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Reliability of physiological and subjective responses to physical and psychosocial exposures during a simulated manufacturing task

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ABSTRACT

Responses to physical and psychosocial exposures can be measured using diverse methods, but their reliability, particularly under multiple exposures, is largely unknown. Five classes of methods were used to assess physiological and subjective responses among 24 participants to four combinations of physical and psychosocial exposures while performing two identical sessions of a simulated overhead manufacturing task. As an exploratory analysis, test–retest reliability was quantified using intraclass correlation coefficients (ICC) and coefficients of variation (CV). Discomfort ratings were reliable under less favorable exposures, and ratings of the psychosocial environment were most reliable under favorable social support. Workload ratings were most reliable with high physical exposure and favorable social support, and task performance was reliable overall. EMG and heart rate had relatively low reliability. Slightly less than half of the variables were considered reliable, but reliability depended on exposure conditions.

Relevance to industry: The study provides information on the reliability of commonly used exposure measurement methods. The results can guide the selection of physiological and psychological work outcome measurements in future studies and work evaluations.

1. Introduction

The National Research Council (1999) and several authors (e.g. Hurrell et al., 1998) have recommended that measurement methods be improved for assessing risks of work-related musculoskeletal disorders (WMSDs) under diverse psychosocial and physical demands, particularly in terms of method validity and reliability. In developing a system of evaluating psychosocial and physical exposures in the workplace, measures chosen must have high validity, which includes the component of reliability. Reliable measures are reproducible, meaning that similar results would be obtained from repeated measurements under the same conditions.

Psychosocial and physical risk factors are both associated with WMSD risk (e.g. Ariëns et al., 2001; Buckle, 1997), so the ability to distinguish the contributions of different WMSD risk factors within an environment consisting of multiple demands, such as are found in actual work environments, is critical to job evaluation and design intervention. However, the reliability of measurement tools that were originally designed to assess one type of factor is called into question when used in multi-factorial environments due to potential influences from other factors. To assess potential WMSD risk factors in these multi-factorial environments, measurements must be done with tools that are reliable under complex conditions. Reliability of physiological measures, such as muscle activity, heart rate, and physical discomfort, has been evaluated under physical demands (e.g. Elfving et al., 1999; Gamelin et al., 2006; Nordander et al., 2004) but not in response to psychosocial demands to our knowledge. Conversely, perceptual responses to the psychosocial environment have been assessed for reliability under varying psychosocial conditions (e.g. Karasek et al., 1998) but not in response to isolated physical demands. Although these previous studies have examined reliability of measurement tools for individual conditions, there is little information available on reliability of measurement tools under multiple physical and psychosocial demands. Such information on reliability can guide researchers in choosing appropriate measurement tools and in interpreting results.

In the current study, reliability of physiological and subjective measurement methods was tested for assessing exposure to physical and psychosocial demands. The purpose was to assess the reliability of diverse, common measures under different levels of combined physiological and psychosocial exposures and to

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determine if and to what extent reliability might differ depending on exposure levels.

2. Methods

2.1. Overview of design

Participants were part of a larger study evaluating the effects of psychosocial and physical exposure on physiological and subjective outcomes (Hughes, 2007). A subset of participants ($n = 24$) completed two identical sessions (to assess reliability), which were among five total sessions completed by each of these participants. All participants in the larger study ($n = 48$), who were recruited from a university community, were informed of the possibility of performing the additional session during an initial informed consent procedure approved by the university's institutional review board. Each of the 24 participants completed two experimental sessions, separated by 2–14 days. Participants were divided into four groups, with each exposed to a different combination of physical and psychosocial exposures:

C1 High physical exposure, no psychosocial manipulation ($n = 6$).
C2 Low physical exposure, no psychosocial manipulation ($n = 6$).
C3 Low physical exposure, favorable job control ($n = 6$).
C4 Low physical exposure, favorable social support ($n = 6$).

These conditions (described below) were chosen to represent a relatively demanding work environment (C1, high physical exposure) and more favorable work environments (C2, lower physical exposure; C3, more control over the job/job control; or C4, a better social environment/social support).

2.2. Participants

Twenty-four participants volunteered to complete this portion of the main study, and the distribution of age and gender of the participants here (Table 1) was similar to the main study. Participants were required to perform upper body strengthening exercise on a regular basis (2–3 h/week minimum) or have recent manual labor experience, and were excluded if they had any medical condition that would limit upper body strength or mobility. To minimize physiological differences between sessions, participants were asked to avoid smoking, alcohol, caffeine, and heavy lifting for 24 h prior to each experiment session, and sessions took place at approximately the same time of day to avoid influences related to circadian rhythms.

2.3. Task

A simulated work environment was developed, based in part on tasks observed at an automotive assembly line and previously tested by Sood et al. (2007). In a laboratory, participants performed two alternating tasks: overhead tapping (T), roughly representing nut and bolt tightening on an automobile chassis, and simple small parts assembly (A: screwing and unscrewing nuts and bolts). Tapping took place on an inverted keyboard oriented horizontally above the participants, using a non-powered drill with the dominant arm, in a fixed four-key sequence, and at a rate of 80 taps/min (Fig. 1). Keyboard height was set for each individual based on two measures: (A) hand height with the upper dominant arm parallel to the ground and the included elbow angle $= 90°$; (B) hand height during maximal overhead reach. Keyboard height was set such that hand height was 40% of the difference between these measures: $A + 0.4(B - A)$.

The tapping and parts assembly tasks were rotated through a 54-s cycle, with either a 33% or 66% duty cycle for the tapping task (e.g. a 33% duty cycle involved 18 s of tapping and 36 s of assembly). Experimental trials involved completing repeated cycles for 1 h. Participants switched between 33% and 66% duty cycles every 15 min when there was no psychosocial manipulation (C1 and C2) in the trial, as illustrated in Fig. 2. A heavier non-powered drill (1.25 kg) was used in the higher physical exposure condition (C1). In the three low physical exposure conditions (C2, C3, C4), participants used a lightweight non-powered drill (0.50 kg) to perform the overhead tapping. In favorable job control and favorable social support conditions (C3 and C4), participants could change between duty cycles as desired (upon verbal request) as long as half of each trial was conducted at each duty cycle. In addition, participants in the favorable social support condition (C4) worked with a partner of their choice and were allowed to converse while completing the tasks.

Table 1
Participant gender distribution and age.

Experiment condition	Males	Females	Age (SD)
High physical exposure	4	2	25.8 (5.0)
Low physical exposure	5	1	22.3 (3.3)
Favorable social support	3	3	20.8 (1.8)
Favorable job control	4	2	26.0 (5.7)

2.4. Dependent variables

Five classes of methods were used to evaluate perceptions and physiological responses to the simulated work environment. Two classes of objective measures included physiological responses (muscle activity and heart rate) and task performance (percentage of correct key taps). Subjective responses were measured using two methods: workload ratings and discomfort ratings. The final method was to assess perceptions of diverse aspects of the psychosocial environment using items from an existing questionnaire.

Fig. 1. Overhead tapping task.