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Effect of fatigue on force production and force application technique during repeated sprints

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ABSTRACT

We investigated the changes in the technical ability of force application/orientation against the ground vs. the physical capability of total force production after a multiple-set repeated sprints series. Twelve male physical education students familiar with sprint running performed four sets of five 6-s sprints (24 s of passive rest between sprints, 3 min between sets). Sprints were performed from a standing start on an instrumented treadmill, allowing the computation of vertical (F_V), net horizontal (F_H) and total (F_{Tot}) ground reaction forces for each step. Furthermore, the ratio of forces was calculated as $RF = F_H F_{Tot}^{-1}$, and the index of force application technique (D_{RF}) representing the decrement in RF with increase in speed was computed as the slope of the linear RF-speed relationship. Changes between pre-(first two sprints) and post-fatigue (last two sprints) were tested using paired t-tests. Performance decreased significantly (e.g. top speed decreased by $15.7 \pm 5.4\%$; $P < 0.001$), and all the mechanical variables tested significantly changed. F_H showed the largest decrease, compared to F_V and F_{Tot}. D_{RF} significantly decreased ($P < 0.001$, effect size $= 1.20$), and the individual magnitudes of change of D_{RF} were significantly more important than those of F_{Tot} (19.2 ± 20.9 vs. $5.81 \pm 5.76\%$, respectively; $P < 0.01$). During a multiple-set repeated sprint series, both the total force production capability and the technical ability to apply force effectively against the ground are altered, the latter to a larger extent than the former.

1. Introduction

Although top running speed and single all-out sprint effort are the basis of the main track and field event (100 m), the ability to repeat shorter sprints is of importance in many sports such as soccer or rugby. Therefore, repeated sprint ability (RSA) has been a recent area of investigations, and the focus of many studies in the past 15 years or so (for reviews, see Glaister, 2005; Spencer et al., 2005), which almost exclusively focused on the physiological features of RSA, contributing to a detailed knowledge of this type of exercise. Comparatively, the biomechanical aspects of running RSA have almost never been explored.

Indeed, except for the mechanical output variables (typically work, velocity or power) measured as indicators of the performance decrement during cycling or running sprints series (e.g. Balsom et al., 1994; Gaitanos et al., 1993; Hughes et al., 2006; Mendez-Villanueva et al., 2008; Serpiello et al., 2011; Spencer et al., 2008), no study focused on how the orientation of the total force produced by lower limbs changes over a series of repeated sprints (RS). Morin et al. (2006) reported changes in running kinematics and spring–mass parameters over four consecutive field 100 m, but their field measurements at each step of the sprints did not include data of ground reaction forces (GRF) amplitude or orientation. More recently, Girard et al. (2011) reported changes in sprinting kinetics, kinematics and spring–mass characteristics over a series of 12 40 m sprints, and showed that positive peaks of horizontal GRF and horizontal positive and net impulses decreased, but peak vertical GRF did not change with fatigue. However, in their study, data were measured using a 5 m force plate yielding measurements of 2–4 steps in the 5–10 m (odd-numbered trials) or 30–35 m (even-numbered trials consisting in sprinting back to the starting point) zones.

In contrast to this limited number of steps analyzed over each sprint, the recent validation of an instrumented sprint treadmill (Morin et al., 2010) makes continuous measurements of instantaneous horizontal and vertical GRF as well as the running speed (S) possible over an entire sprint, whatever its duration.

On the basis of these GRF measurements, we recently proposed the computation of the ratio of support-averaged net horizontal and vertical forces ($RF = F_H F_{Tot}^{-1}$) as an indicator of the

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