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ABSTRACTS



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Motor modularity to effectively applied force during pedaling

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Introduction

It has been proposed that the central nervous system modulates the activation of muscle groups, also called motor modules, to coordinate multiple muscles in the building of complex motor behaviors [1]. We tested this hypothesis in comparing changes in the muscle synergies during a pedaling task under different mechanical constraints.

Methods

Eleven experienced male cyclists (height: 179 cm \pm 5, mass: 72.8 kg \pm 5). randomly performed two trials at 90 rpm, lasting 1 minute each. One trial consisted of a bilateral pedalling task at 250 W (BIL) while the second one was a unilateral task with the right leg at 125 W (UNI). Effective pedal forces (FE, Powerforce, 500 Hz) and the surface electromyographic (EMG, Delsys, 2000 Hz) activity of 11 muscles of the right side were recorded: *tibialis anterior* (TA), *soleus* (SOL), *gastrocnemius lateralis* (LG) and *medialis* (MG), *vastus lateralis* (VL) and *medialis* (VM), *rectus femoris* (RF), *tensor fascia latae* (TFL), *biceps femoris* (BF), *semitendinosus* (ST) and *gluteus maximus* (Gmax). Mean FE and EMG amplitude (RMS) were averaged over 15 cycles and split into four 90° sectors (315°-45°, 45°-135°, 135°-225° and 225°-315°). The EMG linear envelopes (low-pass filtered at 6 Hz) were decomposed by the non-negative matrix factorization to obtain muscle synergies composition (motor modules) and activation (motor primitives). The EMG RMS values were weighted by the motor modules to estimate the level of activity of each muscle synergy according to the four sectors. The duration of motor primitive was approximated by the full width at half maximum. The effect of pedaling tasks was assessed by means of one-dimensional statistical parametric mapping on motor modules and primitives. Two-way ANOVA for repeated measures were used to assess changes in FE and in level of activity of muscle synergies according to the pedaling tasks and sectors.

Results

FE was lower during the downstroke phase of the UNI task phase than during the BIL task ($p < 0.001$), but higher during the upstroke phase ($p < 0.001$). For both tasks, three muscle synergies were extracted. The first one implied SOL, VL, VM and Gmax and was mainly activated during the downstroke. The second one was composed by SOL, LG, MG, BF and ST and was activated around the bottom dead centre. The third muscle synergy was activated during the

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upstroke phase and composed by TA, RF and TFL muscles. Neither the motor modules, nor the shapes of motor primitives differed between both pedaling tasks. However, the UNI task widened the third motor primitive ($p=0.026$). Estimate of muscle synergies level of activity changed according to the pedaling tasks ($p\leq 0.001$) and to the sectors ($p < 0.001$), while solely the second and third synergies presented an interaction effect ($p < 0.001$ and $p=0.012$, respectively). For these two synergies, the pull up action in UNI task implied an increase in the level of activity in sectors 3 and 4 ($0.01 < p < 0.001$), and in sector 1 for the third synergy only ($p=0.037$).

Discussion

Our results agreed with the literature relative to the robustness of the motor modules among different mechanical constraints during pedaling [2] and extend those about the pulling up effect on muscle coordination and activation [3]. According to the principle of motor modularity, we showed that the central nervous system widened and increased the activation of robust motor modules in order to adjust the amount of effective force to produce on the pedal.

References

- [1] d'Avella & Bizzi, 2005.
- [2] Hug et al., 2011.
- [3] Mornieux et al., 2010.

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