Original article

Muscle fatigue in participants of indoor cycling

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Summary

Background: **Indoor Cycling (IC) has been gaining recognition and popularity within recent years and few studies have investigated its benefits for sedentary participants.**
Objective: **The aim of this study was to evaluate differences in the surface electromyography (sEMG) variables, heart rate (HR), and subjective effort in sedentary participants while they performed an IC session and to compare their results with the trained subjects, to answer the question: Are trained cyclists less susceptible to muscle fatigue, since it is expected that they make less effort?**
Design: **Twenty-six volunteers were split into two groups according to their fitness status and weekly training load. Each participant completed an IC session in a private gym, lasting 45 minutes and were encouraged to follow the pedaling frequency and cycle resistance, within their limitations. Main Outcome Measures: HR, participants' subjective effort on the Borg Scale of Perceived Exertion (Borg Scale) and sEMG data were compared between groups.**
Results: **28.6% of the sedentary participants withdrew from the study. Exercise intensity, assessed using the HR, was similar in both groups. The subjective perceived effort, assessed using the Borg Scale, was significantly higher in the sedentary group. All muscles considered in the sedentary group had higher variation levels of Root Mean Square (RMS) and Median Frequency (MF) than those in the trained group.**
Conclusion: **Sedentary participants are more likely to present fatigue and IC can be incorporated into protocols for this population, but their fitness levels should be taken into account because each performance depends on the individual's physical fitness.**
Level of evidence: IIIb.

KEY WORDS: cycling, muscle fatigue, surface electromyography.

Introduction

Indoor cycling (IC) has recently been increasing in popularity and gaining recognition as an effective training activity, due to its proposal of losing weight as part of a fitness program[1]. During cycling, lower extremities are responsible for producing energy imparted to the bike and are highly demanded, experiencing high loads that may adversely affect tissues and contribute to overuse injuries[2]. Some evidence of risk factors for muscle strains during cycling are decreased muscle control, poor technique (i.e. whether under training or not), lack of conditioning, muscle fatigue and ethnicity[3-5].

All these risk factors are related to biomechanical aspects modulated by the central nervous system (CNS) which adjusts motor output for pedaling tasks based on different elements. Authors have found that cycling requires the subject to continuously adjust the force produced and its timing relative to the pedal position to obtain a specific self-selected pacing. Changes in riding positions (provoked by either the rider or the bike) may alter cycling variability both due to fatigue or to mechanical factors[6-8].

Muscle fatigue is defined as exhaustion or loss of strength and/or muscle endurance following strenuous activity and is commonly present among causes of injuries[9]. The causes of fatigue during muscular exercise include factors that reside in the brain (central mechanisms) as well as the muscles themselves (peripheral mechanisms). There is existing evidence proposing a feedback loop paradigm, in which the peripheral muscle fatigue provides inhibitory feedback to the CNS, and thereby influences the magnitude of central motor drive during high-intensity whole-body endurance exercise, such as cycling[10].

Using surface electromyography (sEMG), we aimed to assess peripheral components of muscle fatigue. Several mechanisms have been proposed to explain the fatigue resistance in some individuals: differences in muscle mass, muscle morphology, patterns of motor recruitment, and energy metabolism or substrate utilization. Many of them are related to the individual physical performance[11,12].

Workout steps, as well as variable intensity and involvement of both the cardiovascular system and skeletal muscles characterize IC. Lessons are undertaken in a dimly lit fitness room where participants cycle together on stationary bikes and follow the loud music rhythm[13], motivation words, and instructions of a teacher[1,3]. IC classes are thought to expend a large amount of energy and are usually very demanding and challenging for participants[14].

Despite its worldwide popularity, few scientific studies have compared the impact of IC cardiovascular functions on surface electromyography (sEMG) between trained and sedentary people[15-18]. Since IC classes have singular features (e.g. rhythm, loud music, verbal motivation) when compared to other kinds of stationery bike trainings, it is unclear whether IC is a fitness activity that should be undertaken by sedentary people (including the elderly and other specific groups, such as those unfamiliar with cycling).

The aim of this study was to evaluate sEMG variables, HR, and subjective effort in sedentary participants, while they performed an IC session, and to compare their results with the trained subjects' results, to answer the question: Are trained cyclists less susceptible to muscle fatigue, since it is expected that they make less effort? Our hypothesis is that, as high-level cyclists, trained subjects may present different EMG patterns, and less incidence of early fatigue.

Material and methods

Participants

Twenty-four volunteers were allocated into two groups according to their fitness status and weekly training load. The trained participants (n=10) had all been cyclists for at least five years before the study, and, on average, they taught five sessions a day, four times a week. The sedentary group (n=16) comprised new clients from fitness clubs, who engaged in less than 150 minutes of moderate intensity exercise each week (ASCM guidelines) and had never experienced an IC session prior to the current study. The exclusion criteria included a history of musculoskeletal dysfunction or trauma 24 months before the study and any training on a cycle ergometer (for the sedentary group). During the study, participants were asked to refrain from alcohol and caffeine. Each volunteer signed a consent and the research was conducted according to ethical guidelines for the field of sports sciences as recommended by MLTJ[19].

Procedures

After some pedaling (15-20 rides) for familiarization with the bike (Kikos; Model Pro F12), the participants pedaled for three times on the maximum load (Maximum load pedaling - MLP) to record the maximum voluntary electrical activation. It consisted of three maximal cycling sprints performed on the IC bike while the load was gradually increased (turning the rotary actuator) until the pedals came to a complete stop. The mean value of the last completed cycles was used for normalization, in line with a technique adapted from Rouffet and Hautier[20].

Each participant completed one IC session, lasting 45 minutes. All procedures took place in a private gym, during the evening (between 6:00 p.m. and 9:00 p.m.; room temperature and relative humidity of 22±2.7° C and 48±4.5%, respectively). The researchers did not change the protocol used by the teacher for the IC session; this encouraged the participants to follow the recommended pedaling frequency and cycle resistance, within their limitations. Sessions were divided in four stages: warm-up (5 min), cardiovascular training period (30 min), cool down (5 min), and static stretching (5 min). All calculations and analyses were related to the cardiovascular training period.

The HR was recorded by a chest HR transmitter (1000 Hz sampled), worn by the participants, and a wrist monitor (Polar FT7, USA). The data from the entire session were downloaded via a Flow Link interface; the mean values of every five-second period of the session were calculated and normalized by the maximum HR. After the end of the session, the participants' Borg Scale of Perceived Exertion (Borg Scale) reports were collected by asking them to choose, from 0 to 10, the number that best represented their level of tiredness[21]. All data were processed and analyzed using MATLAB (Matlab10; Mathworks Inc, Natick, MA, USA).

EMG data acquisition and analysis system

Disposable 10 mm surface electrodes (Meditrace Al/AgCl) were used. The electromyographic signals were recorded through a bipolar arrangement with an interdistance of 20 mm. Surface electrodes were placed on the skin of the dominant leg, parallel to the muscle fibers, to record muscle activity of the gluteus maximus (GM), biceps femoris (BF), rectus femoris (RF) and semitendinosus (ST). The reference electrode was attached to the olecranon, according to SENIAM guidelines[22]. An 8-resolution channel data acquisition system (model EMG820C, Emgsystem Inc; São José dos Campos, Brazil), consisting of a signal conditioner with a band-pass filter of 20-450 Hz and amplifier gain of 2000, was used to obtain biological signals. All data were processed and exported for analysis by a specific software (EMGLab Emgsystem, Inc). sEMG activity was captured by differential surface electrodes (SDS500) and converted by an A/D board (Emgsys 30306, EMG System do Brasil, Brazil) with a 14-bit resolution input range, sampling frequency of 2000 Hz, common rejection module greater than 100dB, signal-to-noise ratio less than 0,3 μV, and impedance of 109 Ω.

Root Mean Square (RMS) was derived from the raw EMG data by full-wave rectification and continuous average. The time was set at 400 ms and in order to reduce variations and condense the data, the system averaged those RMS values in 10-s epoch and normalized by the maximum voluntary electrical activation during pedaling with MLP[20]. Mean RMS was plotted against time and then analyzed using the linear regression method. Power spectra density (PSD) from every 1024 samples (1-s period) was calculated by means of fast Fourier transformation and the median frequency (MF) was estimated. MF was plotted against time and analyzed using the linear regression method. Both parameters, RMS and MF, were calculated only during the muscle activation pattern (onset). The criteria for establishing the onset and offset activation were based on a voltage threshold (3 standard deviations beyond mean value during baseline)[16].

sEMG data were analyzed using a pre-specified routine described in MATLAB and the following variables were compared both between and within groups: MF variation (initial MF – final MF) and RMS variation (initial RMS – final RMS). The initial MF and initial RMS relate to the first 5 minutes of the cardiovascular training period. The final MF and final RMS relate to the last 5 minutes of the same period.

Also, sEMG data were expressed as a pair of parameters representing the slopes of the RMS and MF, as previously proposed by Lin et al.[23]. With this method, both EMG characteristics are considered and represent muscle behavior according to the quadrant methodology, as follows:

1. Upper-right (increase in both RMS and MF) and Upper-left (decrease in RMS and increase in MF) quadrants: indicates an increase in muscle force, followed by adaptation of the involved muscles;
2. Lower-right (increase in RMS with decrease in MF) and Lower-left (decrease in both RMS and MF) quadrants: indicates decline in produced force, followed by muscle fatigue.

Therefore, lower quadrants are a sign of physiological failure.

Statistical analysis

Sample size was estimated using SigmaStat 3.5. Assuming a confidence interval of 95% and power of 80%, the required sample was determined as 10 per group. Data were tested for normality using the D'Agostino test. Data are presented as mean and standard deviation. The statistical analysis was performed using SPSS (version 15.0, SPSS Inc., Chicago, USA). Student's independent t-test was employed to test differences in Anthropometric, Borg Scale and HR parameters between sedentary and trained participants. One-way analysis of variance (ANOVA) was used to determine the effect of physical fitness status as a categorical variable (factor 1: trained *vs* factor 2: sedentary) on EMG variables during the IC session. All levels of significance were set at $\alpha=0.05$. The Intra-class Correlation Coefficient (ICC) was used to evaluate reliability of the repeated EMG measures during the session. In addition, the effect size was calculated with eta squared ($\eta 2$) and classified as small ($0.01 < \eta 2 < 0.06$) medium ($0.06 < \eta 2 < 0.146$) and large ($\eta 2 > 0.14$)[19,24].

Results

General details

Four sedentary participants (28.6%) withdrew from the study due to microtraumas or pain during the session. Groups had no difference in age and anthropometric data. Sedentary participants had higher resting HR compared to trained ones (Tab. I).

Heart rate and subjective effort

At the end of the class, the trained group showed a significantly lower level of perceived fatigue on the Borg Scale and a lower HR in comparison with the sedentary group ($p< 0.001$) (Tab. II).

sEMG data

Muscle variation in BF, ST, GM, and RF is summarized in Figure 1. Statistical analysis revealed higher variation (RMS and FM) in the sedentary compared to the trained group (group effect), showing that the factor group had interaction with the measurement from the beginning to the end of the class. Following the class, there was a main group effect in RMS and FM for all muscles, as exposed in Table III.

EMG showed good reliability, with the ICC values for

Table I. Anthropometric characteristics of the participants.

Variables	Sedentary participants (n=12) Mean (SD)	Trained (n=10) Mean (SD)
Age (years)	23.8 (1)	25.9 (2.3)
Weight (kg)	55.5 (2.9)	62.3(2.2)
Height (m)	1.67 (3.2)	1.68 (1.8)
Resting HR (beats/min)	83.8 (2.1)	60.9 (2.7)*
Resting HR (% Max HR)	42.8 (1)	30.3 (1.3)

*Mean and standard deviation (SD): age, weight, height, resting HR and normalized resting HR . *$p < 0.05$, differences between groups.

Table II. Comparison between groups and IC classes.

	Mean heart rate (beats/min)	Mean heart rate (% Max HR)	Borg Scale of Perceived Exertion
Trained	135.2 (10.9)	69.5(1.1)	3.9 (1.4)
Sedentary	151.8 (9.7) *	77(4.9) *	9.3 (0.5)

* Mean heart rate and subjective effort assessed using the Borg Scale in IC classes for both groups. Values are given as mean (SD). $p < 0.001$

Table III. Summary of group effect (F, p-values, and effect size).

		F- value	p-value	ES
RMS				
	BF	$F_{(2.32)} = 30.12$	**0.0003***	**large**
	GM	$F_{(2.32)} = 25.65$	**0.0008***	**large**
	RF	$F_{(2.32)} = 104.82$	**0.0007***	**large**
	ST	$F_{(2.32)} = 10.12$	**0.0000***	**large**
FM				
	BF	$F_{(2.32)} = 5.72$	**0.0040***	**medium**
	GM	$F_{(2.32)} = 86.02$	**0.0001***	**large**
	RF	$F_{(2.32)} = 53.11$	**0.0006***	**large**
ST		$F_{(2.32)} = 143.12$	**0.0000***	**large**

Summary of ANOVA. group effect. Root mean square (RMS), gluteus maximus (GM), biceps femoris (BF) rectus femoris (RF) and semitendinosus (ST). Effect size (ES). *$p < 0.05$

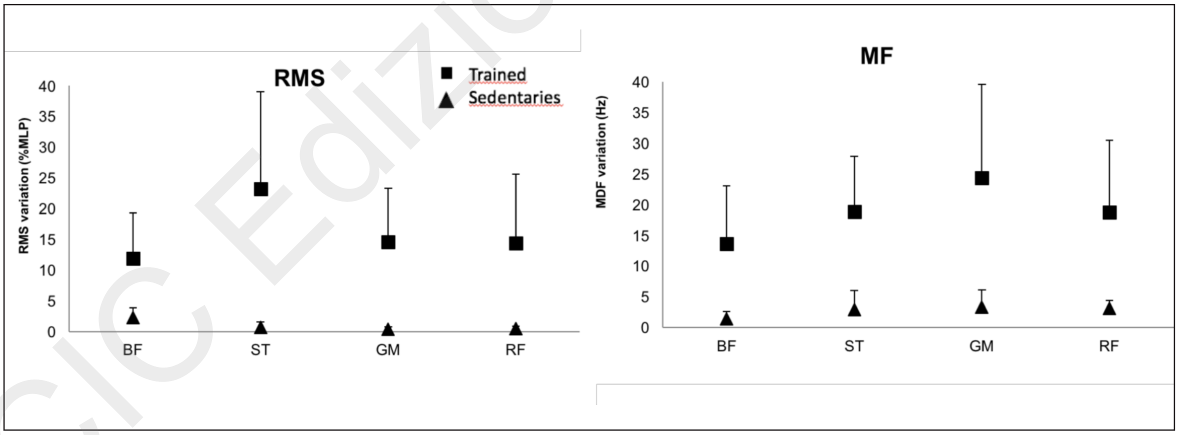

Figure 1. RMS (% MLP) and MF (Hz) variation during the IC session in trained and sedentary groups. *$p < 0.05$ group effect.

the four muscles ranging from 0.75 to 0.97 (BF= 0.75, GM= 0,9=89, RF= 0,92, ST= 0,97) (Figure 1).

JASA method

Figure 2 summarizes the JASA analysis of the 10 trained and 12 sedentary participants, respectively. After the IC session, the sedentary group was located in lower quadrants (classified according to the method as muscle fatigue or force decrease quadrants) in 83% of the participants for GM, 63% for ST, 71% for BF and 63% for RF. For the trained group the percentages in lower quadrants for these muscles were 17, 37, 29 and 37% respectively.

Discussion

The main purpose of this study was to evaluate the exercise intensity pattern of an IC session in a real setting (fitness club) and to compare inexperienced

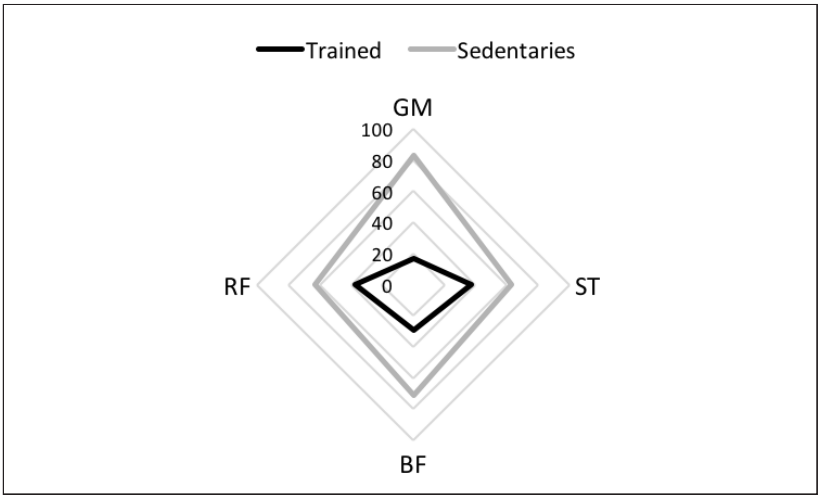

Figure 2. Summary of RMS and MF percentages in the lower quadrants of JASA plot, for muscles in both groups. GM: gluteus maximum; ST: semitendinosus; BF: biceps femoris; RF: rectus femoris.

sedentary individuals with trained instructors.

Our results answered our initial question and showed that the exercise intensity, in terms of the HR, was significantly higher for the untrained group, as well as the subjective perceived effort, measured by the Borg Scale. This is explained by the nature of this exercise. Some Authors recommend that the exercise intensity for novice individuals should be lower than the 50-85% recommended by ASCM[25]. They also suggest that the volume of standing climb during the session should be reduced for novices[1]. In our study, the teacher instructed participants to increase intensity when cycling on the stationary bikes, but this was done voluntarily and at a level chosen by the participant. The participants applied the teacher's command in a rotary actuator on the bike, deducting subjectively the amount of load. Furthermore, the teacher requested the participants to control their effort using their HR reading. This was done with reference to their maximum HR (HR max), which was calculated using the formula 220-age beats/min. However, quantifying participants' effort consistently can be an issue, since the use of chest HR transmitters is not a practice typically followed by the fitness club, and only the participants in our study received one. Considering this, we can affirm that trained subjects have made less effort to perform the same activity. However, considering the muscle activity, is this lower effort related to less muscle fatigue? Our answer is yes, different patterns of sEMG were observed between the two groups, indicating different fatigue status. In our study, separate and joint analyses of RMS and MF values were used to compare the behavior of individuals who had not previously taken part in IC with trained instructors.

The RMS values of all four muscles were significantly higher in the sedentary group which may be due to the pedaling technique that high-level cyclists often adopt and that allows the agonist and antagonist muscles in the leg to pedal more efficiently[26,27]. This supports that their muscles can perform the biomechanics of cycling with less intensity, which preserves this group from early fatigue[4,28-30]. Also, the MF variation was significantly lower in the trained group, which demonstrates that the sedentary group experienced more fatigue than the trained group.

Variation in RMS and MF values represents an adequate indicator of fatigue[9,31], especially in the case of sustained isometric exercise. Increases in action potential amplitude and changes in the order of motor unit recruitment contribute to increases in RMS values. When muscle fatigue sets in, the amplitude of the MF power spectrum increases and shifts to lower frequencies due to motor unit recruitment, action potential firing rate decreases and desynchronization, or reductions in their conduction velocity[32,33]. These variations are considered to represent physiological strategies that compensate for functional loss by recruiting additional fibers to maintain muscle activity close to the required threshold[9,33]. Luttmann (2000) proposed JASA as a new method to assess fatigue of muscular activity, since it simultaneously considers the changes in the EMG amplitude and spectrum throughout the task. Therefore, one great advantage of JASA method is that the subjects do not have to interrupt the task intermittently to perform isometric contractions, such as the MVC test[34].

Previous reports have shown that reductions in frequency, action potential amplitude, and conduction velocity that occur during static and dynamic muscle contraction are associated with an accumulation of metabolic by-products and changes in the intracellular pH, a feature that varies according to the quality and duration of the exercise[35,36].

We also used the JASA method to consider both RMS and MF over the session. The JASA results supported the isolated RMS analysis and showed a significant decrease in the number of participants who fell into the lower quadrants, representing fatigue, in the trained group.

It has been proposed that greater cycling efficiency and more economical cadence are evidence of skilled muscle recruitment in highly trained cyclists and that this prevents early fatigue and muscle strain[22,24,31]. Our hypotheses were then confirmed[13,37,38].

This study attempted to identify differences in musculoskeletal activation behavior between sedentary and trained participants of IC classes. One limitation of our research is that parameters such as the amount of load on the cycle, pedaling frequency and cycle resistance could not be assessed in the real setting of the session. Nevertheless, all measurements were made on the same day, and all participants were encouraged to follow the teacher's recommendations within their limitations, which guaranteed equal conditions for all participants in the research.

This sport has been gaining recognition and popularity within recent years and few studies have investigated its benefits for sedentary participants. The results of this study are relevant to fitness clubs, instructors, athletic trainers, and new participants since it will clarify which risks the participants might be exposed to. Individuals wishing to begin IC classes should make sure that they have conducted appropriate exercise screening and have had no exposures to cardiovascular or musculoskeletal risks.

IC requires a considerable effort and there are doubts about its suitability for sedentary people. These findings suggest that IC can be incorporated into protocols for this population, but their fitness levels should be taken into account because each performance depends on the individual's physical fitness. This could include the possibility of developing a specific class/protocol for beginners, who might then be included in an advanced class after some training.

Conclusion

IC classes were more exhausting for the sedentary group in terms of the HR and the subjective perceived effort, measured by the Borg Scale. Variation in RMS and MF values also confirmed different muscular behavior with more presence of fatigue in this group. The JASA results supported the isolated RMS in MF analysis and showed a lower number of participants who fell into the lower quadrants, representing fatigue, in the trained group.

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Conflicts of interest

The Authors declare no conflicts of interest concerning this article.

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