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Impact of loading and work rest intervals on muscle micro-trauma

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ABSTRACT

Purpose: To examine whether rest intervals of different durations ("High Rest, Low Frequency" v. "Low Rest, High Frequency"), and load at different force exertion levels with different repetition frequencies ("High Load, Low Repetition" v. "Low Load, High Repetition") have an impact on muscle micro-trauma, as such micro-trauma over repetitive loading and long-term muscle overuse can lead to musculoskeletal disorders (MSDs).

Method: Twenty-four adult males (mean age: 24.1 years; 3.6 SD) were randomly assigned to one of 4 bicep muscle eccentric exercise treatment groups ($n = 6$; "High Load, Low Repetition; High Rest, Low Frequency", "High Load, Low Repetition; Low Rest, High Frequency", "Low Load, High Repetition; High Rest, Low Frequency", or "Low Load, High Repetition; Low Rest, High Frequency") with non-dominant arm to induce muscle micro-trauma reactions in serum. Subjects in all treatment groups had equivalent total work volume, total rest duration and total work duration for comparison of muscle micro-trauma between and within the treatment groups. Muscle micro-trauma biomarker serum Creatine Kinase (CK) level was measured pre-exercise (Day 0) and post-exercise on Days 1, 2, 4, and 8. ANOVA with repeated measures was used to examine significance of rest and load-repetition combination over pre and post experiment days, as well as possible interactions.

Result: CK levels fluctuated significantly across different "Day" ($P = 0.0115$). Interaction was disordinal and significant between "Day" and "Rest" ($P = 0.0000$), and "Load" and "Rest" ($P = 0.0322$). Under "High Load, Low Repetition" condition, CK levels on Day 4 were significantly higher than on Days 0 and 2; CK levels on Day 8 were significantly higher than Day 0. CK level peaked on Day 4. Under "Low Rest" Condition, CK level on Days 4 and 8 are significantly higher than Day 0.

Conclusion: Shorter but more frequent rest intervals led to more extreme muscle micro-traumatic responses than the longer but less frequent ones, especially under "High Load, Low Repetition" condition when non-dominant bicep brachii was subscribed with eccentric exercise regimen.

Relevance to industry: The exploration of how rest scheduling affects progression of microtrauma from a biomechanical and molecular level in this study furthers current understanding of the early stage development of WMSDs. With future studies' further research and confirmation, the findings of this study may be able to serve as a first attempt to guide shift scheduling and job design at manufacturing facilities.

1. Introduction

The US Department of Labor defines work-related Musculoskeletal Disorders (WMSDs) as musculoskeletal system and connective tissue diseases and disorders, involving overexertion, repetitive motion and vibration that lead to living tissue sprains, strains, tears, as well as pain, swelling, and numbness. MSDs represent one of the leading causes of lost workdays in industry and are associated with major economic costs. Occupational Safety and Health Administration (OSHA) estimated that "work-related MSDs in the United States account for over 600,000 injuries and illnesses and 34 percent of all lost workdays reported to the Bureau of Labor Statistics (BLS, 2016). These disorders now account for one out of every three dollars spent on workers' compensation. It is estimated that employers spend as much as 20 billion dollars a year (U.S.) on direct costs for MSD-related workers' compensation, and up to five times that much for indirect costs, such as those associated with hiring and training replacement workers" (OSHA, 2014). In

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addition, MSDs require long recovery time and pose significant challenges to affected worker's personal lives (American Academy of Orthopaedic Surgeons, 2008, 2009).

Several known MSD risks include high force demands, high repetition rates, the interaction between the two, awkward postures, and long durations (Bernard, 1997; Hoogendoorn et al., 1999; Gallagher and Heberger, 2013). Several well advocated treatment approaches include thermotherapy (usage of ice or heat at the site of pain) (Wyss and Patel, 2013), manual therapy (Bove et al., 2016), medications and dietary supplements such as protease enzyme that modulates the inflammatory response. Existing preventative measures include stretching and warm-up programs (Choi and Woletz, 2010). However, the efficacy of these therapeutic and preventative approaches has not been convincingly validated (Choi and Woletz, 2010Manufacturers; Wyss and Patel, 2013). It would also be costly to implement such program in a manufacturing facility. Compared to post hoc remedies, designing jobs with MSD prevention in mind would be an effective and affordable alternative (Smith and Gallagher, 2016).

The MSD development process starts with tissue micro-traumas occurring as a consequence of performing repetitive and/or forceful tasks, leading to local and maybe systemic inflammation, followed by structural tissue damage and eventually MSDs (Barbe and Barr, 2006). This study examined the beginning stage of MSD development – muscle micro-trauma, aiming to prove hypotheses that rest interval plays a significant role in MSD prevention and development, in addition to the known risk factors. Previous studies have demonstrated subjects assigned with longer rest intervals (3 min) between eccentric exercise work periods were able to perform a significant larger total work volume than the ones assigned with shorter rest intervals (1 min). Quantitative marker for skeletal muscle micro-trauma, Creatine Kinase (CK) level was significantly more elevated 48-h and 72-h post-experiment in the longer rest interval group than the shorter rest interval groups (Machado and Willardson, 2010; Evangelista et al., 2011). Such results indicated that rest intervals played a significant role in muscle strength endurance in eccentric exercise. Different durations of rest intervals could also lead to different levels muscle micro-trauma, although not all subjects compared in these previous studies performed equal amount of workload. To provide common ground for comparisons of different subjects' muscle micro-trauma, the authors of this study set up the experiment so all subjects share the same total work volume (equal number of multiples of their maximum voluntary isometric contraction of the non-dominant biceps, which are explained in the Method section), total work time and total rest time. If proven a significant contributor in MSD development, though requiring confirmation and extensive further research, the finding may serve as an initial evidence that select rest intervals could be implemented at manufacturing jobs to serve as an affordable MSD preventive measure without impeding the production rate or having to recruit additional employees.

2. Method

2.1. Subjects

After acquiring approval from Auburn University Institutional Review Board (IRB), 24 healthy men between the ages of 19 and 50 (mean: 24.1 years; standard deviation: 3.61 years) were recruited to participate in this study. Male subjects were selected because 70.1% of current 15,338 manufacturing workers are men (Bureau of Labor Statistics, 2014). In addition, significantly higher CK levels were reported in men than women despite their racial diversities (Wong et al., 1983). The age limit was decided based upon a previous study, which concluded that the healthy elderly (64–84 years) demonstrated a significant CK decline compared to its younger counterpart (24–47 years) (Steinhagen-Thiessen and Hilz, 1976).

Subjects submitted written confirmation for not using medical drugs, dietary supplements, or anabolic steroids, and being free of joint, muscular or cardiovascular diseases within the prior 6 months or during the week of the experiment (Evangelista et al., 2011). Subjects had also confirmed to have not performed eccentric, concentric, isometric or other forms of weight training six months prior to the experiment. Participants agreed not to perform weight training or strenuous physical activities during the week of and a week after the experiment, as significant increases of CK occurred after exercise are usually lower in healthy trained subjects compared to healthy untrained subjects (Brancaccio et al., 2007).

Qualified subjects of the above criteria filled out a medical screening form to ensure that no pain or discomfort was present in the non-dominant limb. Two levels of load-repetition combination regimens were studied: "High Load, Low Repetition" v "Low Load, High Repetition" (abbreviated as "High Load" v "Low Load" from here on); two levels of rest schedules were studied: "High Rest, Low Frequency" v "Low Rest, High Frequency" (abbreviated as "High Rest" v "Low Rest" from here on). Subjects were then randomly assigned to one of the four treatment combinations using a random number generator: "High Load; High Rest" (HLHR; n = 6), "High Load; Low Rest" (HLLR; n = 6), "Low Load; High Rest" (LLHR; n = 6), or "Low Load; Low Rest" (LLLR; n = 6) (Table 1). All 24 subjects completed the experiment. Subjects were compensated for their participation.

2.2. Eccentric exercise

Eccentric exercise was selected because it provided a basis for examining the impact of load-repetition combination and rest frequency on muscle tissue fiber damage and micro-trauma (Prasartwuth et al., 2005; Liao et al., 2010; Komi and Buskirk, 1972). The symptoms of such micro-trauma include muscle soreness and tenderness, known as delayed-onset muscle soreness (DOMS) (Schwane et al., 1983; Ebbeling and Clarkson, 1989; Jones et al., 1989; Clarkson et al., 1992; Cleak and Eston, 1992).

Table 1
Treatment combinations.

Treatment (a)	Treatment (b)	Treatment (c)	Treatment (d)
High Load; High Rest	Low Load; High Rest	High Load; Low Rest	Low Load; Low Rest
5 min, 90% MIVC, 2 rep/min	5 min, 22.5% MIVC, 8 rep/min	3 min, 90% MIVC, 2 rep/min	3 min, 22.5% MIVC, 8 rep/min
2 min Rest	2 min Rest	1min Rest	1min Rest
5 min, 90% MIVC,2 rep/min	5 min, 22.5% MIVC,8 rep/min	3 min, 90% MIVC,2 rep/min	3 min, 22.5% MIVC,8 rep/min
2 min Rest	2 min Rest	1min Rest	1min Rest
5 min, 90% MIVC, 2 rep/min	5 min, 22.5% MIVC, 8 rep/min	3 min, 90% MIVC,2 rep/min	3 min, 22.5% MIVC,8 rep/min
		1min Rest	1min Rest
		3 min, 90% MIVC,2 rep/min	3 min, 22.5% MIVC,8 rep/min
		1min Rest	1min Rest
		3 min, 90% MIVC,2 rep/min	3 min, 22.5% MIVC,8 rep/min