ISSN: 2476-5279; International Journal of Musculoskeletal Pain Prevention. 2025;10(1): 1149-.1158.

Tarbiat Modares University

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

ARTICLEINFO

Article Type
Original Article

Authors

Aida Naghshbandi[1],, MSc candidate
Omran Ahmadi[1], PhD

How to cite this article

Naghshbandi A, Ahmadi O, Determining the cause-effect relationship between risk factors affecting work-related musculoskeletal disorders (WMSDs) using the Fuzzy DEMATEL method. IJMPP. 2025; 10(1): 1149-1158.

[1] Occupational Health and Safety Engineering, Faculty of Medical Sciences, Tharbiat Modares University, Tehran, Iran

* *Correspondence*
Occupational Health and Safety Engineering, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran
P. O. Box: 14115-331
Tel: 0098 21 82884504
Fax: 0098 21 82884555
E-mail: O.ahmadi@modares.ac.ir

Article History
Received: Jan 21, 2025
Accepted: Mar 4, 2025
ePublished: Mar 20, 2025

ABSTRACT

Aims: One of the major global occupational diseases and injuries is musculoskeletal disorders, which lead to increased costs and reduced working productivity. It is essential to assess the risk factors that influence the development of these diseases. The purpose of this study was to determine the relationship between risk factors affecting 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 related articles and classified according to the 4m 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 other identified risk factors (is the most causal), and the job satisfaction factor compared to other identified risk factors, is the most influential factor (D-R=-2.26). According to the results, the most important risk factor is the duration of work (D+R=7.46) and the least important is related to the genetic risk factor (D+R=2.64).

Conclusion: The DEMATEL method allows us to plan better and solve problems. In this way, to better understand cause-effect relationships, it can be divided several criteria into cause-effect groups to build a correlation map.

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

Introduction

One of the most important 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 As Musculoskeletal Disorders related (MSDs) to the job, may arise in the food manufacturing industry [2]. The role of working conditions, which are associated with various etiologies, is widely known to have a significant effect on the onset and persistence of these diseases [3] Every year in the world, due to work-related diseases, 2.78 million people die. 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, which results 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 illnesses 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 appraised the total economic cost of WMSDs to be roughly $50 billion a 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 have high direct costs associated with diagnosis and treatment, as well as higher indirect costs associated with skilled workers' absence 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 like heavy lifting, carrying, tugging, and pushing, their level of fatigue rises, increasing 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 improve decision-making in fuzzy environments, fuzzy logic must be added to the DEMATEL method [15]. Even though traditional quantification techniques offer precise answers, the complexity resulting from human factors renders them unhelpful 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-known and frequently applied multi-criteria decision-making (MCDM) technique that is used to visualize the cause-and-effect relationship among various factors and analyze their interrelationships [17]. The fuzzy DEMATEL method is one of the multicriteria methods used to make decisions in these processes [18]. DEMATEL was initially applied to resolve intricate social events, based on graph theory and matrix to build structural models by way of analysis to study the causal relationships between adjectives of intricate events and identify essential attributes for better analysis of events [19]. DEMATEL can be used to identify important factors, as well as to compute the weights and ranks of various factors [20]. The DEMATEL method has the advantage of not requiring a lot of data and can be used to reveal the relationship 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 biggest effects on the system—are essential to its success [22]. Control systems, e-learning evaluation, strategy or policy analysis, measurement and evaluation, hospital service quality, decision-making, and sustainable supply chain management are just a few of the complex problems that the DEMATEL technique is frequently used to solve [23].

The main 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 find out their relationship with the cause-effect relationship.

Method and Matrials

Risk factors affecting musculoskeletal diseases in the food industry were extracted from articles related to the topic. Based on the 4m method, 46 risk factors were classified into 4 categories: man, machine, method, 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 4m 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, and then the points obtained by them are divided by the total points of the experts to get their final weight. Clemen and Winkler's linear survey method is used for expert consensus [25].

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

where W_i is the weight of experts, A_i is the expert's number with W_i Weight, j is the linguistic terms 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:

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

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

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

Equation 4 was used to compute the inconsistency rate, which was used to determine the samples' reliability.

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

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

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

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

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

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

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

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

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

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 the basis for decision was making. If $\tilde{D} - \tilde{R} > 0$, the corresponding criterion is cause, and if $\tilde{D} - \tilde{R} < 0$, the corresponding criterion was effective.

According to equations 16 and 17, causal relationships whose complete correlation values are lower than the average of the complete 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 the cause-effect relationships were established, 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 (experts are removed in order). In the new matrix, we created a new matrix using the ABS (E1-E2)/E1 formula and validate the new matrix using the sum of all the matrices/ number of rows*column) formula. Finally, we took the average of the obtained numbers for each expert. The obtained value should be less than 5%.

Findings

10 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 important 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
Technique and method 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 and treatment and health care program	-1.33
Ignoring safety rules and principles	-1.62
Job satisfaction	-2.26

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
Technique and method 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 and 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 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

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 can be seen in Table 7, the final validation number was less than 5%, i.e. 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 better understand 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 related articles and classified according to the 4m 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 allows us to plan better and solve problems. In this way, to better understand cause-effect relationships, it can be divided several criteria into cause-effect groups to build 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 factor. According to the results, the most important risk factor is the duration of work and the least important is related to 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, and work stress, excessive weight in the workplace, smoking habits, and alcohol consumption. Work management, ergonomics training, workplace modifications, enhanced services of occupational health (including routine examinations), and adjustments of manual handling load are all important components of MSD control in the food industry [1].

Milhem et al. conducted a study to examine the current knowledge about how common WMSDs are among physical therapists, the factors that contribute to their risk, and the ways they can be prevented. They concluded low back pain of therapists is related to their jobs and is not possible to prevent 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 there has been a significant correlation 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 during the years 2000 to 2015 intending to investigate the risk factors of musculoskeletal disorders related to work in the working society. 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 that was found was divided into eleven categories, which included biomechanical, tools, 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 musculoskeletal disorder's prevalence and related risk factors among students at Qazvin University. They concluded effective risk factors on the students' musculoskeletal disorders included age, weight, job, education level, marital status, exercise, and stress [30].

An overview of ergonomics and musculoskeletal disorders was conducted by Buckle et al.. It is mentioned the first step in primary prevention still understands their causes, particularly those that are related to the workplace. This collection of in-depth reviews takes into account the issue from several 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 ergonomics knowledge can be applied to comprehend musculoskeletal disorders in computer-using individuals [31].

Conclusion

Since one of the important work-related diseases is musculoskeletal disorders, it is necessary to know which risk factors cause this disease in different industries. To investigate the risk factors affecting the occurrence of musculoskeletal disorders related to the work, several studies have been carried out; But, no study has identified all risk factors or classified risk factors based on causality and importance. All risk factors were identified and ranked in this study. Therefore, it facilitates planning and design as well as maintenance and prevention in the work environment.

Acknowledgments: The authors consider it necessary to appreciate and thank all the participants.

Authors' Contribution: AN conducted all stages of the study and wrote the first draft of the manuscript. OA designed and supervised the study and confirmed the manuscript.

Conflict of Interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethical Permission: In this study, all ethical principles were considered.

Funding: This research did not receive any grant from funding agencies

References

1. Ariyanto J, Palutturi S, Russeng SS, Birawida AB, Warsinggih W, Rosyanti L. Control of the risk of musculoskeletal disorders in the food industry: Systematic review. Annals of the Romanian Society for Cell Biology. 2021;25(1):4254-61.
2. Fazi HM, Mohamed NM, Ab Rashid MF, Rose AN. Ergonomics study for workers at food production industry. InMATEC Web of Conferences 2017 ;90: 01003. doi:10.1051/matecconf/20179001003
3. Direksunthorn T, Polpanadham P, Summart U, Mahem K, Kempanya P, A'la MZ, et al. Association of electronic learning devices and online learning properties with work-related musculoskeletal disorders (WMSDs): A cross-sectional study among Thai undergraduate students. PLoS One. 2023;18(10):e0291597. doi: 10.1371/journal.pone.0291597.
4. Haftu D, Kerebih H, Terfe A. Prevalence of work-related musculoskeletal disorders and its associated factors among traditional cloth weavers in Chencha district, Gamo zone, Ethiopia, an ergonomic study. PLoS One. 2023 9;18(11):e0293542. doi: 10.1371/journal.pone .0293542. PMID: 37943828; PMCID: PMC10635530.
5. Milhem, M., Kalichman, L., Ezra, D., & Alperovitch-Najenson, D. Work-related musculoskeletal disorders among physical therapists: A comprehensive narrative review. Int. J. Occup. Med. Environ. Healt 2016;29(5), 735-747.
6. van de Wijdeven, B., Visser, B., Daams, J. et al. A first step towards a framework for interventions for individual working practice to prevent work-related musculoskeletal disorders: a scoping review. BMC Musculoskelet Disord 2023; 24(87) ' https://doi.org/10.1186/s12891-023-06155-w
7. Ding X, Guan Z, Liu N, Bi M, Ji F, Wang H, et al. Prevalence and risk factors of work-related musculoskeletal disorders among emerging manufacturing workers in Beijing, China. Front Med (Lausanne). 2023 12;10. doi: 10.3389/fmed.2023.1289046.
8. Kee D. Characteristics of Work-Related Musculoskeletal Disorders in Korea. Int J Environ Res Public Health. 2023;20(2):1024. doi: 10.3390/ijerph20021024.
9. Munhall CC, Gudipudi R, Nguyen SA, Halstead LA. Work-related musculoskeletal disorders among otolaryngology-head and neck surgery residents. Am. J. Otolaryngol. 2024 ;45(1):104070.
10. Yang, F., Di, N., Guo, Ww. et al. The prevalence and risk factors of work related musculoskeletal disorders among electronics manufacturing workers: a cross-sectional analytical study in China. BMC Public Health 23, 10 (2023). https://doi.org/10.1186/s12889-022-14952-6
11. ntwi-Afari MF, Li H, Chan AHS, Seo J, Anwer S, Mi HY. A science mapping-based review of work-related musculoskeletal disorders among construction workers. J Safety Res. 2023; 85:114-

128. doi: 10.1016/j.jsr.2023.01.011.
12. Lind CM, Abtahi F, Forsman M. Wearable Motion Capture Devices for the Prevention of Work-Related Musculoskeletal Disorders in Ergonomics—An Overview of Current Applications, Challenges, and Future Opportunities. Sensors. 2023;23 (9):4259. doi: 10.3390/s23094259.
13. Huang K, Jia G, Wang Q, Cai Y, Zhong Z, Jiao Z. Spatial relationship-aware rapid entire body fuzzy assessment method for prevention of work-related musculoskeletal disorders. Appl. Ergon. 2024;115:104176.
14. Bolghanabadi, S., & Pour, M. The relationship between musculoskeletal disorders, stress and fatigue in the food industry employees. Iran J Ergon 2014; 2(1), 54-63.
15. Wu WW, Lee YT. Developing global managers' competencies using the fuzzy DEMATEL method. Expert Syst. Appl. 2007;32(2):499-507.
16. Seker S, Zavadskas EK. Application of fuzzy DEMATEL method for analyzing occupational risks on construction sites. Sustainability. 2017 ; 9(11):2083. doi: 10.3390/su9112083
17. Zhang ZX, Wang L, Wang YM, Martínez L. A novel alpha-level sets based fuzzy DEMATEL method considering experts' hesitant information. Expert Syst. Appl. 2023;213:118925. https://doi.org/10.1016/j.eswa.2022.118925
18. Çelik MT, Arslankaya S. Analysis of quality control criteria in an business with the fuzzy DEMATEL method: Glass business example. J. Eng. Res. 2023;11(2). doI: 10.1016/j.jer.2023.100039
19. Yan H, Yang Y, Lei X, Ye Q, Huang W, Gao C. Regret Theory and Fuzzy-DEMATEL-Based Model for Construction Program Manager Selection in China. Buildings. 2023; 13(4):838. doI: 10.3390/buildings13040838
20. Šmidovnik T, Grošelj P. Solution for Convergence Problem in DEMATEL Method: DEMATEL of Finite Sum of Influences 2023; 15(7):1357.doi: 10.3390/sym15071357
21. Chang B, Chang CW, Wu CH. Fuzzy DEMATEL method for developing supplier selection criteria. Expert Syst. Appl. 2011;38(3):1850-58.
22. Zhou Q, Huang W, Zhang Y. Identifying critical success factors in emergency management using a fuzzy DEMATEL method. Saf Sci. 2011;49(2):243-52.
23. Lin KP, Tseng ML, Pai PF. Sustainable supply chain management using approximate fuzzy DEMATEL method. Resour Conserv Recycl. 2018;128: 134-42.
24. Renjith VR, Madhu G, Nayagam VLG, Bhasi AB. (2010). Two-dimensional fuzzy fault tree analysis for chlorine release from a chlor-alkali industry using expert elicitation.JHM, 2010; 183(1-3):103-110.
25. Clemen RT., Winkler R. Combining probability distributions from experts in risk analysis. Risk analysis 1999; 19(2):187-203.
26. Bevan S. Economic impact of musculoskeletal disorders (MSDs) on work in Europe. Best Practice & Research Clinical Rheumatology. 2015;29(3):356-73.
27. Vargas C, Bilbeny N, Balmaceda C, Rodríguez MF, Zitko P, Rojas R, Eberhard ME, Ahumada M, Espinoza MA. Costs and consequences of chronic pain due to musculoskeletal disorders from a health system perspective in Chile. Pain Rep. 2018 10;3(5):e656. doi: 10.1097/ PR9.0000000000000656.
28. Yusuf M, Santiana M, Lokantara WD. Improvement of work posture to decrease musculoskeletal disorder and increase work productivity jewelry worker in bali. InProceedings 2018; 1(1):242-247.
29. Mazloumi A, Mehrdad, R, Kazemi Z, Vahedi Z, Hajizade L. Risk Factors of Work Related Musculoskeletal Disorders in Iranian Workers during 2000-2015. Saf Health Work, 11(3): 395-416.
30. Ansari, S, Rezapoor, M, Hematgar, MA, Ghazi, AS, Varmazyar, S. Musculoskeletal disorders and its related risk factors among students of Qazvin university of medical sciences. JHEHP 2017;2(3): 161-167.
31. Buckle, P. Ergonomics and musculoskeletal disorders: overview. Occup Med, 2005; 55(3): 164-167.