SUMMARY
Motorcycle riders must endure high levels of muscle tension for long periods of time, especially in their arms and forearms, when steering and using handlebar controls. Because the right hand operates the gas handle and front brakes, the present research focuses on fatigue in the right hand flexor muscles. During a 24 h race, riders were evaluated on: 1) 10 s of EMG recording at rest, 2) One 3-sec maximal voluntary contraction (MVC), 3) 1 min rest interval and 4) 50% MVC maintained during 10 s. This sequence test was repeated after each race relay. EMG amplitude and EMG median and mean frequency of finger flexors were recorded using surface electrodes. MVC values were maintained during the first two relays (50-60 min duration total) and dropped gradually thereafter (p<0.01). During the monitoring of the 50% MVC, EMG mean amplitude increased significantly (p=0.024) while median and mean frequency had a tendency to decrease across relays. These results suggest fatigue is produced in motorcycle riders in a 24h race. However, the expected reduction of EMG frequency was not confirmed potentially due to large variability.

INTRODUCTION
Motorcycle riders in a 24 h race are exposed to a high-force, high-repetitive hand-grip task when steering and using handlebar controls resulting potentially in fatigue and decrement of their performance. Hand flexor fatigue should result in lower MVC values and induce poorly coordinated tasks as well as a reduction in hand steadiness while completing these tasks [4]. Previous studies [5,7,9] report how isometric contractions, constant effort, and maintained postures produce increments in electromyography (EMG) amplitude, whereas the frequency spectrum becomes compressed at lower frequencies. Nevertheless, it is very important to take into account that this EMG pattern is typical of a fatigue protocol of short duration, i.e. isometric muscular contraction maintained no more than 1 up to 5 min depending on the experimental protocol [1]. With longer duration (more than 25 min to hours) and changing or intermittent muscle contraction, other authors [3] reported no significant EMG changes due to fatigue. But this later observation is not always confirmed, because after 30 min aerial combats, neck, abdomen and back muscles demonstrated significantly decreased MVC levels, increased EMG amplitude and diminished EMG frequency [10]. This conflicting literature, invited us to study the force and EMG patterns in long duration, intermittent muscle contraction in an endurance sport race.

METHODS
Ten adult riders, aged 32.5 ± 5.5 years with a body mass index score of 23.9 ± 1.7, volunteered to participate in this study. A week before the race, the riders were informed about the sequence of measurements and they completed the handgrip test two or three times in order to familiarize themselves with it. The day before the official training session a handgrip test was applied to obtain the maximal voluntary contraction (MVC) base values. Each rider completed between six to eight relays of 50 to 60 min duration each and, as a consequence, each rider received between six to eight handgrip tests.

Each handgrip test comprised the following sequence of measurements: 1) 10s of EMG recording at rest, 2) One 3-sec MVC, 3) 1 min rest interval and 4) 50% MVC maintained during 10 s. The time elapsed from the end of the rider's relay to the MVC/EMG measures was restricted to a maximum of 5 min.

To assess the grip strength of the right hand (used in operating the gas handle and front brakes), we used the Harpenden dynamometer (British Indicators Ltd, England). The subjects were seated, with their knees flexed at 90º, their feet flat on the ground, and with their trunk tilted slightly forward. The subject’s arm was flexed, with the forearm in a supinated position reclined over a horizontal support.

We used an ME6000 electromyography system (Mega Electronics, Kuopio, Finland), with adhesive surface electrodes. To target the flexor digitorum superficialis (FDS), the electrodes were placed 2-cm apart (from center to center) on the middle third of the anterior forearm along a line drawn from the middle of the wrist to the biceps tendon, according to Mogk et al. [8]. The riders’ skin was marked for future data collection. The raw signal was recorded at a sampling frequency of 1000 Hz and the preamplifier was located 6 cm from the electrodes (sensitivity of 1µV, a gain of 305, range of frequencies 8-500 Hz). The specification for the amplification was analog differential amplifier and the common mode rejection ratio was 110 dB. To compute EMG amplitude variables, we used the quadratic mean (root mean square - RMS) at an interval of 0.05 s. The resulting 20 RMS values per second were computed for the entire trial (200 RMS values) and averaged for future analyses. To compute the frequency related EMG variables, FFT were used with frame width at 1024, FFT shift was selected at 30%. The EMG parameters used were: mean potential (RMS: µV) for amplitude, and median frequency (MF, Hz) and mean power frequency (MPF: Hz) for frequency. MVC values were normalized to body weight and presented as a ratio of basal
values. For the 50% MVC assessment all three parameters were normalized with respect to the basal MVC values.

RESULTS AND DISCUSSION
When examining the changes of the normalized handgrip MVC, a significant relay main effect was observed ($F(2.18, 45)=20.36; p≤0.001$), with a large effect size ($\eta^2=0.69$) and a significant linear trend ($F(1,9)=54.8; p≤0.001$). Our results suggest that fatigue is the main factor in accounting for the fall in normalized MVC (Fig. 1) after the second relay and are in agreement with previous studies [10].

![Figure 1: Mean and SD of the handgrip maximal voluntary contraction normalized to body mass and with respect to the basal value (NMVC)](image)

The absence of EMG amplitude changes (neither increment or decrement) recorded from MVC, suggest that the decrement of MVC may not be related with the EMG amplitude but with the combination of other factors instead, such as motor unit force twitch, number of active motor units, and/or muscle fibres interaction [2].

For the 50% MVC assessments, a significant relay main effect ($F(1.72, 40)=4.34; p=0.039$) was observed for the normalized RMS mean potential, with a significant linear and positive trend ($F(1,8)= 7.74; p=0.024$), and a large effect size ($\eta^2=0.35$). However, no significant effect could be attributed to the relay factor neither for the normalized MF ($p=0.08$) nor for the normalized MPF ($p=0.092$). The variability of the EMG frequency did not allow us to identify significant differences, restraining us to propose any conclusive trend (Fig. 2). Our results during the 50% MVC assessment support that EMG amplitude, from sub-maximal contractions, increases because of muscle fatigue, as it has been reported in the literature [1,5,7,9]. The combined decrement of the normalized MVC with the increment of the EMG amplitude from 50% MVC could be interpreted as the necessity by the neural system to recruit additional motor units to maintain the same sub-maximal level of force [6].

![Figure 2: Mean and SD of the EMG parameters at the 50% of the MVC handgrip. We used Median Frequency (MF) and Mean Power Frequency (MPF) for the EMG frequency and RMS potential for the EMG amplitude.](image)

CONCLUSIONS
MVC values were maintained during the first two relays (50-60 min duration in total) and dropped gradually thereafter ($p<0.01$). During the monitoring of the 50% MVC, mean amplitude increased ($p=0.024$) while median and mean frequency tended to decrease. These results suggest fatigue is produced in motorcycle riders in a 24h race. However, the expected reduction of EMG frequency was not confirmed given to a potentially large variability in the timing of measurements.

All riders answered negatively when asked if the handgrip protocol had increased fatigue to a point at which their riding was compromised. Thus, we believe that this protocol could be valid for assessing local muscle fatigue during a motorcycle endurance race.

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