EXPOSURE ASSESSMENT AND MUSCULOSKELETAL DISORDERS: WILL ERGONOMISTS EVER DEVELOP A DOSIMETER?

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During the last few decades, applications of epidemiology to the problems of musculoskeletal disorders in the workplace have become increasingly common. Previously, many of the outcome variables studied by ergonomists were acute responses of the human body or the production process, including localized muscle fatigue, productivity, and errors. Musculoskeletal disorders, on the other hand, are more insidious responses that have proven to be quite a challenge in terms of understanding their causation. The concept of dose with respect to work-related musculoskeletal disorders has yet to be defined, and may be one of the factors that have impeded more substantial progress. Moving towards a more formal definition or at least conception will be examined as a means of making progress towards understanding the cause and prevention of these disorders in the workplace.

INTRODUCTION

The prevention of work-related musculo-skeletal disorders (WRMSDs) has become one of the more contentious areas of ergonomics. Especially in the U.S. and the European Union, various consensus and regulatory standards, even in draft form, have initiated spirited debates about the role of work in the occurrence of WRMSDs. Of course, these debates have taken political overtones, but regardless of political stance, it is clear that these debates highlight the uncertainties regarding the causation and control of WRMSDs.

One of the reasons that there is so much contention about WRMSDs is because there are still many questions that have gone unanswered, or the answers are tentative. Definitive answers about work-relatedness and the role, in quantitative terms, of specific risk factors remain elusive. Practitioners often want a very simple question answered: “How much exposure is too much?” Currently, it is difficult or impossible to precisely answer such a question, beyond “more is worse.” Unfortunately, bringing these questions into political circles only exacerbates the problems associated with the uncertainties. Several means of moving towards firmer answers will be explored, in particular with respect to the concept of ‘dose.’

Ergonomics and Epidemiology

From the early days of the field of ergonomics, the focus has been enhancing human performance through the design of tasks, tools, equipment, and work environments to suit the capabilities and limitations of workers. Included under the human performance umbrella are factors such as sickness absence and ‘injury,’ but it should be noted that the majority of dependent variables studied were acute responses of the worker such as localized muscle fatigue, or throughput

measures such as pieces per hour that could be accurately measured. The perceptual and cognitive aspects of work, including the design of controls and displays, process control, inspection, and related topics formed a large piece of ergonomics research and practice.

Although safety was a concern of ergonomists from the beginning, the prevention of soft-tissue injuries was considered to be within the realm of the engineering function of the discipline. There was an implicit assumption that primary prevention through the proper use of engineering controls, such as workplace design, could be applied to these problems. For example, early work on low-back disorders was predicated on limiting spinal compression to avoid mechanical damage, which was implicitly assumed to be a fairly immediate or acute response.

For about the last two decades, there has been increasing interest in applying the concepts and methods of epidemiology to ergonomics. In particular, there has been an interest in using the principles of epidemiology to understand the frequency, association, and impact of WRMSDs (Hagberg, 1992). This interest is clearly evident in ergonomics journals and conferences, as epidemiology has become an increasingly common topic.

EXPOSURE AND DOSE

Exposure and dose are two fundamental concepts of epidemiology. When considering WRMSDs, these concepts are difficult to define, and even more difficult to measure. In this context, exposure can be thought of as the amount of a factor to which a worker is exposed, whereas dose is the amount that enters or interacts with the worker (Last, 1995).

In ergonomics literature, force, posture, and repetition (or frequency) are often stated as the risk factors for WRMSDs. Occasionally, additional risk factors such as cold and vibration are mentioned with respect to particular disorders. These are considered to be risk factors to which exposure in the work environment can be measured. Many ergonomic assessment tools and epidemiologic studies measure various aspects of the magnitude, duration, and frequency of the exposure to these basic risk factors.

The relationship between exposure and dose is not well understood for numerous, or perhaps most, musculoskeletal disorders. In the case of chemical exposure, dose is a more intuitive concept in that the amount of the chemical that reaches the tissue of interest is fairly exact, even if measurement is impossible. For example, the amount of asbestos fibers in the environment below a particular size can be measured, and the amount that enters the lungs is a specific quantity, albeit immeasurable. In the case of physical exposures, it remains unclear just what tissues are of interest, and how the risk factors contribute specifically to dose. In fact, unlike chemicals or particulates, the worker is not exposed until he or she chooses to interact with the environment to create the exposure, i.e., a material handler does not become exposed to forces that compress the spine until they handle materials.

AN ERGONOMICS DOSIMETER?

Anyone who has measured exposure to known or suspected risk factors for WRMSDs will appreciate the convenience that an ‘ergonomics dosimeter’ would afford. In occupational hygiene, dosimeters have been developed for different exposures such as noise and radiation. Thus, it may be beneficial to examine whether or not such a concept could be applied to the study of musculo-skeletal disorders in the workplace.

Unlike ambient exposures such as noise, radiation, and airborne particulates, exposure to risk factors for WRMSDs are more difficult to define and observe. If we take noise as an example, a proper microphone placed in a position that will experience noise

of the same magnitude, duration, and frequency as the ear could serve as the basis for collecting the requisite exposure information. In fact, there are many noise dosimeters available commercially, and many assess whether or not a given work environment complies with various standards such as those issued by the International Organization for Standardization.

Moving on to WRMSDs, the first question is whether or not it is possible to accumulate exposure throughout the workday similar to what a noise dosimeter accomplishes. It is clear that no simple device placed in the environment will be able to achieve this for several reasons. One is that while it may be possible to arrive at video-based solutions for assessing posture and frequency, force becomes a particularly challenging risk factor to assess for all but the simplest jobs. Most highly repetitive jobs requiring, for example, lifting or lowering a consistent load have been mechanized or automated. Thus, there needs to be measurement by the analyst of loads and forces exerted by workers. Also, the amount of exposure depends not only on the task and environment, but also on how the individual chooses to perform the task. This does not imply that a dosimeter cannot be developed, just that development will be far from trivial.

In order to assess dose, it is necessary to accumulate exposure. The problems associated with comprehensive exposure assessment of *jobs* have been attempted using observational techniques. Two examples will be used to illustrate the barriers to the development of a dosimeter.

The first example is the study by Jäger et al. (2000), where full work shifts were analyzed using a biomechanical model. The data collection, reduction, and analysis demands associated with integration of full shift physical demands are enormous. On the other hand, this burden leads to perhaps one of the few examples of what approximates the ‘dose’ of a full shift. The problem with such an approach is that few ergonomists are capable of such measurement approaches, and almost no practitioners would have the capabilities.

The second example is that of Dempsey (2002), which examined the issues associated with attempting to perform comprehensive exposure assessments of materials handling jobs using the revised NIOSH lifting equation (Waters et al., 1993). This is one of the most widely advocated approaches for assessing lifting and lowering tasks, and has been integrated into numerous regulatory and consensus standards. In a sense, the equation incorporates the major risk factors (posture, load, and frequency) into an equation, and is far simpler than biomechanical modeling to implement.

Dempsey (2002) found that very few materials handling jobs in the US were amenable to comprehensive exposure assessments using the equation. In spite of attempting to select jobs that were within the assumptions of the equation, 63% of lifting and lowering tasks studied required other types of materials handling (push, pull, or carry) that technically invalidated use of the equation. Also, slightly more than 20% of the 449 workers surveyed reported shifts longer than the 8-hour limit for the equation.

The two examples above illustrate the problems encountered when attempting to perform comprehensive exposure assessments for WRMSDs. Thus, moving towards the principle of measuring dose is even more problematic. However, it is possible that starting at dose, and moving backwards may be a prudent approach to take to arrive at more definitive answers regarding the causative factors for WRMSDs.

When examining the concept of dose, it will be necessary to consider different disorders separately, as well as potentially different stages of the morbidity process. It is generally agreed that force, posture, and the temporal demands of work can influence the occurrence of WRMSDs. However, not all WRMSDs affect the same types of tissues.

First, different WRMSDs affect different tissues including ligaments, muscles,

and tendons. Thus, the different WRMSDs may require different definitions or concepts of dose. Even in the case of the "low-back disorders," there is pain and disability due to different tissues being affected. When considering different disorders, repetition may be a more important risk factor for disorders of tendons, whereas disorders involving ligaments may more likely involve fewer insults of higher force magnitude. Of course, this is speculation but entirely plausible. Better understanding of the specific pathologies involved in different disorders could help to better define what we believe dose is so that investigations could be based upon more theoretical hypotheses.

Another issue is that relevant to the concept of dose is what stage of prevention is being attempted for a particular disorder. For example, once a worker has been diagnosed with tendonitis, secondary prevention aimed at minimizing sickness absence may be attempted. The same can be said of low-back pain. It is becoming increasingly common for ergonomists to contribute to the return-to-work process; however, it is unclear if there needs to be an adaptation of methods. In the case of low-back pain, it may be important to consider what leads to pain of a magnitude such that the worker does not continue to work. In a sense, dose would be the amount pain induced by a particular exposure, which can at least be measured through subjective means. Although the guidelines for primary prevention may be appropriate, ergonomics research has largely focused on healthy subject populations. Understanding human performance of workers with WRMSDs could help achieve better return-to-work results.

DISCUSSION

The concept of dose is not well-defined in the context of soft-tissue disorders. Similarly, comprehensive exposure assessments of jobs continue to prove problematic. Currently, the notion of an ergonomics dosimeter is therefore a ways away from being possible.

There have been applications of dosimeters to problems of occupational hygiene that exemplify the advantage that such a device would afford. Moving from more general concepts of risk factors to more theoretically-derived contributors to dose will require that we first better understand the pathophysiology of different musculoskeletal disorders. Just as different environmental airborne contaminants require different sampling strategies, it is likely that different WRMSDs will require different, although likely related, sampling strategies and measurement approaches. This will in turn lead to more definitive answers regarding the causation and preventions of WRMSDs.

REFERENCES

Dempsey, P.G. (2002). Usability of the revised NIOSH lifting equation. Ergonomics, 45(12), 817-828.

Hagberg, M. (1992). Exposure Variables in Ergonomic Epidemiology. American Journal of Industrial Medicine, 21, 91-100.

Jäger, M., Jordan, C., Luttmann, A., and Laurig, W. (2000). Evaluation and assessment of lumbar load during total shifts for occupational materials handling jobs within the Dortmund Lumbar Load Study - DOLLY, International Journal of Industrial Ergonomics, 25, 553-571.

Last, J.M. (ed.) (1995). A Dictionary of Epidemiology (3rd Edition). New York: Oxford University Press.

Waters, T.R., Putz-Anderson, V., Garg, A., and Fine, L.J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks, Ergonomics, 36, 749-776.