D1	0.689	0.531	0.818	F	F1	0.696	0.573	0.842
	D2	0.767				F2	0.763		
	D3	0.758				F3	0.798		
	D4	0.696				F4	0.766		
O	O1	0.716	0.538	0.854	M	M1	0.732	0.547	0.858
	O2	0.725				M2	0.767		
	O3	0.742				M3	0.739		
	O4	0.727				M4	0.703		
	O5	0.76				M5	0.756		
B	B1	0.741	0.551	0.831					
	B2	0.772							
	B3	0.723							
	B4	0.733							

According to the analysis results in **Table 6**, it can be seen that in the validity test of the scale after fitting, the AVE value of each impact factor is above 0.5, and the CR value is above 0.7, which indicates that each impact factor has good convergence validity and combination reliability, and the scale is reasonably formulated.

4.3.2. The scale describes statistics and normality tests

Before using fitted model output results, descriptive statistical analysis and normality tests should be carried out for each influencing factor used in this study to verify whether the data of each measurement item meets the approximately normal distribution. If not, the reliability of the model output results will be reduced. Specific test results are shown in **Table 7**.

Table 7. Each dimension describes the results of the normality test of statistical and measurement items

Latitude	Measurement item	M	SD	Skewness	Kurtosis	Total M	Total SD
Operator	D1	3.81	1.137	-0.894	0.22	3.8524	0.93959
	D2	3.89	1.16	-1.035	0.342		
	D3	3.85	1.236	-1.118	0.361		
	D4	3.86	1.14	-1.004	0.391		
Job	O1	3.87	1.166	-0.995	0.231	3.846	0.9441
	O2	3.9	1.152	-1.099	0.555		
	O3	3.84	1.188	-0.979	0.181		
	O4	3.82	1.216	-0.947	0.082		
	O5	3.8	1.222	-0.961	0.031		
Environment	B1	3.82	1.183	-0.927	0.129	3.8037	0.95559
	B2	3.87	1.177	-0.953	0.056		
	B3	3.78	1.145	-0.855	0.086		
	B4	3.74	1.187	-0.837	-0.08		
Equipment	F1	3.77	1.218	-0.938	0.093	3.8195	0.97379
	F2	3.8	1.19	-0.894	-0.032		
	F3	3.91	1.185	-0.971	0.131		
	F4	3.8	1.148	-0.838	-0.058		
Enterprise management	M1	3.88	1.153	-1.067	0.489	3.876	0.9058
	M2	3.88	1.116	-1.082	0.598		
	M3	3.93	1.137	-0.986	0.222		
	M4	3.87	1.101	-1.048	0.634		
	M5	3.82	1.167	-0.925	0.16		

According to the analysis results in **Table 7**, it can be seen that the mean score (M) of each variable is between 3 and 4, and the score range of the mean score (M) is positive between 1 and 5. Therefore, it can be seen that the cognitive level of the subjects in this study on the influencing factors of online work fatigue in the manufacturing industry is above medium, which proves the authenticity and validity of the data.

The normality test of each measurement item is tested by skewness and kurtosis. According to the standard proposed by foreign scholars, the absolute value of the skewness coefficient is less than 3, and if the absolute value of the kurtosis coefficient is less than 8, then the data can be considered to meet the requirements of approximate normal distribution [20]. According to the analysis results in **Table 7**, the absolute values of skewness and kurtosis coefficients of each measurement item in this study are within the standard range, so it can be proved that the measurement data conforms to the characteristics of normal distribution, and the output data of the fitted model can be used for further analysis.

5. Conclusion and suggestions for improvement

5.1. Conclusion

After a series of confirmatory factor analyses, the data output results of the fitted model have high reliability, which can reflect the load size of various influencing factors that cause the work fatigue of online workers in the manufacturing industry to a certain extent, and the larger factor load means that it is more likely to cause the work fatigue. The factor loads of specific influencing factors are summarized in **Table 8**.

Table 8. Summary table of influencing factors and factor loads

First-order factor	Weight	Second-order factor	Weight	First-order factor	Weight	Second-order factor	Weight
D	0.61	D1	0.689	F	0.71	F1	0.696
		D2	0.767			F2	0.763
		D3	0.758			F3	0.798
		D4	0.696			F4	0.766
O	0.69	O1	0.716	M	0.71	M1	0.732
		O2	0.725			M2	0.767
		O3	0.742			M3	0.739
		O4	0.727			M4	0.703
		O5	0.76			M5	0.756
B	0.76	B1	0.741				
		B2	0.772				
		B3	0.723				
		B4	0.733				

The influence weight of the working environment (B) is 0.76, which has the largest influence on online work fatigue, and the influence of dust (0.772) is particularly obvious.

The influence weight of operating equipment (F) is 0.71, indicating that it has a greater impact on the fatigue of online workers, and the coordination of machinery and equipment (0.798) has the greatest impact.

The influence weight of enterprise management (M) is 0.71, which is roughly the same as the influence of operating equipment on job fatigue, among which salary and welfare (0.767) have the most significant influence on job fatigue.

The influence weight of the job itself (O) on job fatigue is 0.69, in which job accuracy (0.76) has the greatest influence on fatigue degree.

The influence weight of operator (D) is 0.61, and the influence degree is relatively small compared with other factors, among which work pressure (0.767) has the most serious impact on work fatigue.

5.2. Suggestions for improvement

Based on the analysis of the above results and the theory of human factor engineering, the following improvement measures are put forward to reduce work fatigue as much as possible.

5.2.1. Improve the working environment

The primary task of improving the working environment is to reduce the dust concentration in the air, increase the number of dust collection equipment without hindering work safety, and the most critical thing is to equip each staff with professional dust prevention equipment, such as dust masks, dust masks, etc. At the same time, strengthen site management to prevent material accumulation, maintain the cleanliness of the work site by increasing cleaning personnel and organizing regular cleaning to prevent the occurrence of dirty and disorderly phenomena; Improve the ventilation, noise reduction, and temperature control system to ensure the working comfort of workers, through the above measures to avoid the maximum extent due to the working environment problems caused by fatigue.

5.2.2. Regular maintenance and replacement of operating equipment

The enterprise should organize training regularly to ensure the proficiency and coordination of workers in operating the machine, and reduce the occurrence of operation fatigue and even production accidents caused by operation problems; Design equipment maintenance point checklist, carry out equipment inspection and maintenance regularly, and prevent equipment failure in advance; Timely upgrade and iteration of outdated equipment to avoid additional work burden caused by equipment function mismatch, and promote man-machine system integration.

5.2.3. Improve the enterprise management system

A good enterprise management system should be in line with "making the best use of people, making the best use of things, matching people", so that reward and punishment are clear, and benevolence and power are applied, which can be started from the following aspects: first, formulate a reasonable salary system and scientific incentive means, appropriately increase welfare benefits, and improve work enthusiasm. The second is to fully understand the skills of workers, organize skills assessments, and ensure that each worker can be assigned to the most suitable post. The third is to develop a scientific overtime system to ensure that workers have enough rest and sleep time, avoid workers due to lack of rest caused by operational errors, and reduce work fatigue. Fourth, set up an open and transparent promotion campaign mechanism to resist the existence of nepotism.

5.2.4. Formulate reasonable operating systems and norms

On the one hand, it is more beneficial to arrange several short breaks in the working process of workers than a long rest. Enterprises arrange the rest time and number of workers according to the work intensity of different positions, to ensure stable efficiency and alleviate work fatigue. On the other hand, the establishment of standard operating instructions, through the experience accumulation of experienced workers and the summary of technical backbone, to develop clear and understandable standard operating instructions, is of great significance for reducing bad working posture, improving production efficiency, and reducing work fatigue.

5.2.5. Pay attention to the health of employees' lives

The physical state of workers has an obvious influence on the production of work fatigue, among which work pressure is the first. First of all, enterprises should formulate production plans scientifically to avoid the work pressure on employees due to the heavy production tasks. Secondly, the enterprise can regularly investigate the mental state of employees through questionnaires and other forms. If necessary, psychological counseling can be conducted to ensure the mental health of employees. Regular medical examinations are organized for employees and they are always concerned about their physical health. Finally, enterprises can regularly organize team building, staff sports, and other recreational activities to let employees relieve pressure.

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