Low-Intensity Cycling Affects the Muscle Activation Pattern of Consequent Countermovement Jumps

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Abstract

Marquez, GJ, Mon, J, Acero, RM, Sanchez, JA, and Fernandez-del-Olmo, M. Low-intensity cycling affects the muscle activation pattern of consequent countermovement jumps. *J Strength Cond Res* 23(5): 1470–1476, 2009—Players (eg, basketball, soccer, and football) often use a static bicycle during a game to maintain warming. However, the effectiveness of this procedure has not been addressed in the literature. Thus, it remains unknown whether low-intensity cycling movement can affect explosive movement performance. In this study, 10 male subjects performed countermovement jumps before and after a 15-minutes cycling bout at 35% of their maximal power output. Three sessions were tested for 3 different cadences of cycling: freely chosen cadence, 20% lower than freely chosen cadence ($FCC_{-20\%}$), and 20% higher than freely chosen cadence ($FCC_{+20\%}$). Jump height, kinematics, and electromyogram were recorded simultaneously during the countermovement jumps. The results showed a significant decreasing in the height of countermovement jump after cycling at freely chosen cadence and $FCC_{-20\%}$ ($p = 0.03$ and $p = 0.04$, respectively), but not for $FCC_{+20\%}$ cadences. The electromyographic parameters suggest that changes in the countermovement jump after cycling can be attributed to alteration of the pattern of activation and may be modulated by the preceding cycling cadence. Our study indicates that to avoid a possible negative effect of the cycling in the subsequent explosive movements, a cadence 20% higher than the preferred cadence must be used.

Key Words vertical jump, cadence, EMG, warmup

Introduction

It is well known that the cadence used during pedaling could affect the metabolic, neuromuscular, biomechanics, and physiological parameters that can produce acute changes in muscular performance (28). Several studies have shown changes in the cardiac rate, oxygen uptake, maximal power output (P_{max}) (17,25), and changes in the neuromuscular activation during pedalling at different cadences (18,26–28). Other studies have studied the strength loss after prolonged cycling (for review, see [22]). Prolonged cycling causes a force reduction during isometric, concentric (17), and maximal voluntary contractions (2,15).

Most studies referenced here have been done in triathletes or cyclists in similar conditions to that of a competition, which means duration of cycling is >30 minutes and power output >50% P_{max}. In these conditions, the effect of the cycling and the cadence used over a subsequent movement can be the result of central and peripheral fatigue (22). Moreover, well-training athletes (triathletes and cyclists) such as those who participated in these studies can show specific adaptations to the pedaling movement induced by continuous practice. Thus, the question whether the pedaling itself can affect a subsequent movement in the absence of fatigue has not been addressed.

This question is relevant when we observe players (eg, basketball, soccer, football) using a static bicycle during a game to maintain the warmup carried out previously. The effectiveness of this procedure has not been addressed in the literature. In addition, it is unknown which parameters of pedaling (cadence, power, intensity) are the most efficient in achieving the goal of maintaining the effect of the warmup and avoiding fatigue.

This study was designed to determine the effect of different cycling cadences at low intensity and short duration on explosive muscular movement. We use the countermovement jump (CMJ) as a good example of a power test because it is well known in the sports training field and a good predictor of the performance in several sport disciplines (24).

We hypothesized that, in absence of muscular fatigue, pedaling itself can affect the performance in vertical jump and this effect is cadence-dependent.

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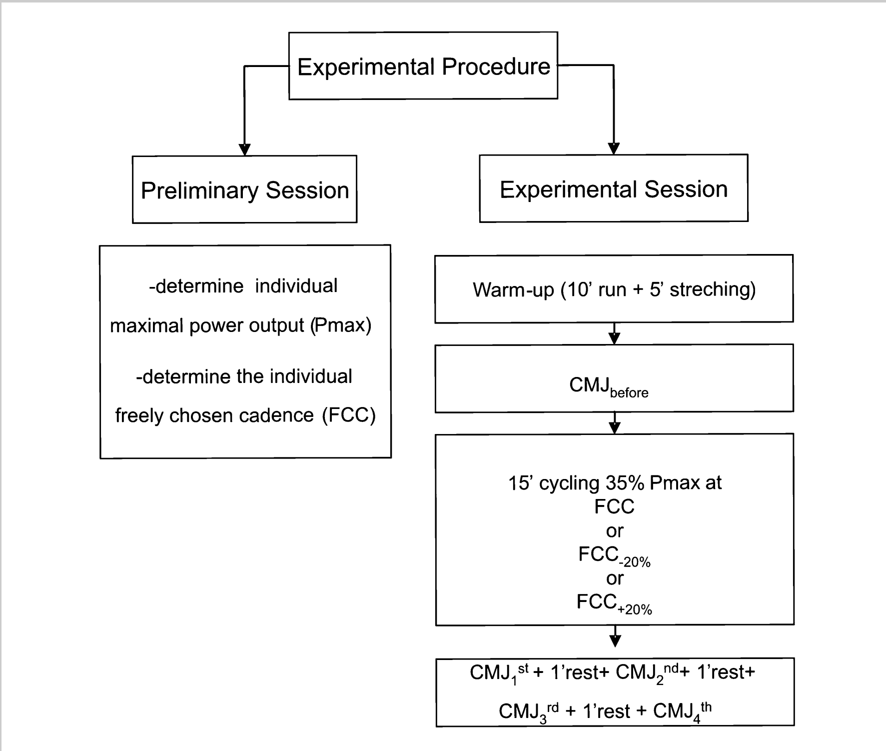

Figure 1. Experimental procedure.

Methods

Experimental Approach to the Problem

Subjects. We recruited 10 males students (age, 21 ± 4 years; weight, 75 ± 6 kg; height, 174 ± 12 cm) from the Institute of Physical Education and Sport of Galicia, Spain. We asked subjects to report their current level of physical activity on a scale of 0 to 10, 0 indicating no physical activity and 10 indicating vigorous exercise daily for at least 60 minutes. All the subjects reported physical activity of 9 or 10 points. No subject had previous experience or practice in cycling sports. Five subjects were basketball players, 4 were soccer players, and one a rugby player. All of subjects participated in their respective local official leagues (with a minimum of 5 years of experience). The basketball players had a moderate weight training background (at least 1-week session of resistance training during the competitive period) and the rugby player had a good weight training background (3 resistance training sessions). In contrast, the soccer players only performed 1-week resistance session during the precompetitive period (1 month, 4 sessions in total).

All subjects gave their informed consent after being informed of the possible risks of the study. The experimental procedures conformed to the Declaration of Helsinki and were approved by the local ethics committee.

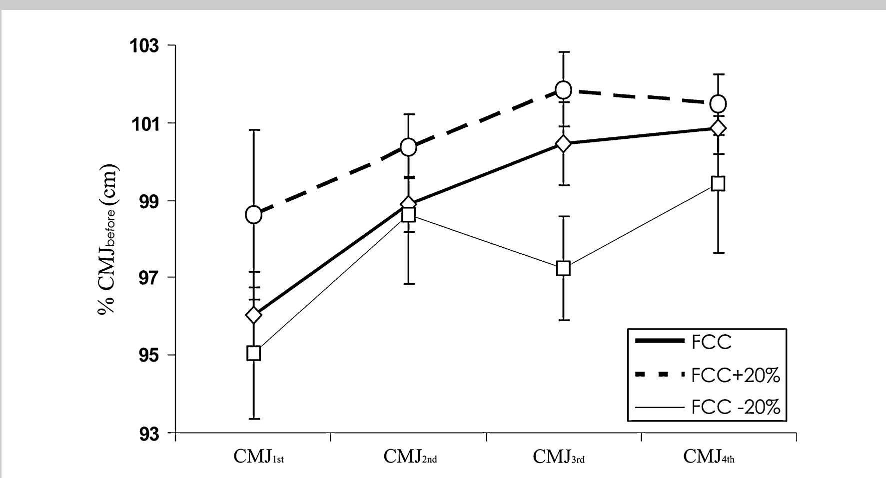

Figure 2. Vertical jump normalized to the CMJ_{before} for freely chosen cadence (FCC), 20% lower ($FCC_{-20\%}$), and 20% higher ($FCC_{+20\%}$). The analysis of variance showed a significant difference between $FCC_{-20\%}$ and $FCC_{+20\%}$ ($F = 5.04$ $p = 0.026$). CMJ, countermovement jump.

Preliminary Session. In a session 1 week before the experiment, all subjects performed a maximal incremental test on an electromagnetically braked ergocycle (Cardgirus, Multitec, Australia) to determine their individual maximal power output (P_{max}). The power output was increased by 25 W every 2 minutes from the first power output level (100 W). The test ended when the subject could no longer sustain the required power output. The researchers encouraged the subjects to ensure they reached the P_{max}.

The P_{max} was defined as the last power output level completed. Ten minutes after the P_{max} test, subjects were asked to pedal at 35% P_{max} during 15 minutes, allowing them to use different cadences to determine the individual freely chosen cadence (FCC). The FCC corresponded to the cadence subjects spontaneously adopted within the first 5 minutes. During the last 10 minutes of this test, the subjects were asked to maintain the same cadence.

Experimental Procedure. The experimental procedure is shown in Figure 1. The subjects took part in 3 different experimental sessions. In each session, the subjects started with a standardized warmup that consisted of 10 minutes tempo run at low intensity and 5 minutes of stretching exercises. After this period, the subjects performed one maximal CMJ (CMJ_{before}) followed by 15 minutes of cycling on the ergocycle at 35% P_{max}. Immediately after this, the subjects performed a total of 4 maximal CMJs (CMJ_1^{st}, CMJ_2^{nd}, CMJ_3^{rd}, and CMJ_4^{th}) with a 1-minute interval between each jump for recovery. During the minutes of recovery, the subjects were seated on a chair. Heart rate (HR) was monitored every 10 seconds during each experimental session using an electronic HR device with a chest electrode (Polar Vantage NV; Polar Electro Oy, Kempele, Finland).

Three different testing sessions corresponding to 3 different cycling cadences were conducted. Each session was separated by 1 week and the order of the cadence was randomized. One session was performed at a FCC that corresponded to the cadence subjects adopted in the preliminary session. For the other 2 sessions, the cadence used was 20% lower ($FCC_{-20\%}$) and 20% higher ($FCC_{+20\%}$) than the FCC. Pedaling rate was recorded instantaneously from the ergocycle and was constantly displayed online to the subject through a visual screen. The ergocycle allowed subjects to keep power output constant independent of the pedal rate they naturally adopted.

Electromyography and Kinematic Recording. Electromyography (EMG) activity from the vastus lateralis (VL), biceps femoris (BF), medial gastrocnemius (MG), and soleus (SL) muscles of the right leg were recorded during the vertical jumps using Ag-AgCl bipolar surface electrodes. After skin preparation (shaved, abrasion, and cleaning with alcohol), the electrodes were coated with electrolytic gel and fixed over the middle of the muscle belly along the longitudinal axis, and the reference

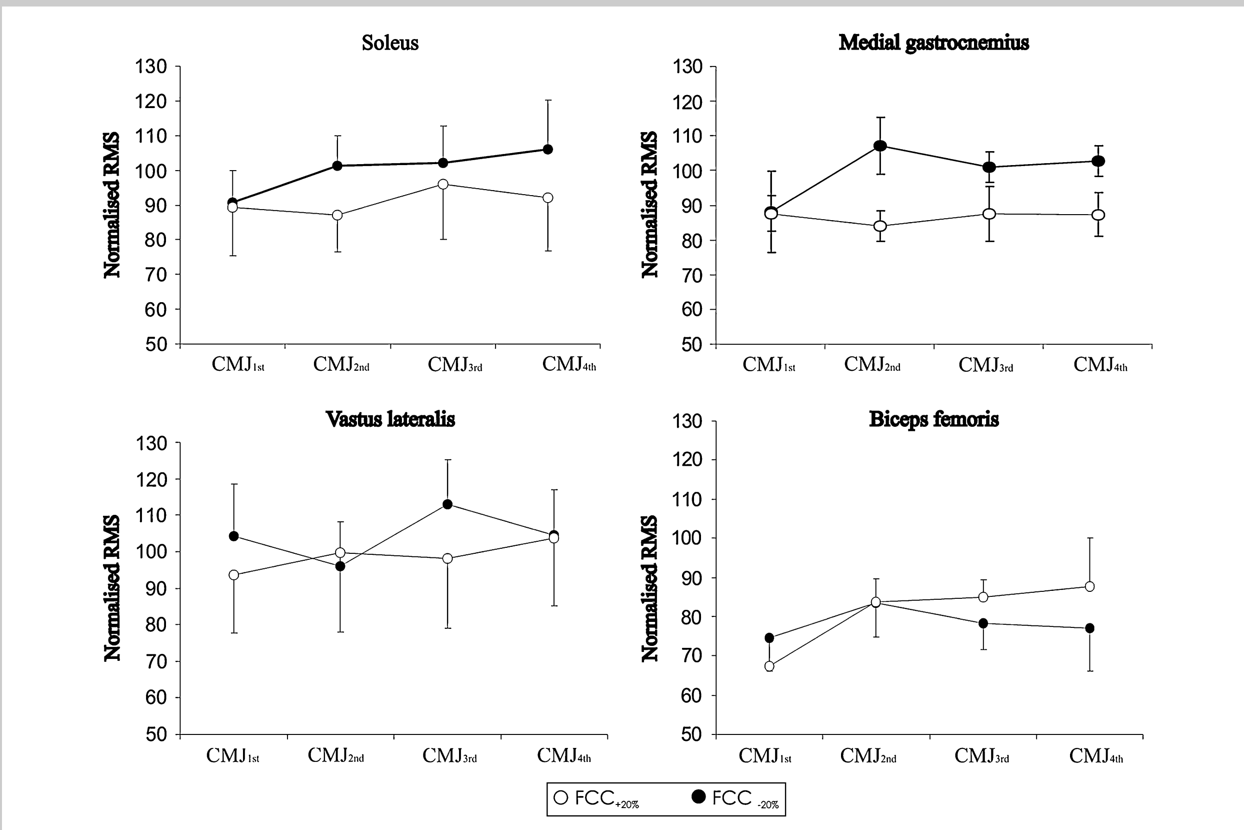

Figure 3. Mean normalized root mean square (RMS) of the electromyogram (EMG) of the soleus, medial gastrocnemius, vastus lateralis, and biceps femoris during the concentric phase of the vertical jumps after $FCC_{-20\%}$ and $FCC_{+20\%}$ cadences. For each muscle, the RMS was normalized with the RMS during the CMJ_{before}. No differences were found between the cadences. FCC, freely chosen cadence; CMJ, countermovement jump.

electrode was secured over a styloid apophysis of the left wrist. All electrode positions were carefully measured in each subject to ensure identical recording sites in the 3 experimental sessions and were wrapped around the leg with adhesive tape to prevent movement artefacts. In addition, an electrogoniometer was placed over the knee to determine kinematic parameters. Electrodes and the electrogoniometer were connected on a portable data acquisition system (Biometrics DataLog P3X8; Biometrics Ltd, Nine Mile Point Ind. Est. Cwmfelinfach, Gwent, UK), and all signals were recorded at a 1,000-Hz sampling rate. The EMG signal was amplified with a bandwidth from 20–450 Hz (input impedance = 100 MΩ, common mode rejection ratio >96 dB, gain = 1,000) and a root mean square (RMS) filter was used in the offline analysis (using DataLog software; Biometrics Ltd).

The EMG recording for the CMJ_{before} was used as a baseline to normalize the EMG. The following parameters were identified in each vertical jump: (a) RMS during the eccentric and concentric phase; (b) time to reach the maximum value of RMS from the beginning of the movement; (c) duration of eccentric and concentric phase; (d) maximum knee flexion and extension; and (e) eccentric and concentric mean angular velocity.

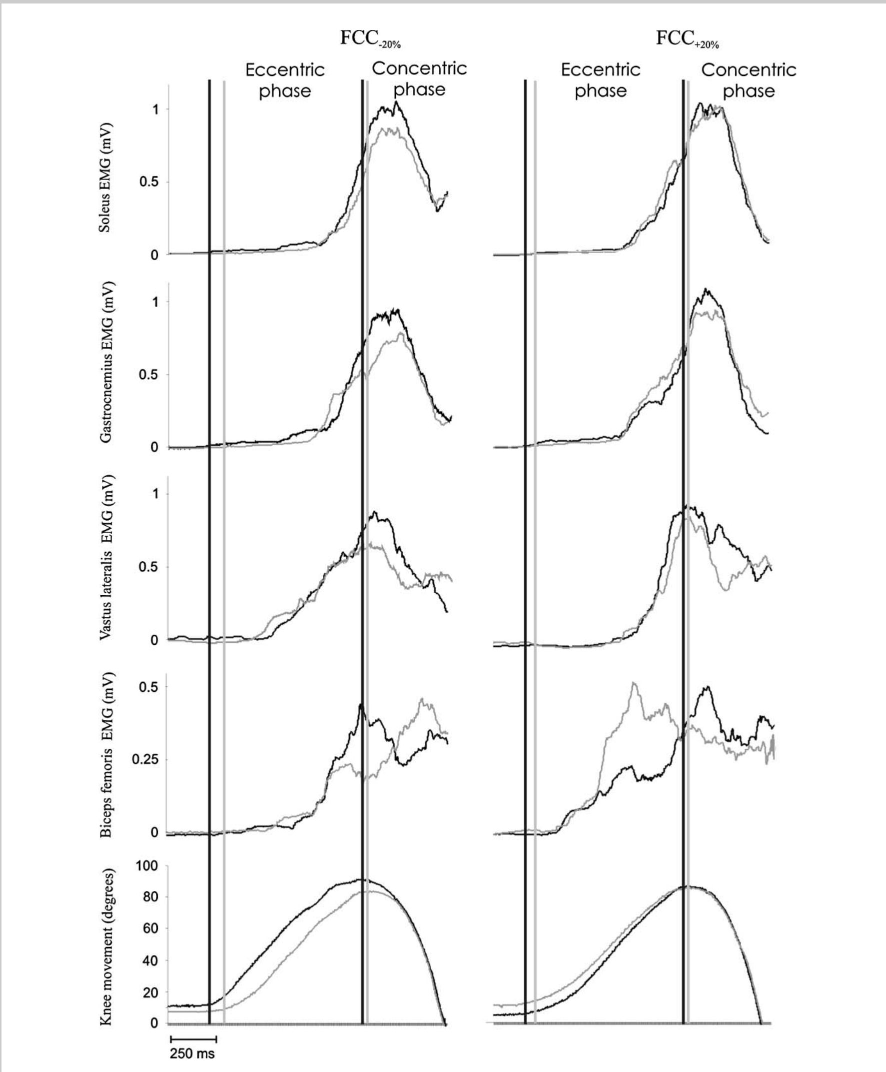

Figure 4. Knee angular displacement and electromyogram (EMG) patterns of vertical jumps before (black traces) and after (gray traces) cycling at $FCC_{-20\%}$ (left column) and $FCC_{+20\%}$ cadences (right column) for one subject. Rectified and smoothed EMG of soleus, medial gastrocnemius, vastus lateralis, and biceps femoris. The vertical black lines indicate the eccentric and concentric phases for CMJ_{before}. The vertical gray lines indicate the eccentric and concentric phases for $CMJ_1{}^{st}$. Note the changes in timing for the biceps femoris in both cadences. The time to reach the maximum EMG activity for the biceps femoris is delayed for $FCC_{-20\%}$ and advanced for $FCC_{+20\%}$. FCC, freely chosen cadence; CMJ, countermovement jump.

Jumping Measurements. In the performance of CMJ, subjects were instructed to start in an upright position, rapidly squat down, and then jump into the air with maximal effort. Subjects' arms were positioned on the hips throughout the test to eliminate the effect of arm swing during the performance of each jump (5). During the CMJ, the angular displacement of the knee was standardized so that the subjects were required to bend their knees to approximately 90°. The height of each individual jump was recorded on a resistive (capacitative) platform (5) connected to a digital timer (accuracy +0.001 second; Ergojump, Psion XP, MA.GI.CA., Rome, Italy).

The reproducibility of the CMJs have been reported to be high (r = 0.90) (6). However, because we focus on the changes of the CMJ after the pedaling phase, it is important to know the reliability of one single trial in our subjects. Thus, before the experimental procedure, the subjects learned the correct performance of the CMJ for 5 sessions. After these 5 sessions, the subjects performed in 2 sessions separated by 1 week a total of 4 maximal CMJ per session. The reliability of vertical jump was evaluated by calculating intraclass correlation coefficients (ICCs) and the coefficient of variation (CV).

Statistical Analysis

To evaluate the effect of the different cycling cadence over the vertical jumps, we normalized the values using CMJ_{before} as baseline for each session. A 2-way repeated-measures analysis of variance was performed with main factors of CADENCE (FCC, $FCC_{+20\%}$, and $FCC_{-20\%}$) and TRIAL (CMJ_1^{st}, CMJ_2^{nd}, CMJ_3^{rd}, and CMJ_4^{th}). Post hoc *t*-tests were computed using a Bonferroni correction. None of the data violated the normality assumption necessary to conduct parametric statistical tests. Statistical significance was set at $p \leq 0.05$ for all analysis. All data were analyzed using SPSS for Windows (version 14.0; SPSS Inc, Chicago, IL).

Results

The subjects showed great reliability among all trials for the jumping tests with an ICC and Cronbach's alpha of 0.98 for the 2 sessions of evaluation and 0.99 for all the jumps together (test–retest). The within-subject variations (CV) were 2.79 and 2.86% for the first and second sessions, respectively.

The maximal power of the subjects was 310.71 (± 38.48) W and the cadences used were 71, 85.2, and 56.8 rpm for the FCC, $FCC_{+20\%}$, and $FCC_{-20\%}$, respectively. The HRs were not significantly different during the ergocycle across the different sessions or between the different cadences of pedaling. The average values of HRs for each cadence were 138 ± 14, 141 ± 14, and 133 ± 13 beats/min for FCC, $FCC_{+20\%}$, and $FCC_{-20\%}$, respectively. The 35% of the P_{max} corresponded to 108 (± 13.47) W.

The height of vertical jump before the ergocycle (CMJ_{before}) was 34.83 (± 3), 34.19 (± 3.5), and 34.30 (± 4.7) cm for FCC, $FCC_{+20\%}$, and $FCC_{-20\%}$ sessions, respectively, without significant difference among them. The CMJ trials (normalized with the CMJ_{before}) after the ergocycle were significantly influenced by the used cadence. The analysis of variance showed a significant effect in the CADENCE factor ($p = 0.02$) and TRIAL ($p < 0.01$) (Figure 2). The post hoc analysis showed significant differences between $FCC_{+20\%}$ and $FCC–_{-20\%}$ ($p = 0.02$). There were no significant differences between FCC and $FCC_{+20\%}$ nor between FCC and $FCC_{-20\%}$.

To determine the changes in the vertical jump before and after the ergocycle, we performed an analysis of variance for the nonnormalized values for each condition. FCC and $FCC_{-20\%}$ showed a significant decrease in the CMJ_1^{st} ($p = 0.03$ and $p = 0.04$, respectively). In the FCC condition, the decrease in CMJ was 4.11% and in the $FCC_{-20\%}$ condition, the decrease was 5.08%. The subjects reached original values of CMJ_{before} in the CMJ_2^{nd}. There was no significant reduction (1.64%) in CMJ for the $FCC_{+20\%}$ condition.

Because no significant changes were found between the FCC and the other conditions, we constrained further analysis of the EMG and kinematics recording for comparison of the $FCC_{+20\%}$ and the $FCC_{-20\%}$. Two-way analysis of variance, with CADENCE ($FCC_{+20\%}$, $FCC_{-20\%}$) and TRIAL (CMJ_1^{st}, CMJ_2^{nd}, CMJ_3^{rd}, and CMJ_4^{th}) as factors, was performed for the RMS measurements for each muscle (VL, MG, BF, SL), and each phase (concentric and eccentric) using the normalized RMS values (Figure 3). There was a significant main effect for TRIAL factor for the RMS of the VL (eccentric phase) ($p = 0.01$) and SL (concentric and eccentric phases: $p = 0.01$ and $p = 0.03$, respectively). A two-way analysis of variance was performed for kinematics measurements (duration of eccentric and concentric phase; maximum knee flexion and extension; eccentric and concentric mean angular velocity). There was a significant main effect for TRIAL in the duration of the concentric phase ($p < 0.01$), maximum knee flexion ($p < 0.01$), and concentric angular velocity ($p < 0.01$). There were no significant main effects for CADENCE for either interactions with TRIAL for the RMS or the kinematics measurements.

The analysis of the EMG pattern (order of muscle activation) in the vertical jump did not show a unique muscle sequence as a result of the great variability across the subjects. However, in the $FCC_{-20\%}$ condition, there was a tendency to activate the BF last. The time to reach the maximum RMS value in each muscle was calculated and a 2-way analysis of variance was performed. There was a significant interaction between CADENCE and TRIAL for the BF ($p < 0.01$) without a significant difference in the other 3 muscles (Figure 4). There were significant differences between $FCC_{-20\%}$ and $FCC_{+20\%}$ for the CMJ_1^{st} and CMJ_2^{nd} ($p = 0.03$ and $p < 0.01$, respectively). We did not find significant differences after the CMJ_2^{nd} between $FCC_{-20\%}$ and $FCC_{+20\%}$.

Discussion

This study was designed to determine the effect of pedaling itself on explosive muscular movement rather to setup a new warmup protocol. The main finding in our study shows that the use of freely chosen or a 20% lower cadence reduced significantly the height of the vertical jump performed immediately after the pedaling. However, the use of a cadence 20% higher than the freely chosen one prevents the significant loss in height of vertical jump. Changes in the timing of the BF activation could explain this effect. We subsequently discuss the possible reasons for this phenomenon.

The freely chosen cadence (approximately 70 rpm) in our subjects was relatively lower than that reported in trained cyclist and triathletes (85–100 rpm) (9,19,29). None of our subjects practiced cycling and it is well known that recreational or novice cyclists tend to use lower pedal rates (7). We decided to select subjects who were not triathletes or cyclists for this study to avoid some possible adaptation to the pedaling movement induced by continuous practice.

Several studies report that pedaling rate could influence fiber-type recruitment. High cadences reduced the force used could recruit fewer fast twitch (type II) muscle fibers compared with slow-twitch (type I) muscle fiber, whereas slow cadences and high force recruit more type II fibers (1). It is well known that the skeletal muscle fiber composition determines performance in CMJ in such a way that the higher the type II fiber ratio is, the higher the height of the vertical jump (4). Thereby, the lower recruitment of type II fiber at high cadences could explain the absence of a decrease in the vertical jump during the pedaling rate at $FCC_{+20\%}$. Thus, it is possible that in the FCC and $FCC_{-20\%}$ conditions, the recruitment of type II fiber was increased, producing a fatigue that led to the significant decrease in the vertical jump. However, this seems an unlikely explanation as a result of the quick recovery of CMJ height that was observed. In fact, in the $FCC_{-20\%}$ and FCC conditions, during the CMJ_2^{nd}, approximately 2 minutes after the ergocycle, the subjects already reached the original baseline height.

Regarding the RMS of the EMG recording during the vertical jump, we could expect some difference between conditions because Sarre et al (28) demonstrated that the cadence affects the level of neuromuscular activity. Recently Sarre and Lepers (27) have explored the neuromuscular activity in several muscles during a prolonged (1-hour) pedaling exercise performed at different cadences (50, 110 rpm, and FCC). Their results showed higher RMS values in the VL at 110 rpm compared with 50 rpm and FCC. Values for the GL muscle were also significantly different among the different cadences and the activity of BF decreased at 50 rpm. However, in our study, we did not find any significant differences in RMS values between the $FCC_{-20\%}$ and $FCC_{+20\%}$ conditions. This may be attributable to the fact that the observed reduction in the vertical jump, although significant, may not be sensitive enough to reflect changes in the EMG. There was only a significant change in the VL and SL across the trials but no significant effect of cadence. These results are in line with Lepers et al (17) who reported that changes in neural and contractile properties after prolonged cycling were not influenced by the pedaling rate in the $FCC_{\pm 20\%}$ range. However, most of the studies to this date have used higher power output and longer duration during pedaling (2,3,16,17,28) than the ones used in our study. We chose lower power output to prevent possible muscle fatigue that could mask the effect of the pedaling muscle pattern on the vertical jump. In fact, the power output and duration used in our study are similar to the parameters used in the warmup sessions in several other studies (27,28). Thus, the changes we found in VL and SL could be the result of the effect of the pedaling movement more so than the used cadence or fatigue.

The analysis of the EMG pattern (order of muscle activation) in the vertical jump showed a great variability across subjects in line with earlier findings (6). However, despite this variability, we were able to show significant differences between $FCC_{-20\%}$ and $FCC_{+20\%}$ conditions. After $FCC_{-20\%}$, the time for the BF to reach the maximal RMS value was prolonged, whereas after the $FCC_{+20\%}$, it was advanced. This change in timing during the vertical jump could be a "residual" effect of the high and low cadences, which could be the result of a change in muscle reflex gain during pedaling. Larsen and Voigt (12) have reported a decrease in the soleus H-reflex when the cadence was doubled from 40–80 rpm. These authors believe that decreases in the reflex gain allow the motoneuron pool to maintain its ability to be dynamically modulated by the afferent feedback when muscle stiffness or the velocity of the length changes in the muscles is high. Moreover, recently changes have been reported in the H-reflex at rest after cycling (20). Although we did not carry out specific measurements of spinal reflex activity, an attractive hypothesis to explain the differences observed is that in the $FCC_{-20\%}$ condition, the muscles could be more affected by the sudden stretch in the eccentric phase during the vertical jump than in the $FCC_{+20\%}$ condition. However, the main question is why the timing was different between both cadences only in the BF. The existence of anticipatory postural (APA) adjustments has been demonstrated in vertical jumps (13,14). The role of the APA is to create the initial disequilibrium to start the movement and compensate for the forthcoming postural disturbance resulting from the movement (11,21,23). During the initial concentric phase of the vertical jump, the BF contributes to allow the shift of the center of pressure in the semisquat position (14) and can adjust the sequential programming of forward and upward movement (13). In fact, the BF is known to have little positive effect on hip extension during vertical jump but is involved more as a stabilizer (8). The delay of the activation in the BF in the $FCC_{-20\%}$ condition could alter the timing and the coordination of the segments during the vertical jump and affect the sequential production of individualized forces. This coordination is an important factor in the jump performance (10) and can explain the decrease in the vertical jump in the $FCC_{-20\%}$ condition. During the second jump after pedaling, the timing in the biceps femoris was inverted, being delayed in the $FCC_{+20\%}$ and advanced in the $FCC_{-20\%}$ condition. This change may be a readjustment of the sequential programming of muscle coordination to adapt to the new muscle stiffness. More studies in combination with video recording and biomechanics analysis must be done to provide further evidences for this hypothesis.

Practical Applications

Our study shows that cycling movement at low intensities and short duration can affect negatively the performance of the CMJ, changing the pattern of muscle activation. The alteration in this pattern can be dependent on the cadence used. This should be taken into account when cycling is used in warmup sessions. Our study indicates that to avoid a possible negative effect of the cycling in the subsequent explosive movements, a cadence 20% higher than the preferred cadence must be used.

Acknowledgments

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