AN ANALYSIS OF REPETITIVENESS MEASURES AND MEASUREMENT/ANALYSIS METHODS FOR HAND-INTENSIVE TASKS

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The repetitiveness of hand-intensive tasks is assessed to determine the level of risk for upper-extremity musculoskeletal disorders at the workplace. Various measures and measurement/analysis methods have been employed to the repetitiveness assessment. However, our understanding of the repetitiveness assessment methodologies is lacking, which results in difficulty to compare and integrate findings of various repetitiveness studies. Reviewing thirty repetitiveness studies (published in the past five years), the present study identified and classified measures, measurement methods, and analysis techniques used in repetitiveness assessment. The repetitiveness measures were largely classified by two major dimensions (time and frequency) and further subdivided by corresponding analysis focuses (work cycle time, rest time, and work/rest time ratio for the time dimension; the number of work cycles, the number of body movements, the number of joint motions, and the number of force exertions for the frequency dimension). Next, the measurement methods were categorized into objective and subjective methods. Lastly, the analysis methods were classified into statistic and spectral methods.

INTRODUCTION

Despite automation in industry, the incidence of musculoskeletal disorders due to hand intensive tasks is still significant. According to the Bureau of Labor Statistics (2002), while the incidence rate of nonfatal occupational injuries and illnesses in the US industries was 5.7 cases per 100 full-time workers (FTWs) in 2001, those in manufacturing and construction industries requiring hand intensive tasks mostly were 8.1 and 7.9 cases per 100 FTWs, respectively; especially, a total of 216,400 cases (65 percents of total nonfatal occupational injuries and illnesses) were related to repetitive hand intensive tasks.

Repetitiveness, representing a periodic property of hand intensive tasks, has been identified a major risk factor of upper extremity musculoskeletal disorders (UEMSDs). Colombini (1998) and Silverstein et al. (1987) found that repetitiveness alone could increase the risk of UEMSDs. In addition, Latko et al. (1999) showed that repetitiveness was highly correlated with the clinical symptoms (such as pain, weakness, clumsiness, numbness, tingling, and nocturnal symptom aggravation) of the tendon and nerve at the upper extremity. Furthermore, NIOSH (1997) indicated a close causal relation between repetitiveness and carpal tunnel syndrome (CTS). Other important risk factors include high force and awkward posture at the workplace (Putz-Anderson, 1988; NIOSH, 1997).

Although studies have employed various different measures and measurement/analysis methods in repetitiveness assessment, our understanding of their differences and similarities is lacking. Due to this lack understanding of repetitiveness assessment methodology, it is often difficult to compare and integrate findings of different repetitiveness studies. Therefore, a systematic classification of assessment methods and corresponding guidelines are necessary in repetitiveness assessment of hand intensive tasks.

The present study is intended to survey and compare repetitiveness assessment methods for hand intensive tasks. Operational definitions, classification criteria, measures, measurement/analysis methods used in repetitiveness assessment were surveyed and compared. Then, a systematic hierarchy of the repetitiveness measures was established. This study provides a guide for comparison of measures and measurement/analysis methods in repetitiveness assessment.

OPERATONAL DEFINITION/CLASSIFICATION

Repetitiveness (the measure indicating the magnitude of same tasks or motions performed at the workplace) has

been evaluated from three aspects: joint motion, body movement, and force exertion. In other words, the number of motions (e.g., flexion/ extension and abduction/adduction) per unit time at preselected joints (Coury et al., 2000; Malchaire et al., 1996; Spieholz et al., 2001), the number of movements (e.g., reach, grasp, and position) per unit time for designated limbs (Colombini, 1998; Genaidy et al., 1993), or the number of force exertions exceeding predefined limits (Malchaire et al., 1997) is counted for repetitiveness assessment.

It is found that classification criteria of repetitiveness for hand intensive tasks vary according to the type of repetitiveness measure: cycle time and joint motion. First, repetitiveness measures of cycle time include work cycle time and fundamental work cycle time. For example, Silverstein et al. (1986) defined that high repetitive tasks are those with a cycle time < 30s or having same motions > 50% of the cycle time; and that low repetitive tasks are those with a cycle time > 30s and having same motions < 50% of the cycle time. In contrast, Hansson et al. (1996) classified the duration of a fundamental work cycle time into four categories: < 2s, 2~5s, 5~10s, and > 10s.

Next, repetitiveness measures of joint motion include the number of joint motions, mean power frequency (MPF), and velocity of joint motion. Examples of classification criteria by the number of joint motions are 10~20 motions (Carey and Gallwey, 2002; Yen and Radwin, 2000) and 4~15 motions per minute (Lin et al., 1997). Next, Hansson et al. (2000) suggested 0.28~0.53Hz of MPF for repetitive hand movement. Marras and Schoenmarklin (1993) reported, by measuring angular velocity at the wrist, 28.7~42.2 deg/sec in flexion/extension, 17~25.9 deg/sec in radial/ulnar deviation, and 67.7~91.3 deg/sec in pronation/supination for highly repetitive hand tasks.

REPETITIVENESS MEASURES

Various measures have been used to assess the repetitiveness of hand intensive tasks. Examples of the repetitiveness measures include work cycle time (Babski-Reeves and Crumtpon-Young, 2002; Juul-Kristensen et al., 2001; Ketola et al., 2001) and the number of wrist joint motions (Carey and Gallway, 2002; Spieholz et al., 2001; Hansson et al., 2000).

To identify repetitiveness measures in a comprehensive manner, this study reviewed thirty studies of the repetitiveness assessment of hand intensive tasks, which were conducted for the past five years. Databases used for the literature survey were ScienceDirect®, Ingenta Select, and MEDLINE. Keywords used for the search were combinations of words for repetitiveness (such as repetition, repetitive, and repetitious), those for upper extremity (such as hand, wrist, finger, elbow, shoulder, forearm, arm, manual, and upper limb), and those for task (such as job, work, motion, and movement). Through a review of the abstracts of searched studies, only ones corresponding to the repetitiveness assessment of hand intensive tasks were selected for further analysis.

From the selected studies, repetitiveness measures were listed and then classified according to their dimensional characteristics and types of analysis focus, as shown in Table 1. Two dimensions were identified among the measures: time (the length of time required for a task or motion) and frequency (the number of tasks or motions per unit time). Then, three and four analysis foci were further identified for time and frequency, respectively: work cycle time, rest time, and work/rest time ratio for the time dimension; the number of work cycles, the number of body movements, the number of joint motions, and the number of

Table 1. Classification of repetitiveness measures for hand intensive tasks

Dimension	Type	Measure
Time	Work cycle time (CT)	Overall work CT
		Fundamental work CT
	Rest time	Rest time within a task
		Rest time between tasks
	Ratio of work/rest (W/R) time	Overall W/R time ratio
		Fundamental W/R time ratio
Frequency	Number of work cycles	# overall work cycles
		# fundamental work cycles
	Number of body movements	# finger movements
		# hand and wrist movements
		# hand and arm movements
	Number of joint motions	# finger joint motions
		# wrist joint motions
		# elbow joint motions
		# shoulder joint motions
	Number of force exertions	# power force exertions
		# pinch force exertions

force exertions for the frequency dimension. Note that a work cycle can be subdivided into several fundamental work cycles depending on the purpose of a repetitiveness analysis (Silverstein et al., 1986).

MEASUREMENT/ANALYSIS METHODS

During the literature survey, it was found that various measurement instruments and analysis methods have been employed in repetitiveness research. Examples of the measurement instruments are stopwatch, video, electrogoniometer, rating index (Killough and Crumpton, 1996), and visual analogue scale (VAS). Theses measurement methods are classified into objective and subjective methods as shown in Table 2. Of the objective methods, electrogoniometer is an effective apparatus to measure angular data in the repetitive tasks. Although Moore et al. (1991) reported up to 11% of cross-talk problems were due to the long axis of the electrogoniometer while recording wrist movements, Coury et al. (2000) indicated that the cross-talk problem could be resolved by balancing errors among all experimental conditions. Moreover, Coury et al. (2000) pointed that the cross-talk problem of the electrogoniometer might not affect the validity of frequency measurements by using angular data. On the other hand, the subjective measurement methods are cheap, flexible, and acceptably precise (Vander-Beek and Frings-Dresen, 1998; Winkel and Mathiassen, 1994). The subjective methods, however, have lack of reliability, accuracy, and validation. Comparing three measurement methods (self-report, video observation, and electrogoniometer), Spielholz et al. (2001) showed that electrogoniometer was most significantly reliable. However, in a comparison between measurement methods, Juul-Kristensen et al. (2001) found difficult to quantify of their differences because they use different reference positions.

Table 2. Measurement methods for repetitiveness assessment

Classification	Description	Example
Objective measurement method	Use measurement devices without including subjective judgment.	stopwatch, video, electrogoniometer
Subjective measurement method	Use categories or ratio scales that can be assessed by subjective judgment.	rating index (RI), checklist, visual analogue scale (VAS)

Next, there were two types of analysis methods: statistical and spectral techniques. While most studies used statistical methods (such as mean and standard deviation) to summarize measurement results for repetitiveness assessment, some studies such as Juul-Kristensen et al., (2001), Hansson et al. (2000), and Yen and Radwin (2000) analyzed data by a spectral method. Radwin and Lin (1993) first applied a spectral analysis (which identifies the distribution of spectral components for measured movements) to repetitiveness assessment. Hansson et al. (1996) supported the use of spectral analysis by indicating that mean power frequency (MPF) (an average frequency weighted by power) can be used as a generalized measure of repetitiveness and is applicable to complex and/or irregular wrist movements.

CONCLUSION

The present study surveyed the definitions, classification criteria, measures, measurement methods and analysis techniques that have been used to analyze the repetitiveness of hand intensive tasks. The repetitiveness measures were classified according to their dimensional characteristics (time and frequency) and types of analysis focus (work cycle time, rest time, and work/rest time ratio for the time dimension; the number of work cycles, the number of body movements, the number of joint motions, and the number of force exertions for the frequency dimension). Then, the measurement methods were summarized for objective and subjective methods. Lastly, the analysis techniques were classified into statistical and spectral methods.

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