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The influence of task design on upper limb muscles fatigue during low-load repetitive work: A systematic review

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A B S T R A C T

Ergonomic interventions such as increased scheduled breaks or job rotation have been proposed to reduce upper limb muscle fatigue in repetitive low-load work. This review was performed to summarize and analyze the studies investigating the effect of job rotation and work-rest schemes, as well as, work pace, cycle time and duty cycle, on upper limb muscle fatigue. The effects of these work organization factors on subjective fatigue or discomfort were also analyzed. This review was based on relevant articles published in PubMed, Scopus and Web of Science. The studies included in this review were performed in humans and assessed muscle fatigue in upper limbs. 14 articles were included in the systematic review. Few studies were performed in a real work environment and the most common methods used to assess muscle fatigue were surface electromyography (EMG). No consistent results were found related to the effects of job rotation on muscle activity and subjective measurements of fatigue. Rest breaks had some positive effects, particularly in perceived discomfort. The increase in work pace reveals a higher muscular load in specific muscles. The duration of experiments and characteristics of participants appear to be the factors that most have influenced the results. Future research should be focused on the improvement of the experimental protocols and instrumentation, in order to the outcomes represent adequately the actual working conditions.

Relevance to industry: Introducing more physical workload variation in low-load repetitive work is considered an effective ergonomic intervention against muscle fatigue and musculoskeletal disorders in industry. Results will be useful to identify the need of future research, which will eventually lead to the adoption of best industrial work practices according to the workers capabilities.

1. Introduction

Muscle fatigue is a complex phenomenon that has been suggested to be an important precursor for work-related upper-limb musculoskeletal disorders (Ding et al., 2000; Nussbaum et al., 2001; Lomond and Cote, 2011). Several authors have reported that repetitive manual work is a risk factor associated with wrist and hand disorders, such as tendon-related disorders, carpal tunnel syndrome (CTS) and cramping of the hand and forearm (Muggleton et al., 1999; Viikari-Juntura and Silverstein, 1999; Hansson et al.,

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2000). According to Thomsen et al. (2002), an increase duration of repetitive non-forceful work results in an increased risk of CTS. The effects of fatigue on functional capacity include reductions in maximal isometric force and power output (Vollestad, 1997; Blangsted et al., 2005; Enoka and Duchateau, 2008; Fuller et al., 2009). Muscle fatigue can occur as a result of alterations in the central nervous system and/or neuromuscular junction (central fatigue) or in the muscle fiber (peripheral fatigue) (Willliams and Ratel, 2009). These mechanisms are dependent on the intensity, duration, the predominantly recruited muscle fiber type and type of contraction, as well as individual capacity and environmental conditions (McLean et al., 2000).

In the industrial environment, it is essential to reduce the occurrence of muscle fatigue because it has a great impact on task performance. Thus, the major challenge for ergonomics is to design the work in order to prevent work-musculoskeletal disorders (WMSD) and with no negative impact on production quality and productivity (Wells et al., 2007). At present, repetitiveness and monotonous work are common in industries with automated work processes. According to Eurofound (2010), more than 60% of workers currently report performing repetitive hand or arm movements at work. Assembly tasks are an example of work where the procedures are strictly standardized with short cycle times (less than 30 s), little task variation and reduced breaks or pauses. Furthermore, there is some evidence that upper limb WMSD risk factors are related to characteristics of the assembly task (van der Windt et al., 2000).

Despite numerous studies suggesting that muscle fatigue can be developed during highly repetitive low-load tasks (<20% maximal voluntary contraction (MVC)), there are several gaps in knowledge concerning the influence of task design, which includes work organization factors such as work duration (hours of work and shift work), duty cycle, cycle time, work pace and job rotation, on fatigue and musculoskeletal health. Changes in temporal organization of work (e.g. change in cycle time) or implementation of job rotation in workplaces may increase physical workload variation and has been proposed to minimize injury risk and fatigue in jobs with repetitive tasks (Fallentin et al., 2001; Aptel et al., 2008; Wells et al., 2010).

Thus, it is very important to study the risk factors associated with task design on the development of disorders in the wrists and hands in highly repetitive hand–arm work.

The purpose of this article is to review the scientific literature concerning the influence of the task design (related to temporal organization of work and job rotation) on muscle fatigue in low-load work development in workplaces or experimental settings.

2. Methods

2.1. Search strategy

The systematic search was focused on literature pertaining to the effect of task design on the development of muscle fatigue in upper limbs in workplaces or experimental settings (simulated occupational tasks). The search strategy consisted of a comprehensive search that could locate the widest spectrum of articles for consideration and was performed in selected electronic databases, namely: PubMed, Scopus and Web of Science, from the earliest date available in the database to 31st December 2013. Based on the electronic database used, the search terms were as follows: “muscle fatigue” combined with another term such as “upper limbs”, “forearm muscles”, “workload”, “work-related musculoskeletal disorders”, “repetitive movements”, “repetitive work”, “assembly work”, “low-force work”, “low-intensity work”, “low-load work“, “work cycle time”, “wrist”, “work rest pattern”, “rest breaks”, “work duration”, “work pace”, “job rotation” and “task design”. The Appendix A describe the search strategies in each database.

2.2. Screening criteria

Articles obtained by the systematic search were exported to EndNote library X4 (Thomson corporation) and duplicates were removed. Exclusion of irrelevant articles was performed using a three-step systematic approach: 1) titles were examined for relevance; 2) abstracts were then considered (in particular, objectives and methods); and 3) the full text article was retrieved and considered. If there was any uncertainty about content or if a title and abstract did not provide sufficient information to determine whether the inclusion/selection criteria were met, then the article proceeded to the next step.

Studies were automatically excluded if one of these conditions were met: 1) studies not published in peer-reviewed journals written in English 2) studies reviewing literature; 3) studies where the intensity of the workload (maximal EMG activity) was higher than 30% MVC; 4) studies that did not apply an objective measuring method to assess the development of fatigue over time; 5) studies comparing different tools to assess muscle fatigue; 6) studies defining muscle fatigue models and/or acceptable limits; 7) studies assessing neuromuscular responses; and 8) studies investigating muscle fatigue caused by torque reaction forces.

2.3. Eligibility criteria

Studies were included in the review if the following conditions were met: (1) those that considered the development of muscle fatigue in upper limbs (including the forearm, arm and shoulder muscles) during repetitive low-load work; (3) those that only investigated the effect of temporal organization of work and job rotation schemes on upper limb muscle fatigue; and (4) those that assessed muscle fatigue in occupational activities performed in real work conditions and/or simulated occupational tasks. Two reviewers evaluated the eligibility of all articles, and disagreements were resolved by consulting a third reviewer.

2.4. Data extraction and risk of bias assessment

From the studies selected after eligibility, the following data (when available) were extracted: size (N) and characteristics of the sample (gender and age), muscle group under study, type of tasks, experimental conditions, methods and/or techniques used to assess fatigue, study design, main outcomes for objective and subjective measure of fatigue and statistical analysis. Data from each study were extracted by one of the reviewers and confirmed by the other. The information obtained from the included studies was organized descriptively in tables.

A quality assessment list was constructed using criteria from Greenhalgh et al. (2005) and from Von Elm et al. (2008), which were adapted to the specific aim of this review. To judge quality, information regarding participant's source (eligibility criteria), definition of variables and their methods of measurement/assessment, description of efforts to address potential sources of bias, outcome data, limitations and generalizability of each study, was collected. For all of these items, specific criteria assessment were defined (details are given in Appendix B). Two reviewers independently assessed the quality of each study by scoring each criteria as positive (+), negative (−), or unclear (?). Disagreements were resolved by consensus. The quality score for every study was calculated by summing the number of positive criteria.