O120- Stabilization of the Locomotor-Respiratory Coupling using a metronome during an endurance exercise

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The Locomotor-Respiratory Coupling (LRC) is often evidenced by phase- or frequency-locking patterns. The model of the sine circle map is used here to characterize LRC. Several studies showed that a sound emitted by an external metronome can stabilize the LRC. Participants were asked during a cycling exercise to synchronize either their respiration or their pedalling rate with an external auditory stimulus corresponding to their preferred respiratory and pedalling frequencies respectively. Our results showed a significant reduction in energy expenditure when participants breathed in sync with the auditory stimulation, but not accompanied by a change in the stabilization of LRC. A large within- as well as between-participants LRC variability, together with the spontaneous adoption of the most stable pace, contribute to explain this result.
Keywords: locomotor-respiratory coupling; anchoring; auditory stimulation; energy saving

INTRODUCTION

Many studies have reported a natural synchronization between respiration and locomotion in various species (fish, birds, mammals) and various forms of locomotion (running, cycling, rowing). Entrainment between locomotion and respiration has been described by stable frequency mode-lockings such as the ones reported in humans: 1/1, 1/2, 1/3, 2/3, or 1/4 (Bramble & Carrier, 1983). The Locomotor-Respiratory Coupling (LRC) is generally understood as originating from mechanical and neurological interactions. However, the LRC literature reveals several discrepancies related to the nature of the coupling, the factors that modulate it, and the concomitant energy expenditure. For instance, Bramble and Carrier (1983) suggested that a greater LRC could lead to a decrease in O_2 consumption (VO_2), a result not found by Rassler and Kohl (1996). Differences are due in part to the different techniques used to assess the synchronization between the two systems. In another research field, bimanual coordination studies have shown that a periodic auditory stimulation stabilizes both in-phase and anti-phase coordinations (local stabilization) and postpones the transition from anti-phase to in-phase (global stabilization). Haas *et al.* (1986) for instance reported a greater stabilization of the respiratory rhythm under rhythmic external auditory stimulation when rhythmic tapping movements were added to the task.

In this study, we propose to consider LRC as the results of non-linear coupled oscillators, we use the sine circle map model to capture this phenomenon, and we examine the stabilizing role on LRC of auditory information together with the concomitant energy expenditure.

METHODS

14 voluntary males athletes (22 to 32 years old) not specialized in endurance sports took part in the experiment. They all signed an informed consent before participating in the experiment, which was approved by the local ethic review board (CPP Sud-Méditerreanée 3). Experimental trials were performed on cycle ergometer. Gaz exchanges, breathing kinematics, and the pedalling rhythm were recorded. Four sessions were involved. In the first session, the VO_2 max was obtained. In the second session, participants performed a 10-minutes exercise to determine their preferred respiratory and locomotor frequencies. In the last two sessions, a periodic, externally-paced, auditory sound was presented to the participants. They were requested to exhale (session 3 or 4) or cycle (session 3 or 4) in sync with the stimulation. The two sessions were randomly distributed among the participants.

To assess the stability of the LRC, three variables were computed, i.e., (i) the most frequent Farey ratio (i.e., the mode of the distribution), (ii) the dispersion of the relative phase between respiratory and pedalling cycles for this mode, and (iii) the mean number of consecutive cycles spent on the modal frequency ratio.

RESULTS

The instant of foot off, and foot contact as well as the walking velocity and step length of the first step did not show any significant differences between the unloaded and loaded trials (see Table 1).

Table 1: Kinematic variables measured for the first step

	Foot Off (s)	Foot Contact (s)	Walking Velocity (m/s)	Step Length (m)
N	0.524 ± 0.091	0.881 ± 0.105	1.12 ± 0.165	0.59 ± 0.07
N+20	0.558 ± 0.084	0.913 ± 0.088	1.15 ± 0.192	0.62 ± 0.08

Peak antero-posterior ground reaction force (pAP-GRF), which occurs slightly after foot contact, was significantly higher in the N+20 condition [$F(1,6) = 30.1$; $P=0.0015$]. The surface area of the rectified and normalized SOL EMG from onset to offset, which gives the unitless average EMG intensity (iSOLn) did not change between N and N+20 conditions [$F(1,6) = 0.02$; $P=0.89$] (see Figure 1).

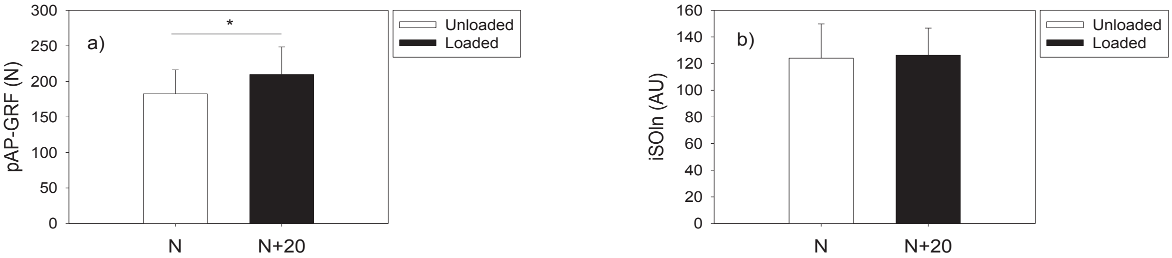

Figure 1: Mean and standard deviation of the measured Peak A/P force (a) and average SOL EMG intensity (b), for the two conditions N and N+20.(*: P<0.05)

DISCUSSION-CONCLUSION

For the same walking velocity, EMG activity remained constant between the control and the loaded series while stronger propulsive forces were generated during the loaded trials. This shows clearly that SOL does not play a role in push-off. Since both the soleus and the gastrocnemii work on ankle plantar flexion and that the activation and deactivation of both muscles are highly correlated in time during single support, we believe that neither participate in generating propulsion force. However, the gastrocnemii are biarticulate and might be controlling knee extension while SOL restrains tibial advancement. Future work might be useful to determine this hypothesis whatsoever. We believe that our findings confirm the pioneer investigation of Cavagna & Franzetti (1986), who stated that the fall of CoM during the single stance phase is sufficient to transform potential energy into forward kinetic energy during normal level walking. In conclusion, while gravity is responsible for generating propulsion force, SOL activity controls the fall of CoM during single support stance.

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