Construction of an Expert System for Assessment of Work-Related Musculoskeletal Disorders for VDT Users

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ABSTRACT

Work-related injuries, especially musculoskeletal disorders create big problems in workstations where employees use computers commonly. Using computers for long durations and in repetitive manner will lead to health problems that are very costly and productivity will be reduced dramatically. Expert systems (ES) can be the solution for dealing with these problems.

This thesis aims to design a rule-based expert system that could be used to analyze and evaluate the working conditions of computer users by ergonomics standards. The knowledge base of this expert system will be acquired from OSHA's (Occupational Safety and Health Administration) and Washington state ergonomic standards. CLIPS (C Language Integrated Production System) is used to construct this ES.

In this research, risk factors which lead to formation of work-related musculoskeletal disorders (WRMSDs) were identified, to draw heuristically solutions to musculoskeletal discomfort problems, notify the computer user about the existence of WRMSDs hazards in the workplace, and to help the computer user to avoid WRMSDs risk factors. Thus, the significance of this study is to help the organizations to overcome costly damages and productivity-reduction.

Keywords: Work-Related Musculoskeletal Disorders, WRMSD, Ergonomic Expert System, CLIPS, MSD risk factors.

ÖZ

İşe bağlı yaralanmalar özelikle de kas iskelet sistemi hastalıkları çalışanların sıklıkla bilgisayar kullandıkları iş yerlerinde büyük sorunlar yaratabilir. Uzun süre ve sürekli bilgisayar kullanımına devam etmek, ciddi sağlık problemlerine yol acmaktadır ki bu durum verimliligi önemli ölçüde azaltır ve iş yeri için cok masraflıdır. Uzman Sistem bu sorunların cözülmesinde bır yol olabilir.

Bu tez ergonomi standartlarına göre bilgisayar kullanıcılarının çalışma ortamlarını analiz etmek ve değerlendirmek için kullanılabilecek bir kural tabanlı uzman sistem tasarımını hedeflemektedir. Bu uzman sisteminin bilgi tabanı OSHA (Mesleki Güvenlik ve Sağlık İdaresi) ve Washington eyaleti ergonomi standartlarından elde edilecektir. Bu sistemi oluşturmak için CLIPS (C Language Integrated Production System) kullanılır.

Bu araştırmada, kas-iskelet sistemi rahatsızlıkları sorunlara heuristically çözümler çizmek için, işyerinde WRMSDs tehlikelerinin varlığı hakkında bilgisayar kullanıcılarını bildirmek ve bilgisayar kullanıcılarına WRMSDs risk faktörleri önlemek için yardımcı olmak amacı ile işle ilgili kas iskelet sistemi bozukluklarının oluşumunda (WRMSDs) etkili olan risk faktörleri belirlenmiştir. Bu nedenle, bu çalışmanın önemi kuruluşları masraflı zararlardan ve verimliliği azaltan etkenlerden uzaklastırmaya yardımcı olmaktır.

Anahtar Kelimeler: WRMSD, uzman sistem, CLIPS, MSD tehlikelerinin

To my father whose memories give me strength to go on and my mother whose entire life was dedicated to me

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I would like to declare my gratitude to my supervisor, Asst. Prof. Dr. Orhan Korhan. That was only with his continuous and generous help and advice that I could complete this thesis. He was the one who lead me all the way through.

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Chapter 1

INTRODUCTION

Ergonomics is the science of adjusting the workplace to meet the worker psychological and physical needs. Ignoring ergonomics will have negative results on productivity, employee satisfaction, customer satisfaction and service quality; it will cost organizations in terms of employee health and turn over. One of the most observed complains among workers is about WRMSD.

WRMSDs are often observed among employees doing repetitive movements or having severe jobs. Computer users experience it because of awkward posture or improper workstation design.

Work-related musculoskeletal disorders (WRMSDs) result in employee discomfort, productivity loss and even disability. A musculoskeletal disorder happens when part of musculoskeletal organism is damaged over a long period of time. MSDs happen when an organ is forced to do an activity tougher than it is ready for. At first it may not seem important, but in a situation that it happens over and over again, it will lead to severe damages.

WRMSDs are painful disorders related to muscles, nerves, and tendons. Activities that are performed in a common and repetitive manner or activities with incorrect

postures lead to these MSDs that will cause pain while working or even at break time. (Canadian Centre for Occupational Health and Safety, 2005)

In this thesis the main goal was creating an expert system to intelligently advice users about ergonomic aspects of the job they are doing especially regarding VDT workstation design. In this context "users" is referred to employees in organizations and other industrial plants especially those working with video display terminals.

For the design of this ES, CLIPS (C Language Integrated Production System) software is used which is a rule based language, it means that its knowledge base must be written as rules. OSHA (Organizational Safety and Health Administration) rules were used as knowledge base and its information was transformed into rules usable for CLIPS.

The system works as follows: User starts the program, a welcome page is displayed which indicates software application that is assessment of WRMSDs, then a navigation pane is shown ,from which the user should chose the desired part, of course after completing one part it is allowed to return to this pane and chose another part. These multiple questions are asked in several parts of the system which enables the user to choose the next step or part of the body to be assessed by the system. Other questions are about posture of the body and design of the workplace. These questions are asked in a way that the answers are yes or no. by answering these questions the system determines whether the situation contains WRMSD hazard, if so, the user is alerted. By some other questions the user is required to enter a number which can be the time spent in a particular posture, weight of the items handled by the user, number of days during which a movement is done and etc. This system

makes ergonomic training available for employees who can check their situation within a short time and learn about WRMSD hazards, therefore its consequent costs would be reduced and employees' health and productivity would be improved.

This system was used by 100 employees consisting of managers, engineers, secretaries and etc. No of WRMSD hazards indicated by the system was recorded for different groups of age, gender, job position and task in addition to pains experienced in various organs. Then these records were analyzed and the results were tested.

Chapter 2

LITERATURE REVIEW

2.1 Musculoskeletal Disorders (MSDs)

Musculoskeletal disorders are among the most observed human suffering. They affect all groups of age and cause disability, injuries, and defects. They contain different disorders that develop damage or pain in the bones and joints, muscles, or contiguous parts, and they may be intense or long term.

Approximately 33 percent of adults living in USA have musculoskeletal symptoms which include motion limitation or joint pain. Occurrence of MSDs normally increases with age, with the majority of people aged 75 and more having some form of MSD, specifically arthritis. The subsequent cost of these MSDs is related to the medicinal and therapeutic care that patients need and work absenteeism. MSDs include a wide range of pains from pains in the back to rheumatoid arthritis. The most common pains experienced are low back pain, osteoarthritis, and soft tissue rheumatism. (FELSONT, 2002).

2.1.1 Work-Related MSDs (WRMSDs)

Almost any kind of activity is done by hands. Hence, most Work-Related MSDs affect the areas related with hands and shoulders. Activities performed with legs involvement can result in disorder of the parts related to legs like hips and foot. Back problems may result from repetitive activities too. MSDs are the most observed work-related health issue in Europe, causing injuries for millions of workers. In

Europe, 25 percent of workers are suffering from backache and 23 percent report muscular injuries (Canadian Centre for Occupational Health and Safety, 2005).

Musculoskeletal disorders are caused mostly by severe physical activity, awkward and fix postures, repetition of movements and vibration. MSD hazards increases with the speed of work, job dissatisfaction, stress and working in cold weather. MSDs are the most important reason of job absence. In some states, MSDs explain 40 percent of the worker compensation costs, and reduces GDP of the country up to 1.6 percent. Musculoskeletal disorders reduce profits of organizations and increase the social costs of governments. Many of these costs can be eliminated through practice of ergonomic instructions. (Podniece, et al., 2007).

WRMSDs are the main reason for pains experienced by workers, reduction of efficiency, and economic costs. More than 20,000 Ontario labor force were paid coverage costs in 1987 because of WRMSDs, which is equal to six hundred thousand days of absenteeism. In Columbia, more than fifty percent of the occupational disease statements are because of WRMSDs. A study on Columbian cashiers showed that more than 30 percent of the employees underwent a sort of Work related MSD (Podniece, et al., 2007).

2.1.1.1 Causes of WRMSDs

Work related MSDs occurs by movements of arm and hand like gripping, bending, straightening, twisting, and holding. These activities are not risky in the daily life but it is the constant recurrence that makes them risky, especially this is intensified by high speed and having no break. Work related MSDs often arise from bad patterns of work that include limited change in body posture or no change at all, continual repetition of movements, force applied to a body part like hands, working with high

speed without break time for recovery between movements. It is the combination of these factors that often result in Work Related MSDs (Podniece, et al., 2007).

2.1.1.1.1 Posture

The 1st is related to the organ that does the activity, often the upper part. For instance, activities which are repetitive in the wrist or elbow lead to the incidence of hurting injuries in those zones. Table 2-1 (Canadian Centre for Occupational Health and Safety, 2005) shows some instances of such activities. A design of the workplace that is not according to ergonomic standards and bad choice of equipment can result in these risky activities.

Table 2-1: Risky movements and the area of pain

Activities	**Pain Zones**
hand activities with repetition (Fig. 2-1)	hands
Working with fingers when the wrist is not in proper posture (Fig. 2-1)	
continuous deviation of the elbow from its normal situation	elbow
twisting the arm or wrist(Fig. 2-2)	
accessing to a level higher than shoulder (Fig. 2-4)	Shoulder-Neck
accessing behind the body (Fig. 2-5)	
Accessing to a place far from the body (Fig. 2-3)	
Arm-twist (Fig. 2-5)	

Another reason leading to Work Related MSD is unchanged posture of the shoulders and the neck. Doing an activity with an upper body organ requires the employee to fix the neck-shoulder zone. Muscles in this zone stay contracted maintain the posture fixed. The blood vessels are squeezed by contracted muscles which lead to restriction

of the blood flow down to the hand muscles that need blood to do the activity. As a result the neck-shoulder muscles become weak, although there may be no activity. This leads to discomfort of the neck. Meanwhile the reduced blood flowing to upper parts of the body speeds up weakness in the muscles that are doing activity and makes them more likely to damage. (Canadian Centre for Occupational Health and Safety, 2005)

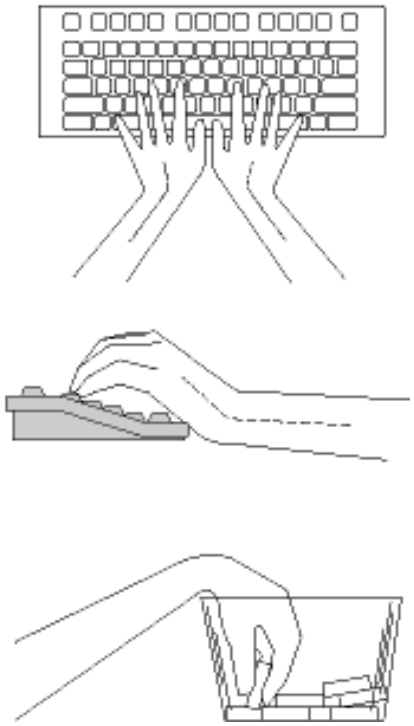

Figure 2-1: risky activities of the wrist-hand

Figure 2-2: applying force with forearm stretched

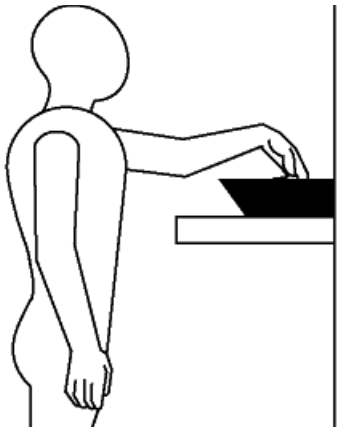

Figure 2-3: risky activities – stretching arm forward

Figure 2-4: risky activities – accessing to a point higher than shoulders

2.1.1.1.2 Repetition

Employees executing activities with great repetition are experiencing greatest Work related MSD risk. This indicates repeating activities is the most important hazard factor. These activities always include other Work Related MSD hazards such as unchanged posture.

Figure 2-5: Risky reaching movements - reaching behind the trunk

Activities including movements repeating so many times would cause tiredness. The reason is that the employee cannot completely refresh in the small breaks given. The strength needed to continue the repetitive actions progressively increase with time. When the job activity is sustained damages occur. (Canadian Centre for Occupational Health and Safety, 2005)

2.1.1.1.3 Force

The necessary force to accomplish the job also is a significant factor in the Work Related MSD occurrence. More force means more exertion of muscles, and therefore, a lengthier period is required to refresh between activities. Forceful activities develop weakness much faster because in repetitive job, there is not enough opportunity for recovery. Applying force in particular hand postures is really risky (Fig. 2-1 to 2-11 (Canadian Centre for Occupational Health and Safety, 2005)). The amount of force required is influenced by the weight of the gears and things which employee is supposed to handle, and their position relative to employee's body. Tools

that cannot be handled with a proper posture of the elbow, shoulder and wrist considerably give rise to the force needed. Damaged tools are very important also, but still ignored. For example, a worn out screwdriver or bad scissors would intensify the working potency up to ten times the normal situation.

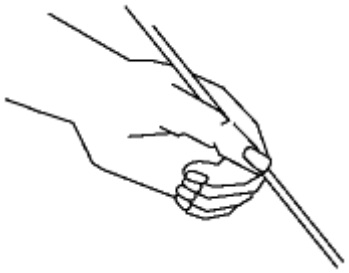

Figure 2-6: Lateral Pinch

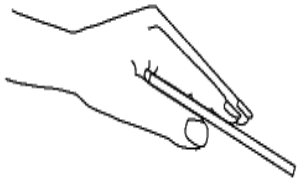

Figure 2-7: Pulp pinch

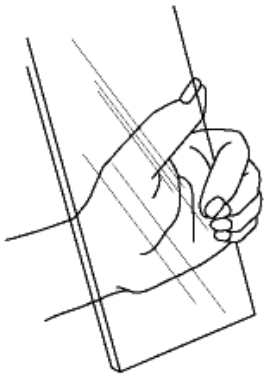

Figure 2-8: Pinching with palm

Figure 2-9: Pressing Finger

Figure 2-10: grasp

Figure 2-11: Pressing with Finger

Figures 2-10 and 2-11: applying force in different situations of the hand.

2.1.1.1.4 Speed of Activity

Speed of activity defines duration needed to refresh organs between repetitions of an activity. The higher the speed, the time available for refreshing is less and the risk is higher for Work Related MSD. When employee has no control over work speed, stress level rises. With greater stress level, muscle tensions which cause weakness increases risk for Work Related MSD.

2.1.1.1.5 Temperature and Vibration

Temperature affects the employee doing repetitive activity. When it is very hot, employees get tire sooner and become more vulnerable to damages. Alternatively, cold environments reduce the muscles flexibility and increase the probability of getting damaged.

Vibration disturbs tendons, joints, nerves and muscles. Personnel using tools that vibrate might feel finger-numbness and pain.

Many of these factors are encountered while dealing with computer. Keyboarding and moussing is a repeated activity, hands perform the same movements regularly without any change in their location, and even shoulders, head and neck do not move. Additionally, wrists may experience continuous pressure over a surface that may lead to damages like carpal tunnel syndrome.

2.1.1.2 Prevention of WRMSD Risks

Hazards should be prevented at the foundation. The main source of Work Related MSD hazard is repetition. Other factors including force, stable body posture, and the speed of activities are also causing WRMSDs. As a result for protecting employees from Work Related MSDs, we should emphasis on eliminating repeated activities by job design which may include automation, activity variation and teamwork. When there is no way for removing activity repetition other ways including workplace layout, tool design, and job rehearses should be considered. Studies have proven that ergonomic training and intervention is a very effective way of eliminating WRMSD risk factors and expert systems can play an important role in this field.

2.1.1.3 WRMSDs due to Computer Use

Using PCs is related with MSDs especially upper parts of the body. Posture of the neck, shoulders, wrists, fingers and arms is very important and special attention must be paid to that. Neck pain is usually caused by the wrong monitor position which can result in neck arthritis. Lots of employees working at a computer workstation complain about visual discomfort and muscular stress. Investigations of PC users indicate that visual discomforts are among the most common recorded disorders that

happen to 70% to 75% of Pc users. These problems regarding PC use is referred to as "computer vision syndrome".

Nowadays most of people are required to work with computers but few users know about the consequences of improper usage of the computer among which we can name reduced sight, fingers arthritis and injuries that could be initiated by sitting in a particular position for a long time without change. These injuries are more likely to happen in old people but improper posture, closeness to the screen, bad workstation design and longtime usage affects all age groups similarly. Researches show that more than75 percent of any profession is somehow related to computers. This matter can be extended to students also. Common PC related injuries are Computer Vision Syndrome (CVS), Carpal Tunnel Syndrome (CTS) and MSDs. CTS is caused by excessive movement of joints and can result in various MSDs. Researches has indicated that the main reason of CTS is improper position of wrists. Right thumb is more vulnerable to CTS and this is explained by bad position of this part while working with mouse. New design such as touchpad screens has aimed this problem; additionally work breaks can reduce CTS. CVS is mostly caused because of ignoring the proper distance from screen which is estimated 2 feet. In new monitors they have tried to reduce this problem by increasing refresh rates and quality and decreasing glare. One of the most observed CVS problems is dry eye that is caused by longtime staring at the monitor (O'Brien & Marakas, 2007). Another problem occurred while working with Pcs are related to improper posture which effects back, shoulder and neck mainly. (Andersen, et al., 2008).

According to a study done among employees of a newspaper office in Mexico City it was observed that employees using PCs experience more WRMSD hazard and

breaks between activities reduces this amount. This hazards increases with prolong unchanged posture, long keyboard and mouse use, improper posture and psychosocial factors (Hernándeza, gonzalez, Martínez-Alcántaraa, & Méndez-Ramírez , 2003).

Studies show that tissue micro traumas happen as a result of doing activities which are repetitive or are associated with applying force and this damage results in organic infection and changes in tissues. Relation of these infections to pain and psychological signs has been investigated (Barbe & Barr, 2006).

In a study efficiency of ergonomic training about posture and low-back-pain in PC employees was investigated. One hundred PC users received the ergonomic training while One hundred users were denied to this instruction. Training improved posture and was effective in decreasing LBP occurrence and these effects persevered for more than thirty months. These findings prove that customized ergonomic education could improve working posture and decrease LBP for PC users (Pillastrini, et al., 2010).

In a study working with mouse was investigated to see if it is related to disorders of the neck and upper parts of the body. It was shown that working with mouse increases WRMSD hazards (Cooper & Straker, 1998).

In research with 40 female typists it was identified that speed of typing has a direct influence on WRMSD hazards (Szeto, Straker, & O'Sull, 2005). In other study it was shown that keyboard position has a significant effect on MSDs. (B.-T. & Smith, 2006).

A comparison was done between mouse and pen input devices. 20 users performed a experiment with each device on five succeeding days. It was proved that mouse performance is better. Muscle activity did not have any difference between two devices. (Müller, Tomatis, & Läubli, 2010).

A new design of mouse with multiple mouse wheels was offered which can promote the effectiveness of OS functions. This opens a new horizon for designers (Lee & Lee, 2010).

In a survey it was shown that intervention can improve workstation behaviors. This improvement was of great amount in the neck zone and it reduced WRMSD up to 42 percent. But these improvements did not reduce absenteeism neither enhanced psychological health (Mahmud, Theadora Kenny, Md Zein, & Hassan, 2011).

In a survey efficiency of ergonomic training was evaluated. 22 participants were divided into 2 groups consisting of 11 each. Only one group received training. WRMSD symptoms was minimum in trained group and their postures were significantly improved which shows the importance of ergonomic training (Robertson, Ciriello, & Garabet, 2013).

2.2 Expert Systems

Talking of artificial intelligence, an ES is a PC program that imitates the expert ability of judgment and conclusion. Expert systems are designed in a way than can solve difficult problems by processing available knowledge just like an expert. The first expert systems were made in the 1970s and then their usage increased in the 1980s.Expert systems were amongst the first effective results of AI. An expert system has an exclusive structure which is different from old languages. It divides

into two parts; one part is independent of the expert system which is the inference engine, and one part is dependent on the purpose of the system which is the knowledge base. The required element for an expert system to work is that the engine must reason based on the knowledge base like a human. In the 80s a user interface was introduced to the system to communicate with users.

Expert systems suggest a good offer when needed. Expert systems collect data and experience (rules) and help both experts and normal people to have the best choices when required and dismiss unnecessary options. So there is no need to try and trials and the expert suggestions are always available.

In this thesis expert systems are used for facilitation of ergonomics applications in computer workstations.

Ergonomics is not a new science and it is about design of equipment, tools and workstation with the aim of optimizing productivity by decreasing employee exhaustion and distress. Ergonomics goal is improving environment and the things we use to get a more compatible result according to our needs and reduce the potential injuries due to daily repetitive works. Ergonomics is rooted back to ancient times, when men manipulated the materials to fit their need such as: shaping of tools, making shelters, creating finished products from raw material, etc. the term ergonomics is rooted from Greek words. “Ergon” means “work” and “nomos” means “law”. This term was first suggested and recognized as the name of the new society, comprised from a group of British researches met in Cambridge at its council meeting on February 16, 1950 (Fan, 2002).

With the improvement of technology and the increasing usage of computers by employees, the importance of ergonomic design of workstations has become more obvious. For this matter organizations hire ergonomic experts for design and controlling workstations but in many countries, specially developing countries , there is not enough resource for ergonomics if any and hiring experts is so expensive that organizations often prefer to ignore it, not knowing the long time result of this action. The solution that we offer here is to use expert systems which are cheaper and more accessible.

2.2.1 Advantages of Expert Systems

Expert systems have a better performance compared to experts; because they do not overlook anything as opposed to experts. ES can be reproduced and distributed fast and without any cost but training a new expert system is both slow and costly. ES construction and updating is costly but their operation is easy. ES costs can be accounted considering long duration of service and these costs are reasonable compared to human experts. ES records all the processes which can be used in future uses and it can prevent Fraud.

2.2.2 CLIPS

There are many languages that expert systems are written by, here CLIPS was used to produce ergonomic ES. CLIPS stands for "C Language Integrated Productions System". CLIPS was Developed at NASA in 1986 and was implemented in C. It was influenced by OPS5 and ART languages. CLIPS Initial version was only a production rule interpreter and the Latest version is named COOL (CLIPS Object-Oriented Language). It is a classical Rule-Based (Knowledge-Based) expert system shell and we can say it's an Empty tool, to be filled with knowledge. This language Forward-Chaining that is starting from the facts, a solution is achieved, its inference

engine internally uses the Rete Algorithm for pattern-matching to find fitting rules and facts.

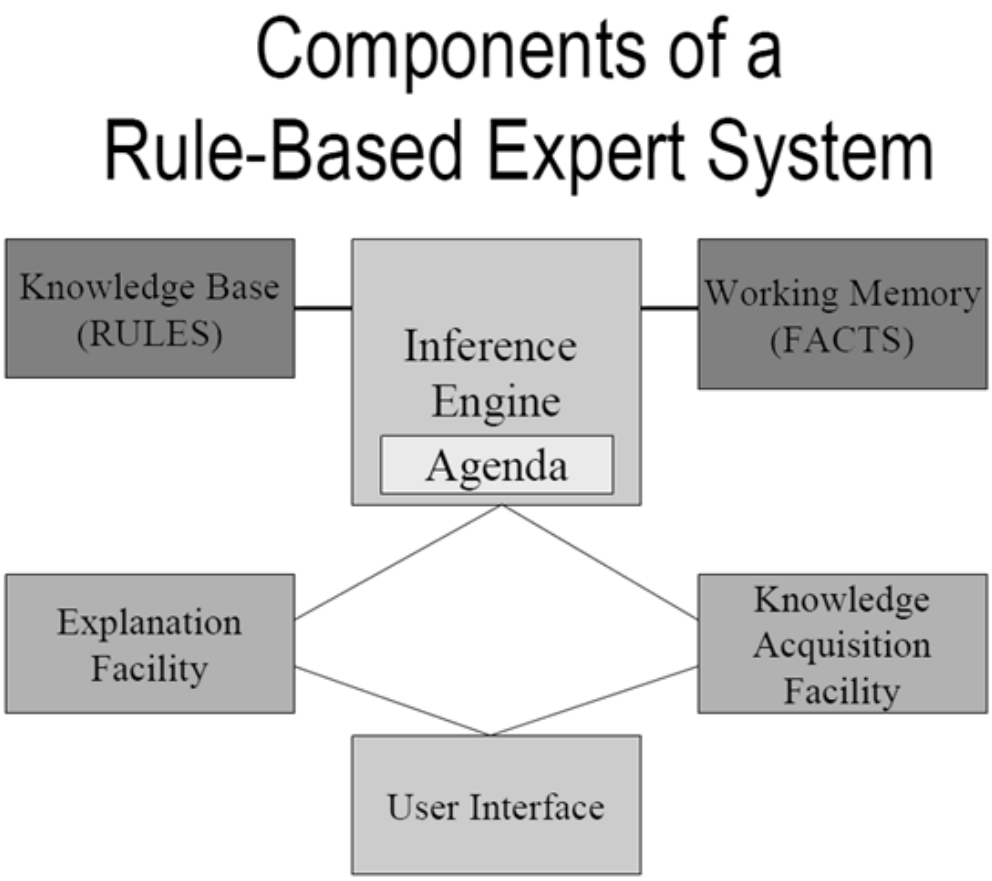

Figure 2-12: Modules of a Rule-Based Language

2.2.2.1 Components of CLIPS

CLIPS is composed of three main parts. Fact Base contains all the information available and describes the current situation. Rule Base contains all the rules and information gathered from experts or other reliable resources, mostly these information are transformed into if-then format. And the third part is Inference Engine which compares facts against rules and checks if the first part of the rule is satisfied, it would activate the command in second part of the rule which has come after "then". In fact it's the brain part of the system.

2.2.2.2 Advantages of CLIPS

CLIPS is a high-level production rule interpreter (shell). Its syntax is similar to LISP. Facts and rule-base is similar to Prolog. It has a Higher-level compared to LISP or Prolog. CLIPS runs on UNIX, Linux, DOS, Windows, Mac OS. It is a public-domain and well-documented software and includes object-oriented constructs (COOL).

2.2.3. Use of Expert Systems in Ergonomic Assessment

With increasing rate of computer usage in everyday-work it's very important for employers to get ergonomic knowledge and be taught the correct posture for doing their job so the WRMSDs get minimized. But, discussed earlier this chapter, ergonomic experts either are not available or they are so expensive that makes managers to ignore this important issue, especially regarding the fact that these trainings should be repeated every 3 months. Expert systems are the solution for this problem that makes it possible to make this information available for everyone at any time. It takes a few minutes to evaluate the person and gives a report on WRMSD risks along with the hint how to avoid these problems.

Construction of ES for lifting tasks was evaluated. This ES is supposed to be used by non-expert users for manual handling of materials. The Rule-Base for this software is resulted from two models established during a study. The models were founded on 2736 observations (Genaidy, Ayoub, & Duggal, 1989).

In their study Jen-Gwo Chen et al. tried to overcome the obstacle of transferring ergonomic knowledge to employees by construction of an interactive computer-aided Ergonomics Analysis SYstem (EASY). The system consists of 3 parts: the Ergonomics Information Analysis System (EIAS) for assessment of activities done by the employee, the Physical Work Stress Index (PWSI) used by the administrator

or the ergonomist explore problems, and the Dynamic Lifting Analysis System (DLAS) for activities related to manual handling of material. The evaluation indicated that 83 percent of EASY's diagnoses were confirmed by the ergonomists (Chen, Schlegel, & Peacock, 1991).

An expert system was designed to give physicians advice about neck and shoulder pains resulting from WRMSD. Rule-base was derived from analysis of literature, various interviews with experts from different fields to determine hazard factors that consist of mechanical, psychosocial and physical groups. These factors were rated with analytic hierarchy processing (AHP) and KBDSS ES was developed. (Padma & Balasubramanie, 2009).

2.2.4 Designing ES for Assessment of WRMSDs

Computer usage is now inevitable in most of the industries, and there are industries that computer is the main tool like banking, telecommunication, insurance, customer service, newspaper and etcetera. The VDT checklist provides these people easy way to control computer-related hazards. The checklist guides employers to adjust their compute workstation to comply with the standard. OSHA checklist instead of checking the equipment, checks the proper posture of the user. It’s good because the user might have adjustable chair which is set to a wrong height but OSHA check list checks neck, hands and body posture.

CLIPS is rule based expert system which means that all the knowledge is transformed into rules which is usable for expert systems. The knowledge used in this expert system is from OSHA. In this research we have considered the video display terminal and workstation design. Starting the expert system, it will ask questions from the users. The questions were asked in such way that answers are in

yes/no format. The answer yes indicated a WRMSD hazard and it alerts user about this hazard so he/she can change his/her posture to the right position. There are also some multi-choice questions which are for navigating through different parts of the system. Some answers require a numeric answer, for example system asks the user about the working hours in a particular position and replying this question, system considers it as actual working hour and will compare it to standard duration allowed for this posture then it will prompt the user about the situation. For example if the user is using the keyboard for 5 hours without interruption, it will show a message that the maximum allowed time in this posture is 2 hours, so user will know that there is a WRMSD hazard for this posture or he/she must have a break every 2 hours.

Chapter 3

METHODOLOGY

In this research, considering its advantages, CLIPS was chosen to produce an expert system to assess work related musculoskeletal risks. CLIPS is a rule base language that its database must be written as rules, these rules should be rewritten in such codes that should be understandable for CLIPS. Our knowledge base and source here is the National Institute for Occupational Safety and Health (NIOSH) standards. All the rules were taken from OSHA Federal register.

OSHA rules were applied to people who have "caution zone jobs" by which it refers to the jobs containing physical risks; if the level of this risks is higher than the standard level mentioned in OSHA, then worker is experiencing WRMSD hazard.

Employers of caution zone jobs must make sure that employees have required ergonomics knowledge and managers should reduce the risk levels their employees may suffer from. The Expert system constructed here, gives the needed information to these employees and notifies them of the existing risks.

Our knowledge base was extracted from basic screening tool, VDT workstation checklist of w-1 and D-2 appendixes from OSHA's ergonomic standard, and Washington state ergonomics standard's appendix B (WAC 296-05174) for VDT workstation risk assessment.

Basic screening tool alarms for assessment of an activity which contains MSD risk. This tool considers legs, knees, back, trunk, shoulder, neck, hand and wrists. Risk factors are repetition, improper posture, vibration and contact stress.

Washington state appendix B; according to rules described in Washington state standard checks if caution zone jobs results in risks in the existing condition. These rules assess shoulder, knees, trunk, neck and different upper parts of the body. Hazard factors include improper posture, force, contact stress and repetition.

VDT workstation analysis; computer usage is inevitable in many organizations and employees spend a lot of their time in VDT workstation. For this important part of expert system, OSHA VDT check list is used that investigates the five most important risk factors and gives guidelines for designing workstation and warning about the risks.

Important advantage of OSHA VDT checklist is that instead of checking the workstation equipment it considers right posture and correct use of the equipment because there is a good chance that the employee has ergonomic equipment but uses it in a wrong way and increases the risk factors. The five risk factors that OSHA focuses on are contact stress, repetition, vibration, awkward posture and force.

Computer use does not involve heavy physical activity thus we did not consider vibration and lifting in our system. For each of these factors there is a duration limit and number of repetition. This time limit for most of activities is 2 hours. If the activity is done for a longer period than two hours per day it is considered a WRMSD hazard and the user is alarmed. This doesn't mean that doing that particular

activity less than 2 hours is safe. According to previous studies doing these activities for more than 2 hours is more likely to lead to WRMSDs. For repetition this limit is effective only when the activity is done in a continuous way and without interruption. For keyboarding and mousing time limit is 4 hours. Also weight limit for lifting is seventy 75 pounds, fifty five pounds if repeated above ten times each day, twenty pounds for higher level than shoulders or beneath repeated above twenty five times a day. Pinching weight limit is 2 pounds for each hand and for gripping it is 10 pounds for each hand. Contact stress means that employee uses some part of body as hammer and its limit is defined 10 times per day by OSHA.

According to each rule, expert system asks user a question. Most of these questions have a yes/no answer that the user should input by typing yes/no/y/n, when the system gets the answer it indicates whether there is a WRMSD hazard. If there is a risk, expert system alarms user about it and he/she can change the situation and if not next question is asked. Some questions require users to input some information. These questions are about an angle of some body part or weight. There are some multiple choices too, for example for navigating between different parts of the system or selecting the body part which is experiencing WRMSD hazard.

This expert system is designed in a way that executing a batch file opens a file named start. A welcome screen is shown and a menu gives the available options from which the user can select the desired part of the system. These options are:

1. General OSHA rules: according to Basic Screening Tool Checklist evaluates working situation against OSHA standards.

2. VDT work station Check: considering VDT workstation checklist checks VDT environment

Then the questions are asked by the system and at the end of each step total number of WRMSD hazards is displayed and then user can choose to exit the system or go to the main menu.

After constructing the expert system, 100 employees were asked to use it. Results were recorded for every step. For each user age, gender, job position and the reason of using computer (task) was recorded in addition to expert system outputs. These data were processed and they were compared and analyzed in an effort to find important factors effecting WRMSDs.

Chapter 4

RESULTS

Using the expert system constructed during this thesis, a survey was conducted; 100 employees were asked to run the expert system and results were recorded. Information about these employees is provided in appendix 3. Number of WRMSD hazards was written for every employee. Then these results were processed and different factors including gender, age and job position were investigated to see whether they have a significant effect on WRMSD hazards. The important point is that because of limited number of data, full factorial test could not be done, so we just assumed there is no interaction between various factors and used one way ANOVA to test the significance of existing factors.

One of the important points observed in this study was the fact that each employee was experiencing 7.66 WRMSD hazards in average, this average did not change so much for different treatments of our experiment except job position factor. For example the average number of WRMSD hazards for female participants is equal to 7.7 and this value for male ones is equal to 7.65. The equality of these means was tested with ANOVA and no significant difference was proved. These hazards can lead to musculoskeletal disorders. This indicates that in spite of many efforts performed in this area, still the ergonomic knowledge is not available for everyone or it is just being ignored not knowing the consequences. Experts systems like the one

we have developed can eliminate this problem by informing people about these hazards and reminding them from time to time.

Table 4-1: Descriptive statistics

Gender	Mean	N	Std. Deviation
Female	7.7000	20	1.62546
Male	7.6500	80	1.49345
Total	7.6600	100	1.51237

The mean value for number of WRMSD hazards for groups of male and female are given in table 4-1. There were no significant difference among males and females. ANOVA test confirmed that gender has no effect on number of WRMSD hazards. This test is done similarly for different treatments of age, Job position and task. Gender and the task are not effective factors but interestingly job position has a significant effect on resulting WRMSD hazards. It is observed that managers and secretaries have the maximum number of WRMSD hazards which can be explained by extensive typing and hours spent using computer.

Table 4-2: ANOVA test for gender efficiency

ANALYSIS OF VARIANCE FOR GENDER-WRMSD HAZARD DATA					
	SS	Degree of freedom	MS	F-value	P-value
Between Groups	.040	1	.040	.017	.896
Within Groups	226.400	98	2.310		
Total	226.440	99			

As discussed earlier P-value for gender effect is equal to 0.896 which shows that it is not an effective factor.

Table 4-3: ANOVA test for age efficiency

ANALYSIS OF VARIANCE FOR AGE-WRMSD HAZARD DATA					
	SS	Degree of freedom	MS	F-value	P-value
Between Groups	53.248	28	1.902	.780	.765
Within Groups	173.192	71	2.439		
Total	226.440	99			

As expected age is not effective on WRMSD hazards, people of every age should be careful about how they deal with computers.

Table 4-4: ANOVA test for job position efficiency

ANALYSIS OF VARIANCE FOR JOB POSITION-WRMSD HAZARD DATA					
	SS	Degree of freedom	MS	F-value	P-value
Between Groups	33.796	7	4.828	2.306	.033
Within Groups	192.644	92	2.094		
Total	226.440	99			

Job position has a significant effect on number of WRMSD hazards .the mean value for different positions is provided in table 4-5.

Table 4-5: Mean value of WRMSD hazards for different positions

Job Position	Mean	N	Std. Dev.
manager	8.5	4	4.726
IT	7.12	8	1.885
Technical office	7.26	31	1.612
supervisor	7.70	27	.775
seretariat	8.57	7	1.397
PMU	7.92	13	.760
financial	7.90	10	.738
Total	7.66	100	1.512

Job position is an important factor and more attention must be paid to ones who have secretary and management positions.

Table 4-6: ANOVA test for task factor efficiency

ANALYSIS OF VARIANCE FOR TASK-WRMSD HAZARD DATA					
	SS	Degree of freedom	MS	F-value	P-value
Between Groups	6.910	6	1.152	.488	.816
Within Groups	219.530	93	2.361		
Total	226.440	99			

Task is not an important factor, the way people do this is important.

Logistic Regression analysis was performed to find out which factors contribute to the formation of the WRMSDs. For this reason, experience of WRMSDs in each body region was selected to be the dependent variable (neck, back, and hands respectively). The independent variables were selected to be age, gender, position, task and VDT workstation design which has 2 parts; first part investigates body posture and the second part checks equipment efficiency. The results show that hazards indicated in the second part of workstation survey result in neck pain (p=0.008) it means that equipment and VDT design is a significant factor on pains experienced in neck. As discussed earlier, second part of workstation design survey, investigates equipment which is used by user and this shows the importance of using ergonomic equipment in workstation design. Also job position (p=0.012) and task (p=0.010) have relation with the pain experienced in neck (table 4-7).

Table 4-7: Effects of different factors on neck pain

						95% CI	
Predictor	Coef.	SE Coef.	Z	P	Ratio	Lower	Upper
Constant	-5.41031	4.24938	-1.27	0.203			
age	0.0272802	0.054632	0.50	0.618	1.03	0.92	1.14
gender	1.32578	1.09922	1.21	0.228	3.77	0.44	32.47
first part	-0.210236	0.360390	-0.58	0.560	0.81	0.40	1.64
second part	0.735724	0.275163	2.67	0.008	2.09	1.22	3.58
position	-1.05491	0.421398	-2.50	0.012	0.35	0.15	0.80
task	1.31532	0.510713	2.58	0.010	3.73	1.37	10.14

Table 4-8 shows that none of the independent variables were contributing to the formation of WRMSDs in the back.

Table 4-8: Effects of different factors on BACK /HIP

						95% CI	
Predictor	Coef.	SE Coef.	Z	P	Ratio	Lower	Upper
Constant	-34.7688	55448.2	-0.00	0.999			
age	0.20796	1132.19	0.00	1.000	1.22	0.00	*
gender	9.57007	13084.1	0.00	0.999	14329.43	0.00	*
first part	-10.2981	6680.31	-0.00	0.999	0.00	0.00	*
second part	5.22947	2236.97	0.00	0.998	186.69	0.00	*
position	4.09577	2304.75	0.00	0.999	60.09	0.00	*
task	-4.30477	5855.32	-0.00	0.999	0.01	0.00	*

Similarly, table 4-9 shows that none of the independent variables were contributing to the formation of WRMSDs in the hands.

Table 4-9: Effects of different factors on HANDS/WRISTS/FINGERS

						95% CI	
Predictor	Coef.	SE Coef.	Z	P	Ratio	Lower	Upper
Constant	-42.5931	89325.8	-0.00	1.00			
age	-0.161880	640.766	-0.00	1.00	0.85	0.00	*
gender	-5.66637	26118.0	-0.00	1.00	0.00	0.00	*
first part	3.78424	6684.48	0.00	1.00	44.00	0.00	*
second part	5.37486	2512.22	0.00	0.99	215.9	0.00	*
position	-3.30355	5232.74	-0.00	0.99	0.04	0.00	*
task	1.80643	6994.70	0.00	1.00	6.09	0.00	*

Chapter 5

CONCLUSION

Studies have shown that ergonomic intervention and training is a very effective way for reducing WRMSD hazards. But hiring ergonomic experts to train employees is very expensive and sometimes experts are not available. In this thesis an expert system was proposed as a solution to this problem. Expert systems are cheap, they are not time-consuming, the can be copied and handed to employees, using it is easy when it is written in an interactive way and they can be updated when desired.

In this thesis an expert system was developed using CLIPS software to assess WRMSD hazards. This expert system has two parts, the first part assesses the body according to general OSHA rules and the second part investigates workstation design considering OSHA VDT CHECKLIST (Appendix 1). If a hazard is indicated, the user will be alarmed and it helps to eliminate that hazard.

This expert system was used by 100 employees of different ages, genders and job positions. The system identified the hazards efficiently. The average number of hazards for each person was equal to 7.7.

All the data acquired was recorded and analyzed. Due to lack of sufficient data, full factorial analysis could not be performed and it was just assumed that there is no interaction among different factors and the data was analyzed using one-way ANOVA and Logistic regression. The mean number of WRMSD hazards for

different groups of age, gender and task did not have a significant difference and using ANOVA test it was proven that they are not important factors for hazards. But there existed significant differences among different job positions and it was shown that it is a significant factor. The average number of hazards experience by secretaries and project managers was about 8.5 which is greater than average number of hazards for other positions which were less than 8. But this does not change the fact that still the mean number of risks which was 7.6 per employee is still very high and managers in every organization should provide ergonomic equipment and training for their employees.

Expert systems offer a reasonable solution for ergonomic training. It is free and it is not time-consuming. It can be made available to employees and used periodically and as a result these hazards would be eliminated.

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APPENDICES

Appendix 1: Appendix D-2 to §1910.900: VDT Workstation Checklist

Using this checklist is one, but not the only, way an employer can comply with the requirement to identify, analyze and control MSD hazards in VDT tasks. This checklist does not require that employees assume specific working postures in order for the employer to be in compliance. Rather, employers will be judged to be in compliance with paragraph (k) and (m) of OSHA's standard if they provide the employee with a VDT workstation is arranged or designed in a way that would pass this checklist.

If employee exposure does not meet the levels indicated by the Basic Screening Tool, you may STOP HERE.

WORKING CONDITIONS The workstation is designed or arranged for doing VDT tasks so it allows the employee's . . .	Y	N
A. Head and neck to be about upright (not bent down/back).		
B. Head, neck and trunk to face forward (not twisted).		
C. Trunk to be about perpendicular to floor (not leaning forward/backward).		
D. Shoulders and upper arms to be about perpendicular to floor (not stretched forward) and relaxed (not elevated).		
E. Upper arms and elbows to be close to body (not extended outward).		
F. Forearms, wrists, and hands to be straight and parallel to floor (not pointing up/down).		
G. Wrists and hands to be straight (not bent up/down or sideways toward little finger).		
H. Thighs to be about parallel to floor and lower legs to be about perpendicular to floor.		
I. Feet to rest flat on floor or be supported by a stable footrest.		
J. VDT tasks to be organized in a way that allows employee to vary VDT tasks with other work activities, or to take micro-breaks or recovery pauses while at the VDT workstation.		
SEATING The chair . . .	Y	N
1. Backrest provides support for employee's lower back (lumbar area).		
2. Seat width and depth accommodate specific employee (seatpan not too big/small).		

3. Seat front does not press against the back of employee's knees and lower legs (seatpan not too long).		
4. Seat has cushioning and is rounded/ has "waterfall" front (no sharp edge).		
5. Armrests support both forearms while employee performs VDT tasks and do not interfere with movement.		
KEYBOARD/INPUT DEVICE The keyboard/input device is designed or arranged for doing VDT tasks so that . . .	Y	N
6. Keyboard/input device platform(s) is stable and large enough to hold keyboard and input device.		
7. Input device (mouse or trackball) is located right next to keyboard so it can be operated without reaching.		
8. Input device is easy to activate and shape/size fits hand of specific employee (not too big/small).		
9. Wrists and hands do not rest on sharp or hard edge.		
MONITOR	Y	N
The monitor is designed or arranged for VDT tasks so that . . .		
10. Top line of screen is at or below eye level so employee is able to read it without bending head or neck down/back. (For employees with bifocals/trifocals, see next item.)		
11. Employee with bifocals/trifocals is able to read screen without bending head or neck backward.		
12. Monitor distance allows employee to read screen without leaning head, neck or trunk forward/backward.		
13. Monitor position is directly in front of employee so employee does not have to twist head or neck.		
14. No glare (e.g., from windows, lights) is present on the screen which might cause employee to assume an awkward posture to read screen.		
WORK AREA	Y	N
The work area is designed or arranged for doing VDT tasks so that . . .		

15. Thighs have clearance space between chair and VDT table/keyboard platform (thighs not trapped).		
16. Legs and feet have clearance space under VDT table so employee is able to get close enough to keyboard/input device.		
ACCESSORIES	Y	N
17. Document holder, if provided, is stable and large enough to hold documents that are used.		
18. Document holder, if provided, is placed at about the same height and distance as monitor screen so there is little head movement when employee looks from document to screen.		
19. Wrist rest, if provided, is padded and free of sharp and square edges.		
20. Wrist rest, if provided, allows employee to keep forearms, wrists and hands straight and parallel to ground when using keyboard/input device.		
21. Telephone can be used with head upright (not bent) and shoulders relaxed (not elevated) if employee does VDT tasks at the same time.		
GENERAL	Y	N
22. Workstation and equipment have sufficient adjustability so that the employee is able to be in a safe working posture and to make occasional changes in posture while performing VDT tasks.		
23. VDT Workstation, equipment and accessories are maintained in serviceable condition and function properly.		
PASSING SCORE = "YES" answer on all "working postures" items (A-J) and no more than two "NO" answers on remainder of checklist (1-23).		

Appendix 2: CLIPS CODES

Try-0.BAT

```
(clear)
(load "C:/CLIPS/program/notepad/final/start-f.txt")
(reset)
(run)
```

Try-1.BAT

```
(clear)
(load "C:/CLIPS/program/notepad/final/general-f.txt")
(reset)
(run)
```

Try-2.BAT

```
(clear)
(load "C:/CLIPS/program/notepad/final/vdt-f.txt")
(reset)
(run)
```

Start.txt

```
;=========================================
; Expert System for assessing WRMSD hazards.
; Beginning Part of the System
; To Start the System, Just Reset and Run
;=========================================
;================
;* DEFFUNCTIONS *
;================
```

```
(deffunction ask-question (?question $?allowed-values)
(printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer)))
(while (not (member ?answer ?allowed-values)) do (printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer))))
?answer))
(deffunction yes-or-no-p (?question) ; yes-or-no-p can have more arguments than one
(bind ?response (ask-question ?question yes no y n))
(if (or (eq ?response yes) (eq ?response y)) then TRUE else FALSE))
(deffacts whole-system-start (start))
(defrule welcome ?w <-(start)
=>
(retract ?w)
(format t"%n**************************************************%n")
(format t "*                                                *%n")
(format t "*        Welcome to Knowledge-Based Expert System        *%n")
(format t "*                                                *%n")
(format t "*                                                *%n")
(format t "**************************************************%n")
(assert (main menu)))
```

```
(defrule main
?main-m <- (main menu)
=>
(retract ?main-m)
(printout t "Please select the number of the corresponding item to run the system:
"crlf crlf crlf)
(format t "---------------------------------------------------------------------------- %n")
(format t ".      1. General OSHA rules                                          . %n")
(format t ".      2. VDT Work Station Check                                      . %n")
(format t ".      3. Leave System                                                .%n")
(format t "----------------------------------------------------------------------------%n")
(assert (get item)))

(defrule get-item
?item <- (get item)
=>
(retract ?item)
(bind ?f (read))
(if (eq 1 ?f)
then (batch "C:/CLIPS/program/notepad/final/try-1.bat")
else (if (eq 2 ?f)
then (batch "C:/CLIPS/program/notepad/final/try-2.bat")
else (if (eq 3 ?f)
then (assert (leave)) else
(assert (get item))))))))
```

```
(defrule leave-system
?L <- (leave)
=>
(retract ?L)
(if (yes-or-no-p "Do you also want to leave CLIPS(yes/no)? ")
then
(exit)
else))
```

---

general-f.txt

```
;;;*************************************************************
;;;*                    Ergonomic Expert System                *
;;;*          This expert system diagnoses some simple problems *
;;;*        about the MSD in Work Shop according to OSHA rules  *
;;;*                    CLIPS Version 6.0                      *
;;;*          To execute, merely load, reset and run.          *
;;;*************************************************************
;;;*********************
;;DEFFUNCTIONS *
;;;*********************
(deffunction ask-question (?question $?allowed-values)
(printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer)))
(while (not (member ?answer ?allowed-values)) do
```

```
(printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer))))
?answer)
(deffunction yes-or-no-p (?question)                    ; yes-or-no-p can have more
arguments than one
(bind ?response (ask-question ?question yes no y n))
(if (or (eq ?response yes) (eq ?response y))
then TRUE
else FALSE))
;;;***************
;;;* START *
;;;***************
(deffacts start-general-questions
(in-depth-analysis))
(defrule welcome
?come <- (in-depth-analysis)
=>
(retract ?come)
(format t"%n ********************************************** %n%n")
(format t" * %n.....Welcome to Knowledge-Based Expert System.....* %n%n%n")
(format t " *%n.....WRMSD analysis.....* %n%n")
(format t " ********************************************** %n")
(assert (uncomfortable-feeling)))
```

```
(defrule uncomfortable-feeling
?poor-feeling <- (uncomfortable-feeling)
=>
(retract ?poor-feeling)
(format t "%n==========================================%n")
(format t" Do you have any of the following uncomfortable feelings (yes/no)? %n")
(format t "          * Painful joints                    %n")
(format t "                                              %n")
(format t "          * Pain, tingling or numbness in hands or feet   %n")
(format t "                                              %n")
(format t "          * Shooting or stabbing pains in arms or legs    %n")
(format t "                                              %n")
(format t "          * Swelling or inflammation          %n")
(format t "                                              %n")
(format t "          * Burning sensation                 %n")
(format t "                                              %n")
(format t "          * Pain in wrists, shoulders, forearms, knees    %n")
(format t "                                              %n")
(format t "          * Stiffness                         %n")
(format t "========================================== %n")
(format t " Do you have any of the above uncomfortable feelings (yes/no)? %n")
(format t "                                              %n")
(if (yes-or-no-p "" )
 then
(assert (list))
```

```
else (assert (continue))))

(defrule continue

?continue <- (continue)

=>

(retract ?continue)

(if (yes-or-no-p "Would you like to know how to avoid the above problems

(yes/no)?")

then

(assert (list))

else

(assert (leave system))))  ; Leave the program

;;;*****************************************************************

;;;* COUNTING THE NUMBER OF WMSD HAZARD FACTORS *

;;;*****************************************************************

(defrule count-first-no

(declare (salience 10))

(not (c ?))

(not (number ?))

?al <- (count)

=>

(retract ?al)

(assert (start count number of WMSD))

(assert (number 0))

(assert (c 1)))
```

```
(defrule  count-next-no
(declare (salience  10))
(c ?c)
(number  ?number)
?a2 <- (count)
=>
(retract ?a2)
(assert (start count number  of WMSD)))

(defrule  count-number-of-no
(declare (salience  10))
?f1 <- (start count number  of WMSD)
?f2 <- (number  ?number)
?f3 <- (c ?c)
=>
(retract ?f1  ?f2 ?f3)
(assert (next-question))
(assert (number  =(+ 1 ?number)))
(assert (c =(+ 1 ?c)))
(printout  t ?number  crlf))
;;;**************************************
;;; PRINT THE NO OF WMSD RISK FACTORS
;;;**************************************
(defrule  risk-factor-no
(declare (salience  9))
```

```
?WMSD <- (have WMSD-risk)
?end <- (print WMSD)
?risk-factor <- (number ?number)
=>
(retract ?end ?risk-factor ?WMSD)
(printout t "You have " ?number " WMSD risk factors!" crlf crlf)
(assert (again)))          ; go to select continue or not


;;;;*****************************************
;;; START THE ASK THE GENERAL QUESTIONS
;;;;*****************************************
(defrule start-general-questions
?print-list <- (list)
=>
(retract ?print-list)
(format t "%n _____%n")
 (format t "          a. shoulders;                    %n")
(format t "          b. Neck;                         %n")
(format t "          c. back/trunk/hip;               %n")
(format t "          d. knees;                        %n")
(format t "          e. hands/wrists/arms;            %n")
(format t "     f. MAIN MENU of the system            %n")
(format t " _____%n")
(assert (next-step)))
(defrule number-selection ?select <- (next-step)
```

```
=>
(retract ?select)
(printout t "Please select a,b,c,d,e or f and then press Enter to choose the part of your
check." crlf crlf)
(bind ?input(read))
(if (eq a ?input)
then (assert (part Shoulders)
(problem shoulder 1))
else (if (eq b ?input)
then (assert (part Neck)
(problem neck 1)) else (if (eq c ?input)
then (assert (part Back/Trunk/Hip)
(problem back 1)) else (if (eq d ?input)
then (assert (part Knees)
(problem knees 1)) else (if (eq e ?input)
then (assert (part Hands/Wrists/Arms)
(problem hands 1)) else (if (eq f ?input) then (assert (main menu))
else
(assert (next-step)))))))) ; if the user doesn't assert a or b or c or d or e,
; it keeps ask the same question
;;=========================
;; Check work time
;;=========================
(defrule check-work-time-0
(declare (salience 10)) ; check time after angle
```

```
 ?duration <- (hour ?s-time)
 =>
(retract ?duration)
(printout t " How many hours do you work by this posture per day?" crlf crlf)
(bind ?a-time(read))
(assert (actual-t ?a-time)
(standard-t ?s-time)))

(defrule check-work-time-1 (declare (salience 10))
?a-t <- (actual-t ?a-time)
?s-t <- (standard-t ?s-time)
=>
(retract ?a-t ?s-t)
(if ( > ?a-time 24) then
(printout t "Please enter the right answer" crlf crlf)
(assert (hour ?s-time))
else
(if (< ?a-time 0) then
(printout t "Duration of your work in this posture should be equal or geater than
zero,enter the right answer" crlf crlf)
(assert (hour ?s-time))
else
(assert (a-t ?a-time)
(s-t ?s-time))
(if (>= ?a-time ?s-time)
```

```
then
(assert (work-time long))
else
(assert (work-time short))))))

;;=========================
;; Check bending degree
;;=========================
(defrule check-bending-degree-0
(declare (salience 15))
?bending-degree <- (degree ?s-degree)
=>
(retract ?bending-degree)
(printout t" What is your bending degree by this posture?" crlf crlf)
(bind ?a-degree (read))
(assert (actual-d ?a-degree)
(standard-d ?s-degree)))          ;tell system the standard bending degree
;and the actual bending degree


(defrule check-bending-degree-1
(declare (salience 15))
?a-d <- (actual-d ?a-degree)
?s-d <- (standard-d ?s-degree)
=>
```

```
(retract ?a-d ?s-d)
(if (> ?a-degree 90)
then
(printout t "Hi buddy, are you an acrobat?" crlf crlf)
(assert (degree ?s-degree))
else
(if (< ?a-degree 0)
then
(printout t " We use extension and flexion to judge the direction of the degree, please reenter degree." crlf crlf)
(assert (degree ?s-degree))
else
(assert (a-d ?a-degree)
(s-d ?s-degree))
(if (>= ?a-degree ?s-degree)
then
(assert (combined-factor bending-degree too high)
(bending degree big)) else
(assert (combind-factor bending-degree small)
(bending degree small))))))
;;================
;; Check force
;;================
(defrule check-force
(declare (salience 15))
```

```
?Force <- (force ?s-force)
=>
(printout t " How much is the force (kg)?" crlf crlf)
(bind ?a-force(read))
(assert (actual-f ?a-force)
(standard-f ?s-force)) ;tell system the standard force
;and the actual force
(if (>= ?a-force ?s-force)
then
(retract ?Force)
(assert (main-factor high hand force))
else
(retract ?Force)))
;**********************************
;check other part of your body?
;**********************************
(defrule check-other-part ; it doesn't need a higher salience
?check<-(check other part)
=>
(retract ?check)
(if (yes-or-no-p "If you have checked your body, do you want to know how much
WMSD hazards you have(yes/no)?") then
(assert (print WMSD)
(check again)) else
(assert (check again))))
```

```
(defrule check-again
?check-a<-(check again)
=>
(retract ?check-a)
(if (yes-or-no-p "Do you want to check other part of your body(yes/no)?") then
(assert (list)) else
(assert (leave system))))
;;;**************************
;;;leave the system
;;;**************************
(defrule leave-system
?leave <- (leave system)
=>
(retract ?leave)
(if (yes-or-no-p "Do you want to leave CLIPS (yes/no)?")
then
(exit)
else
(if (yes-or-no-p "Do you want to see other part of our system (yes/no)?" )
 then
(assert (main menu)) else
(printout t "you are leaving the system by your choice, hope you have benefited from
it" crlf))))
;;=============================
;; go to main menu of the system
```

```
;;============================

(defrule main-menu

?main <- (main menu)

=>

(retract ?main)

(batch "C:/CLIPS/program/notepad/final/try-0.bat"))

;*****************************************************

;*        REPORT         *

;*****************************************************

;; Awkward posture - to report duration

(defrule physical-risk-factor-report

(declare (salience 10))

?R-0 <- (REPORT awk)

?main <- (physical-f $?physical)

=>

(retract ?R-0 ?main)

(printout t " The potential physical risk factor of WMSD is " ?physical crlf crlf)

(assert (report duration)))

;;_____________________________________________


;;============================

;; Main problem factors Report

;;============================

(defrule main-factor-report

(declare (salience 10))
```

```
?R-1 <- (REPORT main)
?main <- (main-factor $?main-factor)
=>
(retract ?R-1 ?main)
(printout t" The main risky factor of WMSD is " ?main-factor crlf crlf)
(assert (report combined factor)))

;;=============================================================
;; combined problem factors report - it's only for combined factor "with high repetitive motion"
;;=============================================================
(defrule combined-factor-report (declare (salience 10))
?R-2 <- (report combined factor)
?c-factor <- (combined-factor $?combined)
=>
(retract ?R-2 ?c-factor)
(printout t "Meanwhile, you have combined WMSD risky factor " ?combined crlf crlf)
 (assert (report duration)))

;;================================
;; When there is no combine factor
;;================================
(defrule no-combined-factor
(declare (salience 10))
```

```
?R-2 <- (report combined  factor)
(not (combined-factor  $?combined))
 =>
(retract ?R-2)
(assert (report duration)))
;;================
;; Main  factor report
;;================
(defrule  main-factor-report-connect-to-degree
(declare (salience  10))
?R-1 <- (REPORT with  degree)
?main  <- (main-factor  $?main-factor)
=>
(retract ?R-1 ?main)
(printout  t" The main  risky  factor of WMSD is " ?main-factor  crlf crlf)
(assert (report combined  degree)))
```

```
;;================
;; Degree report
;;================
(defrule  bending-degree-report-big
(declare (salience  10))
```

```
?R-4-l<- (report combined degree)
?big <- (bending-degree big)
?standard-degree <- (s-d ?s-degree)
?actual-degree <- (a-d ?a-degree)
=>
(retract ?R-4-1 ?big ?standard-degree ?actual-degree )
(printout t "The bending degree by this posture is too big." crlf crlf)
(printout t "The actual bending degree is " ?a-degree " degree" crlf crlf)
(printout t "The bending degree should be smaller than " ?s-degree " degree." crlf crlf)
(assert (report duration)))

(defrule bending-degree-report-small
(declare (salience 10))
?R-4-1 <- (report combined degree)
?small <- (bending-degree small)
?standard-degree <- (s-d ?s-degree)
?actual-degree <- (a-d ?a-degree)
=>
(retract ?R-4-1 ?small ?standard-degree ?actual-degree )
(printout t "The bending degree by this posture is not too big." crlf crlf)
(printout t "The acutal bending degree is " ?a-degree " degree" crlf crlf)
(printout t "The bending degree should be smaller than " ?s-degree " degree." crlf crlf)
(assert (report duration)))
```

```
;;=================================
;; When no degree dievation
;;=================================

;;=====================================
;; work time report - from every part
;;=====================================

(defrule work-time-report-long
(declare (salience 10))
?R-3-l<- (report duration)
?long <- (work-time long)
?standard-time <- (s-t ?s-time)
?actual-time <- (a-t ?a-time)
=>
(retract ?R-3-l ?long ?standard-time ?actual-time )
(printout t "The working time by this posture is too long." crlf crlf)
(printout t "The acutal working time is " ?a-time " hours" crlf crlf)
(printout t "The working time should be shorter than " ?s-time " hours." crlf crlf)
(assert (work time long)))
(defrule work-time-report-short
(declare (salience 10))
?R-3-l<- (report duration)
?short <- (work-time short)
?standard-time <- (s-t ?s-time)
```

```
?actual-time  <- (a-t ?a-time)
=>
(retract ?R-3-1 ?short ?standard-time  ?actual-time  )
(printout  t "The  working  time  by this  posture is okay." crlf crlf)
(printout  t "The  acutal working  time  is " ?a-time " hours" crlf crlf)
(printout  t "The  working  time  should be shorter than " ?s-time " hours." crlf crlf))

;;The  upper part is for the report to the section  of high  hand  force motion
;;_____________________________________________________________________________
_____________
;;=========
;; flexion  30
;;=========
(defrule  high-hand-force-flexion
(declare  (salience  20))
?t <- (h ?s-time)
?problem <- (flexion)
=>
(retract ?problem  ?t)
(if(yes-or-no-p  "Do you bend your wrist in flextion  (yes/no)?")
then
(printout  t "Bend  wrist in flextion."  crlf crlf)
(assert (degree 30)
(hour  ?s-time))            ; if has angle,  then tell system  the working  time
else
```

```
(assert (extension))))   ; if no flexion,  then check extension


;;===============
;; extension  45
;;===============
(defrule  high-hand-force-extension
(declare (salience  20))
?t <- (h ?s-time)
?problem <- (extension)
=>
(retract ?problem  ?t)
(if(yes-or-no-p  "Do you bend your wrist in extension  (yes/no)?")
then
(printout  t" Bend wrist in extension.  " crlf crlf)
(assert (degree 45)
(hour  ?s-time))
else
(assert (ulnar))))  ; if no extension,  then check if there is ulnar



;;======================
;; ulnar  deviation
;;============================
(defrule  high-hand-force-ulnar
(declare (salience  20))
```

```
?t <- (h ?s-time)
?problem <- (ulnar)
=>
(retract ?problem ?t)
(if(yes-or-no-p "Do you bend your wrist in ulnar deviation (yes/no)?")
then
(printout t "Bend wrist in ulnar deviation. " crlf crlf)
(assert (degree 30)
(hour ?s-time)) else
(assert (no other risk factors))))
;;=========================================
;; When no other riks factors with gripping or pinching
;;=========================================
(defrule no-other-risk-factors
(declare (salience 20))
?no-risk-t <- (no-other-risk ?s-time) ?problem <- (no other risk factors) =>
(retract ?problem ?no-risk-t)
(assert (hour ?s-time)
(REPORT main)
(report WMSD)))
;;==================
;; WMSD hazard report
;;==================
(defrule WMSD-hazard-report
?S-R <- ( report WMSD)        ; tell the system to report
```

```
?PRF <- (physical risk factor)
?overtime <- (work time long)
=>
(retract ?S-R ?PRF ?overtime)
(assert ( WMSD alert)))


(defrule WMSD-no-over-time
?S-R <- ( report WMSD)
?PRF <- (physical risk factor)
(not(work time long))
=>
(retract ?S-R ?PRF))

(defrule WMSD-no-PRF
?S-R <- ( report WMSD)
?overtime <- (work time long)
(not(physical risk factor))
=>
(retract ?S-R ?overtime))
;;;**********************
;;;*WMSD Alert *
;;;**********************
(defrule WMSD-state-conclusions ""
(declare (salience 10))
```

```
?alert <- (WMSD alert) =>
(retract ?alert)
(assert (count))
(printout t "============================" crlf crlf)
(printout t " Alert: Here is a WMSD hazard !" crlf crlf)
(printout t "============================" crlf)
(assert (have WMSD-risk)))
;;*****************************************
;;         QUERY RULES
;;*****************************************
;;;=========================
;;; Check the body part
;;;=========================

(defrule check-the-body-part
?body <- (part ?part)
=>
(assert (body ?part))
(retract ?body)
(printout t "Let's check the " ?part" part." crlf crlf))
;;*********************************
;; PROBLEM ANALYSIS
;;*********************************
;;====================================
;; About awkward postures – Shoulders
```

```
;;=====================================
(defrule awkward-posture-shoulders-1
(body Shoulders)
?problem <- (problem shoulder 1)
=>
(retract ?problem)
(if (yes-or-no-p "Do you work with your hand(s) above the head or the elbow(s)
above the shoulders (yes/no)? ")
then
(assert (physical-f awkward posture at shoulders)
(physical1 risk factor)
(hour 4)
(REPORT awk)
(report WMSD)          ; output a report
(problem shoulder 2))
else
(assert (problem shoulder 2))))

(defrule awkward-posture-shoulders-2
(body Shoulders)
?problem <- (problem shoulder 2)
=>
(retract ?problem)
(if (yes-or-no-p "Do you repetitively raise your hand(s)
above the head or the elbows above the shoulder(s)
```

```
more often than once per minute (yes/no)? ")
then
(assert (physical-f awkward posture at shoulders)
(physical risk factor)
(hour 4)
(REPORT awk)
(report WMSD)          ; output a report
(problem shoulder high repetitive motion))
else
(assert (problem shoulder high repetitive motion))))
;;=========================
;;Awkward Posture Neck
;;=========================
(defrule awkward-posture-neck-1
(body Neck)
?problem<- (problem neck 1)
=>
(retract ?problem)
(if (yes-or-no-p "Do you work with your neck bending without support or ability to
vary posture(yes/no)?")
then
(assert (physical-f awkward posture at neck)
(physical risk factor)
(degree 45)
(hour 4)
```

```
(REPORT awk)
(report WMSD)
(check other part))
else
(assert (check other part))))
;;=======================
;; Awkward Posture Back
;;=======================
(defrule awkward-posture-back-1
(body Back/Trunk/Hip)
?problem <- (problem back 1)
=>
(retract ?problem)
(if (yes-or-no-p "Do you work with your back bent forward(without support, or the
ability to very posture) (yes/no)? ")
then
(assert (physical-f awkward posture at back)
(physical risk factor)
(degree 30)
(hour 4)
(REPORT awk)
(report WMSD)
(problem back 2))
else
(assert (problem back 2))))
```

```
(defrule  awkward-posture-back-2
(body Back/Trunk/Hip)
?problem <- (problem back 2)
=>
(retract ?problem)
(if (yes-or-no-p "Do you work with your back bent forward near 45 degree (without support or the ability  to vary posture)(yes/no)?  ")
then
(assert (physical-f awkward posture at back)
(physical risk factor)
(degree 45)
(hour 2)
(REPORT awk)
(report WMSD)
(check other part))
else
(assert (check other part))))     ; finish  back part and check other part


;;;==============================
;;; Awkward Posture Knees
;;;==============================
(defrule  awkward-knees-squatting
(body Knees)
```

```
?problem <- (problem knees 1)
=>
(retract ?problem)
(if (yes-or-no-p "Do you squat while  working(yes/no)?  ")
then
(assert (physical-f awkward posture at knees by squatting)
(physical risk factor)
(hour 4)
(REPORT awk)
(report WMSD)
(problem knees 2))
else
(assert (problem knees 2))))


(defrule  awkward-knees-kneeling
(body Knees)
?problem <- (problem knees 2)
=>
(retract ?problem)
(if (yes-or-no-p "Do you have kneeling  while  working(yes/no)?  ") then
(assert (physical-f awkward posture at knees by kneeling)
(physical risk factor)
(hour 4)
(REPORT awk)
(report WMSD)
```

```
(problem knees 3)) else
(assert (problem knees 3))))
;;=========================
;; Repeated Impact Knees
;;=========================
(defrule knees-repeated-impact
(body Knees)
?problem <- (problem knees 3)
=>
(retract ?problem)
(if (yes-or-no-p "Do you use the knee as a hammer more than once per minute
(yes/no)? ")
then
(assert (physical-f repeated impact at knees by use knee as a hammer)
(physical1 risk factor)
(hour 2)
(REPORT awk)
(report WMSD)
(check other part)) else
(assert (check other part))))
;;=============================
;; High Hand Force – Pinching
;;=============================
(defrule high-hand-force-l-l
(body Hands/Wrists/Arms)
```

```
?problem <- (problem hands 1)
=>
(retract ?problem)
(if(yes-or-no-p "Do you need to pinch an unsupported object(s) while working
(yes/no)?")
then
(assert (physical risk factor)
(no-other-risk 4)
(main-factor pinching an unsupported object while working))
(if(yes-or-no-p "Do you have highly repetitve motion meanwhile (yes/no)?")
then
(assert (combined-factor highly repetitive motion)
(force 0.7)
(h 3)
(REPORT main)
(report WMSD)
(problem hands 1-2))
else
(assert (flexion)
(force 0.7)
(h 3)
(REPORT main)
(report WMSD)
    (problem hands 1-2)))       ;check flexion -> extension -> ulnar-> no
; other risk factors
```

```
else
(assert (problem hands 1-2))))

(defrule high-hand-force-1-2
(body Hands/Wrists/Arms)
?problem <- (problem hands 1-2)
=>
(retract ?problem)
(if(yes-or-no-p "Do you just pinch an object(s) while working (yes/no)?")
then
(assert (physical risk factor)
(no-other-risk 4)
(main-factor pinching an object while working))
(if(yes-or-no-p "Do you have highly repetitve motion meanwhile (yes/no)?")
then
(assert (combined-factor highly repetitive motion)
(force 1.5)
(h 3)
(REPORT main)
(report WMSD)
(problem hands 2-1))
else
(assert (flexion)
(force 1.5)
(h 3)
```

```
(REPORT main)
(report WMSD)
(problem hands 2-1))); check degrees starting from flexion
else
(assert (problem hands 2-1))))          ;go to gripping


;;=================================
;; High Hand Force – Gripping
;;=================================
(defrule high-hand-force-2-1
(body Hands/Wrists/Arms)
?problem <- (problem hands 2-1)
=>
(retract ?problem)
(if(yes-or-no-p "Do you need to grip an unsupported object(s) while working
(yes/no)?")
then
(assert (physical risk factor)
(no-other-risk 4) ; when there is no other factors,
; the system know the working time is 4 hours
(main-factor gripping an unsupported object while working))
(if(yes-or-no-p "Do you have highly repetitve motion meanwhile (yes/no)?")
then
(assert (combined-factor highly repetitive motion)
(force 4)
```

```
(h 3)
(REPORT main)
(report WMSD)
(problem hands 2-2))
else
(assert (flexion)
(force 4)
(h 3)
(REPORT main)
(report WMSD)
(problem hands 2-2))) ;check flexion -> extension -> ulnar
else
(assert (problem hands 2-2))))

(defrule high-hand-force-2-2
(body Hands/Wrists/Arms)
?problem <- (problem hands 2-2)
=>
(retract ?problem)
(if(yes-or-no-p "Do you just need to grip an object(s) while working (yes/no)?")
then
(assert (physical risk factor)
(no-other-risk 4 hours)
(main-factor gripping an unsupported object while working))
(if(yes-or-no-p "Do you have highly repetitve motion meanwhile (yes/no)?")
```

```
then
(assert (combined-factor highly repetitive motion)
(force 4)
(h 3)
(REPORT main)
(report WMSD)
(problem hand high repetitive motion))
else
(assert (flexion)
(force 4)
(h 3)
(REPORT main)
(report WMSD)
(problem hand high repetitive motion)))
else
(assert (problem hand high repetitive motion))))

;;=================================
;; Highly Repetitve Motion - shoulders
;;=================================
(defrule high-repetitive-motion-shoulder
(body Shoulders)
?problem <- (problem shoulder high repetitive motion)
=>
(retract ?problem)
```

```
(if (yes-or-no-p "Do you use the same motion with little or no variation every few seconds (excluding keying activities) (yes/no)? ")
then
(assert (main-factor higly repetitive motion at shoulders)
(physical risk factor)
(hour 6)
(REPORT main)
(report WMSD)
(check other part))
else
(assert (check other part))))

;;============================
;; Highly Repetitve Motion – hands
;;==================================
(defrule high-repetitive-motion-hands
(body Hands/Wrists/Arms)
?problem <- (problem hand high repetitive motion)
=>
(retract ?problem)
(if (yes-or-no-p "Do you use the same motion with little or no variation every few seconds (excluding keying activities) (yes/no)? ")
then
(assert (main-factor higly repetitive motion at shoulders)
(no-other-risk 6)
```

```
(physical risk factor)
(h 2)
(flexion)
(REPORT main)
(report WMSD)
(high force exertions))
else
(assert (intensive keying)))) ; go to intensive keying

(defrule high-force-exertion
?problem <- (high force exertions)
=>
(retract ?problem)
(if (yes-or-no-p "Do you have high, forcefl exertions with hands(yes/no)? ")
then
(assert (combined-factor high, forcefl exertions with hands)
(h 2)
(report combined factor)
(intensive keying)) else
(assert (intensive keying)))) ; to check intensive keying
(defrule high-repetitive-motion-4
(or (body Neck)
(body Hands/Wrists/Arms))
?problem <- (intensive keying)
=>
```

```
(retract ?problem)
(if (yes-or-no-p "Do you have intensive keying(yes/no)? ")
then
(assert (main-factor intensive keying)
(physical risk factor)
(no-other-risk 7)
(flexion)
(h 4)
(REPORT main)
(report WMSD)
(repeated impact hands)) else
(assert (check other part)
(repeated impact hands))))

(defrule problem-upper-body-9
(body Hands/Wrists/Arms)
?problem <- (repeated impact hands)
=>
(retract ?problem)
(if (yes-or-no-p "Do you use the hand as a hammer more than once per minute
(yes/no)'? ")
then
(assert (main-factor repeated impact)
(physical risk factor)
(hour 2)
```

```
(REPORT main)
(report WMSD)
(check other part)) else
(assert (check other part))))    ; finish the hands part and go to other part
```

VDT-f.txt

```
;;;*****************************************************************
;;;*              Ergonomic Expert System Part Two - Questions for VDT          *
;;;*                    This expert system diagnoses some simple                *
;;;*                          problems with a general questions                 *
;;;*****************************************************************
;;;*****************************
;;;*     START          *
;;;*****************************
(deffacts start
(start))
(defrule start
(start) =>
(format t "%n*****************************************************%n")
 (format t "*              Welcome to Knowledge-Based Expert System      * %n")
(format t "*                    VDT Workstation Check                   * %n")
(format t "*  If employee exposure does not meet the levels indicated   * %n")
(format t "*       by the Basic Screening tool, you may STOP HERE       * %n")
 (format t "*****************************************************%n")
(assert (question A)))
```

```
;;***************************
;;
;;*DEFFUNCTIONS *
;;***************************
;;
(deffunction ask-question (?question $?allowed-values)
(printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer)))
(while (not (member ?answer ?allowed-values)) do
(printout t ?question crlf crlf)
(bind ?answer (read))
(if (lexemep ?answer)
then (bind ?answer (lowcase ?answer))))
?answer)

(deffunction yes-or-no-p (?question)
(bind ?response (ask-question ?question yes no y n))
(if (or (eq ?response yes) (eq ?response y))
then TRUE
else FALSE))

;;;;*****************************************
;;;;
;;;* WMSD STATE RULES FIRST *
;;;;*****************************************
;;;;
(defrule normal-state-conclusions ""
```

```
(declare (salience 10))
?b <- (body-state normal) =>
(retract ?b)
(assert (no WMSD-risk )))

(defrule WMSD-state-concIusions
(declare (salience 10))
?b <- (body-state unsatisfactory)
=>
(retract ?b)
(assert (have WMSD-risk ))
(printout t" Alarm: You have WMSD risk !" crlf crlf))

;;;*****************************************************************
;;;*      COUNTING THE NUMBER OF "NO" ANSWERS          *
;;;*****************************************************************
(defrule count-first-no
(declare (salience 10))
(not (c ?))
(not (number ?))
?al <- (count) =>
(retract ?al)
(assert (start count number of no))
(assert (number 0))
(assert (c 1)))
```

```
(defrule count-next-no
(declare (salience 10))
(c ?c)
(number ?number)
?a2 <- (count) =>
(retract ?a2)
(assert (start count number of no)))

(defrule count-number-of-no
(declare (salience 10))
?f1 <- (start count number of no)
?f2 <- (number ?number)
?f3 <- (c ?c)
=>
(retract ?f1 ?f2 ?f3)
(assert (next-question))
(assert (number =(+ 1 ?number)))
(assert (c =(+ 1 ?c)))
(printout t ?number crlf))
```

```
;;;**********************************
;;; PRINT NO FOR 1ST PART
;;;;**********************************
(defrule printout-out
(declare (salience 9))
?first-end <- (first-end)
?print <- (number ?number)
=>
(retract ?first-end ?print)
(if (> ?number 0) then
(printout t "The total no you have: " ?number crlf)
(assert (question 0))
else))
;;;**********************************
;;; PRINT IF ALL YES 1st PART
;;;**********************************
(defrule all-yes
(declare (salience 9))
(not (have WMSD-risk))
?first-end <- (first-end)
=>
(retract ?first-end)
(printout t "All yes for this part! " crlf)
(assert (question 0)))
```

```
;;;*****************************************************************
;;;* COUNTING THE NUMBER OF "NO" ANSWERS IN THE 2nd PART *
;;;*****************************************************************
(defrule calculate-first-no
(declare (salience 6))
(not (m ?m))
(not (n ?n))
?c-1 <- (calculate)
=>
(retract ?c-1)
(assert (calculate number of no))
(assert (n 0))
(assert (m 1)))
(defrule calculate-next-no
(declare (salience 6))
(m ?m)
(n ?n)
?c-2 <- (calculate)
=>
(retract ?c-2)
(assert (calculate number of no)))

(defrule calculate-number-of-no
(declare (salience 6))
?wl <- (calculate number of no)
```

```
?w2 <- (n ?n)

?w3 <- (m ?m)

=>

(retract ?wl ?w2 ?w3)

(assert (next-question))

(assert (n =(+ 1 ?n)))

(assert (m =(+ 1 ?m)))

(printout  t ?n crlf)

 (if (>= ?n 1)

then

(assert (WMSD-risk-2nd))

(printout  t "Alarm:  You have WMSD hazard!"  crlf crlf)

else))

;;;**************************************

;;; PRINT NO FOR THE 2nd PART

;;;**************************************

 (defrule  printout-out-2nd

(declare  (salience  5))

?second-end <- (second-end)

?print <- (n ?n) =>

(retract ?second-end ?print)

(if (> ?n 0) then

(printout  t "The  total no you have:  " ?n crlf)

(assert (question-next))

else))
```

```
;;;;**********************************************
;;; PRINT IF ALL YES FOR THE 2ND PART
;;;;**********************************************
(defrule all-yes-second
(declare (salience 5))
(not (WMSD-risk-2nd))
?second-end <- (second-end)
=>
(retract ?second-end)
(printout t "All yes for this pan! " crlf crlf)
(assert (question-next)))
;;;;************************
;;;* QUERY RULES *
;;;;************************
;;;;============================
;;;  The first question
;;;============================
(defrule question-A ""
?question <- (question A) =>
(retract ?question)
(if (yes-or-no-p "Are your head and neck about upright (yes/no)? ")
then (assert (question B))
else (assert (count))
(assert (question B))
(assert (body-state unsatisfactory))))
```

```
;;;======================
;;;The following questions
;;;======================
(defrule question-B ""
?question <- (question B)
=>
(retract ?question)
(if (yes-or-no-p "Do your head, neck and trunk face forward (yes/no)? ")
then (assert (question C))
 else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question C))))

(defrule question-C ""
?question <- (question C)
=>
(retract ?question)
(if (yes-or-no-p "Is your trunk about perpendicular to floor (yes/no)? ")
then (assert (question D))
else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question D))))
```

```
(defrule question-D ""
?question <- (question D)
=>
(retract ?question)
(if (yes-or-no-p "Are your shoulders and upper arms about perpendicular to floor
(yes/no)? ")
then (assert (question E))
else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question E))))

(defrule question-E""
?question <- (question E)
=>
(retract ?question)
(if (yes-or-no-p "Are your upper arms and elbows close to body (yes/no)? ")
then (assert (question F))
 else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question F))))

(defrule question-F""
?question <- (question F)
```

```
=>
(retract ?question)
(if (yes-or-no-p "Are your forearms, wrists and hands straight and parallel to floor
(yes/no)? ")
then (assert (question G)) else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question G))))
(defrule question-G ""
?question <- (question G)
=>
(retract ?question)
(if (yes-or-no-p "Are your Wrists and hands straight (not bent up/down or sideways
toward little fingert) (yes/no)? ")
then (assert (question H))
else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question H))))

(defrule question-H""
?question <- (question H)
=>
(retract ?question)
```

```
(if (yes-or-no-p "Are your thighs about parallel to floor and lower legs about
perpendicular to floor (yes/no)? ")
then (assert (question I))
else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question I))))

(defrule question-I""
?question <- (question I)
=>
(retract ?question)
(if (yes-or-no-p "Are your feet to rest flat on floor or supported by a stable footrest
(yes/no)? ")
then (assert (question J)) else
(assert (body-state unsatisfactory))
(assert (count))
(assert (question J))))

(defrule question-J ""
?question <- (question J)
=>
(retract ?question)
```

```
(if (yes-or-no-p "Are VDT tasks organized in a way that allows employee to vary VDT tasks with other work activities, or to take micro-breaks ro recovery pauses while at the VDT workstation.(yes/no)? ")
then (assert (first-end)) else
(assert (body-state unsatisfactory))
(assert (count)
(have WMSD-risk))
(assert (first-end))))
;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
;;                    CONTINUE TO THE SECOND PART
;;%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 (defrule question-0 ""
?question <- (question 0)
=>
(retract ?question)
(printout t "Let's come to check some further conditions." crlf crlf crlf)
(assert (question 1)))
;;;*****************************
;;;* SEATING
;;;*****************************
(defrule question-1 ""
?question <-(question 1)
=>
(retract ?question)
```

```
(if (yes-or-no-p "Backrest provides support for employee's lower back (lumbar area)
(yes/no)? ")
then (assert (question 2))
else
(assert (calculate))
(assert (question 2))))

(defrule question-2 ""
?question <- (question 2)
=>
(retract ?question)
(if (yes-or-no-p "Seat width and epth accommodate specific employee (seatpan not
too big/small) (yes/no)? ") then
(assert (question 3))
else (assert (calculate))
(assert (question 3))))

(defrule question-3 ""
?question <- (question 3) =>
(retract ?question)
(if (yes-or-no-p "Seat front does not press against the back of employee's knees and
lower legs (yes/no)? ")
then (assert (question 4))
else (assert (calculate))
(assert (question 4))))
```

```
(defrule question-4 ""
?question <- (question 4) =>
(retract ?question)
(if (yes-or-no-p "Seat has cushioning and is rounded/has (waterfall-front/no sharp edge) (yes/no)? ")
then (assert (question 5))
else (assert (calculate))
(assert (question 5))))

(defrule question-5 ""
?question <- (question 5) =>
(retract ?question)
(if (yes-or-no-p "Armrests support both forearms while employee performs VDT tasks and do not interfere with movement(yes/no)? ")
then (assert (question 6))
else (assert (calculate))
(assert (question 6))))
;;;**********************************
;;; KEYBOARD/INPUT DEVIE
;;;**********************************
(defrule question-6 ""
?question <- (question 6)
=>
(retract ?question)
```

```
(if (yes-or-no-p "Keyboard/input device platform(s) is stable and large enough to
hold keyboard and input device(yes/no)? ")
then (assert (question 7))
else (assert (calculate))
(assert (question 7))))

(defrule question-7 ""
?question <- (question 7)
=>
(retract ?question)
(if (yes-or-no-p "Input device (mouse or trackball) is stable and large enough to hold
keyboard and input device, (yes/no)? ")
then (assert (question 8))
else (assert (calculate))
(assert (question 8))))

(defrule question-8 ""
?question <- (question 8)
=>
(retract ?question)
(if (yes-or-no-p "Input device is easy to activate and shape/size fits hand of specific
employee (not too big/small) (yes/no)? ")
then (assert (question 9))
else (assert (calculate))
(assert (question 9))))
```

```
(defrule question-9 ""
?question <- (question 9)
=>
(retract ?question)
(if (yes-or-no-p "Wrists and hands do not rest on sharp or hard edge (yes/no)? ")
then (assert (question 10))
else (assert (calculate))
(assert (question 10))))

;;;*****************************
;;; MONITOR
;;;*****************************
(defrule question-10 ""
?question <- (question 10)
=>
(retract ?question)
(if (yes-or-no-p "Top line of screen is at or below eye level so employee is able to
read it without bending head or neck down/back.(yes/no)? ")
then (assert (question 11))
else (assert (calculate))
(assert (question 11))))

(defrule question-11 ""
?question <- (question 11) =>
(retract ?question)
```

```
(if (yes-or-no-p "Employee with bbifocals/trifocals is able to read screen without bending head or neck backward(yes/no)? ")
then (assert (question 12))
else (assert (calculate))
(assert (question 12))))

(defrule question-12 ""
?question <- (question 12)
=>
(retract ?question)
(if (yes-or-no-p "Monitor distance allows employee to read screen without leaning head, neck or trunk forward/backward(yes/no)? ")
then (assert (question 13))
else (assert (calculate))
(assert (question 13))))

(defrule question-13 ""
?question <- (question 13)
=>
(retract ?question)
(if (yes-or-no-p "Monitor position is directly in form of employee so employee does not have to twist head or neck.(yes/no)? ")
then (assert (question 14))
else (assert (calculate))
(assert (question 14))))
```

```
(defrule question-14 ""
?question <- (question 14)
=>
(retract ?question)
(if (yes-or-no-p "No glare (e.g., from windows, lights) is present on the screen which might cause employee to assume an awkward posture to read screen.(yes/no)? ")
then (assert (question 15))
else (assert (calculate))
(assert (question 15))))
;;;**********************
;;; WORK AREA
;;;**********************
 (defrule question-15 ""
?question <- (question 15)
=>
(retract ?question)
(if (yes-or-no-p "Thighs have clearance space between chair and VDT table/keyboard platform (thigh's not rapped).(yes/no)? ")
then (assert (question 16))
else (assert (calculate))
(assert (question 16))))

(defrule question-16 ""
?question <- (question 16) =>
```

```
(retract ?question)
(if (yes-or-no-p "Legs and feet have clearance space under VDT table so employee is able to get close enough to keyboard/input device.(yes/no)? ")
then (assert (question 17))
else (assert (calculate))
(assert (question 17))))
;;;**************************
;;; ACCESSORIES
;;;**************************
(defrule question-17 ""
?question <-(question 17)
=>
(retract ?question)
(if (yes-or-no-p "Document holder, if provided, is stable and large enough to hold documents that are used.(yes/no)‘?")
then (assert (question 18))
else (assert (calculate))
(assert (question 18))))

(defrule question-18 ""
?question <-(question 18)
=>
(retract ?question)
```

```
(if (yes-or-no-p "Document holder, if provided, is placed at about the same height
and distance as monitor screen so there is little head movement when employee looks
from document to scree.(yes/no)? ")
then (assert (question 19))
else (assert (calculate))
(assert (question 19))))

(defrule question-19 ""
?question <- (question 19)
=>
(retract ?question)
(if (yes-or-no-p "Wrist rest, if provided, is padded and free of sharp and square
edges.(yes/no)? ")
then (assert (question 20))
else (assert (calculate))
(assert (question 20))))

(defrule question-20 ""
?question <- (question 20)
=>
(retract ?question)
(if (yes-or-no-p "Wrist rest, if provided, allows employee to keep forearms, wrists
and hands
straight and parallel to ground when using keyboard/input device.(yes/no)? ")
then (assert (question 21))
```

```
else (assert (calculate))
(assert (question 21))))

(defrule question-21 ""
?question <- (question 21)
=>
(retract ?question)
(if (yes-or-no-p "Telephone can be used with head upright (not bent)and shoulders are relaxed if VDT task is done at the same time .(yes/no)? ")
then (assert (question 22))
else (assert (calculate))
(assert (question 22))))
;;;**********************
;;; GENERAL
;;;**********************
(defrule question-22 ""
?question <- (question 22)
=>
(retract ?question)
(if (yes-or-no-p "Workstation and equipment have sufficient adjustability so that the employee is able to be in a save working posture and to make occasional changes in posture while performing VDT tasks..(yes/no)? ")
then (assert (question 23))
else (assert (calculate))
(assert (question 23))))
```

```
(defrule question-23 ""
?question <- (question 23)
=>
(retract ?question)
(if (yes-or-no-p "VDT Workstation, equipment and accessories are maintained in
serviceable condition and function properly.(yes/no)? ")
then (assert (second-end))
else (assert (calculate))
(assert (second-end))))

;;;**************************************************
;;; CONNECTION TO THE NEXT SECTION
;;;**************************************************
(defrule next-step
?end <- (question-next)
=>
(retract ?end)
(if (yes-or-no-p "Would you like to try again (yes/no)?") then
(reset)
(run)
else
(assert (check other part))))
```

```
;=========================
;Check other part
;=========================
(defrule  to-main
?main<-  (check other part)
=>
(retract ?main)
(if (yes-or-no-p " Do you want to run other part of the system (yes/no)?" )
then (batch "C:/CLIPS/program/notepad/final/try-0.bat")
else
(assert (leave system))))
;;====================
;;leave  system
;;====================
(defrule  leave-system
?leave <- (leave syetem)
=>
(retract ?leave)
(if (yes-or-no-p " Leave CLIPS (yes/no)?" ) then
(exit)  else))
```

Appendix 3: Data acquired from employees by expert system

age	gender	Number of WRMSD Hazards					Workstation Hazards			position	task
		shoulders	Neck	Back	knees	Hands	1st part	2nd part	total		
31	m	0	1	0	0	1	5	10	15	project manager	Dealing with records, reports…
28	f	0	0	1	0	0	3	8	11	secretary	Dealing with records, reports…
40	m	0	0	0	0	0	7	3	10	technical office	Dealing with records, reports…
30	m	0	0	0	0	0	8	2	10	technical office	Dealing with records, reports…
30	f	0	0	0	0	0	7	3	10	technical office	Dealing with records, reports…
50	m	0	0	0	0	0	8	2	10	technical office	Dealing with records, reports…
44	m	0	0	0	0	0	7	2	9	project manager	Dealing with records, reports…
29	m	0	0	0	0	0	6	3	9	technical office	Dealing with records, reports…
25	f	0	0	0	0	0	6	3	9	technical office	Dealing with records, reports…
48	m	0	0	0	0	0	7	2	9	technical office	Dealing with records, reports…
24	f	0	0	0	0	0	7	2	9	IT	PC administrative activities
33	m	0	0	0	0	0	7	2	9	IT	PC administrative activities
29	m	0	0	0	0	0	7	2	9	IT	PC administrative activities
42	m	0	0	0	0	0	4	5	9	secretariat	communicating database
28	f	0	1	0	0	0	4	5	9	secretariat	communicating database
31	f	0	1	0	0	0	4	5	9	secretariat	communicating database
38	m	0	1	0	0	0	4	5	9	supervisor	daily reports
35	m	0	1	0	0	0	4	5	9	supervisor	daily reports
34	m	0	1	0	0	0	4	5	9	supervisor	daily reports
39	m	0	0	0	0	0	4	5	9	supervisor	daily reports
41	m	0	0	0	0	0	4	5	9	PMU	project management
25	m	0	1	0	0	0	4	5	9	PMU	project management
37	m	0	1	0	0	0	4	5	9	PMU	project management
37	m	0	0	0	0	0	4	5	9	financial unit	financial …
33	m	0	1	0	0	0	4	5	9	financial unit	financial …
33	f	0	0	0	0	0	6	2	8	technical office	Dealing with records, reports…
37	m	0	0	0	0	0	6	2	8	technical office	Dealing with records, reports…
42	m	0	0	0	0	0	5	3	8	technical office	Dealing with records, reports…
46	f	0	0	0	0	0	5	3	8	technical office	Dealing with records, reports…
27	m	0	0	0	0	0	6	2	8	technical office	Dealing with records, reports…

age	gender	Number of WRMSD Hazards					Workstation Hazards			position	task
		shoulders	Neck	Back	knees	Hands	1st part	2nd part	total		
36	m	0	0	0	0	0	6	2	8	technical office	Dealing with records, reports…
41	m	0	0	0	0	0	5	3	8	technical office	Dealing with records, reports…
38	f	0	0	0	0	0	4	4	8	secretariat	communicating database
36	m	0	0	0	0	0	4	4	8	supervisor	daily reports
31	m	0	0	0	0	0	3	5	8	supervisor	daily reports
40	m	0	1	0	0	0	3	5	8	supervisor	daily reports
38	m	0	1	0	0	0	3	5	8	supervisor	daily reports
40	m	0	0	0	0	0	3	5	8	supervisor	daily reports
31	m	0	1	0	0	0	3	5	8	supervisor	daily reports
39	m	0	1	0	0	0	3	5	8	supervisor	daily reports
39	m	0	0	0	0	0	3	5	8	supervisor	daily reports
36	m	0	1	0	0	0	4	4	8	supervisor	daily reports
43	m	0	0	0	0	0	4	4	8	supervisor	daily reports
40	m	0	1	0	0	0	4	4	8	supervisor	daily reports
34	m	0	1	0	0	0	4	4	8	supervisor	daily reports
26	f	0	0	0	0	0	4	4	8	PMU	secretary
25	f	0	0	0	0	0	4	4	8	PMU	secretary
29	m	0	0	0	0	0	4	4	8	PMU	project management
42	m	0	0	0	0	0	4	4	8	PMU	project management
26	m	0	0	0	0	0	4	4	8	PMU	project management
39	m	0	1	0	0	0	4	4	8	PMU	project management
32	m	0	1	0	0	0	4	4	8	financial unit	financial …
25	m	0	1	0	0	0	4	4	8	financial unit	financial …
35	m	0	0	0	0	0	4	4	8	financial unit	financial …
43	m	0	0	0	0	0	4	4	8	financial unit	financial …
27	m	0	0	0	0	0	4	4	8	financial unit	financial …
53	m	0	0	0	0	0	6	1	7	technical office	Dealing with records, reports…
38	m	0	0	0	0	0	5	2	7	technical office	Dealing with records, reports…
37	f	0	0	0	0	0	4	3	7	technical office	Dealing with records, reports…
27	f	0	0	0	0	0	6	1	7	IT	PC administrative activities
28	m	0	0	0	0	0	6	1	7	IT	PC administrative activities
27	f	0	0	0	0	0	6	1	7	IT	PC administrative activities
26	f	0	1	0	0	0	4	3	7	secretariat	communicating database
39	f	0	1	0	0	0	4	3	7	secretariat	communicating database
36	m	0	0	0	0	0	3	4	7	supervisor	daily reports
45	m	0	1	0	0	0	3	4	7	supervisor	daily reports
43	m	0	1	0	0	0	3	4	7	supervisor	daily reports

age	gender	Number of WRMSD Hazards					Workstation Hazards			position	task
		shoulders	Neck	Back	knees	Hands	1st part	2nd part	total		
35	m	0	0	0	0	0	3	4	7	supervisor	daily reports
35	m	0	1	0	0	0	3	4	7	supervisor	daily reports
42	m	0	0	0	0	0	3	4	7	supervisor	daily reports
42	m	0	1	0	0	0	3	4	7	supervisor	daily reports
43	m	0	1	0	0	0	4	3	7	supervisor	daily reports
42	m	0	1	0	0	0	4	3	7	supervisor	daily reports
39	m	0	1	0	0	0	4	3	7	supervisor	daily reports
22	f	0	0	0	0	0	4	3	7	PMU	secretary
29	m	0	0	0	0	0	4	3	7	PMU	financial
33	m	0	0	0	0	0	4	3	7	PMU	project management
29	m	0	0	0	0	0	4	3	7	PMU	project management
32	m	0	0	0	0	0	4	3	7	financial unit	financial …
37	m	0	0	0	0	0	4	3	7	financial unit	financial …
29	m	0	1	0	0	0	4	3	7	financial unit	financial …
51	m	0	0	0	0	0	4	2	6	technical office	Dealing with records, reports…
32	m	0	0	0	0	0	3	3	6	technical office	Dealing with records, reports…
28	m	0	0	0	0	0	4	2	6	technical office	Dealing with records, reports…
42	m	0	0	0	0	0	5	1	6	technical office	Dealing with records, reports…
34	f	0	0	0	0	0	5	1	6	technical office	Dealing with records, reports…
28	m	0	0	0	0	0	4	2	6	technical office	Dealing with records, reports…
24	m	0	0	0	0	0	3	3	6	technical office	Dealing with records, reports…
53	m	0	0	0	0	0	5	1	6	technical office	Dealing with records, reports…
39	m	0	0	0	0	0	3	3	6	technical office	Dealing with records, reports…
33	m	0	0	0	0	0	4	2	6	technical office	Dealing with records, reports…
28	m	0	0	0	0	0	5	1	6	technical office	Dealing with records, reports…
47	m	0	0	0	0	0	4	2	6	technical office	Dealing with records, reports…
40	m	0	1	0	0	0	3	3	6	supervisor	daily reports
42	m	0	0	0	0	0	4	1	5	project manager	Dealing with records, reports…
39	m	0	0	0	0	0	3	2	5	contract manager	Dealing with records, reports…
35	m	0	0	0	0	0	3	2	5	technical office	Dealing with records, reports…
32	f	0	0	0	0	0	3	2	5	IT	PC administrative activities

age	gender	Number of WRMSD Hazards					Workstation Hazards			position	task
		shoulders	Neck	Back	knees	Hands	1st part	2nd part	total		
48	m	0	0	0	0	0	3	1	4	technical office	Dealing with records, reports…
31	f	0	0	0	0	0	2	2	4	IT	PC administrative activities