FACTA UNIVERSITATIS
Series: **Medicine and Biology** Vol.9, No 2, 2002, pp. 150 - 156 UC 616.74:616.057

HUMAN ACTIVITY AND MUSCULOSKELETAL INJURIES AND DISORDERS

Miroljub Grozdanović

Faculty of Occupational Safety, University of Niš, Yugoslavia
E-mail: mirko@znrfak.znrfak.ni.ac.yu

Summary. *Musculoskeletal injuries and disorders produced by various human activities, cause an increasing number of human and economic losses. In our country this problem is not well enough understood and studied, therefore serious research activities and financial resources should be invested in its solving,*
Beacause of that, the aetiological approaches and methods for gathering date for solving this, more and more problem are presented, in this paper.

Key words: *Musculoskeletal injury, cumulative trauma disorders, human work*

Introduction

One of the goals of the ergonomic process is to design or modify people's work and other activities to be within their capabilities and limitations. One possible outcome of poor harmonization is disorder of the musculoskeletal system known as repetitive strain injuries (RSI), cumulative trauma disorders (CTD) or activity and work – related musculoskeletal disorders (WMSD).

About 58 percent of the world's populations over the age of 10 spend one third of their time at work (1). However, approximately 30 – 50 percent of workers are exposed to significant physical occupational hazards, and an equal number of working people report psychological overload resulting in stress symptoms. Globally about 120 million occupational accidents and 200 000 fatalities were estimated to occur annually in addition to 68 – 157 million new cases of occupational diseases due to various exposures. Given that work is essential to our society and the nature of work is largely predetermined, it may appear that little can be done to change the situation. However, an understanding of the mechanism of causation of occupational injuries and accidents will put us in a better position to design effective strategies of control and prevention (2).

Workers in different economic sectors have injuries which are characteristic of regional musculoskeletal problems. In forestry, construction, and manufacturing workers have a higher proportion of back injuries.

Those working in office - type jobs involving keyboarding have cumulative trauma disorders (3).

Cumulative trauma disorders are defined as disorders of the muscles, tendons, peripheral nerves, vascular system, or other tissues. They can result from, be precipitated by, or be aggravated by intense, repeated, sustained or insufficient recovery from: exertions, motions of the body, vibration, or cold (4).

Characteristics of CTDs include:

CTDs are multi-factorial in origin; they may be associated with one or more work or non-work-related risk factors.

CTDs generally develop over periods of weeks, months or years.

If not detected/treated early, recovery may require weeks, months, and years, and in some cases, may never be complete.

Tentative conclusions from ANSI Z-365, 1996. are:

It is possible to quantify exposure to work-related CTD risk factors.

It is possible to identify many work situations in which CTDs are likely to occur.

It is possible to identify broad principles of design to reduce exposure to CTD risk factors that are applicable to all jobs and industries. These principles can be used in the design of work or for modifying existing operations, and in the design of new equipment and processes.

It is not yet possible to specify precise quantitative work design parameters for a given level of risk in a given population.

It is possible to develop and implement control measures for suspected or established work-related risk factors for cumulative trauma disorders.

It is possible to manage cumulative trauma disorders cases in ways which minimize impairment and disability.

It is possible to reduce CTD severity with early evaluation and appropriate treatment of symptomatic employees by an HCP.

It is possible to specify principles and practices in a standard to control work-related CTDs.

Since it does not happen the other way round, i.e. the heavy physical workers developing cumulative trauma disorder and the office workers injuring their backs, this offers credence to the argument that the nature of the physical stress and the region enduring the load largely determine the affected area and probably the nature of injury.

An injury, by definition, means mechanical disruption of tissues. The term "injury" is distinguished from that of "disorder" which is frequently used in any malfunctioning of an organ or an organism. Contrary to injury, a disorder can result without a mechanical perturbation of the tissues involved. Another difference between injury and disorder is that while the onset of a disorder may be gradual and mediated by a pathogen or prepathological, the onset of an injury is sudden and does not involve prepathogenesis. In the cases of occupational musculosekeletal injuries the organs or tissues are invariably exposed to factors which place mechanical stresses on the tissues. Most frequently such exposure is repetitive and prolonged and hence is considered a hazard or risk factor.

The aim of this paper is to encourage research directed at the identification of risk factors related to the work process, which influence the appereance and development of musculoskeletal disorders. These risks accurately defined as ergonomic risks, refer to the physical stress factors and work conditions, which contain the risk of musculosceletal injuries and disorders, and are present always when the requirements excede the man's possibilities for performing working tasks.

Aetiology of tendon, nerve and muscle, and injury precipitation

"Aetiologically, reduced lubrication between tendons and tendon sheaths due to excess relative movement has been suggested in tenosynovitis, whilst high peak loads and cumulative strain have been suggested for tendinitis.

Mechanical stresses due to impingement are also important.

In-vivo animal experiments under high load, high frequency movements conditions have created tendon damage in rabbits due to high frequency movements. High frequency, low load conditions have created tendon damage in rabbits due to high frequency movements. High frequency, low load conditions produced by electrical stimulation did not however produce any tendon damage in monkeys' finger flexor tendon or sheath. More recently Archambault *et al.* (1997) have supported the findings of Backhouse and colleagues but at more realistic movement rates. Damage was found in the paratenon, the outer covering of the tendon. It is suggested that this is consistent with frictional damage due to the long-term sliding of the tendon under load" (5).

Direct mechanical compression of nerves can be seen at many sites: in the wrist between the flexor retinaculum and the flexor tendons, in the lumbar spine between adjacent spinal motion units or due to extruded nuclear material or in the neck between scalene muscles or against the upper ribs.

Szabo *et al.* (1994) found that median nerve excursion with flexion-extension of the fingers is 43 per cent of the excursion experienced by the flexor tendons (6).The difference between specimens was significant but the difference before and after sectioning the TCL was not. It has been found that there is reduced sliding of the median nerve in patients with CTS, indicating that there may be increased frictional forces or adhesions in the diseased arm. If sliding is restricted at some level, perhaps by adhesions, the excursion of the nerve due to joint motion will increase the stretch in the segments adjacent to the restriction with possible chronic effects. This is the base for a provocative test such as straight leg raising in sciatica.

Muscular loading during upper limb intensive work has been linked to the development of chronic muscle problems in the shoulder and neck. Recent clinical findings have suggested that forearm muscle pain may be an overlooked problem in studying work-related chronic musculoskeletal disorders. While work-related muscle pain is well accepted in the shoulder area, pain in the forearm is usually attributed to tendinitis or epicondylitis. Suggested mechanisms for muscle pain include fatigue induced hypoxia leading to metabolic changes as a result of low level continuous activation, increased intracompartmental pressure and physical disruption of the muscle with high force contractions.

Static muscle loading, even at low levels, has been linked to muscle fatigue, pain and myalgia. Examination of the muscle fibres has revealed that in chronically statically loaded muscles there exist increased numbers of type 1 (slow twitch) fibres and so called "ragged red" fibres. Ragged red fibres have damaged mitochondria and are indicative of present or past ischaemia. These findings and an understanding of motor recruitment termed the "Cinderella motor unit".

From the consideration of the nature of injury, the biomechanical basis of injury, and risk factors one may state that a precipitation of injury is an interactive process between genetic, morphological, psychosocial and biomechanical factors (Figure 1).

Hildebrandt (1987) identified in published literature 73 individual factors and 25 work-related factors which were considered as risk or potential risk factors for low-back pain (LBP). All risk factors can be placed in one of four categories: genetic; morphological; psychosocial and biomechanical. While not much can be done about genetic and morphological factors, knowledge of their role in causation or association with LBP, combined with management strategies of biomechanical and psychosocial factors, could allow significant and effective control strategy.

Unfortunately, however, a comprehensive study of these factors with a view to controlling the LBP problem has not been undertaken. The genetic and morphological factors (as non-manipulatable factors) and psychosocial and biomechanical factors (as manipulatable factors) can be used for prediction. Such a combined approach is necessary, especially when no single test or small battery of tests can be used to identify the potential LBP patient (7).

CTD_s represent almost 50% (even over 60%) of all occupational illnesses reported by the Bureau of Labor Statistics. Simmilar statistics are reported by many developed states.

Unfortunately, similar statistics for our contry don't exist, or it is difficult to find them. Some data that can be found in some occupational medical centres reveal a similar situation. For example, reviewing the book of evidence of workers' occupational illness from the Institute of workers' health safety in Niš, we can see similar increasing trends of illnesses which are caused basically by ergonomic risk factors.

Medical Center in Obrenovac is presenting the results of the investigation on those topics conducted in one smeltery. The number of workers is over 1500. In the analyzed year the annual rate of absenteeism caused by the musculoskeletal diseases was 15.1 per 100 workers. The annual rate of absenteeism caused by injuries was 19.0 per 100 workers. In the total number of the lost working days 15.4% is caused by the musculoskeletal disorders. The sick leaves absenteeism caused by musculoskeletal diseases in smelters is almost twice higher than in other workers (21.0%). The diseases related to the spine are the most frequent cause of the sick leave absenteeism (13.8%). The diseases related to soft tissues are in 2% cause of the sick leave absenteeism. The lowest rate of absenteeism is in the group of younger workers (20-29 years old), so the degenerative changes are not the cause of the diseases. We may conclude that the main causes of the high rates of absenteeeism due to musculoskeletal diseases are the workplace conditions and hazards.

At the Faculty of Occupational Safety in Niš, the program for the control of CTD is developed as the constituent part of the program for the occupational safety and health. This program should contribute to the decrease the ergonomic risk level, because, in that way, the degree of workers' musculosceletal injuries and disorders is also decreased.

The gathering of data on musculoskeletal problems

The human body is continuously required to perform physical work. Three main demands must be met: moving the body or its parts, transporting or moving other objects and maintaining the body posture. When exposed to these demands the human body responds with complex series of events, leading to the performance of muscular exercise. Thus the muscle contraction is the end point of events taking place in the sensory

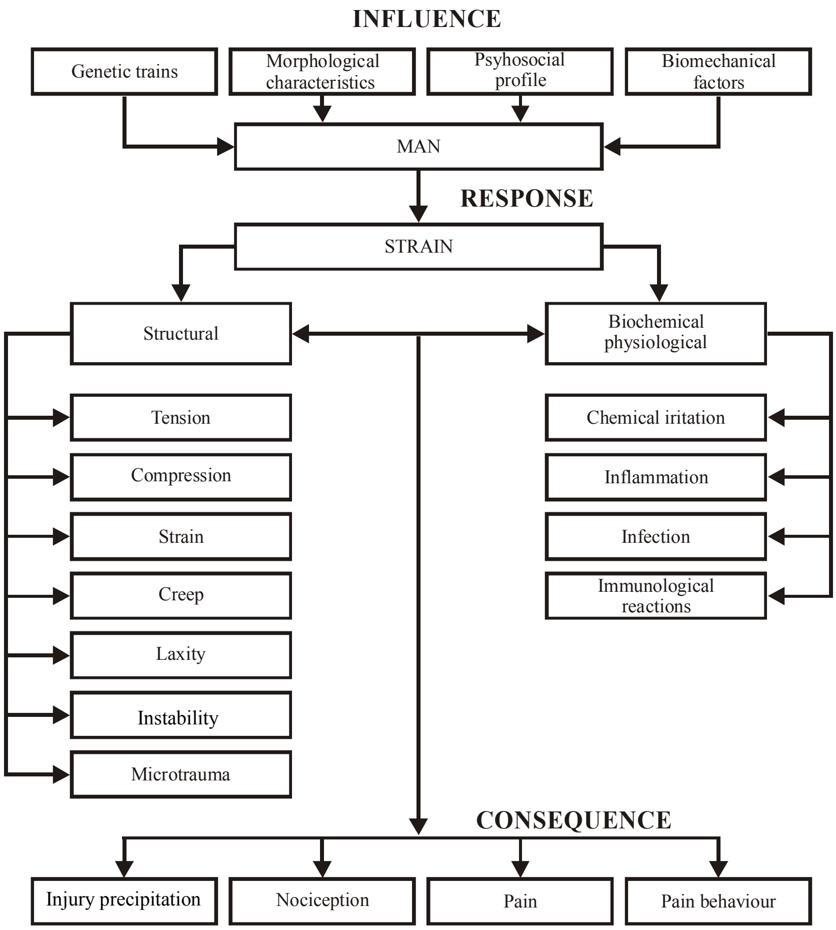

Fig. 1. The theory of musculoskeletal injury (modified from Kumar, 1999)

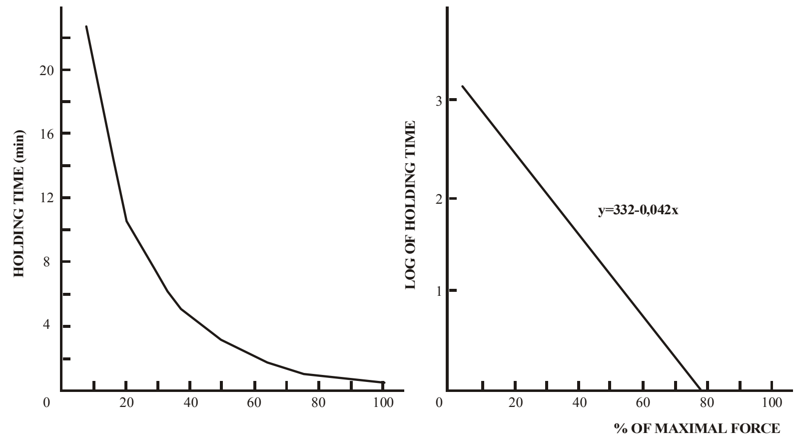

Fig. 2. The force holding – time relationship

organs, the brain, nervous system, lungs, heart and blood vessel and musculoskeletal systems.

The term physical stress is often used to describe the demands, while strain is used to describe the response of the human body. The assessment of these physical stresses and strains is an important component of ergonomics. It is used to identify excesive physical strsses and to design external demands so that they fit the capacity of the workers.

Obviously the response – the strain – will be influenced by the capacity of the individual and not only by the demands. For optimum performance all systems of the body must function efficiently. However, any of the organs participating in the events leading to muscle contractions can have low functional capacity or small dimensions, thereby limiting the capacity for muscular work. Those systems that most commonly limit the rate of physical work are the cardiovascular system and the muscles.

Perhaps the earliest scientific approach to estimating the appropriateness of static loads was to evaluate, experimentally, the holding times for various loads, expressing the result as the times for which a person could hold portions of the maximum load. The force required to achieve maximum load is referred to as maximum voluntary contraction (MVC).

Whilst MVC may be measured quite simply there are some essential controls. An impulse force is not required for the measurement; the instruction to a subject is usually of the form "build up your maximum force gradually, over a period of 2-3 s, and hold it for 3 s. The value used is the mean force and holding time is a logarithmic one (Figure 2). Today it is accepted that a long-term constant static effort greater than 2-3 % of MVC is unacceptable, although at one time 15 % was believed to be possible. Knowledge of the force holding-time relationship, which appears to hold for most skeletal muscles, does allow us to estimate the effects of some postures, and provide guidance as to their appropriateness. The maximum holding time for a posture is not, by itself, a very useful measure, since we wish to know the frequency with which the posture may be held, and the consequent likelihood of damage. Hence recovery from static work-loads is of interest (8).

As a major contribution to the faster gathering of data on musculoskeletal problems, the Institute of Occupational Health in the Nordic countries have designed Nordic Questionnaire (NMQ) (9). This provides a standard format for gathering date on musculoskeletal problems. Increased information about the incidence and epidemiology of these complaints is very necessary. Where data are needed for a particular investigation, such a questionnaire can be supplemented by additional questions, but its use will enable data from different studies to be compared, and large data pool arising from its use in the Nordic countries can be used for comparative purposes also. To specify the site of discomfort a body map is used, divided into segments (Figure 3).

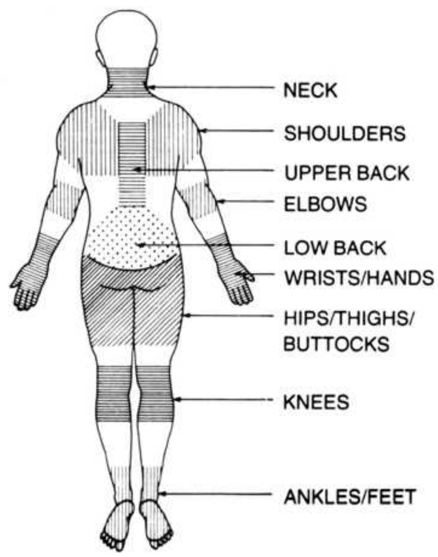

Fig. 3. The body map for evaluating body part discomfort

The tool developed by the Swedish National Board of Occupational Safety and Health is the single sheet analysis for identifying musculoskeletal stress factor (Figure 4). This is self-explanatory and uses the site of discomfort or injury to focus attention on a number of possible

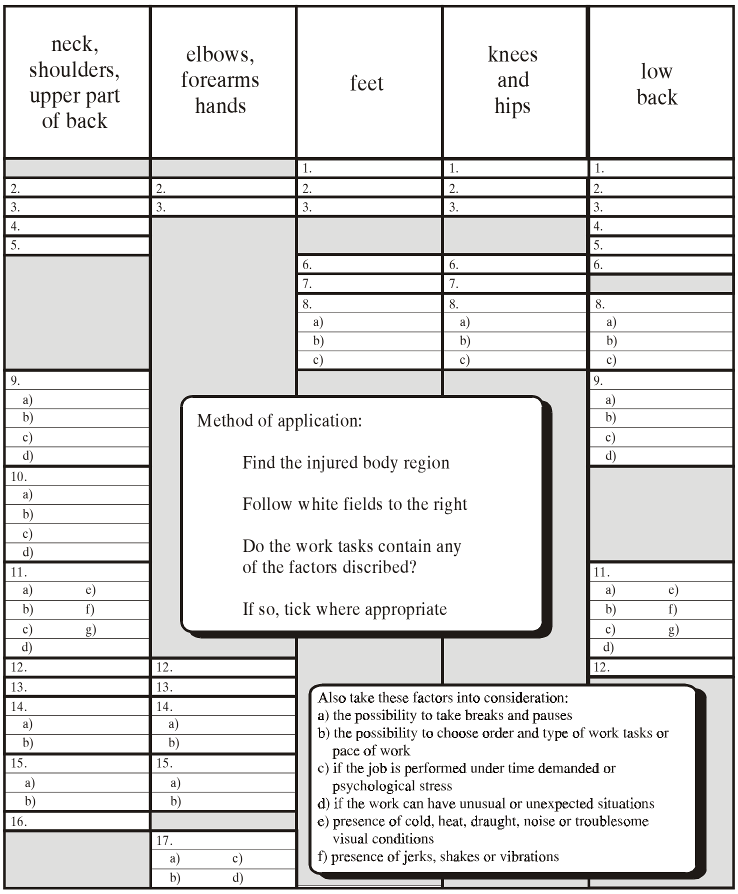

Fig. 4. The sheet analysis for the identification of musculosketal stress factors which may have injurious effect

workplace faults which could be their causes. The list of possible causes (Table 1) is equally applicable to the body-map, enabling direct link to be made to the sources of the problems. After changes have been introduced, it is clear that these same methods can be used to demonstrate any improvements which have been achieved.

Table 1. The list of possible causes

1. Is the walking surface uneven, sloping, slippery or nonresilent?
2. Is the space too limited for work movements or work materials?
3. Are tools and equipment unsuitably designed for the worker or the task?
4. Is the working height incorrectly adjusted?
5. Is the working chair poorly designed or incorrectly adjusted?
6. (If the work is performed whilst standing): Is there no possibility to sit and rest?
7. Is fatiguing foot-pedal work performed?
8. Is fatiguing leg work performed eg: a) repeated stepping up on stool, step etc.? b) repeated jumps, prolonged squatting or kneeling? c) one leg being used more often in supporting the body?
9. Is repeated or sustained work performed when the back is: a) flexed forward, more than 20^o? b) severely flexed forward, more than 60^o? c) bent sideways or twisted, more than 15^o? d) severely twisted, more than 45^o?
10. Is repeated or sustained work performed when the neck is: a) flexed forward, more than 15^o? b) bent sidewaus or twisted, more than 15^o? c) severely twisted, more than 45^o? d) extended backwards?
11. Are loads lifted manually? Notice factors of importance as: a) periods of repetitive lifting b) weight of load c) awkward grasping of load d) awkward location of load at onset or end of lifting e) handling beyond forearm length f) handling below knee height g) handling above shoulder height
12. Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?
13. Is sustained work performed when one arm reaches forward or to the side without support?
14. Is there repitition of: a) similar work movements? b) similar work movements beyond comfortable reaching distance?
15. Is repeated or sustained manual work performed? Notice factors of importance as: a) weight of working materials or tools b) awkward grasping of working materials or tools
16. Are there high demands on visual capacity?
17. Is repeated work, with forearm and hand, performed with: a) twisting movements? b) forceful movements? c) uncomfortable hand positions? d) switches or keyboards?

The work of ANSI Z365 Committee for Control of Cumulative trauma disorders as summarized in the present working draft describes a performance oriented standard that includes surveillance for affected workers and risk factors, analysis and design of jobs and management of affected workers (Figure 5).

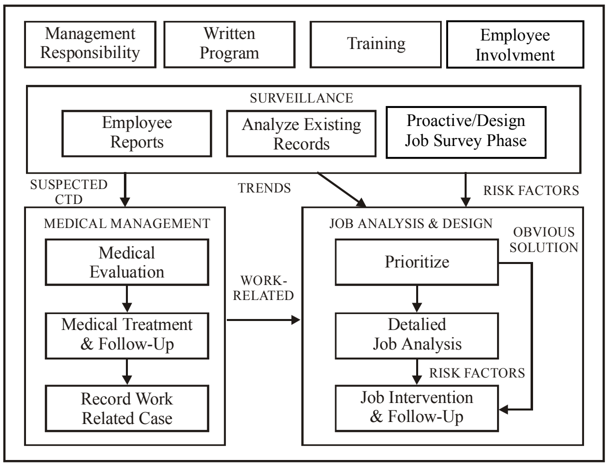

Fig. 5. Components of a program for controling work – related cumulative trauma disorders

The present draft also describes management responsibility, employee evolvement, the need for a written program and training (10), (11).

Discussion and conclusion

The recent rise in work – related health problems, such as cumulative trauma disorders of the upper extremity and lower back, which are believed to be caused, among other factors, by poorly designed workplace environments, often leads to decrease in productivity, quality and efficiency in the workplace (12). In 1990, among industries with highest number of disorders associated with repeated trauma, the household appliances ranked sixth with 3,400 cases (13). As part of the major industry group, electronic and other electric equipment manufacturing, the household appliances industry produces a wide range of items which bring added convenience, comfort, cleanliness to the functions of daily living. The large majority of the approximately 21,000 total injury and illness cases reported in the household appliances establishments in 1990 involved events or exposures, classified as occupational injuries.

From an economic perspective, the costs of injuries on the job can be staggering. Many manufacturing companies in need of creativity and accuracy, high productivity and quality, lower workers compensation and medical insurance costs, and strong competitive advantage are turning to ergonomics. However, as with any other business investment, ergonomics must be economically justified. Traditionally, the role of ergonomics in industry has been justified primarily on health and safety grounds with occasional, and usually vague, reference to potential performance improvements. A review of the literature has shown an emphasis on the need for a wider justification of ergonomics, in particular on benefits arising from ergonomic change (14).

References

1. World Health Organisation, Global strategy on occupational health for all, WHO, Geneva, 1995
2. Kumar S. Selected theories of musculoskeletal injury causation, In: Kumar S. (ed), Biomechanics in Ergonomics, Taylor and Francis, 1999: 3-24.
3. ANSI Z365, Control of Work-related Cumulative Trauma Disorders, National Safety Council, 1121 Spring Zake Drive Itasca, 11 60143, 1996.
4. Armstrong T. Development of a voluntary standard for the control of work-related cumulative trauma disorders in the United States: ANSI Z365, 13th Trienal Conference IEA, Tampere, Finland, 1997: 483-485.
5. Wells R, Keir P. Work and activity-related musculoskeletal disorders of the upper extremity/ In: Kumar S. (ed), Biomechanics in Ergonomics, Taylor and Francis, 1999: 165-177.
6. Szabo RM, Bay BK, Shankey NA, Gant C. Median nerve displacement through carpal canal, I Hand Surg, 1994, 19 A: 901-906.
7. Hildebrandt, VA. A review of epidemiological research on risk factors of low-back pain, In: Buckl P. (ed), Musculoskeletal Disorders at Work, Taylor and Francis, 1997: 9-16.
8. Corlet EN. In: Wilson IR, Corlett EN. (ed), The evaluation of posture and its effects, Taylor and Francis, 1995:662-713.
9. Kuorinka I, Jonson B, Kilbam A, Vinterberg H, Biering – Sorenson F, Andersson G, Jorgensen K. Stanardized Nordic questionnaires for the analysis of musculoskeletal symptoms, Applied Ergonomics, 1987, 18: 233-237.
10. Pavlović S, Grozdanović M. Kontrola rizika nastanka mišićno – skeletnih poremećaja gornjih ekstremiteta, Ergonomija '98, Beograd, 1998: 81-85.
11. Milutinović S, Pavlović S, Grozdanović M, Manić M. Multiple Criteria Estimation of CTD Risk Factors Importance, In: Karwowski W, Goonetillake R. (ed), Manufacturing Agability and Hybrid Automation II, IEA Press, 1998: 509-512.
12. Karwowski W, Marras WS. Cumulative Trauma Disorders, In: Salvendy G. (ed), Handbook of Human Factors and Ergonomics, John Wiley, New York, 1997.
13. Kane JJ. A Safety and Health Profile of Household Appliances Manufacturing, Compensation and Working Conditions, 1992, 44: 3-4.
14. Smith VH, Karwowski W. Economic justification of ergonomic intervention: an empirical study approach, 13th Triennial Congress of the IEA, Tampere, Finland, 1997: 638-640.

LJUDSKE AKTIVNOSTI I MIŠIĆNO-SKELETNE POVREDE I POREMEĆAJI

Miroljub Grozdanović

Fakultet zastite na radu, Univerzitet u Nišu
E-mail: mirko@znrfak.znrfak.ni.ac.yu

Kratak sadržaj: *Mišićno-skeletne povrede i poremećaji koji su nastali zbog raznovrsnih ljudskih aktivnosti prouzrokuju sve veći broj ljudskih i ekonomskih gubitaka. U našoj zemlji ovaj problem nije dovoljno shvaćen i proučavan, te se njegovom rešavanju moraju posvetiti znatno ozbiljnije istraživačke aktivnosti i veća finansijska sredstva.*
Zbog toga su u ovom radu predstavljeni etiološki pristupi i metode sakupljanja podataka za rešavanje ove sve aktuelnije problematike.

Ključne reči: *Mišićno-skeletne povrede, kumulativni traumatski poremećaji, ljudski rad*