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Domain experts' knowledge-based intelligent decision support system in occupational shoulder and neck pain therapy

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ABSTRACT

This research develops a fuzzy knowledge-based decision support system (FKBDSS) that measures and predicts the degree of severity of the work-related risk associated with shoulder and neck pain (SNP) that is a prevalent pain complaint in an occupational environment. Assessing the harshness of SNP is a dreary chore, since the risk factors are featured with imprecision, uncertainty and vagueness. Predicting SNP subjective risk level provides key decision support information to medical practitioners in diagnosis. The objective involves knowledge acquisition performed through literature analysis, traditional and concept mapping interviews with domain experts comprising neurologist, orthopaedist, psychologist and physiotherapist to identify risk factors that include mechanical, physical and psychosocial categories. The determination of ranking the relative factor importance has accomplished using analytic hierarchy processing (AHP) analysis. The linguistic variables that qualify risk levels are quantified using fuzzy set theory (FST) that provides linguistic and numeric value outputs to predict the hazard level of SNP.

1. Introduction

In occupational medicine, terms such as repetitive strain injury (RSI), cumulative trauma disorder (CTD), occupational cervicobrachial disorder (OCD), or work-related musculoskeletal disorder (WMSD), have been used [1]. Musculoskeletal disorders (MSDs) have become an increasing problem in the working environment. It is the vital reason for occupational hazard [2]. It has been estimated that in every month as many as one-third of adults in general population experience SNP symptoms with some associated disability namely limitation in activities of daily living [3]. According to van der Windt et al. [4], inability to work, loss of productivity, occupational illness and inability to carry out household activities can be a considerable burden to the patient as well as to society. According to the large survey made by Bongers [5] three-fourth of the general population have musculoskeletal symptoms specifically SNP. Also the number of epidemiological studies, i.e., studies of the distribution and determinants of disease in human population (here SNP) reporting on potential risk factors for SNP has greatly increased in the past decade. Though several factors cause SNP, work-related factors play an important part. Work place conditions are important contributors to SNP occurrence and so there has been much research into the possible relation between features of the working environment and the development of SNP in the occupational group [6]. Many studies have been conducted on SNP and variety of risk factors at work has been documented [3–5,7,8]. It is hypothesized that many factors impact an individual's likelihood of developing SNP. There is a 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 that creates SNP and predict their severity [4,7]. Also SNP occurs due to individual or combination of more than one specialized medical fields such as orthopedics, neurology, psychology, etc [3,8]. So it involves diagnosis of medical practitioners of all or few above said fields. This practice will complicate the diagnosis process, finding the risk factors causing SNP from any single or combination of many of the specialized medical fields will become a tedious procedure. Nowadays practitioners are interested in identifying accurate methods for evaluating the risk factors of SNP in an occupational setting. The inconsistency in the occurrence of SNP in workers with similar backgrounds and work activities provides an uncertain block in the development of a system for widespread use in evaluating the development of SNP. Thus SNP is one of the most important problems threatening the occupational society; it is essential to find a system that is capable of handling all of the medical fields causing SNP and quantifies the risk level of SNP. This research is an attempt to build a

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FKBDSS that assists to overcome this problem. The proposed system uses AHP for representing the magnitude of the qualitative risk factors, since it provides a quantitative method for analyzing subjective information [9,10]. To address the uncertainty associated with the definition and modeling of SNP risk factors FST has been incorporated [10,11]. It derives relative strength of the risk factors from three predominant predefined factors thereby enabling the construction of the proposed model. The justification for applying such Fuzzy Knowledge-Based Systems (FKBS) driven solutions is that biological systems are so complex that the development of computerized systems within such environments is not always a straightforward exercise. In practice, a precise model may not exist for biological systems or it may be too difficult to define a model. In most cases fuzzy logic is considered to be an ideal tool as human minds work from approximate data, extract meaningful information and produce crisp solutions [12–14].

2. Statement of the problem

SNP is multi-facet. Several studies illustrate the work-related exposures for SNP are categorized into mechanical, physical and psychosocial factors [3,4,15,16]. Many workers are simultaneously exposed to several risk factors, especially combination creating SNP. A set of risk factors generating SNP in each category is diagnosed by an individual medical expert. Different categories simultaneously contribute 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.

The success of the proposed system depends on creating a focused knowledge base that consists of domain expert's experience and expertise in the form of knowledge (risk factors) towards the SNP problem domain. Knowledge acquisition process (KAP) has been done initially to identify and categorize the set of risk factors causing SNP. Domain expert's experience, engineering knowledge analysis and concept mapping techniques are used to identify and classify the risk factors. AHP model has been used to determine relative measures of significance and priority weights for different risk categories of SNP. AHP is effective in obtaining domain knowledge from numerous experts and representing them in knowledge guided index. FST predicts the SNP risk level. 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. The desired system output can also be obtained without an intervention of a medical practitioner. The functional flow of the proposed FKBDSS is shown in Fig. 1.

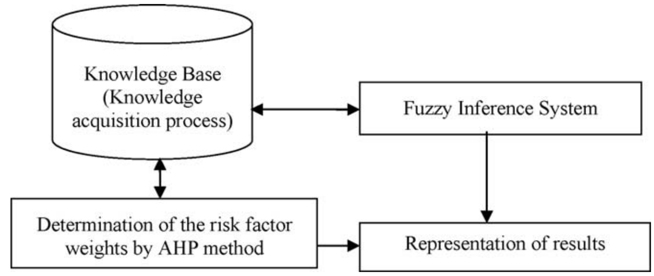

Fig. 1. Functional flow of the FKBDSS.

3. Knowledge acquisition process

KAP obtains information and knowledge required for constructing knowledge base and deriving its priority weights. It consists of a hybrid of knowledge acquisition methodologies. The most important methods used in this work include prelude analysis, literature analysis, domain expert's knowledge engineering analysis and concept mapping method.

The prelude knowledge acquisition obtains an overview of the problem and utilizes literature and interview analysis to determine probable modular risk categories. Documented risk factors and common characteristics are obtained from literature that represents the categories mechanical-related, personal-related, and psychosocial-related risk factors. Literature analysis is an extension of prelude analysis. The literature contains wealth of information about the potential causes of SNP [3–5,7,8]. Based upon the expertise, experience, and accessibility the group of domain experts consisting of an orthopedic surgeon, a neurologist, a psychologist and a physiotherapist are selected for interview analysis. The purpose of domain experts selection is to obtain individuals with a well-formed knowledge of SNP so as to strengthen all the three modules identified in the prelude analysis. The interview analysis consists of a question answer session, verbal problem solving and observation analysis.

Concept mapping is a knowledge acquisition tool that captures and graphically represents the relationships that exist between concepts of various domain expert's understanding of the problem space. Concept mapping minimizes the likelihood that important knowledge is discarded by providing a user-centered knowledge acquisition methodology that captures the entire solution domain. The detailed knowledge acquisition methodology for SNP prediction has been given in the previous work [17,18]. The results of the knowledge acquisition lead to the generation of different risk categories and primary risk factors within each category. The final risk factors determined as shown in Table 1 are considered to be the best candidates for inclusion in the risk assessment of FKBDSS.

4. AHP analysis

The array of risk factors within each identified category may have tremendous variability from patient to patient, a viable means for evaluating and finding some degree of significance of the risk factors are necessary. AHP analysis does this in SNP. AHP has been successfully applied to a wide range of problems in medical decision

Table 1
Final risk factors identified.

Mechanical-related risk factors (B_1)	Personal-related risk factors (B_2)	Psychosocial-related risk factors (B_3)
Carrying or lifting heavy loads (HL)	Age (AG)	Mental stress (MS)
Working in awkward postures (AP)	Gender (GE)	Job pressure (JP)
Engaging in repetitive movements (RM)	Smoking (SM)	Social factors (SF)
Performing similar work for a prolonged period (PP)	Body mass index (BMI)	Job satisfaction (or) stimulus at work (JS)
	Physical deconditioning due to lack of exercise (LE)	