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Assessment of Occupational Hazards Faded by Healthcare Workers Using Multi-Criteria Decision-Making Methods

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ABSTRACT
Objective: This study aims to assess the impact of risk factors that healthcare workers are exposed to in their workplaces on occupational health and safety. **Materials and Methods:** Considering the importance of healthcare workers for society and humanity, the risks they face at work have been evaluated using Multi-Criteria Decision-Making (MCDM) methods, specifically the Entropy and AHP methods. The Entropy method is an objective evaluation method used to determine the importance levels of each criterion in MCDM methods. The AHP method involves both objective and subjective decisions to select the best option among multiple alternatives. The criteria and sub-criteria used in the study were prepared based on the opinions and suggestions of field experts and a literature review. Microsoft Excel was used for the analysis. **Results:** According to the analysis results of the AHP method, the criterion with the highest weight was psychological risks (C-5) with a value of 0.351542. The criterion with the lowest weight was physical risks (C-3) with a value of 0.1121. In contrast, the analysis results of the Entropy method indicated that the criterion with the highest wj value was physical risks (C-3) with a value of 0.273, while the criterion with the lowest weight was biological risks (C-1) with a value of 0.152. **Conclusion:** The most significant risk factors for healthcare workers in workplaces, as identified by the AHP method, were psychological risks, while the Entropy method identified physical risks as the most significant.
Keywords: AHP Method, Entropy Method, Health Sector, Occupational Health and Safety.

Sağlık Çalışanlarının İş Yerlerinde Maruz Kaldıkları Risklerin Çok Kriterli Karar Verme Yöntemleri ile Değerlendirilmesi

ÖZ
Amaç: Bu çalışma, sağlık çalışanlarının iş yerlerinde maruz kaldıkları risk unsurlarının iş sağlığına ve güvenliğine olan etkisini değerlendirmek amacıyla yapılmıştır. **Gereç ve Yöntem**: Sağlık çalışanlarının toplum ve insanlık için öneminden yola çıkılarak işyerinde maruz kaldıkları riskler Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden Entropi ve AHP yöntemleri ile değerlendirilmiştir. Entropi yöntemi, ÇKKV yöntemlerinde her bir kriterin önem düzeylerinin belirlendiği objektif bir değerlendirme yöntemidir. AHP yöntemi, birden çok alternatif arasından en iyisini seçmek için kullanılan nesnel ve öznel kararları içeren bir yöntemdir. Çalışmada kullanılan ölçüt ve alt ölçütler, alanında uzman kişilerin görüş ve önerileri ile literatür taraması dikkate alınarak hazırlanmıştır. Analizlerin çözümünde Microsoft Excel kullanılmıştır. **Bulgular:** AHP yönteminin analiz sonucuna göre en yüksek ağırlığa sahip kriter, 0,351542 değeri ile C-5 psikolojik riskler olmuştur. En düşük ağırlığa sahip kriter 0,1121 değeri ile C-3 fiziksel risk kriteri olmuştur. Entropi yönteminin analiz sonucuna göre wj değeri en yüksek olan kriter 0,273 değeri ile C-3 fiziksel riskler olmuştur. En düşük ağırlığa sahip kriter ise 0,152 değeri C-1 ile biyolojik riskler olmuştur. **Sonuç:** İş yerlerinde sağlık çalışanları için en önemli risk unsurları (AHP yöntemi) psikolojik riskler ve (Entropy yöntemi) fiziksel riskler olmuştur.
Anahtar Kelimeler: AHP Metodu, Entropi Metodu, Sağlık Sektörü, İş Sağlığı ve Güvenliği.

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INTRODUCTION

The main purpose of those working in the health sector is to provide quality health services to the society. However, most of the time, health workers, as in other sectors, may be exposed to various occupational risks and work accidents while performing this service (Meydanlioglu, 2013). Covering protection, rehabilitation and treatment services, this service class addresses a wide range of work areas. The health sector has been evaluated within the scope of dangerous and very dangerous class according to the Workplace Hazard Classes Communiqué on Occupational Health and Safety. Providing a safe, high quality and effective health service can only be achieved by giving sufficient importance to and improving the working conditions, working environments and work safety of health workers. Some regulations have been made in this field at the national and international level. For example, the details regarding occupational health and safety, which were previously included in the Labor Law No. 4856, have been included in the Occupational Health and Safety Law No. 6331 and its scope has been expanded. Accordingly, all provisions employed in public or private workplaces based on their status, including 657 civil servants, are included for the first time, all public institutions and organizations/workplaces, unlike the previous laws. This regulation also imposes some duties and responsibilities on the employer and employee (Gurer & Gemlik, 2020; Law on Occupational Health and Safety, 2012; Workplace Hazard Class Notification on Occupational Health and Safety, 2012). Joint Commission International (JCI) has not only addressed patient safety but also highlighted issues related to employee safety, ensuring the occupational safety of healthcare workers through various initiatives (Workplace Hazard Class Notification on Occupational Health and Safety, 2011). In the health sector, there are various risks such as physical, ergonomic, biological, chemical, and psychosocial. The negative effects of these risks include diseases such as hepatitis C, tuberculosis, hepatitis B and AIDS. Radiation, penetrating-cutting materials, anesthetic gases, carcinogenic agents, etc. factors can cause serious inconveniences to employees. Musculoskeletal disorders may occur due to non-ergonomic working conditions. Finally, shift work system, intense work tempo and exposure to violence can cause serious psychosocial problems for health workers (Caruso, 2014; Saygun, 2017). The most important occupational disease and cause of death of healthcare workers is infection. This situation arises as a result of both the working environment and the contact with the infected materials of the patients. Although its negative effects can be prevented by vaccination, it is of great importance to make the necessary risk assessment in this context (Meydanlioglu, 2013). NIOSH stated that there are 25 types of chemical, 29 types of physical, 6 types of ergonomic, 24 types of biological, and 10 types of psychosocial hazards and risks in hospitals. The provision of safe, efficient and qualified health services depends on the performance and capacity of health workers. This is an important issue that needs to be emphasized as it will only be provided by a healthy and safe working environment for healthcare professionals (Ozkan & Emiroglu, 2006). This situation has gained even more importance with the declaration of the World Health Organization (WHO) as a Covid-19 pandemic on 12 March 2020, which emerged at the end of 2019 (https://www.who.int/). Mass closures and curfews have been declared around the world, and healthcare workers have been at the forefront of the fight against the pandemic. This study addresses the employees working in the health sector and the risks caused by sector-specific hazards. There are many studies in the literature on the health sector. However, no study was found in which AHP and ENTROPY methods were used together. The AHP method is one of the MCDM methods used to select the best one among multiple alternatives. The ease of making group decisions and the ability to handle inconsistency makes the AHP method more advantageous than many other MCDM methods (VIKOR, PROMETREE, TOPSIS, etc.). ENTROPY is a method in which criterion weights are determined in an objective manner (Kucukonder & Demirarslan, 2017; Kocoglu, 2019). The criteria and sub-criteria used in the study were developed as a result of the opinions and suggestions of experts in the field and literature research. In this study, methods that include the objective-subjective decisions of the participants, such as AHP-ENTROPI, were used, unlike the classical risk assessment or checklist applications. In this way, it is expected that the study will contribute significantly to the literature. In the literature research, Liu (2010) used the AHP method to measure digital capital for the hospital service website (Liu, 2010). Karagiannidis et al. (2010) they evaluated the alternatives for the heat treatment process of infectious wastes in hospitals with AHP methods (Karagiannidis et al., 2010). Tsai et al. (2010) used the AHP method to propose a model for evaluating hospital organizational performance (Tsai et al., 2010). Tuzuner & Ozaslan (2011) conducted a study on the evaluation of occupational health and safety in hospitals. With the study, they tried to determine the safety climate perceptions of hospital employees (Tuzuner & Ozaslan, 2010). Agac & Baki (2016) investigated the use of multi-criteria decision-making methods in the field of health. As a result of the study, they determined that the AHP method is the most used method, and the ANP method is the most preferred integrated method (Agac & Baki, 2016). Solmaz and Solmaz (2017) researched the issue of occupational health and safety in hospitals (Solmaz & Solmaz, 2017). Gurer (2018) conducted a study on employee safety in healthcare services. The research emphasized the importance of ensuring the safety of healthcare professionals and discussed the risks they may encounter as well as the preventive measures that can be taken to mitigate these risks (Gurer, 2018).

MATERIAL AND METHODS

The term entropy was first proposed by Rudolf Clausius in 1865. It is known as a criterion of dispersion and disorder in thermodynamics. It has become information entropy by finding a different usage area by Sahnnon. Accordingly, entropy is stated as a measure of uncertainty about random variables (Zhang et al., 2011). The entropy method is the calculation of uncertainty. (Altan et al., 2021). This term was developed by Lee and Wang for the purpose of measuring weight. If the data of the decision matrices are known, the weights can be calculated objectively (Konuşkan & Uygun, 2014). Entropy method is one of the most preferred methods in the literature in terms of including objective decisions (Kucukonder & Demirarslan, 2017). For this reason, the entropy method was preferred. AHP is a mathematical theory used for decision making and measurement developed by Thomas L. Saaty in the 1970s (Saaty & Niemira, 2006). The AHP method is a frequently preferred method in the literature and has been used in almost many studies on multi-criteria decision making in recent years (Ho, 2008). The most important reason for this is thought to be easier to understand by decision makers (Supciller & Capraz, 2011). The fact that AHP includes objective and subjective decisions to choose the best one among multiple alternatives in decision making problems makes this method more advantageous than other decision making methods. The AHP method was preferred due to the ease and clarity of its analysis. The criteria and sub-criteria used in the study were determined based on verbal opinions and suggestions gathered from experts working in three different institutions. Additionally, a literature review was conducted to further support the study (Bulut et al., 2020; Workplace Hazard Class Notification on Occupational Health and Safety, 2011; Meydanlıoglu, 2013; Solmaz & Solmaz, 2017; Aydın Yuksekdag, 2019; Tuzuner & Özaslan, 2010). Consent was obtained from each participation in the study. In this context, the main criteria for the risks that health workers are exposed to were determined as follows: biological risks (such as viral and bacterial infections), chemical risks (including disinfectants, nanomaterials, and anesthetic agents), physical risks (such as thermal discomfort and ionizing radiation), ergonomic risks (such as patient lifting and maintaining fixed positions), and psychological risks (such as exposure to violence, shift work, and stress).The healthcare industry is one of the most dangerous business lines. It is an extremely important business line for the society to maintain a healthy life. Especially in the Covid-19 process, this situation has been felt much more deeply and many academic studies have been carried out for the health sector and its employees. In this study, it is aimed to prioritize the risks faced by healthcare professionals apart from classical studies. Two different analysis methods were used in the study, emergency service personnel (4 people), emergency medical technicians (2 people), other health personnel (3 people), radiology (1 person), paramedics (1 person), nurses (2 people) and workplace physicians (2 people). The selection of participants for the study was carefully made to include individuals who had received occupational health and safety training from universities, public institutions, and private organizations. The results of the analysis were compared within the framework of the literature and recommendations were made for a more sustainable occupational safety of the health sector and its employees.

Entropy method

The following steps are followed in solving the entropy method (Karaatlı, 2016).

Step 1: The pij in equation 1 is calculated by normalizing to eliminate the outliers in different measurement units.

$$p_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}}; \forall j \quad (1)$$

Step 2: The entropy of Ej seen in Equation 2 is calculated.

$$E_j = \frac{-1}{\ln(m)} \sum_{i=1}^{m} [Pij ln Pij]; \forall j \quad (2)$$

Step 3: The dj uncertainty in equation 3 is calculated as the degree of diversity.

$$dj = 1 - Ej\ ; \forall j \quad (3)$$

Step 4: The wj weights are calculated as the degree of importance of the j criterion in Equation 4.

$$Wj = \frac{d_j}{\sum_{j=1}^{n} d_j}; \forall j \quad (4)$$

Here aij j. For index i. the value of the alternative; Pij i. j for alternative. is the value scale of the index.

Analytic hierarchy process methods

The following steps are followed in the solution of the AHP method. After determining the problem, a hierarchical structure is created. A pairwise comparison matrix is created between the criteria. The purpose of the pairwise comparison is to determine the importance levels of the criteria. After this process, the comparison matrix is normalized and all priorities vector are calculated. The consistency index is calculated. At this point, the consistency index is divided by the random index. Thus, the consistency ratio is calculated. Finally, it is checked whether the consistency ratio is less than 0.1>. If the result is below this value, it is accepted that the importance levels of the criteria are consistent (Supçiller & Çapraz, 2011; Sacak et al., 2019).

Ethical consideration

Ethics Committee Approval Gumushane University Rectorate Scientific Research and Publication Ethics Board was obtained for this study on 29/08/2023 (Approval no: 2023/4).

Equation 1 is used to normalize the pairwise comparison matrix.

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

Equation 2 is used in all priorities vector calculation.

$$w_i = \left(\frac{1}{n}\right)\sum_{j=1}^{n} a'_{ij} \quad (2)$$

i,j= 1,2,3,….n

λ_{max} Equation (3) is used to calculate the value (Ozbek, 2017).

$$\lambda_{max} = \left(\frac{1}{n}\right)\sum_{i=1}^{n}\left(\frac{\sum_{j=1}^{n} a_{ij}.w_j}{w_i}\right) \quad (3)$$

Table 1 is taken into account in determining the random index.

Table 1. Random index (Guner, 2005).

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**
R1	0	0	0.58	0.90	1.12	1.24	1.32

Finally, equation 4 is used to calculate the consistency index (Ozbek, 2017).

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (4)$$

RESULTS

The steps followed in the study and the results obtained from the analysis are given below. The risks that healthcare workers are exposed to at work were evaluated by Entropy and AHP methods. In the analysis, a total of five main criteria and thirteen sub-criteria were formed; C-1-Biological Risks (pin sting, viral infection, Bacterial infection), C-2 Chemical Risks (Disinfectants, Nanomaterials, anesthetic agents), C-3 Physical Risks (thermal comfort, ionizing radiation), C-4 Ergonomic Risks (Patient lifting, fixed position) and C-5 Psychological Risks (exposure to violence, shift work, stress). In the first stage of the study, the Entropy method was used. Entropy method analysis results are as follows. In the solution of the analysis, the results were obtained by following the order specified in the method section. In Table 2, each criterion decision matrix was created. In Table 3, the normalized matrix was calculated. Entropy values for the criteria are calculated in Table 4. In Table 5, wj weights were calculated and each criterion was ranked according to the level of importance.

Table 2. Decision matrix.

	C-1	**C-2**	**C-3**	**C-4**	**C-5**
C-1	1	2.71	4.72	0.64	4.78
C-2	0.37	1	4.79	5.43	0.94
C-3	0.21	0.21	1	3.68	0.33
C-4	1.56	0.18	0.27	1	0.18
C-5	0.21	1.06	3.03	5.55	1
Total	3.35	5.16	13.81	16.3	7.23

Table 3. Normalized matrix.

	C-1	**C-2**	**C-3**	**C-4**	**C-5**
C-1	0.2985	0.5251	0.3417	0.0392	0.6611
C-2	0.0649	0.1314	0.2091	0.1699	0.0971
C-3	0.0394	0.0317	0.0552	0.1387	0.0377
C-4	0.3046	0.0281	0.0157	0.0437	0.0214
C-5	0.0589	0.1704	0.1799	0.2540	0.1215
Total	1	1	1	1	1

Table 4. Entropy values for the criteria.

	C-1	**C-2**	**C-3**	**C-4**	**C-5**
C-1	-0.3608	-0.3382	-0.3272	-0.1271	-0.2735
C-2	-0.1775	-0.2666	-0.1599	-0.3011	-0.2264
C-3	-0.1274	-0.1095	-0.0654	-0.274	-0.1237
C-4	-0.3621	-0.1004	-0.3086	-0.1369	-0.0822
C-5	-0.1669	-0.3015	0	-0.3480	-0.2561
Total	-1.1948	-1.1164	-0.8612	-1.1873	-0.9621

Table 5. Calculation of wj weights.

k=1ln(m)	0.62					
k=0.621						
ej=	0.74	0.69	0.53	0.73	0.59	
ed=	0.258	0.30	0.46	0.26	0.41	
	5(C1)	4(C2)	1(C3)	3(C4)	2(C5)	**Total**
wj=	0.152	0.18	0.27	0.15	0.24	1

In the second stage of the study, the AHP method was used. The analysis results of the AHP method are as follows. In solving the analysis, the steps specified in the methodology section were followed, and the results were obtained. In Table 6, the decision matrix for each criterion was created. Subsequently, the normalized matrix and priority vector calculations were performed. In Table 7, the λmax value and consistency index were calculated.

Table 6. Decision matrix.

	C-1	**C-2**	**C-3**	**C-4**	**C-5**
C-1	1	1.414	2.451	1.732	0.948
C-2	0.707	1	2.451	1	0.332
C-3	0.408	0.408	1	1.414	0.332
C-4	0.577	1	0.707	1	0.316
C-5	1.055	3.012	3.012	3.165	1
Total	3.747	6.834	9.621	8.311	2.928

Table 7. Consistency index calculation.

Total	**W**	**T/W**	**Average**	**Lamda Max.**
1.246	0.252	4.94	5.0966	**Consistency İndeks**
0.847	0.165	5.133		0.0242
0.565	0.111	5.09		**Rassal İndeks**
0.617	0.12	5.14		0.0242/RI
1.826	0.352	5.18		**0.1>0.0216**

DISCUSSION

The analysis results of Entropy and AHP methods used in the study are given in Table 8. Considering the results obtained from each analysis, the following conclusions were reached. As a result of the comparison made between the main criteria used in the entropy method, the criterion with the highest weight (wj) was C-3 (physical risk factors) with a value of 0.273. This was followed by C-5 (psychological), 0.154 C-4 (ergonomic factors), 0.180 C-2 (chemical risks), 0.152 C-5 (biological factors) with a value of 0.241, respectively. As a result of the entropy method, the risk with the highest level of importance that health workers are exposed to in the workplace was physical risks (thermal comfort and ionizing radiation). The following results were obtained from the analysis of the AHP method. According to the results of the comparison between the main criteria, the criterion with the highest weight was the C-5 criterion, namely psychological risks, with a value of 0.351542. This was followed by C-1 biological risks, C-2 chemical risks, 0.12041 C-4 ergonomic risks, and 0.111121 C-4 physical risks with a value of 0.252142, respectively. As a result of the comparison between the sub-criteria, the following results were obtained. As a result of the comparison made between the sub-criteria related to the C-1 main criterion, the sub-criterion with the highest weight was viral infection with 0.44093. This result was followed by 0.31826 needle sticks and 0.24081 bacterial infections, respectively. As a result of the comparison made between the sub-criteria related to the main criterion of C-2 chemical risks, the sub-criterion with the highest weight was 0.56555 aesthetic substances. This was followed by 0.24684 nanomaterials and 0.18763 disinfectants, respectively. As a result of the comparison made between the sub-criteria related to the C-3 main criterion, the following results were obtained. The highest sub-criteria was 0.55761 ionizing radiation. This result was followed by thermal comfort at 0.44240. In the comparison among the sub-criteria related to the main criterion C-4, the sub-criterion with the highest value was patient lifting at 0.22656, while the lowest sub-criterion was fixed positions at 0.16698. In the comparison of sub-criteria under the main criterion C-5, the highest weighted sub-criterion was stress at 0.51313. This was followed by shift work at 0.28712 and exposure to violence at 0.19974, respectively. As a result of the analysis using the entropy method, the criterion with the highest weight was C-3 physical criteria at 0.273, whereas the highest weighted criterion in the AHP method analysis was C-5 psychological factors at 0.351542. Considering the method and subject content, it is possible to find similar studies in the literature. For example, Yüksekdağ (2019) examined the situation of exposure to occupational risks in healthcare institutions using the AHP method. According to the analysis results among the criteria, the highest-weight criterion was physical risks at 0.231, followed by psychosocial risks at 0.216, chemical risks at 0.193, biological risks at 0.189, and ergonomic risks at 0.172 (Yüksekdağ, 2019). Gül et al. (2017), using fuzzy AHP and Fuzzy VIKOR methods, ranked the most significant hazards in hospitals as electricity, infection, fire, and other risks arising from emergencies (Gül et al., 2017).

The Importance of Psychological and Physical Risks: The high weight of psychological risks in the AHP analysis indicates the critical importance of healthcare workers' mental health. Stress management programs, counseling services, and psychosocial support systems can be recommended to support employees' psychological well-being.

Management of Physical Risks: The significance of physical risks identified through the entropy method (such as thermal comfort and ionizing radiation) is of vital importance. At this point, stricter safety standards and training programs can be implemented in the healthcare sector to reduce physical risks.

Table 8. Entropy and AHP method analysis data.

AHP Method				**Entropi Method**					
Criteria	**W**	**Sub-Criteria (S.C.)**	**S.C. W.**		**C-1**	**C-2**	**C-3**	**C-4**	**C-5**
		Needle stick	0.31826	Ranking of Importance	5	4	1	3	2
		Viral infection	**0.44093**	k=1ln(m)					
Biological Risks (C-1)	0.252142	Bacterial infection	0.24081	**k=0.621**					
		Disinfectants	0.18763	ej	0.742	0.693	0.535	0.737	0.59
		Nano materials	0.24684	ed	0.258	0.307	0.465	0.263	0.41
Chemical Risk (C-2)	0.164695	Anesthetic substances	**0.56555**	wj	0.152	0.180	0.273	0.154	0.241
		Thermal comfort	0.44240						
Physical Risks (C.-3)	0.11121	Ionizing radiation	**0.55761**						
		Patient lift	**0.22656**						
Ergonomic Risks (C-4)	0.12041	Fixed position	0.16698						
		Exposure to violence	0.19974						
		Shift work	0.28712						
Psychological Risks (C-5)	0.351542	Stress	**0.51313**						

CONCLUSION

Identifying existing and new risks in the health sector is of great importance for the sustainability of a healthy society. For this reason, the risks that health workers are exposed to in the workplace were evaluated with Entropy and AHP methods, taking into account both expert opinions and literature research. The study was carried out using methods that are thought to respond to people's needs other than traditional risk assessment-detection. For this reason, analysis methods that include objective and subjective decisions were preferred in the study. According to the results of the analysis using the AHP method, the criterion with the highest level of importance was psychological risks, while the criterion with the lowest level of importance was physical risks. As a result of the analysis using the entropy method, the wj value with the highest weight was the physical risk factors. When the results of the two analyzes were compared, it was seen that the significance levels were different. The main reason for this difference is thought to be due to the fact that the participants in the research consist of people with different job descriptions and their interest in different needs. Health sector is in the very dangerous class according to the Occupational Health and Safety Workplace Hazard Class Notification. In this respect, it is important for the sustainability of occupational health and safety of health workers. In particular, issues such as irregular working conditions of healthcare workers, mobbing, fear of being beaten, poor concentration, insomnia should be addressed comprehensively. Because the health sector and its employees to keep the possible risks at a minimum level is an important element for the development of societies and countries. For this reason, authorities should develop permanent solutions for these problems that the health sector and health workers are exposed to. Future researchers are encouraged to prioritize the study of risk factors affecting the psychological well-being of healthcare workers. This focus can help identify the most significant stressors in the healthcare environment and inform targeted interventions to improve mental health support for healthcare professionals. You can speed up data collection and analysis processes by utilizing digital platforms and technological tools, leading to the development of innovative solutions for the health of healthcare workers.

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Conflict of Interest
No conflict of interest has been declared by the author(s).

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Plan, design: OD; **Material, methods and data collection:** OD; **Data analysis and comments:** OD; **Writing and corrections:** OD.

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