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Determining the cause-effect relationship between risk factors affecting work-related musculoskeletal disorders (WMSDs) using the Fuzzy DEMATEL method

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ABSTRACT

Aims: Musculoskeletal disorders are one of the significant global occupational diseases and injuries, leading to increased costs and reduced productivity at work. It is essential to assess the risk factors that influence the development of these diseases. The purpose of this study was to investigate the relationship between risk factors that affect work-related musculoskeletal disorders (WMSDs) in the food industry using the Fuzzy DEMATEL method.

Method and Materials: In this study, 46 occupational risk factors related to musculoskeletal disorders in the food sector were selected from relevant articles and classified using the 4 M method. The fuzzy DEMATEL study is designed and delivered to experts. Finally, these risk factors were evaluated using the Fuzzy DEMATEL method.

Findings: The cause-effect relationship between 46 risk factors was determined using the fuzzy DEMATEL method. According to the results, the age factor (D-R = 2.26) has a greater influence compared to the other identified risk factors, and the job satisfaction factor (D-R =- 2.26) is the most influential among the identified risk factors. According to the results, the most significant risk factor is the duration of work (D+R = 7.46), and the least significant is related to the genetic risk factor (D+R = 2.64).

Conclusion: The DEMATEL method enables us to plan more effectively and solve problems more efficiently. In this way, to better understand cause-effect relationships, it can be divided into several criteria to form cause-effect groups, thereby building a correlation map.

Keywords: Work-related Musculoskeletal Disorders, Fuzzy DEMATEL, Cause-Effect, Risk Factors

Introduction

One of the most essential industries in the industrial sector is food processing. Inevitably, there will always be high-frequency manual handling or manual load handlers in the Food processing industry [1]. Employee health risks, such Musculoskeletal disorders (MSDs) related to the job may arise in the food manufacturing industry [2]. The role of working conditions, which are associated with various etiologies, is widely recognized as having a significant impact on the onset and persistence of these diseases [3]. Every year, worldwide, work-related diseases claim the lives of approximately 2.78 million people. In addition, work-related causes accounted for 5% of all deaths in the world [4]. The World Health Organization's definition of a wide range of inflammatory and degenerative diseases and disorders that result in pain and functional Impairment is defined as work-related musculoskeletal disorders" [5]. All types of diseases, from mild, impermanent disorders to permanent, disabling damages, are classified as MSDs [6]. Work-related Musculoskeletal Disorders (WMSDs) severely impair dexterity and mobility, resulting in early retirement from the workforce, decreased well-being, and a diminished capacity to engage in society. The number of people with WMSDs and the functional restrictions that go along with them is rapidly rising due to population growth and aging, and this has made WMSDs a serious occupational illness that affects the safety of working people [7]. One-third of diseases and injuries at work are WMSDs [8]. A 2001 study by the

National Institute for Occupational Safety and Health (NIOSH) showed that WMSDs caused an average loss of 8 working days. An additional study estimated the total economic cost of WMSDs to be approximately $50 billion per year [9]. According to research on the disease burden in 2019, among people aged 25 to 49, Lower Back Pain (LBP) ranks fourth globally in terms of disability-adjusted life years [10]. Work-related Musculoskeletal Disorders are the cause of 57% of 81,000 work-related illness cases in the United Kingdom, according to the Health and Safety Executive (HSE) (HSE, 2020). Low back aches, tendinitis, carpal tunnel syndrome, and shoulder aches are a few WMSDs [11]. Apart from discomfort, aches, or similar symptoms, MSDs and WMSDs can hinder an individual's ability to perform their job, raise the likelihood of illness and missed work, and result in an early retirement from work [12]. The US Bureau of Labor Statistics reports that there were 147,050 incidents with WMSD in private industry between 2017 and 2020. These were responsible for 29.5% of the average yearly number of days missed from work [13]. One of the most common reasons for occupational damage and disabilities in developing countries is musculoskeletal disorders. These conditions are associated with high direct costs, including diagnosis and treatment, as well as higher indirect costs resulting from the absence of skilled workers from work. One sector where musculoskeletal disorders are prevalent due to repetitive movements is the food industry because workers in this industry are directly involved in the production process and must perform strenuous physical tasks, such as heavy lifting, carrying, pulling, and pushing, their level of fatigue increases, thereby elevating the risk of musculoskeletal disorders [14].

Due to the principle that man's judgment regarding priorities is frequently imprecise and difficult to quantify using precise numerical values, fuzzy logic is required to handle situations where these characteristics are present. To enhance decision-making in complex environments, fuzzy logic should be integrated with the DEMATEL method [15]. Although traditional quantification techniques provide precise answers, the complexity resulting from human factors renders them ineffective in solving problems involving people. For that reason, the notions of fuzzy set theory were founded by Zadeh [16]. The DEMATEL method is a well-established and widely applied multi-criteria decision-making (MCDM) technique used to visualize the cause-and-effect relationships among various factors and analyze their interrelationships [17]. The fuzzy DEMATEL method is one of the multicriteria decision-making methods used in these processes [18]. DEMATEL was initially applied to resolve complex social events, utilizing graph theory and matrix analysis to construct structural models, thereby examining the causal relationships between attributes of complex events and identifying essential attributes for improved event analysis [19]. DEMATEL can be used to identify important factors and to compute the weights and ranks of various factors [20]. The DEMATEL method has the advantage of not requiring a large amount of data and can be used to reveal the relationships between factors that influence other factors [21]. Using this approach, we can define which factors are more fundamentally significant for the entire system than others by studying and disputing the structural model. Therefore, it is evident that these causal factors—which have the most critical effects on the system—are essential to its success [22]. Control systems, e-learning evaluation, strategy or policy analysis, measurement and assessment, hospital service quality, decision-making, and sustainable supply chain management are just a few of the complex problems for which the DEMATEL technique is frequently used [23].

The primary purpose of this study is to find out the relationship between the risk factors affecting the occurrence of musculoskeletal diseases caused by work in the food industry and to investigate the cause-and-effect relationship.

Method and Materials

Risk factors associated with musculoskeletal diseases in the food industry were identified from articles related to the topic. Based on the 4m method, 46 risk factors were classified into four categories: man, machine, method,

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and material (Table 1)

To define the relationship between the risk factors, a Fuzzy DEMATEL questionnaire was created and sent to the experts. Specialists are ranked based on their level of experience, knowledge, and access to resources.

Table 1) Classification of risk factors according to the 4 M method

4M	Risk factors
Man	▪ Working posture ▪ Personal and mental health ▪ Individual characteristics (height, weight, physical fitness, body mass index) ▪ Age ▪ Gender ▪ Character ▪ Education ▪ The degree of mastery of the work and the skill and competence of the person ▪ The level of experience and knowledge of the person ▪ Ignoring safety rules and principles ▪ Job satisfaction ▪ Working in unsafe conditions ▪ Factors outside the work environment (exercise, smoking, having other jobs) ▪ Underlying disease/drug use ▪ Level of Education ▪ The amount of work experience ▪ Socio-economic status of people ▪ Genetic factors ▪ Weakness in work and organizational communication ▪ Working while injured ▪ Distraction/stress/overconfidence ▪ Having a history of musculoskeletal diseases
Machine	▪ Environmental factors (noise, vibration, ventilation, thermal and cold stresses) ▪ Lighting ▪ Improper use of equipment/use of equipment inappropriate to the job ▪ Standard and adequacy of equipment ▪ Periodic visits ▪ Design of tools and equipment
Material	▪ Air pollutants ▪ Material waste control ▪ Standard material quality
Method	▪ Type and nature of work ▪ repeated work ▪ work intensity ▪ Duration of work ▪ Violence and pressure in the workplace ▪ Work-rest period ▪ Workstation design ▪ Increasing work pressure (for example, for more production) ▪ Supervision ▪ Prevention and treatment, and health care program ▪ risk management ▪ Technique and method of doing work ▪ Using up-to-date and safe methods ▪ Low budget ▪ Up-to-date rules and guidelines

Renjith et al.'s index table is used to weight the experts (Table 2) [24]. Based on the experience, level of education, organizational position, and age of the experts, their points are determined. Then, the points obtained by each expert are divided by the total points of all experts to calculate their final weight. Clemen and Winkler's linear survey method is used for expert consensus [25].

$$M_i = \sum W_i A_i j \ (i = 1، 2، 3، \ldots ، m) \quad (1)$$

where W_i is the weight of experts, A_i is the expert's number with W_i Weight, j is the linguistic term of the expert's opinion and M_i is the consensus of experts' opinion.

The experts' opinion was ascertained by utilizing five expressions ranging from "no effect" to "very high effect," which correspond to the linguistic variables listed in Table 3, whose equivalent fuzzy numbers l_{ij}، m_{ij}، u_{ij} are also given in the last column of the table.

Table 2) Determining weighted average indicators.

Indicators	Ranking	Points
Organizational position	CEO	4
	Head/supervisor	3
	the expert	2
	officer	1
Experience(year)	>30	4
	20-30	3
	10-20	2
	5-10	1
level of education	PhD	5
	Master	4
	Bachelor	3
	associate	2
	Diploma	1
Age(year)	>50	4
	40-50	3
	30-40	2
	<30	1

Table 3) Linguistic scale for pairwise comparisons

Linguistic scale	Definitive equivalent	Fuzzy equivalent
No effect	0	(1,1,1)
Low effect	1	(2,3,4)
Avg effect	2	(4,5,6)
High effect	3	(6,7,8)
Very high effect	4	(8,9,9)

Questionnaires are provided to compare the effective factors in pairs, from the effect of the row factor (i) to the column factor (j), to assess the relationship between risk factors affecting musculoskeletal disorders related to work. Expert opinion suggests that the following fuzzy direct correlation matrix $\tilde{A}$ is produced:

$$\tilde{A} = [\tilde{x}_{ij}]_{n\times n} \quad (2)$$

If there are n experts and $\tilde{x}_{ij}$ represents each row of the fuzzy direct matrix, $\tilde{x}_{ij}$ is calculated as follows:

$$\tilde{x}_{ij} = \left(\frac{\sum l_{ij}}{n}، \frac{\sum m_{ij}}{n}، \frac{\sum u_{ij}}{n}\right) \quad (3)$$

Equation 4 was used to calculate the inconsistency rate, which was then used to assess the reliability of the samples.

$$\text{Inconsistency rate } (\%) = \frac{1}{n(n-1)} \sum_{i=1}^{n} \sum_{j=1}^{n} \left| \frac{t_{ij}^{n} - t_{ij}^{n-1}}{t_{ij}^{n}} \right| \times 100\% \quad (4)$$

In this case, n was the number of samples, t_{ij}^{n} was the average effect of criterion i on criterion j. less than 5% is the recommended reliability for the inconsistency rate.

To normalize the values, $\sum u_{ij}$ of each row must be calculated and the fuzzy normal matrix $\tilde{N}$ is obtained:

$$k = \left(\sum_{j=1}^{n} u_{ij}\right) \quad (5)$$

$$\tilde{N} = \frac{1}{k} \times \tilde{X} \quad (6)$$

$$\tilde{N} = [\tilde{e}_{ij}]_{n\times n} \quad (7)$$

$$\tilde{e}_{ij} = \left(e_{ij}^{l}، e_{ij}^{m}، e_{ij}^{u}\right) \quad (8)$$

An n×n identity matrix was first created, and then its inverse was obtained. The resultant matrix was then multiplied by the normal matrix. This fuzzy number has all of its roots in equations 9–12.

$$\tilde{T} = [\tilde{t}_{ij}]_{n\times n}, \tilde{t}_{ij} = (t_{ij}^{l}، t_{ij}^{m}، t_{ij}^{u}) \quad (9)$$

$$T^{l} = N^{L} \times \left(I - N^{l}\right)^{-1} \quad (10)$$

$$T^{m} = N^{m} \times (I - N^{m})^{-1} \quad (11)$$

$$T^{u} = N^{u} \times (I - N^{u})^{-1} \quad (12)$$

In this step, according to equation 13, the fuzzy numbers were defused. $\tilde{T} = [\tilde{t}_{ij}]_{n\times n}$ and in the complete correlation matrix with definite

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numbers $T = [t_{ij}]_{n\times n}$ are entered.

$$B = \frac{l_{ij}^t + 2 \times m_{ij}^t + u_{ij}^t}{4} \quad (13)$$

B was the defused triangular fuzzy number. $\tilde{t}_{ij} = (l_{ij}^t, m_{ij}^t, u_{ij}^t)$ of the matrix $\tilde{T}$.

Using equations 14-15, the sum of the $\tilde{T}$ The matrix's rows and columns are obtained.

$$\tilde{D} = (\tilde{D}_i)_{n\times 1} = \left[\sum_{j=1}^{n} \tilde{T}_{ij}\right]_{n\times 1} \quad (14)$$

$$\tilde{R} = (\tilde{R}_i)_{n\times 1} = \left[\sum_{i=1}^{n} \tilde{T}_{ij}\right]_{1\times n} \quad (15)$$

Where $\tilde{R}$ and $\tilde{D}$ are $1 \times n$ and $n \times 1$ matrices, respectively.

Here, the relationship between indicators $\tilde{D} - \tilde{R}$ and the degree of significance of indicators $\tilde{D} + \tilde{R}$ were drawn, which formed the basis for decision-making. If $\tilde{D} - \tilde{R} > 0$, the corresponding criterion is cause, and if $\tilde{D} - \tilde{R} < 0$, the corresponding criterion was adequate.

According to equations 16 and 17, causal relationships whose complete correlation values are lower than the average of the whole matrix are not considered.

$$TS = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} V_{ij}}{m \times n} \quad (16)$$

$$U_{ij} = \begin{cases} V_{ij} & V_{ij} \geq TS \\ 0 & \text{Others} \end{cases} \quad (17)$$

After establishing the cause-effect relationships, we confirmed the fuzzy model. We compared the table of average opinions of all experts with the average opinions of experts, except for one expert (who was removed in order). In the new matrix, we created a new matrix using the ABS (E1-E2)/E1 formula and validated it by calculating the sum of all the matrices divided by the number of rows times the number of columns (using the formula). Finally, we took the average of the obtained numbers for each expert. The obtained value should be less than 5%.

Findings

Ten experts answered Fuzzy DEMATEL's questionnaire. The weight of experts was based on Table 4.

According to Table 5, the age factor (D-R=2.26) has a greater influence on musculoskeletal disorders (is the most causal). Based on the classification, the job satisfaction factor, compared to other identified risk factors, is the most influential factor (D-R=-2.26).

Based on D+R values, the risk factors were ranked. Table 6 shows the ranking of factors based on D+R.

The most crucial risk factor, according to the results of Table 6, was the duration of work (D+R=7.46), and the least important is related to the genetic risk factor (D+R=2.64). In the next step, we validated the fuzzy model. Table 7 shows the validation results.

Table 4) The expert's weight

Experts	Points earned	Points earned/Total points
1	8	0.086021505
2	9	0.096774194
3	9	0.096774194
4	11	0.11827957
5	7	0.075268817
6	10	0.107526882
7	9	0.096774194
8	12	0.129032258
9	9	0.096774194
10	9	0.096774194

Table 5) Risk factors were classified from cause to effect.

Risk factors	D-R
Age	2.26
Low budget	2.26
Up-to-date rules and guidelines	2.01
Gender	1.67
Genetic factors	1.60
Type and nature of work	1.44
Standard material quality	1.14
Lighting	0.70
Environmental factors (noise, vibration, ventilation, thermal, and cold stresses)	0.68
Level of Education	0.53
Air pollutants	0.51
Individual characteristics (height, weight, physical fitness, body mass index)	0.47
Material waste control	0.43
risk management	0.40
Education	0.34
The amount of work experience	0.28
Standard and adequacy of equipment	0.21
Using up-to-date and safe methods	0.14
Workstation design	0.09
Weakness in work and organizational communication	0.03
repeated work	0.01
Design of tools and equipment	-0.08
The level of experience and knowledge of the person	-0.08
Socio-economic status of people	-0.17
Having a history of musculoskeletal diseases	-0.31
Periodic visits	-0.37
Factors outside the work environment (exercise, smoking, having other jobs)	-0.37
Violence and pressure in the workplace	-0.37
Techniques and methods of doing work	-0.38
work intensity	-0.41
Character	-0.59
The degree of mastery of the work and the skill and competence of the person	-0.60
Working while injured	-0.62
Supervision	-0.63
Improper use of equipment/use of equipment inappropriate to the job	-0.65
Duration of work	-0.77
Work-rest period	-0.78
Increasing work pressure (for example, for more production)	-0.78
Underlying disease/drug use	-0.89
Working in unsafe conditions	-0.92
Working posture	-0.95
Distraction/stress/overconfidence	-1.12
Personal and mental health	-1.21
Prevention, treatment, and health care program	-1.33
Ignoring safety rules and principles	-1.62
Job satisfaction	-2.26

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Table 6) Ranking of risk factors based on their degree of importance.

Duration of work	7.46
work intensity	7.26
Work posture	7.24
Increasing work pressure (for example, for more production)	7.16
The degree of mastery of the work and the skill and competence of the person	7.11
Techniques and methods of doing work	7.02
Improper use of equipment/use of equipment inappropriate to the job	6.74
Ignoring safety rules and principles	6.68
Work-rest period	6.68
Distraction/stress/overconfidence	6.63
Air pollutants	6.55
Design of tools and equipment	6.44
Workstation design	6.44
Personal and mental health	6.43
Working in unsafe conditions	6.38
Violence and pressure in the workplace	6.31
repeated work	6.30
Lighting	6.27
Work while injured	6.27
Program planning, treatment, and health care	6.22
Job satisfaction	6.19
Using up-to-date methods and faith	6.18
Standard and adequacy of equipment	6.13
Having musculoskeletal diseases	6.08
Education	5.97
The level of experience and knowledge of the person	5.94
Supervision	5.87
Type and nature of work	5.61
risk management	5.51
Background disease/drug use	5.50
Material waste control	5.38
Periodic visits	5.32
Character	5.27
Weakness in work and organizational communication	4.85
Standard material quality	4.70
Socio-economic status of people	4.59
Up-to-date rules and guidelines	4.46
Factors outside the work environment (exercise, smoking, having other jobs)	4.46
The amount of work in the report	4.36
Low budget	4.28
Individual characteristics (height, weight, body proportion, body mass index)	3.71
Environmental factors (noise, vibration, ventilation, thermal, and cold stresses)	3.52
Age	3.31
Level of Education	2.81
Gender	2.73
Genetic factors	2.64

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Table 7) Validation of the fuzzy model

1	0.016
2	0.005
3	0.005
4	0.020
5	0.027
6	0.009
7	0.005
8	0.033
9	0.007
10	0.007
Average	0.014
Average(%)	1.358

As shown in Table 7, the final validation rate was less than 5%, specifically 1.36%.

Discussion

The results of this study indicate the relationship between several risk factors that can cause Work-related Musculoskeletal Disorders. To put the decision maker in a better position to understand the relationships, a large number of complex factors are divided into causal groups. This question helps to understand better the position of the participants and their role in the process of mutual influence. In this study, 46 occupational risk factors related to musculoskeletal disorders in the food sector were selected from relevant articles and classified using the 4 M method. The fuzzy DEMATEL study is designed and delivered to experts. Finally, these risk factors were evaluated using the Fuzzy DEMATEL method. The DEMATEL method enables us to plan more effectively and solve problems more efficiently. In this way, to better understand cause-effect relationships, it can be divided into several criteria to form cause-effect groups, thereby building a correlation map. According to the results, the age factor has a greater influence compared to other identified risk factors (is the most causal), and the job satisfaction factor, compared to other identified risk factors, is the most influential. According to the results, the most critical risk factor is the duration of work, and the least important is the genetic risk factor. Ariyanto et al. conducted a study to determine the control of musculoskeletal disorders in the food industry. They concluded the following factors have been linked to the MSDs in workers in food processing: manual load handling, age, gender, work stress, excessive weight in the workplace, smoking habits, and alcohol consumption. Work management, ergonomics training, workplace modifications, enhanced occupational health services (including routine examinations), and adjustments to manual handling loads are all essential components of MSD control in the food industry [1].

Milhem et al. conducted a study to examine the current knowledge about the prevalence of WMSDs among physical therapists, the factors that contribute to their risk, and the ways they can be prevented. They concluded that low back pain among therapists is related to their jobs and is not possible to avoid work-related injuries with skills and knowledge of proper body mechanics. Physical therapists should utilize mechanical aids during patient transfers, and they should devise fresh approaches to lower their WMSDs without sacrificing the standard of care [5]. In a descriptive-analytical study based on simple random sampling, Bolghanabadi et al. concluded that a significant correlation was found between musculoskeletal symptoms and BMI, work experience, average number of hours worked per day, and fatigue [14].

Mazloumi et al. conducted a study in Iran from 2000 to 2015, aiming to investigate the risk factors associated with musculoskeletal disorders among the working population. The greatest rating was given to employees in industrial, administrative, service, and agricultural environments for perceived discomfort in the lower back. Additionally, every risk factor identified was categorized into eleven categories, including biomechanical, tools and equipment, organizational aspects, time aspects of work design, work content, social, financial, and economic issues, training, and individual specifications [29].

Samira Ansari et al. looked into the prevalence of musculoskeletal disorders and related risk factors among students at Qazvin University. They concluded that effective risk factors for the students' musculoskeletal disorders included age, weight, occupation, education

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level, marital status, physical activity, and stress [30].

An overview of ergonomics and musculoskeletal disorders was conducted by Buckle et al. It is mentioned that the first step in primary prevention is to understand the causes, particularly those related to the workplace. This collection of in-depth reviews considers the issue from multiple perspectives and system requirements. It is crucial to evaluate how exposed employees are to recognize risk factors, and suitable techniques are examined. Analogously, an examination of psychosocial elements believed to have an indirect role in the issue has also been conducted. The final review examines how ergonomic knowledge can be applied to understand musculoskeletal disorders in individuals who use computers [31].

Conclusion

Since musculoskeletal disorders are among the most prevalent work-related health issues, it is essential to identify the risk factors that contribute to this condition across various industries. To investigate the risk factors affecting the occurrence of musculoskeletal disorders related to work, several studies have been conducted; however, no study has identified all risk factors or classified them based on causality and importance. All risk factors were identified and ranked in this study. Therefore, it facilitates planning, design, as well as maintenance and prevention in the work environment.

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