

Alterations in Surface Electromyography of the Upper Leg Muscles at Specified Respiratory Exchange Ratio Thresholds Ranges During a Maximal Exercise Test

Direct Original Research

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Abstract

Introduction: Assessing muscle electromyography (EMG) in conjunction with physiological alterations to exercise may be valuable to determine a more holistic approach to exercise-induced fatigue.

Methods: Thirteen, recreationally trained individuals ($n = 7$ female, $n = 6$ males) underwent a maximal exercise test. Throughout the test, physiological variables were measured in addition to surface electromyography (sEMG) of the upper legs. Physiological and sEMG data was then grouped in to four category thresholds based on respiratory exchange ratios (RER) greater than 0.95.

Results: There was a main effect of group ($p < 0.001$) as an increase in exercise intensity assessed by RER threshold ranges resulted in a subsequent reductions in sEMG frequencies with the exception of the sEMG frequencies recorded at VO_{2peak} ($p < 0.055$).

Conclusions: Upper leg sEMG frequencies decrease with increases in high intensity exercise, with the exception of near maximal loads.

Key Words: muscles; maximal exercise test, high intensity

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Introduction

Wearable technology enables the remote quantification of physical workloads and exercise training intensities, heart rate intensities, distances, and even muscle electromyography¹⁻⁵. As fatigue increases, sEMG frequency of a muscle will likely decrease⁶, however, it is not well known how physiological responses (i.e., VO_{2peak} , respiratory exchange ratio (RER), and heart rate (HR)) change relative to muscle sEMG of upper leg muscles during a maximal treadmill exercise test. Therefore, the purpose of the study was to assess if sEMG utilizing wearable compression short technology can detect changes in muscle activity that corresponds to physiological during a graded, maximal exercise test on a treadmill.

Methods

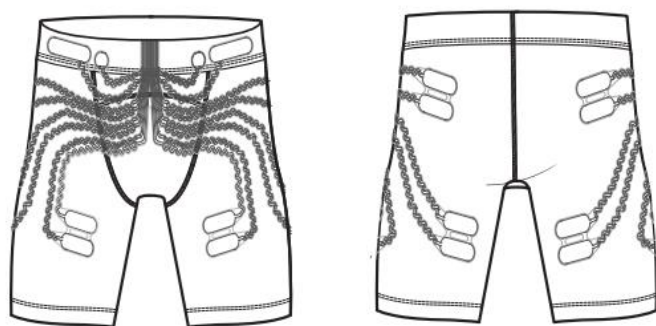
Participants

Thirteen recreationally trained participants (18–30 years old, $n=7$ females, $n=6$ males) participated. The criteria for recreationally trained, was defined by the American College of Sports Medicine, and participants reported such as running, biking, or weightlifting, 2-3 times a week for at least 30-60 minutes per session with no contraindications to exercise. Then participants read and signed an informed consent form prior to participation in the study. The university Institutional Review Board approved the laboratory study.

Protocol

The following methods were previously cited by Sanders et al.⁷. Participants were fitted with a validated, wearable sEMG compression short containing accurate electrode placements on the left and right rectus femoris (RF), biceps femoris (BF) and gluteus maximus (GM)⁸. All participants were fitted with a heart rate (HR) monitor (Polar Global, Kempele, Finland) and an appropriate sized face mask to measure oxygen consumption. Participants completed a warm-up at a self-selected pace for 10-minutes. Once each participant indicated they were ready to perform the exercise test, they participated in a step-incremental protocol that began with a 2-minute starting phase at 3.5 mph and a 6% grade. Throughout the test, sEMG electrodes within the compression shorts recorded muscle activity while 5-second sample rates were measured for physiological data such as oxygen consumption (VO_2), RER, HR (Pravo Medics, Truemax 2400, UT, USA) and $\text{VO}_{2\text{peak}}$ was reported as the highest relative VO_2 in $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$. Heart rate was reported as $\text{beats} \cdot \text{min}^{-1}$ (BPM) and HR_{peak} was reported as the highest heart rate achieved at any point throughout the test. Following the first, 2-minute phase, speed increased to 5.0 mph and then increased 0.5 mph every two minutes until the athlete reached volitional exhaustion. The 6% grade stayed constant throughout the test. Once volitional exhaustion was achieved, the participant stopped the test on their own and were instructed to complete a self-selected cool-down. Throughout the exercise treadmill test, the sEMG electrodes within the compression shorts recorded muscle activity. Physiological data such as oxygen consumption (VO_2), respiratory exchange ratio (RER), and HR, were measured using 5-second sample rates (Pravo Medics, Truemax 2400, UT, USA) and $\text{VO}_{2\text{peak}}$ was reported as the highest relative VO_2 in $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ [12]. Heart rate was reported as $\text{beats} \cdot \text{min}^{-1}$ (BPM) and HR_{peak} was reported as the highest heart rate achieved at any point throughout the test [12].

Figure 1. sEMG Compression Short Technology.



RER Threshold Ranges

The goal was to assess sEMG activity upon the onset of anaerobic threshold. Therefore the first RER range was set at <0.95 . Then the ranges were as follows, RER range 2: 0.96-1.02, RER range 3: >1.02 , RER range 4: RER at $\text{VO}_{2\text{peak}}$. For each participant, all variables for the final RER range were recorded for 2-3 data points (roughly 10-15 second samples) once $\text{VO}_{2\text{peak}}$ was achieved.

Statistical Analysis

Descriptive statistics for all participants were calculated for age, height, weight, and mean frequencies from the sEMG compression shorts were time merged with 5-second sample rates which equated to 1135 data points throughout the total 13 treadmill tests. To assess changes in sEMG frequencies at the RER thresholds, fixed effects models were utilized. All statistics were analyzed using IBM SPSS 27.0 (Version 27.0, IBM Inc., Armonk, NY). The criterion for statistical significance was set a priori at $P \leq 0.05$.

Results

Physical Characteristics and Physiological Performance

Physical characteristics for age, height, and weight were calculated for all participants (Table 1).

Table 1. Physical characteristics and exercise testing results for all participants.

All (N=13)	Male (n = 6)	Female (n=7)
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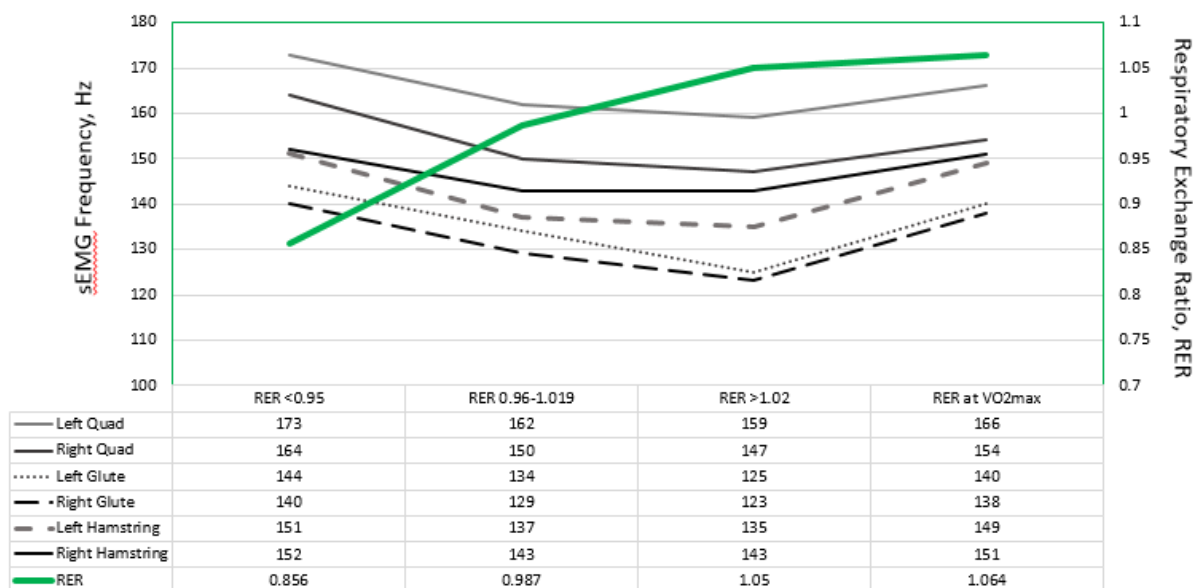
Age (years)	27.0 ± 6.0	28.8 ± 6.4	25.4 ± 5.5
Height (cm)	172.9 ± 11.0	183.9 ± 4.1	163.4 ± 2.1
Weight (kg)	74.1 ± 15.6	88.4 ± 8.5	61.8 ± 6.9

Data are means ± SD.

Table 2. Physiological variables at RER thresholds.

	Heart Rate		RER		VO ₂	
RER <0.95	161.43 ± 19.77	0.86 ± 0.06	31.36 ± 10.64			
RER 0.95-1.02	183.01 ± 12.55	0.99 ± 0.02	40.08 ± 6.68			
RER >1.02	187.68 ± 12.90	1.05 ± 0.03	40.85 ± 4.83			
RER at VO _{2peak}	194.34 ± 11.03	1.06 ± 0.02	43.75 ± 8.35			

Figure 1. RER thresholds and sEMG frequencies of the upper legs



Data are shown as the mean for each dependent variable. Significant main effect of RER threshold ranges was found for each muscle, $p < 0.001$ for all.

RER Threshold Ranges and sEMG of the Upper Legs

There was a significant main effect ($p < 0.001$ for all) of RER threshold range for sEMG frequencies for all upper leg muscles in measured via the wearable sEMG compression short. Post hoc analysis revealed that all sEMG measurements of the upper legs were significantly different from RER range 1: 0.95 ($p < 0.001$ for all), except the sEMG measurements of all upper leg muscles at RER range 4: at VO_{2peak} ($p > 0.055$ for all).

Discussion

The main findings revealed that sEMG significantly decreased throughout a maximal treadmill exercise test while physiological variables, concurrently significantly increased. The interesting finding demonstrated that sEMG in the upper leg muscle groups were not different from RER range 1 to RER range at VO_{2peak}. This may suggest a type of acute supercompensation effect of the muscles thereby over exerting in an aerobically fatigued state. While the mechanism of such phenomenon warrants substantial research, one may postulate there could be a subconscious cognitive aspect that is overriding the maximal or near maximal physiology of fatigue, for a brief time¹⁰.

Conclusions



Based on sEMG activity during a maximal exercise test, muscular function may be able to compensate for the exhaustive effects of physiological fatigue at near maximal aerobic work. All physiological factors increased throughout the test, even at maximal intensity, whereas sEMG frequency decreased significantly, except at maximal intensity.

Acknowledgments: None

Conflicts of Interest: The authors declare no conflict of interest

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