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Full Length Article

# Lower limb mechanical asymmetry during repeated treadmill sprints

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ABSTRACT

Stride mechanical imbalances between the lower limbs may be detrimental to performance and/or increase injury risks. This study describes the time course and magnitude of asymmetries in running mechanical variables during repeated treadmill sprints and examines whether inter-limb differences in sprinting mechanics increase with fatigue. Thirteen non-injured male athletes performed five 5-s sprints with 25-s recovery on an instrumented treadmill, allowing the continuous (step-by-step) measurement of running kinetics/kinematics and spring-mass characteristics calculation. For each variable, bilateral leg asymmetry (BLA%) between the left and the right leg was defined as: {[(high value − low value)/low value] × 100}. BLA% for propulsive power and horizontal forces averaged ~12–13%, while lower values occurred for step-averaged values of running velocity, resultant and vertical forces (all ~4%). For all sprints, kinematic BLA% ranged from 1.6 ± 1.0% (swing time) to 9.0 ± 5.3% (aerial time). BLA% for vertical and leg stiffness was 6.4 ± 4.9% and 7.6 ± 3.6%, respectively. While distance covered decreased across repetitions ($P < 0.05$), there was no significant interaction between sprint repetitions and leg side for any of the mechanical variables studied (all $P > 0.05$). Although inter-limb differences were observed for many running kinetics/kinematics and spring-mass characteristics during repeated treadmill sprints, the lack of interaction between sprint repetitions and leg side suggests that lower limbs fatigued at a similar rate.



## 1. Introduction

There is a tendency among humans for preferential lateralization of the lower limbs (*i.e.*, lateral dominance) in sport actions such as jumping, cycling or running (Carpes, Mota, & Faria, 2010). This is associated with mechanical asymmetries, often described as differences in lower extremity kinetics and/or kinematics between the left and right sides (Fousekis, Tsepis, & Vagenas, 2010). Inter-limb difference is widely used by physicians, physiotherapists or strength and conditioning specialists to quantify the functional deficit resulting from ankle/knee injury and/or surgery, to monitor the effectiveness of

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sport rehabilitation programs, and to establish baseline data for readiness to return-to-play following an injury (Clark, 2001; Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Zifchock, Davis, Higginson, McSaw, & Royer, 2008).

The ability to perform or repeat "all-out" efforts such as sprinting (repeated-sprint ability; RSA) is a key parameter in many team sports (*e.g.*, soccer, rugby, field hockey) and the focus of various conditioning programs (*e.g.*, repeated-sprint training, sprint-interval training) (Girard, Mendez-Villanueva, & Bishop, 2011). Beyond its physiological features, RSA-related biomechanical determinants are also important for successful preparation (*i.e.*, performance enhancement). Biomechanical manifestations of fatigue during repeated sprinting typically include substantial decrease in step frequency and increase in contact time, while smaller changes in step length generally occur (Brocherie, Millet, & Girard, 2015; Girard, Micallef, & Millet, 2011; Girard, Racinais, Kelly, Millet, & Brocherie, 2011). In addition, studies that used an instrumented "sprint" treadmill (Girard, Brocherie, Morin, Degache, & Millet, 2015; Morin, Samozino, Edouard, & Tomazin, 2011) or a number of over-ground force plates installed in series (Girard, Micallef, et al., 2011) also indicated that reductions in horizontal forces were larger than those in the vertical direction across sprint repetition.

While inter-limb differences exist for kinetics and kinematics at moderate-to-high velocities (Carpes et al., 2010), its effects on sprinting mechanics are poorly documented. To our knowledge, only one study reported a kinetic (*e.g.*, horizontal and vertical forces, power) inter-limb difference of 15–20% in male youth undertaking a 30-m treadmill sprint (Rumpf et al., 2014). To date, however, inter-limb differences in ground reaction force characteristics during repeated sprinting remain unknown.

Musculo-skeletal stiffness regulation is a key mechanical property of sprint performance (Brocherie et al., 2015; Girard, Racinais, et al., 2011; Girard, Micallef, et al., 2011; Morin et al., 2011). However, its pattern of lateralization is still undetermined. Over recent years, changes in spring-mass model as a result of repetitive sprinting have been described: there is a consistent decrement in vertical stiffness accompanying slower sprint times (Brocherie et al., 2015; Girard, Racinais, et al., 2011; Girard, Micallef, et al., 2011; Girard et al., 2015). So far, no study has investigated patterns of lateralization in spring-mass characteristics during "all out" run-based efforts. Furthermore, whether fatigue amplifies the running mechanical inter-limb differences when sprints are repeated is unknown.

The aim of this study was twofold: (i) to describe patterns of lateralization (bilateral leg asymmetry or BLA%) in the main kinetic/kinematic and spring-mass characteristics during repeated treadmill sprints, and (ii) to examine the fatigue-induced changes in inter-limb differences across sprint repetitions. While mechanical variable-specific asymmetry exists between legs, we hypothesized that asymmetrical responses would increase under fatigue, as evidenced by significant interactions between sprint repetitions and leg side.

## 2. Methods

### *2.1. Participants*

Thirteen physically active male (31.2 ± 4.8 y; 178.4 ± 6.6 cm; 74.3 ± 8.2 kg) with a recreational team- and/or racket-sport background volunteered to participate in the study. All participants were right-handed and for them the right leg was always the dominant leg. In the 6 months preceding the study, participants trained on average 4.5 ± 2.5 h.wk$^{-1}$, which included activity-specific training (*i.e.*, technical and tactical skills), aerobic and anaerobic training (*i.e.*, on- and off-court/field exercises) and basic strength training. All included participants declared not suffering from any neuromuscular or musculoskeletal disorders that might affect their running patterns at the time of testing (*i.e.*, no reported injuries to the lower body within the previous 3 months). Written informed consent was obtained from participants, and the study was approved by the *Shafallah Medical Genetics Centre* Ethics committee, and conducted according to the Declaration of Helsinki.

### *2.2. Experimental procedure*

About one week prior to testing, subjects undertook a preliminary session where they successively performed 7–10 short (<5 s) "familiarization" sprints and, after 10 min of rest, the complete RSA test (see below). For the testing session, the warm-up consisted of 10 min of running at 2.78 m.s$^{-1}$, followed by 15 min of sprint-specific muscular preparatory exercises (*i.e.*, skipping, high knee, butt- kick, high heels for ∼10 s with 30-s walking in between), and finally 3–5 sub-maximal sprints before performing three "reference" maximal 5-s sprints separated by 2 min of passive rest (the best of these three trials was used as the 95% criterion score, which was satisfied by all participants). The RSA test consisted of performing five 5-s sprints with 25-s of passive recovery. Strong verbal encouragement was given during all maximal efforts.

### *2.3. Instrumented sprint treadmill*

The sprints were performed on an instrumented motorized treadmill (ADAL3D-WR, Medical Development – HEF Tecmachine, Andrézieux-Bouthéon, France), as previously described (Morin, Samozino, Bonnefoy, Edouard, & Belli, 2010). Briefly, it is mounted on a highly rigid metal frame fixed to the ground through four piezoelectric force transducers (KI 9077b; Kistler, Winterthur, Switzerland). This motorized treadmill allows participants to sprint due to the use of constant motor torque (Girard, Brocherie, Morin, & Millet, 2016; Morin et al., 2010). The motor torque, set to 160% of the default torque necessary