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Abstract

Effect of pedaling cadence on physiological responses and neuromuscular fatigue during a single interval-training session.

Sébastien Duc [1,*], Jérémie Allinger and Stéphane Verrier [1]

[1]University of Reims Champagne Ardennes; Laboratory PSMS (Performance, Health, Metrology, Society) (EA7507), chemin des rouliers, UFR STAPS Bat25 Campus Moulin de la Housse, 51100 Reims France

* Correspondence: (SD) sebastien.duc@univ-reims.fr

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Abstract: The present study investigated the effect of pedaling cadence on neuromuscular fatigue of the knee extensor muscles following an interval training (IT) session. Nine trained male cyclists performed three 45-min IT session (6 x 5 min work intervals at 80% of peak power output separated by 2.5 min active recovery period) with 3 different pedaling cadence (60, 90 and 110 rpm), in a random order. Neuromuscular tests were performed before and immediately after the three trials. Heart rate (HR) and electromyography (EMG) activity of thigh muscles were measured throughout IT sessions and RPE at the end of each work interval. Although reduction in maximal voluntary contraction torque was similar after the 3 IT sessions, decreases in peak doublet and peak twitch were significantly greater after IT110. Compared to IT60 and IT90, HR and EMG activity of vastus medialis were significantly higher during IT110. Performing IT session with high pedaling cadence resulted in additional peripheral muscular fatigue and cardiovascular demand that may be explained in part by a greater fast fiber recruitment in quadriceps.

Keywords: muscular torque; isometric twitch; heart rate; electromyography; neuromuscular stimulation

1. Introduction

Several previous studies [1,2,6] have reported a significant reduction in neuromuscular fatigue (NMF) following prolonged (~30 min) and intense (~80% of peak power output (PPO)) cycling exercise. NFM, which refers to a reduction in maximal voluntary contraction (MVC) force or power production, can resulted from changes in both central and peripheral process [2].

While changes in pedaling cadence (PC) influence physiological responses during a prolonged and intense cycling exercise [3], alterations in central and peripheral components of NMF are similar when PC varied from 50 to 110 rpm [2,6]. Despite interval training (IT) is frequently performed by cyclists, at our knowledge, no study has investigated the influence of PC on both physiological responses and NMF components during an intermittent cycling exercise (i.e, a single IT session).

2. Materials and Methods

Subjects —Nine trained male cyclists and triathletes (age: 23.7 ± 6.5 years, height: 1.80 ± 0.04 m; body mass: 70.1 ± 4.8 kg; PPO: 365 ± 37 W) volunteered to participate in this study after being informed of any potential risk. The study was approved by the local ethical committee and was performed accordingly to the ethical standards established by the Helsinki Declaration of 1975.

Design—Each subject performed three IT sessions separated by at least 2 days on their own road bike mounted on a braked Cyclus2 ergometer (RBM GmbH, Leipzig, Germany). Each IT session consisted of 6 × 5 min work intervals at 80% of PPO with 2.5 min recovery at 30% of PPO in between. Three pedaling cadence (~60, 90 and 110 rpm) were used in a random order. All the subjects were required to perform the same individualized 20-min warm-up before starting the IT session, and to pedal in a seated position throughout all work intervals.

Methodology— Heart rate (HR) and surface EMG activity of right muscle vastus lateralis (VL), vastus medialis (VM), rectus femoris (RF) and biceps femoris (BF) were recorded continuously during each IT session at 1 and 2000 Hz, respectively, while rating of perceived exertion (RPE) was reported on Borg scale (6-20) after each work interval. HR was expressed in % of HR_{peak} (measured previously during a graded exhausted test) and amplitude of EMG activity was assessed from mean RMS normalized in % to the value measured at 90% of PPO during the warm-up.

Neuromuscular test of right knee extensors was performed prior and after each IT session and consisted of two 5-s Maximal Voluntary Contraction (MVC) with doublets (paired stimuli at 100 Hz) delivered (1) over the MVC isometric plateau (superimposed doublet) and (2) 3 s after the MVC (potentiated doublet), to assess voluntary activation level (VAL) according to the twitch interpolation technique. A single twitch was evoked 3 s after and 60 s of recovery was interspersed between trials. Strong verbal encouragement was given to the subjects during each MVC. Electrically evoked contractions were induced using a high-voltage (maximal voltage 400 V) constant-current stimulator (model DS7, Digitimer, Hertfordshire, UK). Quadriceps belly was stimulated using two rectangular electrodes 10 x 5 cm (Compex SA, Ecublens, Switzerland). The site of stimulation was marked on the skin so that it could be repeated after the cycling exercise. The optimal intensity of stimulation determined prior performing the first MVC was kept constant throughout each IT session for each subject. The stimulus duration was 1 ms and the interval between paired stimuli was 10 ms. Isometric knee extension torque was recorded using a Con-Trex@MJ isokinetic dynamometer (Physiomed Elektromedizin AG, Schnaittach, Germany). Subjects were placed in the seated position (with a knee angle of 90°) and were securely strapped into the test chair. Peak MVC torque, peak single twitch torque (ST), peak potentiated doublet torque (DT) and VAL corresponded to the maximal values measured before and after each IT session. VAL was estimated according to the following formula (Behm et al., 1996):

$$VAL = \left(1 - \frac{surimposed\ doublet}{potentiated\ doublet}\right) \times 100$$

Statistical Analysis— Kolmogorov–Smirnov tests confirmed that all data were normally distribute. Subsequently, a one-way (pedaling cadence) ANOVA with repeated measures was performed on variables measured during the cycling IT sessions (HR, RPE, RMS) while paired t-test was used sto compare pre-to-post IT session changes in neuromuscular variables. All significant differences were set at $p \leq 0.05$. Data were presented as the mean ± SD in the text and as the mean ± standard error in the figures.

3. Results

Neuromuscular variables— No significant differences were found between the three pedaling cadence conditions in MVC, VAL, ST and DT values measured before the cycling IT session. While MVC torque was significantly ($p < 0.05$) reduced after cycling exercise by -4.6 ± 5.3% for IT60, -5.5 ± 4.2% for IT90, and -8.2 ± 5.1% for IT110 (Figure 1A), no significant difference was found between the 3 pedaling cadence conditions. Although VAL was reduced by ~3% after each IT session (Figure 1B), the decrease was not significant. The reduction in DT amplitude was significantly ($p = 0.05$) greater after IT110 (-14.2 ± 4.8%) than after IT60 (-9.6 ± 6.2%) and IT90 (-8.5 ± 5.1%) (Figure 1C). The reduction in ST amplitude was significantly (p = *0.03 and 0.015*) lower after IT90 (-15.2 ± 8.1%) than after IT60 (-20.8 ± 9.3%) and IT110 (-24.1 ± 7.7%) (Figure 1D).

Physiological cycling variables— Mean HR was significantly ($p = 0.009$) greater during IT110 (90 ± 2 $\%HR_{peak}$) than during IT60 (85 ± 3 $\%HR_{peak}$) and IT90 (86 ± 5 % HR_{peak}). No significant differences were found in mean RPE between the three IT sessions (16 ± 1, 16 ± 1, and 17 ± 2, respectively for IT60, IT90 and IT110).

Mean EMG activity of RF and BF was significantly higher ($p = 0.043$ and $p = 0.033$) during IT60 (138 ± 43% and 113 ± 32, respectively) than during IT90 (91 ± 16% and 86 ± 23, respectively) and IT110 (94 ± 5% and 77 ± 18, respectively) while EMG activity of VM was significantly higher ($p = 0.05$) during IT90 (101 ± 8%) and IT100 (105 ± 14%) than during IT60 (95 ± 6%). No significant differences were in found in mean EMG activity of VL between the three IT sessions (114 ± 24%, 104 ± 9%, and 107 ± 13%, respectively for IT60, IT90 and IT110).

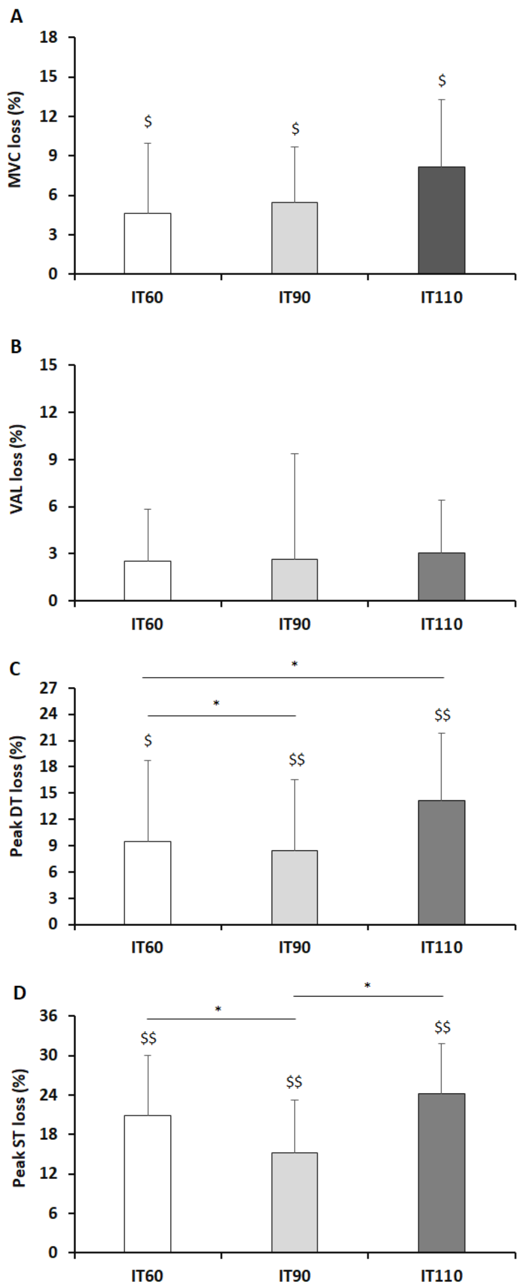

Figure 1. (**a**) Reduction in maximal voluntary contraction (MVC) torque immediately after interval training (IT) session performed with a pedaling cadence of 60 rpm (IT60), 90 rpm (IT90) and 110 rpm (IT110). (**b**) Reduction in voluntary activation level (VAL) immediately after IT60, IT90 and IT110. (**c**) Reduction in peak potentiated doublet torque (DT) immediately after IT60, IT90 and IT110. (**d**) Reduction in peak single twitch torque (DT) immediately after IT60, IT90 and IT110. Significant loss: $: $p<0.05$, $$: $p<0.01$. Significant difference: *: $p < 0.05$.

4. Discussion

The main findings of the present study were that compared to low (~60 rpm) and moderate (~90 rpm) PC, the use of high pedaling cadence (~110 rpm) during a IT session (6 × 5 min at 80% of PPO) induced higher HR and VM recruitment, and a greater decrease in peak torque of potentiated doublet (PD) and single twitch (ST). Low PC involved a higher recruitment of RF and BF muscles and a greater decrease in peak single twitch (ST) than moderate PC. As PD and ST torques are considered to reflect the slow and all (slow + fast) fibers force production ability, respectively, these results suggest that peripheral component of NM fatigue is more exacerbated by high PC (probably in fast fiber) and to a lesser extent by low PC (probably in slow fiber) even if the MVC reduction was comparable between the 3 PC conditions.

Our results are not in accordance with those of Lepers et al. (2001b) and Sarre et al. (2005) since these authors did not found any significant influence of PC during a 30 min constant power cycling exercise (80% of PPO). Surprising, unlike to these two previous studies, we did not find any significant reduction in VAL after IT session. This difference could be explained by the method used to obtain evoked contractions (electrically stimulation of quadriceps belly in the present study vs. motor nerf stimulation in the previous studies)

5. Practical Applications.

Performing a 6 × 5 min IT session with high pedaling cadence resulted in additional cardiovascular demand and peripheral muscular fatigue in quadriceps. In contrast, the use of low pedaling cadence did not induce greater NM fatigue. However, it involves higher recruitment of both hip flexor (RF) and extensor (BF) muscles, to produce probably higher effective force during the push and pull-up phases. All these findings should be taken into account to optimize the training plan and avoid accumulation of muscular fatigue.

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Conflicts of Interest: The authors declare no conflict of interest.

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