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The influence of job rotation and task order on muscle responses in females

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ABSTRACT

Job rotation aims to reduce muscle fatigue by switching between functionally different tasks to theoretically lessen the risk of site-specific fatigue and work-related musculoskeletal disorders (WMSDs). The effectiveness of job rotation in mitigating the onset of muscle fatigue is partially known, but there is limited ergonomic data on female populations despite comparatively lower upper body strength and increased risk of WMSDs. Rotating between two functionally different tasks, continuing a single task, and varying task order were assessed in the present study for influence on muscle fatigue indicators in a female population. Participants performed a randomized set of four task combinations involving two unilateral, repetitive shoulder tasks (forward flexion and internal rotation). During these combinations, maximal voluntary force, mean power frequency, average EMG (aEMG) and ratings of perceived exertion (RPE) were recorded. Differences between task combinations and time were tested using a two-way repeated measures ANOVA. Indications of fatigue were limited in the results. Forward flexion ($p = 0.004$) and internal rotation ($p = 0.002$) maximum voluntary force declined in all task combinations while RPE increased ($p < 0.0001$); non-rotating task combinations had the greatest declines in force and increases in RPE. Results from EMG amplitude were less clear, and were muscle and task specific. While non-rotating task combinations had the greatest decrements in aEMG submaximal force, rotating task combinations often had similar decrements, creating limited statistical differences. Changes in aEMG were too small to distinguish an order effect. The EMG results suggest muscular demand overlap between the two tasks, despite being functionally different. The effectiveness of job rotation is partially dependent on selecting tasks that engage distinct muscle groups.

1. Introduction

A primary goal of industrial workplace and task design is minimization of the potential development of work-related musculoskeletal disorders (WMSDs). WMSDs are often chronic disorders that prevent previously healthy adults from engaging in occupational and social pursuits (Luger et al., 2014). Fatigue is a recognized risk factor for WMSD development (Allison and Henry, 2002; Dugan and Frontera, 2000; Gorelick et al., 2003; Weist et al., 2004). Shoulder WMSDs are common (van der Heijden, 1999), and are often attributed to awkward body postures, repetitive work and high force exertions (van Rijn et al., 2010). Recent trends toward more sedentary, automated, and stereotyped work tasks have resulted in higher workloads, less exposure variation, fewer breaks, and prolonged, low-level exertions (de Looze et al., 2009; Mossa et al., 2016; Sato and Coury, 2009; Straker and Mathiassen, 2009; Yung et al., 2012). This may result in continuous static low-level localized overexertion, which may progress to fatigue and WMSDs (Yung et al., 2012).

Task rotation is a commonly used low-cost ergonomic measure intended to mitigate muscle fatigue (Leider et al., 2015; Mathiassen, 2006; Rodrigues and Barrero, 2017). Jobs that involve one, monotonous, repetitive task are associated with increased risk for many upper extremity musculoskeletal disorders (Buckle and Devereux, 1999; Sluiter et al., 2001). Example jobs include computerized office work, and short-cycle industrial assembly work (Mathiassen, 2006). Diversifying these jobs through temporal or activity variation of job tasks is posited to prevent WMSD development (Balogh et al., 2016; Davis and Jorgensen, 2005; Luger et al., 2014). In particular, increasing the variety of tasks performed may mitigate this risk. The relevance of job rotation as an ergonomic intervention is important as many industries are moving greater percentages of their employees to low level, monotonous exposure tasks (de Looze et al., 2009; Docherty et al., 2002; Neumann et al., 2002; Straker and Mathiassen, 2009).

Despite its popularity as an administrative control, evidence for the effectiveness of job rotation is inconclusive (Leider et al., 2015; Luger et al., 2014). Employees often find the change in job environment through rotation beneficial (Balogh et al., 2016; Guimaraes et al., 2012; Hinnen et al., 1992; Kuijer et al., 1999). Rotating workloads between

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distinct body regions or rotating between high and low load tasks has shown reduced indications of muscular fatigue in the form of overall reduced EMG activity, limited reductions in maximal and submaximal force production and reductions in perceived exertions and muscular pain (Hinnen et al., 1992; Keir et al., 2011; Rissen et al., 2002; Yung et al., 2012). However, increases in musculoskeletal complaints have also occurred following the implementation of job rotation (Kuijer et al., 2005; Olafsdottir and Rafnsson, 1998; Rodrigues and Barrero, 2017), and prevention of muscular fatigue does not always occur across all observed muscles (Keir et al., 2011; Richter et al., 2009). Further, reported posture loads and time in epidemiological studies often rely on expert judgment and self-reports which may be vague and lack quantitative description (Mathiassen, 2006). Understanding the relationship between the exposure and WMSD risk is central to the success of job rotation as an ergonomic intervention. There is a need for controlled analysis on specific musculoskeletal exposures that change with feasible job rotations to demonstrate their effectiveness (Mathiassen, 2006; Padula et al., 2017).

The effects of job rotation are not easily determined due to multiple interacting factors such as body region-specific tissue loading and fatigue, perceived discomfort, and task intensity and order (Sato and Coury, 2009; Frazer et al., 2003; Rodrigues and Barrero, 2017). Current job rotation ergonomic guidelines emphasize loading different body regions (Wells et al., 2010). This is not necessarily feasible in many work environments where all candidate tasks are likely to recruit the same specific body regions (such as office-based jobs), or load multiple regions of the body concurrently (such as the shoulder and low back) (Brewer et al., 2006). Introducing variability to a single body region through task rotation may be effective, if the two tasks have low functional similarity and do not engage similar muscle groups (Wells et al., 2010; Yung et al., 2012). However, tasks rotated between are often not clearly distinct from each other with respect to muscle engagement, which dictates how much rest and recovery is possible, and in what muscles (Keir et al., 2011; Richter et al., 2009). The order of rotation, especially when the tasks have varying intensity, may also affect the perceived and objective musculoskeletal benefits of job rotation (Horton et al., 2012; Raina and Dickerson, 2009). These confounding factors are especially relevant for the shoulder region. At the shoulder, many muscles have multiple mechanical functions and are active across a variety of tasks, which poses a challenge in terms of limiting muscle exposure (Raina and Dickerson, 2009). Musculoskeletal task differences must be objectively defined in order to improve workplace usage of job rotation, including distinguishing the muscular structures being challenged by each task (Mathiassen, 2006; Richter et al., 2009; van Dieen and Toussaint, 1997).

Despite an increased proportion of females in the working population over preceding decades, there is still a paucity of female strength data present in the ergonomic literature, including on task rotation. Females are known to be at a higher risk of developing WMSDs, especially of the neck and upper extremity (Miller et al., 1993; Nordander et al., 2008; Treaster and Burr, 2004). While differences in the physical demands of work environments that females traditionally occupy likely partly modulate the gender specific risk of developing WMSDs, differences still exist even when accounting for occupational class (de Zwart et al., 2001). Males on average have 75% greater upper body muscle mass, indicating a greater force producing capacity and potential for delaying fatigue onset for identical demands (Lassek and Gaulin, 2009). As a result, females often have significantly higher muscular activity and musculoskeletal complaints than males for identical work (Chow, 2010; Nordander et al., 2008). The relationship between strength, work capacity and fatigue is complicated by observations of females experiencing neuromuscular fatigue differently than males (Keller et al., 2011; Yoon et al., 2007). Females demonstrate more fatigue resistance than male peers when sustaining maximal and submaximal contractions, with less deficits in maximal force than males (Hunter et al., 2004, 2006; Russ and Kent-Braun, 2003; West et al., 1995). However, in many workplace settings, task exertions are scaled to worker capacity, and this may affect differences in fatigability between sexes.

The purpose of this study was to examine the consequences of rotating between four combinations of two functionally different upper extremity tasks on indicators of muscle fatigue, including force production and EMG, and to assess the influence of task order on muscle fatigue in a job rotation scenario in a female population. It was hypothesized that combinations that rotate between the two tasks would cause responses consistent with delayed fatigue: smaller decreases in mechanical measure of maximal force, smaller increases in ratings of perceived exertion (RPE), less decrease in mean power frequency (MPF) and less increases in EMG amplitude than the two combinations that did not include task rotation.

2. Methods

2.1. Participants

Fifteen university-aged females participated in this study (mean age = 22.2 years ± 1.5, height = 1.64 m ± 0.053, weight = 60.7 kg ± 6.86). All participants were right hand-dominant and self-identified as free of shoulder disorders or injuries in the last year. The study had full approval from the Office of Research Ethics at the University of Waterloo.

2.2. Experimental protocol

Participants performed a randomized set of four combinations of two right-sided shoulder tasks. Data was collected over four sessions with at least 24 h in between sessions. The experimental protocol as (Fig. 1) was identical for each collection.

2.2.1. Tasks

Two unilateral (right-sided), repetitive shoulder tasks intended to mimic occupational scenarios were used as the foundational tasks for the four task combinations. Both tasks were completed while seated at a table with knee and hip angles set at 90° using an adjustable chair in accordance with current ergonomic guidelines. Task A consisted of a static, forward flexion push at 15% maximum voluntary force (MVF) with arm positioned at 90° humeral flexion and arm fully extended in

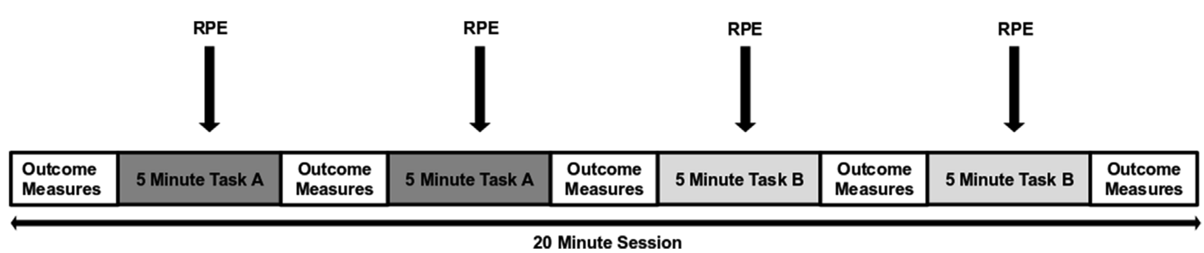

Fig. 1. Sample of data collection protocol for AB task combination. Outcome measures included two static maximal exertions, two static submaximal exertions, and rate of perceived exertion (RPE). These five measures were taken at the beginning of the session and repeated once every 5 min. RPE was reported verbally every 2.5 min. This schematic represents data collection of one task combination AB (20 min); all task combinations follow the same collection protocol.