MULTIMEDIA VIDEO TASK ANALYSIS (MVTA) AS AN EXPOSURE ASSESSMENT TOOL IN ERGONOMIC STUDIES

Angela L. Dartt, Colorado State University
John Rosecrance, Colorado State University

adartt@lamar.colostate.edu

ABSTRACT

Musculoskeletal disorders (MSDs) of the upper extremities are painful and potentially disabling conditions that affect the hands, arms, shoulders, and neck. Recent literature reviews have indicated a clear relationship between physical workplace factors and MSDs. The same reviews also suggest that quantitative exposure methods to assess physical workplace factors need to be improved. Based on this evidence, the National Institute for Occupational Safety and Health has made musculoskeletal disorders and exposure assessment methods two priorities in the National Occupational Research Agenda. Inadequate measures of exposure may lead to erroneous conclusions in studies that investigate the relationship between risk and outcome. The purpose of this presentation is to introduce and describe the usefulness of a relatively new video-based exposure assessment program called Multimedia Video Task Analysis (MVTA). We will also describe how this assessment method is currently being used in a prospective cohort study of manufacturing workers. We will be using MVTA to assess posture of the neck, shoulder, and wrists of manufacturing workers, while also logging other risk factors such as repetition, contact forces, and trigger motions of the finger. The primary variable of posture will be defined as the duration of task time spent in specific anatomical positions of the neck, shoulder, and wrists. Using MVTA, we can preset all of the risk categories for neck, shoulder, and wrist and, while watching video footage of the employees, use keystrokes to mark each time the worker's neck, shoulder, or wrist fits into one of the categories. The results of the MVTA analysis yield the frequency and duration that each worker spent in each of the risk categories for a specific task cycle. The exposure information derived from the MVTA (as well as other variables) can then be modeled to assess risk of incident cases of upper limb MSDs or MSD symptoms that the employees experience over the study period.

INTRODUCTION

Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) of the upper extremities are painful and potentially disabling conditions that affect the hands, arms, shoulders, and neck. Examples of frequently reported

upper extremity MSDs include such disorders as carpal tunnel syndrome, tendonitis of the hand and wrist, epicondylitis, and several neck and shoulder disorders. Literature indicates a clear relationship between physical workplace factors (force, repetition, and vibration) and MSDs (NIOSH, 1997 and NRC/IOM, 2001).

Magnitude of the Problem

Since 1972, the Bureau of Labor Statistics (BLS) has routinely published surveys about U.S. worker occupational injuries and illnesses. In 2001, the BLS released survey information stating that "disorders associated with repeated trauma" accounted for 65% of all work-related illness in the United States (BLS, 2001). Besides human suffering, economic consequences are also a huge burden. The exact cost of work-related MSDs is not known. Some annual estimates are as conservative as $13 billion, while others are upwards of $54 billion (NRC/IOM, 2001).

Purpose/Rationale

Due to the magnitude of the problem, the National Institute for Occupational Safety and Health (NIOSH) has included upper extremity MSDs in its National Occupational Research Agenda (NORA). Additionally, recent literature reviews suggest that quantitative exposure methods to assess physical workplace factors need to be improved. Therefore, exposure assessment methods are another priority listed in NORA. This paper addresses these two priority areas by introducing a relatively new video-based exposure assessment program that allows for semi-quantitative ergonomic analysis. The data gathered from the program can then be modeled to assess risk or symptoms of MSDs.

EPIDEMIOLOGICAL EVIDENCE

The relationship between workplace factors and MSDs has been the subject of two major reviews. In 1997, NIOSH published "Musculoskeletal Disorders and Workplace Factors" with the purpose of critically reviewing the epidemiological evidence for work-related MSDs of the neck, upper extremities, and low back, paying particular attention to the strength of the association between MSDs and work factors. The National Research Council (NRC) and Institute of Medicine (IOM) released the other major review, "Musculoskeletal Disorders and the Workplace," in 2001. This review was written in response to a charge from NIOSH to conduct a comprehensive review of the scientific literature on the relationship of work to MSDs of the low back and upper extremities.

NIOSH Conclusions

Neck and neck/shoulder disorders. Upon review of 46 epidemiological studies of neck MSDs and 23 epidemiological studies of neck/shoulder MSDs, NIOSH concluded that there is "reasonable evidence for a causal relationship between highly repetitive work" and neck and shoulder MSDS and "reasonable evidence for forceful exertion and neck MSD" (NIOSH, 1997). They found "strong evidence that working groups with high levels of static contraction, prolonged static loads, or extreme working postures" are at increased risk for neck and shoulder

MSDs (NIOSH, 1997). They also concluded that "cumulative exposure-response data is lacking" (NIOSH, 1997).

Shoulder disorders. Over 20 epidemiological studies were reviewed that examined workplace factors and their relation to shoulder disorders. NIOSH concluded that there is "evidence for a positive association between highly repetitive work and shoulder MSDs" (NIOSH, 1997), and found evidence for a "relationship between repeated or sustained shoulder postures with greater than 60 degrees of flexion/abduction and shoulder MSDs" (NIOSH, 1997). There was insufficient evidence for an association between force and shoulder MSDs (NIOSH, 1997).

Elbow disorders. NIOSH concluded that there is evidence for the "relationship between forceful work and epicondylitis" (NIOSH, 1997). Insufficient evidence was found for an association of repetitive work and extreme posture with epicondylitis (NIOSH, 1997).

Carpal Tunnel Syndrome. NIOSH reviewed over 30 epidemiological studies examining workplace factors in relation to CTS. They found evidence for a "positive association between highly repetitive work and CTS", evidence between force and CTS, evidence between vibration and CTS, and "strong evidence for a relationship between exposure to a combination of risk factors and CTS" (NIOSH, 1997). Insufficient evidence was found for an association between posture and CTS (NIOSH, 1997).

Hand/wrist tendinitis. NIOSH reviewed eight epidemiological studies that had examined workplace factors in relation to hand/wrist tendinitis and found evidence of an association between repetition, force, and posture with hand/wrist tendinitis. They found "strong evidence that job tasks that require a combination of wrist factors increase risk for hand/wrist tendonitis" (NIOSH, 1997).

NRC/IOM Conclusions

The NRC/IOM panel concluded that repetition, force, and vibration are important workplace factors for disorders of the upper extremities and that the combination of repetition and force, as well as vibration, is associated with carpal tunnel and other wrist disorders (NRC/IOM, 2001). They also concluded that literature on ergonomic interventions complemented the epidemiological literature since several interventions that decreased exposure to force, repetition, and awkward postures were found to decrease upper extremity symptoms (NRC/IOM, 2001). The biological and biomechanical literature provides enough evidence of "plausible mechanisms" between workplace factors and MSDs (NRC/IOM, 2001). The panel recommended developing improved exposure assessment tools and further quantification between exposures and outcomes.

Summary of Evidence

While the two reviews above took different approaches in reviewing the literature, their conclusions were quite similar. Both reviews indicated a clear relationship between physical workplace factors and MSDs. Repetition and force were found to be important risk factors in the development of upper extremity MSDs. The suggestion was also made that quantitative

exposure methods to assess physical workplace factors need to be improved (NIOSH, 1997 and NRC/IOM, 2001).

PROBLEM AND CHALLENGE

Problem: Inadequate measures of exposure may lead to erroneous conclusions in studies that investigate the relationship between exposure and outcome.

Challenge: Determine a valid method of characterizing levels of exposure that is efficient enough to analyze subject variability across a large sample population and to produce exposure data at the level of detail needed to study etiological relationships with MSDs.

MULTIMEDIA VIDEO TASK ANALYSIS

Multimedia Video Task Analysis (MVTA) is a relatively new video-based exposure assessment program that automates time and motion studies and ergonomic analyses from video (Ergonomics Analysis, 2003). The program enables users to identify events interactively with the use of breakpoints (identifying the start and end of an event). It uses a computer controlled VCR that allows interactive study of video footage. Video can be reviewed at any speed and in any sequence (real-time, slow/fast motion, or frame by frame in forward or reverse direction). Any event can be reviewed as long as needed by stopping/pausing the video or by replaying it in a continuous loop. MVTA produces time study reports, computes the frequency of each event, and performs postural analysis. A very powerful feature of MVTA is record interaction, which means two independently observed activities can be combined to produce an interaction. For example, one may want to interact trigger motion and wrist posture to see if there are any relationships (Ergonomics Analysis, 2003).

Application to a Current Study

In a current prospective cohort study being conducted in a home appliance manufacturing facility in the Midwest, MVTA is used to assess the postures of the neck, shoulder, and wrists of manufacturing workers. Other risk factors such as repetition, contact forces, and trigger motions of the finger are also being looked at. Approximately 600 study participants at the facility will be enrolled in the study over a 1.5 year period. Other data collection methods in addition to MVTA will include questionnaires, surface electromyography, and the HAL method.

Methods

Task analysis will involve watching video footage of the employees from two different camera angles and using pre-designated keystrokes to mark the beginning and end of the different posture categories. This will be continued for several cycles. Due to the cyclic nature of the work being assessed, we will start by analyzing 10 cycles. Fewer or more cycles may be needed for an adequate representation of the type of work being performed. The primary variable of posture will be defined as the duration of task time spent in specific categories of posture of the neck, shoulder, and wrists. Neck posture will be categorized as neutral (20^0 extension to 20^0 flexion), mild flexion (>20^0 to 45^0 flexion), severe flexion (>45^0 flexion), severe extension

(>20^0 extension), and radial/ulnar deviation (Keyserling, 1986; Juul-Kristensen et al, 1997). Shoulder posture will be categorized as neutral (0^0 to 45^0 flexion/abduction), mild flexion/abduction (>45^0 to 90^0), and severe flexion/abduction (>90^0) (Keyserling, 1986; Juul-Kristensen et al, 1997). Wrist posture will be categorized as neutral (30^0 flexion to 30^0 extension), non-neutral wrist flexion (>30^0 flexion) and non-neutral wrist extension (>30^0 extension) (Spielholz et al, 2001). These angles will be measured using MVTA's built-in angle estimator option. The video can also be freeze-framed so that an angle can be estimated. Figure 1 is an example of the types of measurements that may be encountered. This angle drawing is less precise than the MVTA angle estimator, but it demonstrates how a shoulder angle measurement might look in MVTA. Notice that the white angle drawn is greater than 90^0, therefore the duration the worker maintains this position would fall under the severe flexion/abduction category for the shoulder.

Figure 1: Example of Angle Measurements

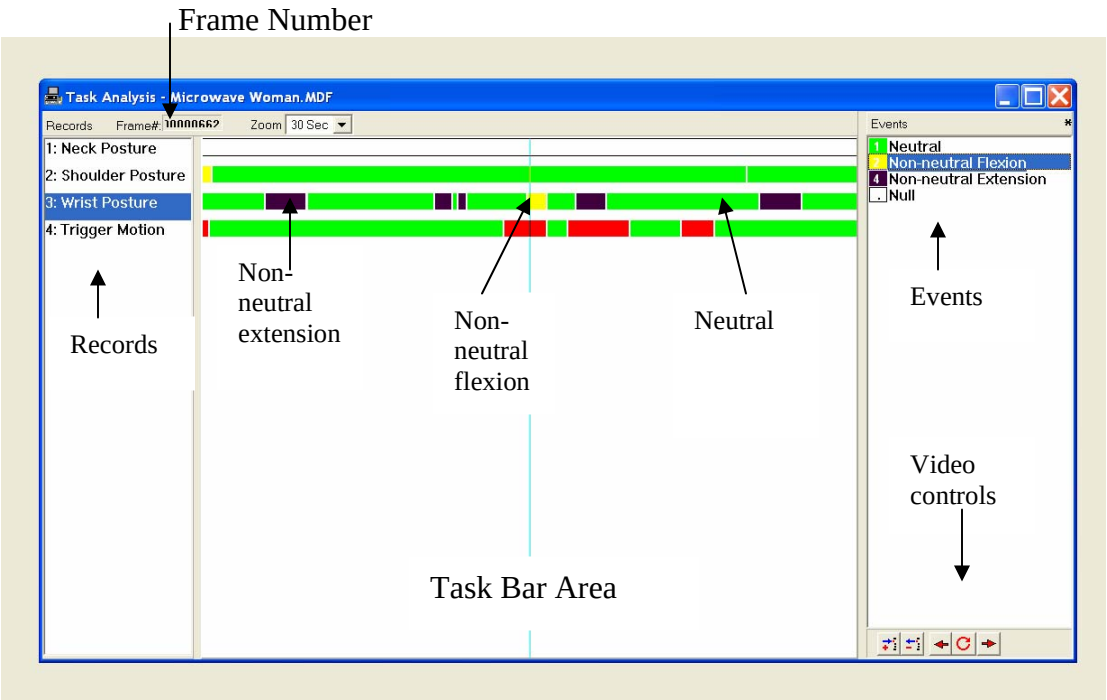
Example of a Task Analysis

Figure 2 is an example of a task analysis. While this is not what a completed or correct analysis will look like, it helps to in explain the program. Note the four record categories listed on the left side of the figure. In this case, a record is simply the specific body part being analyzed. Also note the events list on the right side of the task window. These events are specific to the wrist (neutral, non-neutral flexion, and non-neutral extension) as discussed earlier. The analysis also displays the frame number, timeline, and video control buttons (lower right corner). The keypad or computer-controlled VCR can be used to control the speed of the video. The VCR allows for play, stop, pause, fast-forward, and rewind with the added features of slow-motion and a continuous looping option (Ergonomics Analysis, 2003).

The task bar to the right of the wrist posture record is the postural analysis for the right wrist of a worker. The length of this task bar is 30 seconds of the workers cycle. Most of this 30-second interval was spent in the neutral wrist position (medium gray color), but non-neutral wrist extension (dark gray color) was also quite common. Non-neutral wrist flexion (light gray color) occurred only once; however, this display covers only 30 seconds of the work cycle. The same type of analysis shown above will be performed for several cycles of work and thus a timeline of

events for each worker will be processed. This task analysis timeline can then be further analyzed into three different types of data reports.

Figure 2: Example of a Task Analysis



Reports

There are three types of reports available through MVTA: time study, frequency, and raw time (Ergonomics Analysis, 2003). These reports can be generated after the task analysis is complete. The time study report provides information on the duration of the event elements. For example, how long in seconds the wrist is in neutral position, flexion, or extension. This is important if a worker reports MSD symptoms or is diagnosed with an MSD. Task analysis results can be reviewed to determine if they performed work more often in non-neutral positions. The frequency report provides information on the interval of occurrence or repetition rate of the event elements. For example, it indicates the actual number of times the wrist is in neutral position, flexion, or extension. This again will be extremely important if a worker reports symptoms or is diagnosed with an MSD. Summary statistics such as mean, standard deviation, percent error, and 95% confidence intervals are provided for the time study and frequency reports (Refer to Table 1). The raw time report provides information on the times at which the events occur. For example, it provides the actual time an event element occurred in the study participant's work cycle. This information will be more applicable in interactions and interventions. Table 1 is an example of the information obtained from performing a time study report. This is a good example, but again it is not complete or correct because it only contains task analysis information on 1 cycle, whereas the study will be looking at 10 cycles.

Table 1: Example of a Time Study Report

Time Study Report
File Name : Microwave Woman.MDF
Record Elements : Wrist Posture
Event# Event Elements :
1 Neutral
2 Non-neutral Flexion
3 Non-neutral Extension
Time Units in seconds

	Neutral	Non-neutral Flexion	Non-neutral Extension
Mean	7.307	0.222	1.11
SD	8.748	0.126	0.946
N	19	3	16
%Error	57.49	104.344	45.139
95%CI Low	3.106	-0.01	0.609
95%CI Hi	11.508	0.454	1.612
N(5%Err)	2512	1307	1304
Total Time	138.833	0.667	17.767
%Total Cycle	88.279	0.424	11.297

DISCUSSION

Exposure information gathered from MVTA can be modeled to assess risk of incident cases of upper extremity MSDs or MSD symptoms that the employees experience over the study period. MVTA provides for individualized assessment of exposure to physical job stressors, which can then be related prospectively to any musculoskeletal health outcomes. The postural exposure data from MVTA and other methods of exposure assessment will be used to determine the incidence of self-reported upper extremity symptoms and verified upper extremity MSDs.

There are some challenges with using MVTA. Due to time and money constraints, each worker will only be taped for the adequate number of cycles needed, and from only two different camera angles. It is impractical to videotape 600 workers for more than a short period of time. However, due to the cyclic nature of the work, the videotapes are still representative of a workday and possible exposures. Appliance manufacturing poses some problems because workers move around often, causing difficult angle measurements in the program. Additionally, workers move their wrists out of the view of the camera when they are working inside an appliance. While two cameras will be placed at optimal positions, it is unlikely that every movement will be assessed due to inadequate angles and obscured body parts. Therefore, error is inevitable. However, this method is an improvement in comparison to previous qualitative and quantitative exposure assessment methods. Previous qualitative methods have involved a researcher categorizing workers into risk categories (low, medium, and high) based on their observations, or the workers categorizing their own exposures. Many attempts at quantifying

worker exposure have been prone to small sample sizes because of the detail that is involved. While MVTA will also be prone to error, it allows attempts to quantify exposure over a large workforce for many different types of jobs.

Literature reviews have indicated a relationship between workplace factors such as force, repetition, and awkward posture and upper extremity MSDs. The literature also discusses the lack of quantitative exposure assessment and the lack of temporal sequence of exposure and outcome. The use of MVTA in this prospective cohort study will attempt to quantify exposure assessment of the upper extremities.

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