Leg-spring behavior and muscular activity during running fatigue

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INTRODUCTION

In the last few years, the effect of fatigue on the leg-spring behavior has been studied for a large range of running intensities, from sprint to ultra-marathon [1-3]. However, to date, quite few information is available regarding the influence of the muscular activity on changes in spring-leg stiffness. The aim of this study was therefore to evaluate, during an exhaustive run imposed at the constant velocity associated to the maximal oxygen uptake, the influence of the modifications in the lower limb muscular activity on the changes in leg spring stiffness.

METHODS

A group of 12 male runners [29.3 (SD 6.7) years; 180(SD 5) cm; 72.5 (SD 7.5) kg] participated in the study. Two runs were required: i) a graded exercise test to determine the velocity associated to the maximal oxygen uptake (VO2max, K4b2, Cosmed®); ii) two days later, a track running until exhaustion fixed at vVO2max. Mean values of VO2max and vVO2max were respectively of 60 (SD 6.4) ml.kg⁻¹.m⁻¹ and 5.1 (SD 0.3) m.s⁻¹ during the incremental test. The time to exhaustion was of 353 (SD 69) s which corresponded to a mean distance of 1780 (317) m.

Mechanical parameters were measured from 6 force platformes (Kistler®, 500 Hz) integrated on a 6.4 m distance into the ground. Leg stiffness (kleg) and vertical stiffness (kvert) were calculated classically [4]. Electromyographical activity (EMG) was recorded using a wireless system (Zerowire, Aurion®) on 8 muscles of the right lower limb: soleus (SOL), gastrocnemius medialis (GM), gastrocnemius lateralis (GL), tibialis anterior (TA), vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF) et biceps femoris (BF). For each muscle, an envelope was computed by smoothing the raw EMG with a moving RMS window and averaging the obtained signals over 6 consecutive strides acquired around the force platform area (Figure 1). EMG changes between the first (BEG) and the last (END) measurements were compared for each stride cycle, i.e. before (PRE), during (CP) and after (SP) the right foot ground contact phase. Each muscle RMS-EMG value was expressed in percent of the maximal value obtained at BEG calculated each 10% of the stride cycle.

RESULTS AND DISCUSSION

The main result of this study was a decrease in kleg while kvert remained unchanged (Figure 2) This can be explained by a significant decrease in the vertical ground reaction force (Fmax) during the run. Up to the anaerobic threshold, it has been suggested that this decrease could be related to neuromuscular impairment which led to failure in sustaining the vertical force in the latter stage of the run [2]. Unexpectedly, EMG data revealed that the activity in knee extensor muscles was not significantly altered (Figure 3). On the contrary, ankle plantarflexors (GM and GL; Figure 3) showed a significant decrease in their activity with fatigue.

Figure 1: A typical example of RMS-EMG activity in 8 lower limb muscles plot against the stride cycle in % [please see the Methods section]

CONCLUSION

The present study shows that, for a maximal fatiguing run performed at vVO2max, the quadriceps neuromuscular impairment does not seem to explain the decrease in whole leg-spring stiffness. Our results suggest that ankle extensors activity is mainly altered as a result of this kind of running exercise. Furthermore, no link was observed between these alterations and the changes in kleg.
REFERENCES


**Figure 2**: Normalized changes in leg stiffness ($k_{leg}$), vertical stiffness ($k_{vert}$), vertical ground reaction force ($F_{zMax}$), leg compression ($\Delta L$), vertical displacement of the center of mass ($\Delta y$) and leg angle at touch down ($\theta$).

**Figure 3**: Comparison between mean values (SD) of EMG changes measured at the beginning (BEG) and the end (END) of the exhaustive run for each stride cycle, i.e. before (PRE), during (CP) and after (SP) the right foot ground contact phase.