Expert Systems with Applications 38 (2011) 15303–15309

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A fuzzy analytic hierarchy processing decision support system to analyze occupational menace forecasting the spawning of shoulder and neck pain

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ARTICLE INFO

Keywords:
Fuzzy analytic hierarchy process
Multi criteria decision making technique
Decision support system
Musculoskeletal disorder
Risk factors
Domain expert

ABSTRACT

This research provides an analytical tool, fuzzy decision support system (FDSS), to find the precedence of jeopardy in occupations spawning shoulder and neck pain (SNP), an important musculoskeletal disorder and the most ubiquitous pain complaint in an occupational environment. FDSS evaluates and prioritizes the relative importance of the imprecise, uncertain and vague nature of risk factors causing occupational SNP. The objective involves derivation of mechanical-, physical- and psychosocial-related risk categories using knowledge acquisition implemented by identifying the risk factors through literature analysis, conventional and concept mapping interviews with expert neurologists, orthopedists, psychologists and physiotherapists. Fuzzy analytic hierarchy process is applied as an evaluation tool to measure the significance of the risk factors in each occupation. The results indicate that the proposed system supplements SNP diagnosis experts with more precise key decision support information. This assists health care organizations to systematically identify appropriate occupations that grounds high risk for the occurrence of SNP and so the curative practices can be executed effectively.

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1. Introduction

A musculoskeletal disorder refers to conditions that involve the nerves, muscles and supporting structures of the body. The association between long term and short term exposure to different work environments plays a vital role in the incidence of musculoskeletal disorders. Now the increase in the use of visual display terminal (VDT) work, work above shoulder level, inclusive opportunities to acquire new knowledge and an increased amount of seated work have become common issues in any work environment. These lead to an important musculoskeletal disorder called SNP as studied by Sillanpää et al. (2003). SNP is the most common disease in the population acquired from an occupational environment. According to Pope, Silman, Cherry, Pritchard, and Macfarlane (2001) and Van der Windt Daniëlle et al. (2000) inability to work, loss of productivity, occupational illness and inability to carry out household activities are the sufferings due to SNP and can be a considerable burden to the patient as well as to society. SNP remains one of the primary occupational hazard classifications in the world with associated costs in the hundreds of billions of dollars per year. SNP has a strong, negative effect on the quality of life, and causes considerable personal suffering. In many countries every year worker's SNP problems lead to time away from jobs and reduce the nation's economic productivity. Risk factors that have been associated with occupational related SNP are numerous. These risk factors may be work-, and psychological-related or individual aspects. These risk factors are very likely not independent and some researchers have attempted to develop theories that describe their interactions (Kumar, 2001; Marras, 2000). SNP occurs due to individual or a combination of risk factors related to fields such as orthopaedics, neurology, psychology etc. and it involves diagnosis by medical practitioners from all those fields. There is disparity in the occurrence of SNP for workers with similar backgrounds and work activities. The risk factors sourcing SNP are uncertain and vague among the people in the same working environment. Hence it is difficult to find the set of risk factors and the level of significance of the risk factors that create SNP.

This will make the diagnosis process as complicated as possible. Identifying the risk factors causing SNP from the single or a combination of many of the specialized medical fields has become a tedious procedure. Now a day practitioners are interested in identifying accurate methods for evaluating the risk factors of SNP in an occupational setup as well as the precedence of occupations in generating SNP. It is highly important to acquire knowledge about the management of SNP and how musculoskeletal health can be maintained. Consequently SNP is one of the most important problems threatening the occupational society; it is essential to find a system that is capable of handling the knowledge of domain experts from all of these medical fields causing SNP and evaluate the risk level of SNP. Such an outsized problem faced by a physician and medical

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doi:10.1016/j.eswa.2011.06.037

community motivates this research. It is an effort to develop a FDSS that can be used by medical practitioners to review the likelihood of the degree of severity of the SNP risk level caused by various risk factors in different occupational environments.

2. Statement of the problem

SNP is multi-faceted. Several studies illustrate the work related exposures for SNP are categorized into mechanical-, physical- and psychosocial-related factors (McCauley & Lesia, 2000; Paulien, 2001). Many workers are simultaneously exposed to several, especially a combination of risk factors creating SNP. A set of risk factors generating SNP in each category is diagnosed by an individual medical expert. Different categories simultaneously grounds for SNP, moreover the risk factors vary among individuals though they have similar occupational backgrounds. Therefore diagnoses by medical experts in different categories are required. But there is no such system in practice that gives a common diagnosis including all the experts due to one or other reason. That is, there is no one universal structure that entirely characterizes qualitatively or quantitatively the status of the occupational risk associated with SNP of person at any point of time. This is due to the great dimensionality of the parameters involved. On the other hand, the available data is featured with imprecision, and subjective, which render very tedious and problematical task to assess the SNP risk level through single index. This research is an attempt to formulate such single comprehensive measure for the set of risk factors and the level of risks associated with SNP in diverse occupations. Fuzzy analytic hierarchy processing (FAHP) model has been used to determine relative measures of significance and priority weights for different risk categories of SNP. FAHP is effective in obtaining domain knowledge from numerous experts and representing them in a knowledge guided index. The intent is that this model will be applied eventually in an occupational setting and the model development is to focus on a method that provides a usable interface to medical practitioners during diagnosis phase.

3. Fuzzy analytic hierarchy processing method

Numerous multi criteria decision making (MCDM) techniques had been developed to date. One of the most common MCDM techniques is analytic hierarchy process (AHP) (Balteiro-Diaz & Romero, 2008; Hajkowicz & Collins, 2007; Ho, 2008; Steuer & Na, 2003; Vadya & Kumar, 2006). Saaty (1990) defines AHP as a decision method that decomposes a complex multi-criteria decision problem into a hierarchy. The use of AHP will keep increasing because of the AHP's advantages such as ease of use, great flexibility, and wide applicability (Ho, 2008). AHP will not provide solution when uncertainty in data of problems is observed (Ayağ, 2005). To address such uncertainties, Zadeh proposed and used Fuzzy Set Theory (FST) (Zadeh, 1998). FST emphasized on humans' thoughts, inference, and cognitions of surroundings. In FST the concept of membership function is used to describe the solutions to uncertain and vague problems. FST can be used as a modeling tool for uncertain and complex systems that are difficult to accurately define. Thus FST is introduced into the pair-wise comparison to deal with the deficiency in the traditional AHP. This is referred to as fuzzy analytic hierarchy processing.

The linguistic assessment of human feelings and judgments are vague and it is not reasonable to represent it in terms of precise numbers. Giving interval judgments is more confident for decision makers than fixed value judgments. So, triangular fuzzy numbers (TFN) are used to decide the priority of one decision variable over other in FAHP (Chan & Kumar, 2005). FAHP is an efficient tool to handle the fuzziness of the data involved in deciding the preferences of different decision variables. The comparisons produced by the expert are represented in the form of TFN to construct fuzzy pair-wise comparison matrices (Ghodsypour & O'Brien, 1998). By using the extent analysis method, the synthetic extent value of the pair-wise comparison is calculated. This approach decides and normalizes the weight vectors and determines normalized weight vectors. As a result, based on the different weights of criteria and attributes the final priority weights of the alternative risk factors are decided that will provide information to the medical practitioners the priority of risk factors that is useful for diagnosis.

3.1. FAHP applications in literature

Numerous authors have presented different ranking methods to rank alternatives under fuzzy environment during the last two decades. Bottani and Rizzi (2008) used fuzzy logic to deal with vagueness of human thought and FAHP to make a selection the most suitable dyad supplier/purchased item. Buyukozkan, Feyzioglu, and Nebol (2008) had proposed the FAHP method to evaluate e-logistics-based strategic alliance partners. Efendigil, Onut, and Kongar (2008) proposed two-phase model based on artificial neural networks and FAHP to select a third-party reverse logistics provider. Cascales and Lamata (2008), proposed FAHP for management maintenance processes where only linguistic information was available. Pan (2008) used FAHP for selecting the suitable bridge construction method. Tsai, Wu, and Liang (2008) used FAHP for market positioning and developing a strategy in order to improve service quality in department stores. Wu, Chang, and Lin (2008), proposed FAHP for measuring the non-profit organizational performance. Huang, Chu, and Chiang (2008) had applied FAHP to represent subjective expert judgments in government-sponsored R&D project selection. Lee, Lee, and Pietrucha (2008) had constructed FAHP to evaluate performance of IT department in the manufacturing industry in Taiwan. Chang, Wu, and Chen (2008) and Chang, Wu, Lin, and Chen (2008) used FAHP to evaluate and control silicon wafer slicing quality. Dagdeviren and Yuksel (2008) developed FAHP for behavior based safety management. Naga, Subburaj, and Ravi (2008) applied fuzzy AHP to identify problem features for injection mold development. Duran and Aguilo (2008) used FAHP for machine-tool selection. Various aspects of river basins to find the most efficient use of water system using FAHP had been proposed in Alias, Hashim, and Samsudin (2009). Measuring intellectual capital using FAHP is given in Chen (2009). A significant finding from all the researchers is they used triangular fuzzy number (TFN) to represent vague data or linguistic information.

3.2. Fuzzy sets and fuzzy numbers

A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function that operates over the range of real numbers [0,1]. The main characteristic of fuzziness is the grouping of individuals into classes that do not have sharply defined boundaries. The uncertain comparison judgment can be represented by the fuzzy number. The TFN used as the membership function is illustrated in Fig. 1. A TFN is the special class of fuzzy number whose membership function is defined by the triplet (l,m,u) defined as in (1). TFN help the decision maker to make easier decisions.

$$U(x) = \begin{cases} (x-l)/(m-l) & l \leqslant x \leqslant m \\ (u-x)/u-m & m \leqslant x \leqslant u \\ 0 & \text{otherwise} \quad u < x > l \end{cases} \tag{1}$$

The calculation of fuzzy numbers can be done according to the extension principle of TFN. If there are two TFN $A = (l_1,m_1,u_1)$ and $B = (l_2,m_2,u_2)$, the basic calculation principles are listed in Table 1. Here A and B are positive.

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