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ORIGINAL ARTICLE

Road Accident Modeling by Fuzzy Logic based on Physical and Mental Health of Drivers

ALI KARIMI[1*], SAMIRA ESLAMIZAD[2], MARYAM MOSTAFAEE[1], MAHIN HAGHSHENAS[3], MAHDI MALAKOUTIKHAH[1]

[1]*Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran;*

[2]*Food Safety Research Center, Shahid-Beheshti University of Medical Sciences, Tehran, Iran;*

[3]*Occupational Health, Occupational and Environmental Health Administration office, Ministry of Health, Tehran, Iran.*

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ABSTRACT

Drivers are vulnerable to musculoskeletal and psychological disorders because of substantially harmful agents in this stressful occupation. This study aimed to investigate the influence of driver’s physical and psychological health on the risk of road accidents using fuzzy logic approach.

Two input variables including musculoskeletal disorders (MSDs) and mental health, alongside accident risk levels as output variables were fuzzed using a fuzzy inference system (FIS). Triangular and trapezoid membership functions were used to graphically define outputs related to low, moderate, high and very high, in fuzzy sets. A Mamdani-type FIS was applied to represent all the rules in the IF-THEN format and the patterns of linguistic variables were designed using AND, OR and NOT operators.

There was significant relationship between MSDs and psychological health with road accidents involving drivers of heavy vehicles ($P<0.05$). Besides, surface graphs illustrated the relationship between MSDs, psychological health and accident risks. FIS as a novel approach was used for predication of accident risk levels involving drivers of heavy vehicles based on health factors.

Physical and psychological health can influence the safe operation of heavy vehicle drivers. The fuzzy inference system provided a method that is advantageous and with promising results for modeling of road accident risk levels on the basis of driver’s physical and mental health.

KEYWORDS: *Physical and psychological health, Heavy vehicle drivers, Road accidents, Fuzzy inference system*

INTRODUCTION

Nowadays, industrialization, rapid population growth, civilization and immigration are the world's biggest problems. These basic changes will result in excessive stress and psychosocial problems and a bloom in epidemiology of diseases as well as human health demands. Mental diseases will be the most important concerns because of their role in causing early death and disorders all around the world. High rates of their prevalence, as well as long-term chronic disabilities have made them high-priority healthcare issues all around the word [1].

“Healthiness” is a difficult term to explain but it refers to unscaled quality of life. Many definitions about “healthiness” have been given by experts. The concept “self-responsibility and healthy lifestyle” exists in almost all the definitions. For example, the

**** Corresponding Author: Ali Karimi***

Email: a_karimi@sina.tums.ac.ir

definition of healthiness according to WHO, refers to a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [2]. Mental health is a grade of sanity that leads to the movement, improvement and fulfillment at the individual, national and international levels.

Musculoskeletal disorders have been ranked second among occupational diseases. Despite all the mechanized and automated processes, occupational musculoskeletal disorders are still the most important reason for loss of time, cost overrun and workforce injuries in industrialized countries. The above-mentioned information confesses the importance of occupational musculoskeletal disorders found in any occupation or industry [3]. Musculoskeletal disorders are more prevalent among drivers rather than other occupational groups. Drivers spend a considerable part of their lives driving, the acute pains will become chronic after years of working and it brings up cumulative musculoskeletal disorders, which in turn affects their quality of private and social lives [4-5].

Different people feel different levels of pain which is hard to scale. People's expression for pain is not trustworthy. In mathematics and statistical sciences, non-existence and existence of musculoskeletal diseases are simply shown by 0 and 1. However, it is not easy to scale the pain and determine the status of health [7]. Therefore, fuzzy logic was used to find reliable data on the musculoskeletal diseases. Fuzzy logic computes the basis of "degrees of truth" rather than "true or false". This logic has been used in many safety-related studies, and has brought up precise and valid results. Studies conducted in safety fields by the use of fuzzy logic were mostly related to accident risk assessments with no approach to health issues. Having uncertainty and unlimited data in this study, fuzzy logic seems to be a reliable way for prediction of musculoskeletal and mental disorders on road accident involvement of drivers [8-9].

The present study was conducted due to high prevalence of musculoskeletal and mental disorders among drivers, having the aim of surveying the relationship between musculoskeletal and mental health and road accidents.

MATERIALS AND METHODS

The cross-sectional study was conducted on 400 drivers, referred to receive their health cards in a center for occupational medicine services in Shiraz, Iran. Subjects who intended to participate in the study were randomly sampled and by the first look, drivers with hereditary, explosion-related and incident-related musculoskeletal disorders and/or mental problems were excluded from the study. According to statistical formula, sample size calculated with taking into account the statistical reliability of 95%, 5% Type I error, statistical power of 90% and Type II error 10% respectively.

(Equation 1)

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times 2 \times \sigma^2}{(\mu_1 - \mu_2)^2}$$

General Health Questionnaire (GHQ) was used to survey the different dimensions of mental health and Nordic Musculoskeletal Questionnaire (NMQ) was also used to survey their musculoskeletal disorders. GHQ contains several items with two short and long forms, had 1 and 28 questions, respectively [2]. In this study, GHQ28 (developed by Goldberg and Hillier, 1979) has been used. The GHQ28 has been categorized in 4 subscales, each having 7 question items to scale the somatic symptoms, anxiety/insomnia, social dysfunction, and severe depression [7]. The test score ranged from 0 to 84 and the cut-off score was 23 [10].

Nordic Musculoskeletal Questionnaire (NMQ) is one of the most common ways to evaluate musculoskeletal symptoms [3]. NMQ has been developed by north European researchers for screening the musculoskeletal disorders to be used in ergonomic and epidemiological programs. Due to the high prevalence of musculoskeletal disorders in workforces (especially pains in the low back region), NMQ can be used in all occupations and industries [9].

After completing the questionnaires, data was statistically analyzed using SPSS 17 (Chicago, IL, USA) by descriptive, analytical and statistical indexes (confidence level of 95% and α = 0.05). Moreover, variables that had significant relationships with the incidents for determination of their roles in risk assessment of incidents and the probability of an event occurring were computed by fuzzy logic. Fuzzy logic has three fuzzy sets including input, output and logical system. Fig.1 shows an overview of the fuzzy system.

Fuzzy logic system is defined as a way to map an input space to an output space in order to determine the level of membership of a variable to a system. Mamdani fuzzy interference system (with the most citations in fuzzy logic-related papers) has been used to analyze the variables with IF/THEN statements. The principles of Mamdani fuzzy system have been explained in many published papers [11-12]. In Mamdani fuzzy logic, all the inputs should be converted to linguistic variables by dividing each variable to 4 subscales. Table 1 shows principles for surveying the severity of risk assessment of incidents. Table 2 demonstrates the subscales and their attached fuzzy numbers. In this study, musculoskeletal disorders have been illustrated by YES/NO answers to the questions related to the 9 human body organs. Answers have been valued in 0 (nonexistence of pain) and 10 (existence of pain). Each person's answer was calculated to gain a mean ranged from 0 to 10, and data was categorized in 4 groups. Incidents were also classified into 4 groups from "no incidence" (number 0) to "the most number of incidences" (number 4). For computing the variables, their membership levels should be obtained in triangular or trapezoidal shapes and their fuzzy diagrams should be drawn with MATLAB software. A score less than 23, is a sign for mental healthiness. Therefore, mental healthiness has been drawn in trapezoidal shape and the rest has been drawn in triangular shapes in MATLAB. The fuzzy membership functions value of each criterion related to four assessment levels can be calculated by the Equations 2 to 5:

(Equation 2):

$$\mu_L = \begin{cases} 1. & 0 \leqslant x \\ \frac{D_A - x}{D_A}. & 0 \leqslant x \leqslant D_A \\ 0. & x \geqslant D_A \end{cases}$$

(Equation 3):

$$\mu_M = \begin{cases} 0. & x \leqslant 0 \;\; or\; x \geqslant D_B \\ \frac{x}{D_A}. & 0 < x < D_A \\ 1. & x = D_A \\ \frac{D_B - x}{D_B - D_A}. & D_A < x < D_B \end{cases}$$

(Equation 4):

$$\mu_H = \begin{cases} 0. & x \leqslant D_A \;\; or\; x \geqslant D_C \\ \frac{x - D_A}{D_B - D_A}. & D_A < x < D_B \\ 1. & x = D_B \\ \frac{D_C - x}{D_C - D_B}. & D_B < x < D_C \end{cases}$$

(Equation 5):

$$\mu_{VH} = \begin{cases} 0. & 0 \leqslant x \leqslant D_B \\ \frac{x - D_B}{D_C - D_B}. & D_B \leqslant x \leqslant D_C \\ 1. & x \geqslant D_C \end{cases}$$

In simple fuzzy classification method, the role of variables in the health risk has been determined by membership function parameters. The patterns of linguistic variables were designed by the use of: AND, OR and NOT operators (Fig. 2). In this study, quantitative solution for the fuzzy inference system was obtained using the MATLAB R2015b fuzzy logic toolbox.

Table 1. Fuzzy membership functions of input and output

parameters		Membership function			
		L	M	H	VH
Inputs	GHQ	[0 0 23 45]	[0 23 45]	[23 45 63]	[45 63 84]
	MSDs	[0 0 3. 3]	[0 3.3 6.63]	[3. 3 6.63 10]	[6.63 10 10]
Output		[0 0 0.33]	[0 0.33 0.63]	[0.33 0.63 10]	[0.63 1 1]

Table 2. Surveyed driver's demographic data (n=400)

	Min	**Max**	**Mean**	**Standard Deviation**
Age	22	67	42	10.13
Driving experience	1	45	15.6	9.07
Working hours	4	22	13.01	3.93
Resting hours	1	16	6.81	2.18
GHQ score	2	75	22.06	13.53

Table 3. Pearson's Chi square test on the relationship between GHQ scores and having accidence experience

Road accident experience		**GHQ scores**		***P* value**
		Less than 23 (% of healthy drivers)	More than 23 (% of healthy drivers)	
Having accident experience	Yes	43	55	0.05>
	No	57	45	
Accident with passers-by	Yes	9	16	0.05>
	No	91	84	
Accident with a car	Yes	30	33	0.57
	No	70	67	
Rollover	Yes	10	18	0.05>
	No	90	82	
Accident with a motorcycle	Yes	5	9	0.22
	No	95	91	
Accident with a barrier	Yes	9	15	0.07
	No	91	85	

RESULTS

All of participants in this study were male. Table 2 demonstrates the demographic data collected from the samples. Primary results indicate that a high percentage of drivers were more than 42 yr of age (56%), 46% of them had secondary and higher education degrees, 89% of them were married and 59% of them had over 10 years' experience in driving. Classification of samples has been done based on the cut-off point (having 23 scores on GHQ questionnaire). By this classification, drivers who scored less than 23 were named "mentally healthy" and those who scored more than 23 were named "mentally sick".

Pearson's chi-squared test had a result in the relationship between the occurrence of accidents and driver's mental unhealthiness (P< 0.05). Having accident with a passer-by and rollover is significantly in relationship with the driver's mental disorders. Although drivers with mental unhealthiness are more vulnerable to accidents, no significant relationship was found between the driver's mental unhealthiness and having accidents with another car, barrier or a motorcycle. Table 3 shows Pearson's Chi square test on the relationship between GHQ scores and having accidence experience.

The results of Pearson's chi-squared test for road accident and musculoskeletal disorder have been shown in Table 4. Having pain in the neck, shoulder, hip and knee had a significant relationship with the driver's experience of accident in the past (P< 0.05).

The accident risk levels surface graph was calculated from combination of any input variable (Fig.3). At last, graphical trend of MSDs and GHQ score are shown in Fig.4 which is a surface view of accident occurrence risk level between 0 and 1. In this model, centroid method of defuzzification is used. For example, Fig.5 shows the defuzzification output, where accident risk level is calculated to be 0.328 by the proposed model, when input variables were 5 and 42 for MSDs and GHQ score, respectively.

Table 4. The results of Pearson's chi-squared test for incidence and musculoskeletal disorder

MSDs		**Accident**		**P value**
		Yes (%)	**No (%)**	
Neck pain	Yes	47.0	37.5	0.05>
	No	53.0	64.3	
Shoulder pain	Yes	40.3	27.1	0.05>
	No	59.7	72.9	
Low back pain	Yes	31.5	23.2	0.066
	No	68.5	76.8	
Hip pain	Yes	43.6	32.9	0.05>
	No	56.4	67.1	
Elbow pain	Yes	14.9	13.0	0.595
	No	85.1	87.0	
Wrist pain	Yes	17.7	16.9	0.841
	No	82.3	83.1	
Thigh pain	Yes	22.1	15.9	0.122
	No	77.9	84.1	
Knee pain	Yes	49.2	38.2	0.05>
	No	50.8	61.8	
Ankle pain	Yes	28.2	19.8	0.053
	No	71.8	80.2	

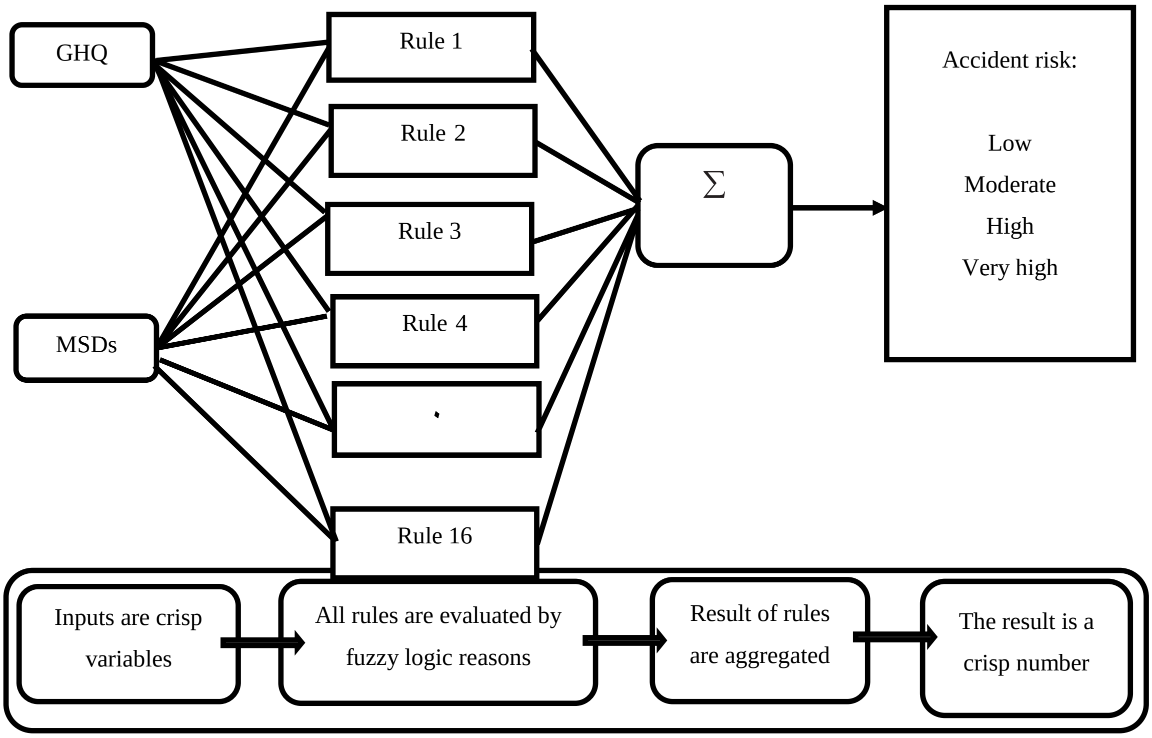

Fig.1. Fizzy logic overview

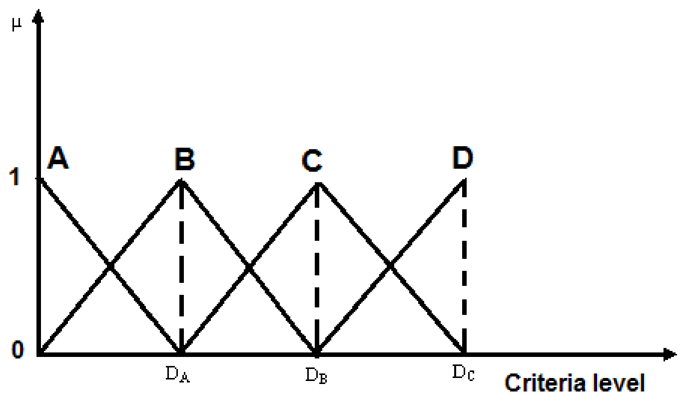

Fig.2. Membership function defined for input and output variables

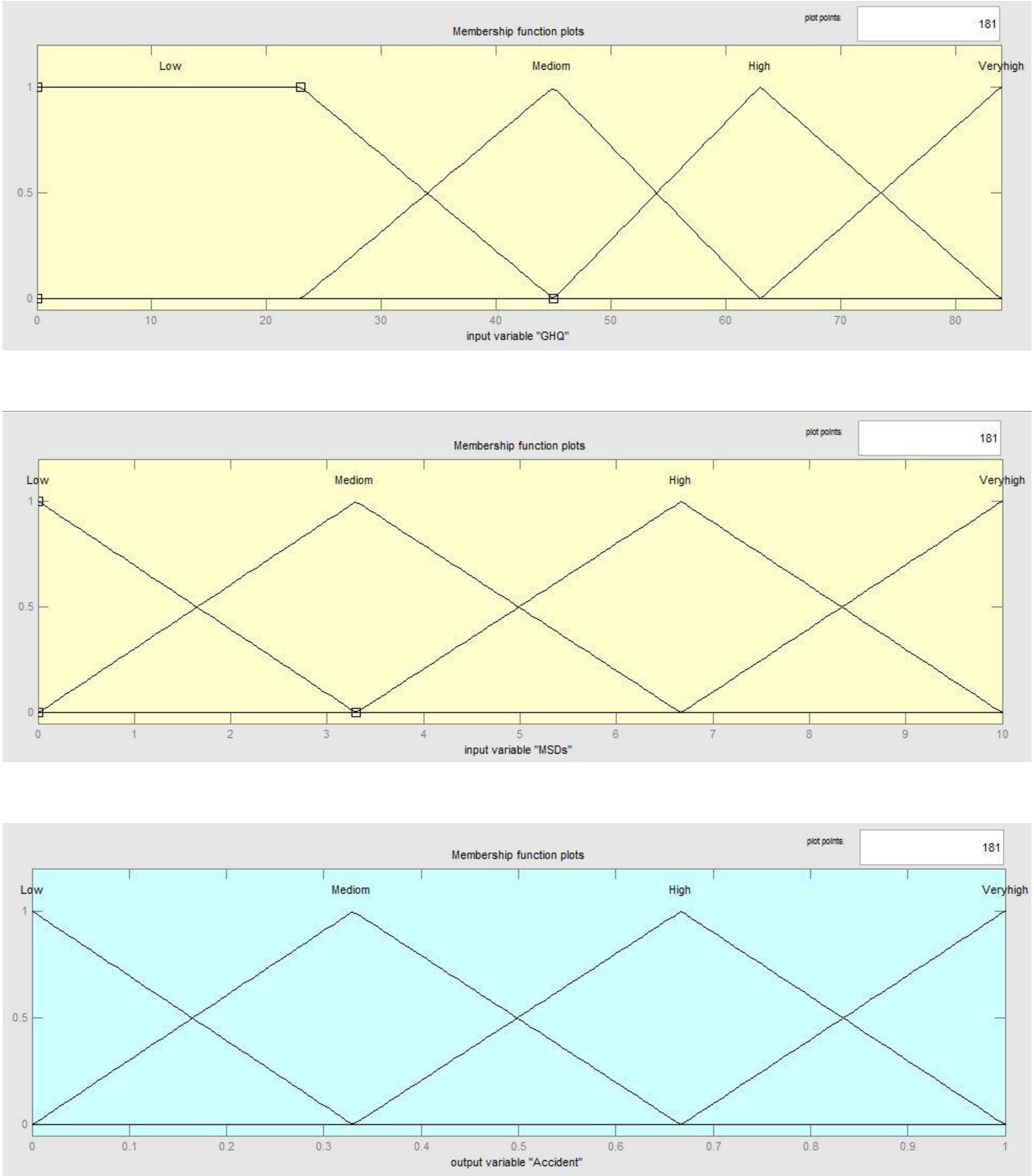

Fig.3. Fuzzy sets for MSDs and GHQ and accident risk categories (LR-Low Risk, MR-Medium Risk, and HR-High Risk).

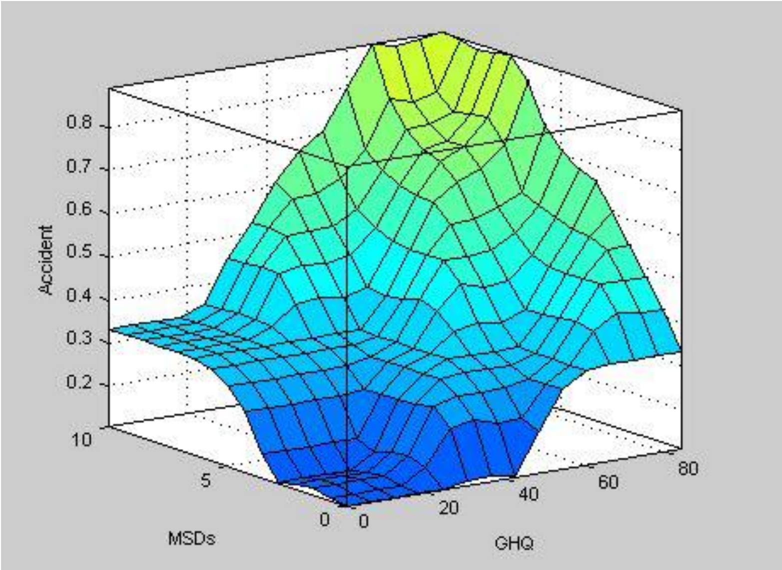

Fig.4. Risk matrix Surfaces graph representing the relationship between different level of MSDs, GHQ and accident Risk

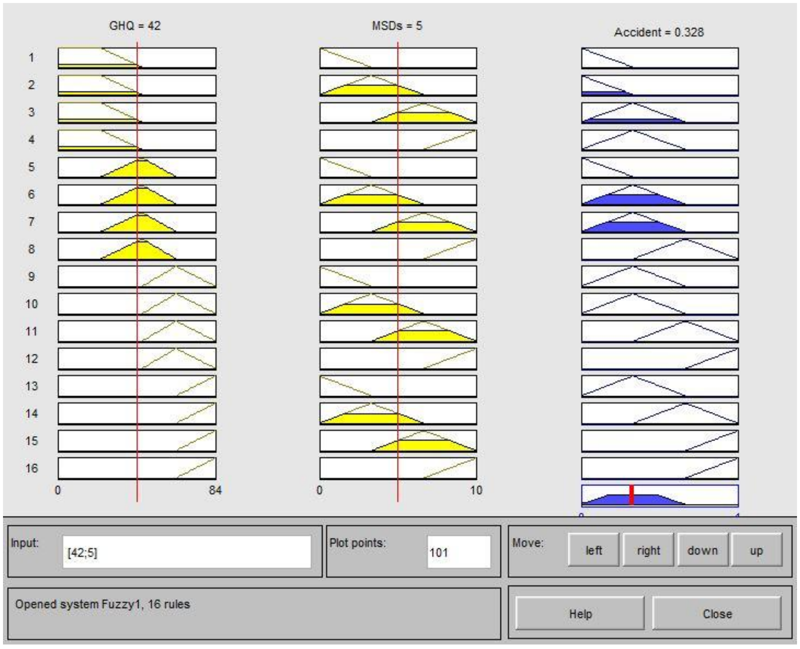

Fig.5. Rules viewer

DISCUSSION

The aim of this study was to present a new model for driver's accident probability assessment using fuzzy logic. Although examination of the root causes of accidents has always been uncertain, the fuzzy model is easy to perceive and its mathematical perceptions are simple. Hence, fuzzy logic can be used for modeling the complicated and non-linear perceptions. Literature reviews demonstrated that most studies have been done on safety issues with results in risk assessment, but no study has been done on introducing a useful model to determine the accident trends based on the mental and physical health of drivers. In this study, driver's mental and musculoskeletal dimensions showed effective parameters [13].

Prediction model in fuzzy approach can control imprecision and uncertainty and eliminate the low-efficient and extra data. Beriha et al., used the fuzzy system to have a survey on effective parameters in safety function among workers of Indian industries. They concluded that fuzzy model was the best incidence predictor model and the correlation between the real and predicted data was strongly significant (0.993) and reliable [14]. However, in this study, we focused on development of the fuzzy investigations and this has resulted in a confidential correlation between the real incidence and its probability, using fuzzy predictor model.

Yuanhua Qiao et al. used the fuzzy system to estimate the repetition of road accidents related to hazardous substances. They found that output data had a significant correlation with the input data and fuzzy system was a suitable way for predicting the causes and estimating the repetition of events [15]. The main difference between Yuanhua Qiao etal's study and the present investigation has been the use of parameters. The current study introduces the fuzzy system as a reliable model for survey and prediction of events.

Abel Pinto et al. used fuzzy predictor system for better analysis of the severity of events and that has been one of the first studies on road accidents and health parameters of drivers by the use of fuzzy system [9]. This study is in line with their results.

Musculoskeletal disorders and mental health affect the occurrence of the accidents. Analysis of the studied parameters in an accurate system such as fuzzy system illustrates the importance of musculoskeletal disorders and mental health scores and their relationship with the accident happenings. Not only the existence or non-existence of the mentioned parameters can result in incidences, but also the differences between the severity of the musculoskeletal disorders (difference between the existence and non-existence of disorders or existence of a problem in all organs) as well as increase or decrease in mental health scores can bring up the same result.

Musculoskeletal diseases, caused by bad body postures such as motionlessness, frequent bending and twisting are big problems in driving. Musculoskeletal disorders decrease the physical power for driving and driver's necessary reactions towards preventing the probable accidents. Driver's reaction including the control of vehicle is quite important. Results show that musculoskeletal disorders are prevalent among drivers and the more they are severe in drivers, the more the probability of occurrence of road accidents. Because of the pains they have and muscular fatigue, those drivers with musculoskeletal problems are not able to react rapidly and normally as well as healthy drivers. Neck and shoulder were responsible for controlling the car wheel and lower organs were responsible for speed control. The existence of problem in any of those organs may result to road accidents (Table 4).

Truck drivers drive for long hours and due to fatigue, high workloads and being far away from their families, they are not usually in a desirable mental health situation. They are somehow forced to drive at nights (by the traffic restrictions) and the consequent sleep deprivation causes serious health and concentration problems. Rise of psychological pressures alongside other job-related problems such as musculoskeletal pains, intensifies each other's influences and consequently results in dysfunctions in driver's reaction and road accidents. Moreover, driver's musculoskeletal pains are connected to the deterioration nature of their mental health status. These disorders come from the same roots. As has been considered in related studies, the central nervous system can be the root, because both the musculoskeletal and mental functions are in connection with the central nervous system.

Many investigations have been done about key roles drivers play in the occurrence of road accidents. Drivers' occupational health has a direct influence on their efficiencies. In 1975, several studies were conducted in Scandinavian countries; having considered driver's occupational health and that resulted in scientific studies on professional drivers in Denmark, Norway, Sweden and Finland [16]. Since 1979 to 1980, investigations were done on health, work situations and professional drivers vacating their jobs by the Finnish Institute of Occupational Health. The target groups were local bus drivers, truck drivers and tanker truck drivers. They finally reported that, truck drivers face high physical workloads nevertheless, bus drivers face mental stresses [17].

Intervention measures by relevant organizations are recommended in order to reduce the occupational adverse consequences on drivers. A good way to release the stress is doing physical activities including fitness and daily exercises. Thirlaway and Benton, after surveying the effect of physical activities on mental and physical health concluded that, having physical activities will lead to cardiovascular fitness, improvement of mental health and manner [18].

Road accidents can be indicated as an index to evaluate driver's occupational safety. In spite the fact that drivers are not the reason for all the accidents, the role of humans in the occurrence of accidents is not negligible.

CONCLUSION

Mental problems are so prevalent among drivers. It should be concluded that, since driver's mental and physical health has a direct effect on road accidents, treating their mental and physical problems can reduce the road accidents. Also, intervention measures by relevant organizations are recommended in order to reduce the occupational consequences on drivers. Furthermore, the fuzzy logic can be useful for surveying the probability of accident and identification of its causes so that a suitable model for changes in imprecise causes of accidents can be presented.

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REFERENCES

1. Abdolmalki A, Farshad A, Bagheri Yazdi S, Nosrati M, Hamedani M, Mohamadi A. Study of lead effects on the mental health of tin laborers in a carmaking company of Tehran city 2007. *Iran Occup Hea J* 2009; 6(2): 26-30.
2. Boruchovitch E, Mednick BR. The meaning of health and illness: some considerations for health psychology. *Psico-USF* 2002; 7(2): 175-83.
3. Aghilinejad M FA, Mostafaei M, Ghafari M. Occupational medicine practice. 1st ed. Arjomand: Tehran, Iran; 2001. 3-12 p.
4. Sadeghi N, Habibi E. The survey of relation between Musculoskeletal Disorders and Anthropometric Indices in the bus drivers in Isfahan. *Iran Occup Hea J* 2009; 6(1): 6-14.
5. Mehdi Jahangiri, Ali Karimi , Samira Slamizad, Mohammad Olyaei, Sekhavat Mosavi, Fatemeh Amiri: Occupational risk factors in Iranian professional drivers and their Iimpacts on traffic accidents. *Int J Occup Hyg, 2013, 5(4): 184-190.*
6. Mohammad Javad Jafari, Ali Karimi, Maryam Haghshenas: Extrapolation of experimental field study to a national occupational noise exposure standard. *Int J Occup Hyg,* 2010, 2 (2), 63-68.
7. Ustakhan M, Mofidi A, Meshkani M. Safety level assessment in the production environment using Fuzzy logic. *JHSW* 2012; 2(1): 63-74.
8. Dutta S, Sheikh TA, Baruah S, Sharma P, Roy S. Accident Control Using Fuzzy Logic: Survey. *EJAET* 2016; 3(1): 62-5.
9. Pinto A, Ribeiro RA, Nunes IL. Fuzzy approach for reducing subjectivity in estimating occupational accident severity. *Accid Anal Prev* 2012; 45: 281-90.
10. Mosavy M. The comparative study of health status of medical students and para-medical students trainee. *Journal of Gorgan University of Medical Sciences* 2004; 6(1): 101-7.
11. Zimmermann H-J. Fuzzy set theory—and its applications. 4th ed. Springer Science & Business Media: New York, USA; 2011.
12. Ross TJ. Fuzzy logic with engineering applications. 3rd ed. John Wiley & Sons: NewMexico, USA; 2009.
13. Kiani M, Mohammad FI, Allahviranloo T. Identification and evaluation of performance indicarotrs affecting human error, based on fuzzy logic (an operation center of gas transmission company). *J Occup Med* 2014; 5(4): 60-7.
14. Beriha G, Patnaik B, Mahapatra S, Padhee S. Assessment of safety performance in Indian industries using fuzzy approach. *Expert Syst Appl* 2012; 39(3): 3311-23.
15. Qiao Y, Keren N, Mannan MS. Utilization of accident databases and fuzzy sets to estimate frequency of HazMat transport accidents. *J Hazard Mater* 2009; 167(1): 374-82.
16. Backman A-L, Järvinen E. Turnover of professional drivers. *Scand J Work Env Hea* 1983: 36-41.
17. Luepker RV, Smith ML. Mortality in unionized truck drivers. *J Occup Environ Med* 1978; 20(10): 677-82.
18. Thirlaway K, Benton D. Participation in physical activity and cardiovascular fitness have different effects on mental health and mood. *J Psychosom Res* 1992; 36(7): 657-65.