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Effects of Limb Dominance on Postural Balance in Sportsmen Practicing Symmetric and Asymmetric Sports: A Pilot Study

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Abstract: The current literature shows no consensus regarding the difference between the dominant leg (D-Leg) and the non-dominant leg (ND-Leg) in terms of postural control. This lack of consensus could stem from motor experience (i.e., symmetric or asymmetric motricity) and/or the physiological state induced by physical exercise. This study aimed to investigate the acute effects of fatiguing exercise on postural control when standing on the D-Leg and the ND-Leg, in athletes practicing symmetric (SYM) and asymmetric (ASYM) sports. Thirty healthy male participants were recruited and divided into two groups, (SYM n = 15) and (ASYM n = 15, on the basis of the motricity induced by the sport they practice. Monopedal postural control was assessed for the D-Leg and the ND-Leg before and after the fatigue period (which consisted of repeating squats until exhaustion). A force platform was used to calculate the spatio-temporal characteristics of the displacements of the center of foot pressure (COP). A significant fatigue effect was observed in both groups on the D-Leg and the ND-Leg for all the COP parameters. There was a tendency (p = 0.06) between the ASYM and SYM groups on the D-Leg, concerning the relative increase in the COP velocity in the frontal plane after the fatigue period. The fatigue condition disturbed postural control in both the SYM and ASYM groups on the D-Leg and ND-Leg. This disturbing effect related to fatigue tends to be more marked in athletes practicing asymmetric sports than in athletes practicing symmetric sports on the D-Leg.

Keywords: dominant leg; acute exercise; fatigue; sport practice

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1. Introduction

Leg dominance can be determined through the use of functional tests, such as ball kick, hop, or step up [1–3]. Most people use the dominant leg (D-Leg) to perform motor tasks, while using the non-dominant leg (ND-Leg) to support the body and stabilize posture [4]. Even though differences in terms of postural control have been reported between the D-Leg and the ND-Leg in athletes [5–8], other studies concluded that postural control was similar between the D-Leg and the ND-Leg among different athletes [9–13]. Paillard [14] hypothesized that this lack of consensus about the impact of limb dominance on monopedal postural control could stem from the nature of the sport practiced. With asymmetric activities that require frequent phases of monopedal posture on the ND-Leg to perform technical movements with the D-Leg (e.g., passing and kicking in soccer), the ND-Leg can display better postural control than the D-Leg [8,14,15]. In contrast, symmetric activities that use the two limbs similarly do not produce such an asymmetry of postural control [14]. Nevertheless, such a hypothesis still needs to be confirmed, since, to our knowledge, only two studies have been conducted to compare monopedal postural control in the D-Leg and the ND-Leg of expert athletes involved in asymmetric (ASYM) and symmetric (SYM) sports [6,15]. Moreover, the physiological state in which the subjects are evaluated can also act as a confounding factor by modulating the difference between the two legs [4,14]. Even though muscle fatigue negatively affects the perception of sensory information and control of the motor command of the postural system of both the D-Leg and ND-Leg [16,17], some studies performed with athletes showed that postural control was less affected by muscle fatigue on the ND-Leg than on the D-Leg [5,18], thus illustrating that the differences in postural control between the D-Leg and the ND-Leg could only be observed after the performance of a fatiguing exercise.

Hence, the present study was undertaken in order to accurately determine the effects of physiological states induced by fatiguing exercise on leg dominance in postural control, comparing athletes practicing SYM and ASYM sports. The latter were found to be more likely to be more sensitive to these acute effects [14]. It was hypothesized that, following the completion of fatiguing exercise, the dominant leg and the non-dominant leg could exhibit greater differences in postural control in athletes who participate in ASYM sports than those who participate in SYM sports.

2. Methods

Participants: Thirty healthy male athletes aged from 18 to 31 years old were recruited to participate in the experiment. They were divided into 2 groups, asymmetric (ASYM, $n = 15$) and symmetric (SYM, $n = 15$), based on the type of motricity in their sport practice, i.e., whether the movements carried out by the right and left side are symmetric or asymmetric. Age, morphological characteristics and details about sports participation for both ASYM and SYM groups are presented in Table 1. Volunteers likely to have musculoskeletal, vestibular, cardiovascular, ankle, knee or hip injuries in the last two years were excluded from the protocol. We asked the participants to avoid strenuous activity and not to eat or drink exciting substances 24 h prior to the data collection sessions. All participants gave their informed consent to participate in the experiment in accordance with the Declaration of Helsinki. The work has been approved by the Ethics Committee of the university authorities (14062014 Annaba).

Table 1. Participants' morphological characteristics expressed in median (IQR), sport practiced and expertise level of both ASYM and SYM groups.

	Groups	
Morphological Characteristics	**ASYM**	**SYM**
Age (years)	19 (5)	20 (7)
Height (cm)	175 (8)	174 (7)
Body weight (kg)	68.30 (10)	66.60 (10)
Body Mass Index (kg·m^{-2})	21.97 (2.28)	22.60 (2.57)
Foot size (cm)	28.38 (1.32)	28.38 (1.32)
Sport practiced	Soccer ($n = 5$) Handball ($n = 2$) Basketball ($n = 1$) Rugby ($n = 1$) Tennis ($n = 3$) Fencing ($n = 2$) Pelota ($n = 1$)	Track and field 800 m ($n = 3$) Track and field 1500 m ($n = 1$) Trail running ($n = 2$) Triathlon ($n = 2$) Biking ($n = 4$) Swimming ($n = 3$)
Sport competition level		
Local	$n = 4$	$n = 3$
Regional	$n = 8$	$n = 9$
National	$n = 2$	$n = 2$
International	$n = 1$	$n = 1$

Experimental Design: The experiment consisted of assessing postural control in a one-legged stance on the D-Leg and the ND-Leg (the dominant leg was defined as the leg used to kick a ball) for the ASYM and SYM groups in the following two conditions: (1) in an initial reference condition (REF condition), and (2) after a fatigue exercise (POST_FAT condition). In each condition and for each group, the D-Leg and ND-Leg were assessed in a counterbalanced order (Figure 1).

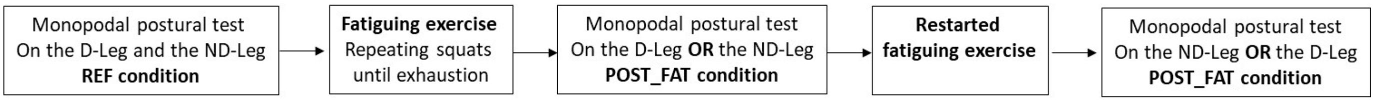

Figure 1. Chronological order of the protocol for both groups (ASYM and SYM).

Postural control assessment: Participants stood barefoot on a force platform (Stabilotest® Techno Concept, Mane, France; 40 Hz sampling frequency) that recorded the center of foot pressure (COP) displacements (spatio-temporal characteristics) with the PosturoWin v4 software. They were asked to sway and move as little as possible in a monopedal stance for 25 s with their arms alongside their body, while looking at a fixed target positioned 1 m in front of them at eye level. The unsupported leg (i.e., the free leg) was raised with a 90° joint flexion at the knee joint.

Reference condition: Participants performed 3 postural test trials on each leg with a 30 s rest between trials in order to achieve a stable postural score on monopedal stance and thus avoid learning effect between trials [19]. The third trial was recorded and corresponded to the REF condition.

Fatigue exercise: The fatigue exercise protocol consisted of repeating body-weight squats (i.e., without barbell) at a fixed and determined 0.5 Hz frequency (given by a metronome's sound beeps) until exhaustion, i.e., the inability to continue the squat exercise. Participants received verbal encouragements. The exercise had to be performed at 70° of knee flexion, which was determined with a goniometer (Comed®, Strasbourg, France). A rope was placed under the participants according to the 70° knee flexion angle and they were asked to touch it with their buttocks during each flexion in order to normalize the amplitude of the squat movements. A final postural control assessment was immediately performed at the end of the fatigue exercise on the D-Leg or the ND-Leg in POST_FAT condition in order to limit recovery, which can quickly impact postural control during the first 30 s following the exercise [17,20]. Since both legs could not be assessed consecutively during a 30 s period, the fatigue exercise was restarted before assessment of the following leg. The first and second durations of the fatigue exercise were recorded.

Data analysis: The COP surface area (90% confidence ellipse in mm^2) and mean COP velocity (sum of the cumulated COP displacement divided by the total time in $mm \cdot s^{-1}$) on the medio/lateral (frontal) and antero/posterior (sagittal) axes (COPx velocity and COPy velocity) were calculated as parameters that characterized postural control [21].

The relative increases between the REF and the POST_FAT conditions were calculated for all the parameters concerning the D-Leg and the ND-Leg as follows:

$$\text{POST\_FAT increase} = [(\text{POST\_FAT} - \text{REF}) \div \text{REF}] \times 100$$

Statistical analysis: Normality of the data was tested with the Shapiro–Wilk test. Nonparametric tests were used since the variables did not meet the assumption of normal distribution. Mann–Whitney tests for unpaired data were used to compare the morphological characteristics and the duration of the fatigue exercise protocol between the SYM and ASYM groups.

Paired samples Wilcoxon signed-rank tests were performed to compare COP parameters between the REF and POST_FAT conditions in order to determine a fatigue effect for the D-Leg and the ND-Leg in both ASYM and SYM groups. In order to test a potential effect of leg dominance, paired samples Wilcoxon signed-rank tests were performed within each group and in the two conditions to compare the values of COP parameters of the D-Leg and ND-Leg. Mann–Whitney tests for unpaired data were performed to compare the relative increases in all the COP parameters between the ASYM and SYM groups in order to determine a group effect. Results were considered significant at the level of 5%.

3. Results

Table 1 presents the morphological characteristics, sport specialty, and expertise level of the participants in the ASYM and SYM groups. Figure 2 presents the postural parameters of the D-Leg and the ND-Leg for the two groups in the two conditions. Figure 3 presents the relative increases in the postural parameters between the REF and POST_FAT conditions of the D-Leg and ND-Leg for the two groups.

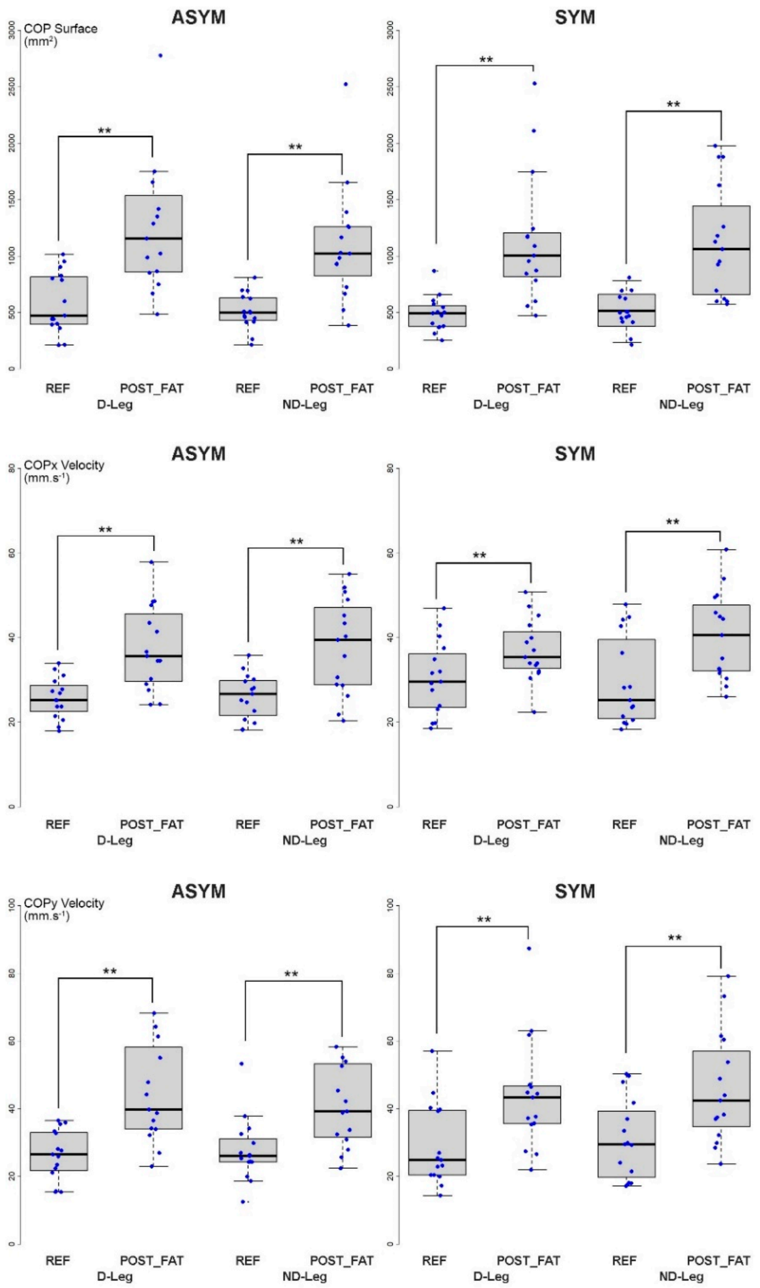

Figure 2. Boxplot representation with individual data points of postural parameter values on the D-Leg and ND-Leg in the ASYM and SYM groups in REF and POST_FAT conditions. Note, ** denotes a significant fatigue effect ($p < 0.01$) from the comparison between the REF and POST-FAT conditions. No significant differences were observed between the two legs.

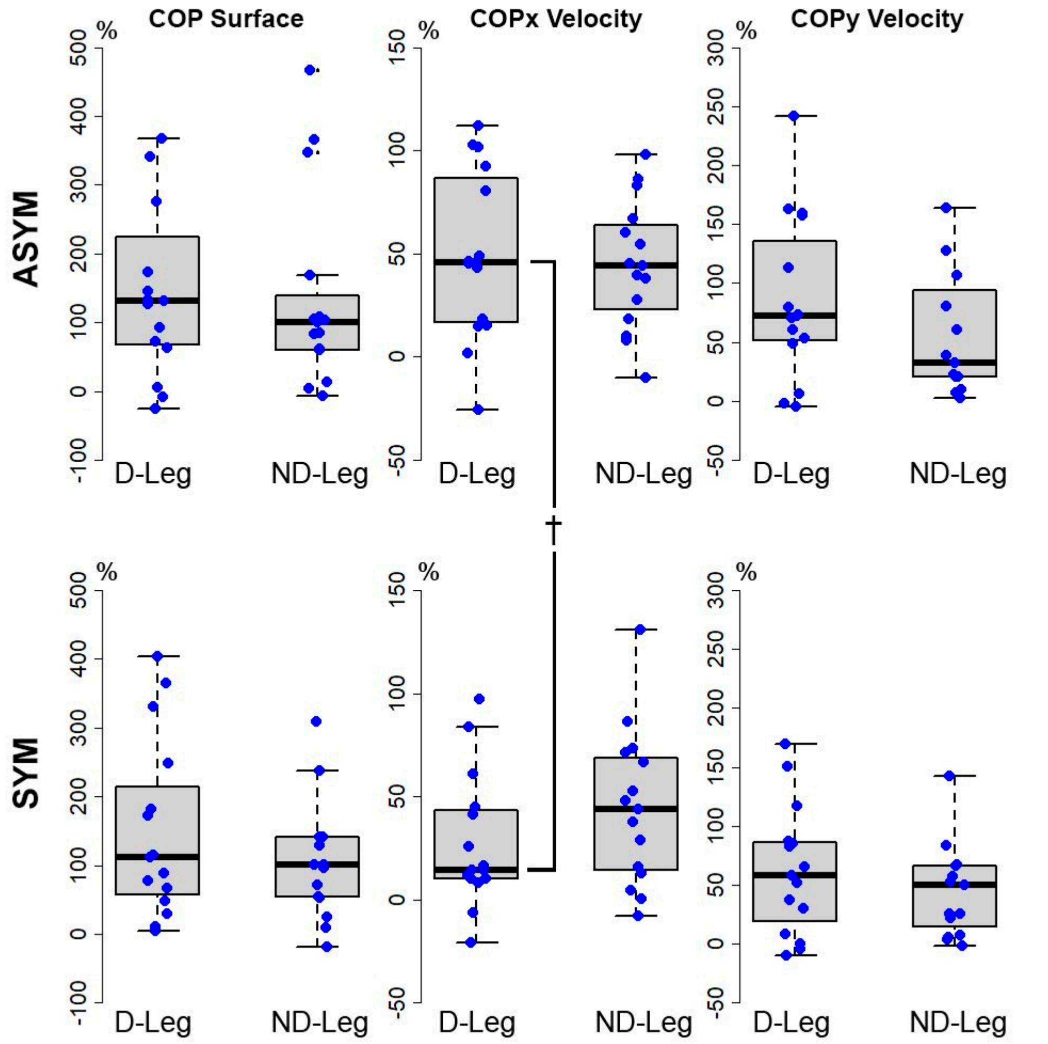

Figure 3. Boxplot representation with individual data points of the relative increases in the postural parameter values on the D-Leg and ND-Leg in the ASYM and SYM groups. Note, † indicates a tendency ($p = 0.06$) between the ASYM and SYM groups.

Fatigue effect: The COP surface, the COPx, and the COPy velocities increased more in the POST_FAT condition compared to the REF condition (Figure 2).

There were no differences between the groups with respect to the duration of the fatigue exercise protocol (ASYM, first period: 30.71 ± 22.56 min, second period: 3.09 ± 1.36 min; SYM, first period: 32.50 ± 28.47 min, second period: 3.94 ± 3.69 min (mean ± SD)).

Leg dominance effect: Statistical comparisons between the D-Leg and ND-Leg showed no difference in the two conditions for both the ASYM and SYM groups.

Group effect: No differences were initially observed between the ASYM and SYM groups under each condition. A strong tendency could be observed in the relative increase in COPx velocity on the D-Leg in the POST_FAT condition (Figure 3), which tended to be higher in the ASYM group than the SYM group ($p = 0.06$).

4. Discussion

The present pilot study was the first study to focus on differences in postural control between the D-Leg and the ND-Leg, following physiological states induced by fatiguing exercise, among ASYM and SYM athletes. The fatiguing exercise had a disturbing effect on monopedal postural control regardless of the leg used and the nature of sport practiced.

This disturbing effect related to fatigue tended to be more marked on the D-Leg in athletes practicing asymmetric sports than in athletes practicing symmetric sports.

The result of this study showed that a voluntary fatiguing exercise adversely affected postural control on both the D-Leg and the ND-Leg in both the SYM and ASYM groups. This supports previous studies that reported a deterioration of postural control regardless of the leg on which the subjects were assessed [16,22]. The fatigue exercise employed in the present study, which consisted of repeating squats until exhaustion, can be considered as a global exercise that solicits a large part of the body musculature [17]. With a mean total duration that exceeded 30 min in both the ASYM and SYM groups, fatigue induced by this type of exercise is likely to generate peripheral and central fatigue, which can alter sensory inputs (i.e., disturbance of proprioceptive myotatic information specifically related to the fatigue engendered at the level of the extensor muscles of the lower limb, and disturbance of the vestibular sensitivity specifically related to the organic and vestibular dehydration induced), their central integration (i.e., degradation of programming, command, and control of movement), and the motor output (i.e., decrease in muscle strength) of the postural function (for a review, see Paillard [17]). Further studies have shown that postural control is less affected by muscle fatigue on the ND-Leg than on the D-Leg, especially with athletes involved in ASYM activities, such as netball [18], basketball [5], or soccer [23]. Our results display concordant findings, since postural control on the D-Leg in the frontal plane tended to be impacted more in the presence of fatigue in the ASYM group than in the SYM group (COPx velocity, $p = 0.06$). Even if the sample sizes should have been larger, in order to expect clear significant results—since Cohen's index [24] only gave a small to medium effect size: d = 0.41— this result would be in line with the hypothesis formulated by Paillard [14], who postulated that the impact of limb dominance on monopedal postural control could be exacerbated by the specificity of motor experience (i.e., the practice of symmetric vs. asymmetric sports), and could be highlighted in the context of a negatively affected physiological condition, such as fatigue, and in the plane (frontal) in which monopedal posture is the most difficult to control. Indeed, there was initially no difference between the two groups on both the D-Leg and the ND-Leg (REF condition), and the tendency on the D-Leg between the SYM group and the ASYM group was only observed after the fatigue exercise in a lessened physiological condition (POST_FAT condition).

With asymmetric activities that require frequent phases of monopedal posture on the ND-Leg to perform technical movements with the D-Leg (e.g., passing and kicking in soccer), the ND-Leg can display better postural balance than the D-Leg [8,9,14]. In contrast, symmetric activities that use the two limbs similarly do not produce such an asymmetry of postural control [14]. This author inferred that particular motor tasks, regularly repeated, induce specific structural and functional adaptations at the central nervous system level, which generates durable modifications of motor and postural behaviors through a learning effect. As part of the study of cross-education, which attests that the motor output of the untrained limb (i.e., the contralateral limb) is improved after unilateral exercise training (i.e., the ipsilateral limb), it was reported that structural and/or functional differences at the cortical, subcortical and spinal levels were linked to the motor command between the dominant leg and the non-dominant leg [25,26]. For a given motor task, in its execution, the specialized limb (trained limb) would provide a better reference of motor information in the cortex, and would induce a better pattern of muscle activation (e.g., coordination of agonists and antagonists, synergist muscle activity, motor control) than the non-specialized limb (untrained limb in the execution of the considered motor task) [27]. These neurophysiological adaptations could enable postural control to be less affected on the ND-Leg (specialized leg) than on the D-Leg (non-specialized leg) in athletes practicing ASYM activities in adverse physiological conditions (fatigue), and in the direction (medio-lateral) that is the most difficult to control.

Thus, fatiguing exercise disturbed postural control on the D-Leg and ND-Leg in both the SYM and ASYM groups. This disturbance tended to be more marked on the D-Leg in athletes practicing asymmetric sports than in athletes practicing symmetric sports. However, this pilot study presents a certain limitation, and thus cannot provide a clear-cut answer to the question asked. At this end, future works dealing with the possible differences between the D-leg and the ND-leg, in terms of postural control, should be carried out with larger sample sizes, in order to possibly obtain clear and meaningful results. These future studies could also include additional experimental analyses, such as, for example, electromyographic measurements, in order to answer the question more precisely.

This article reports an innovative protocol including the nature of sport practiced and the physiological states in which the subjects were evaluated, in order to determine the possible differences between the D-Leg and the ND-Leg in terms of postural control. The D-Leg seems to be more sensitive than the ND-Leg in athletes practicing asymmetric sports than in athletes practicing symmetric sports. Therapists and trainers should be aware of the possible difference between the dominant leg and the non-dominant leg during their intervention protocol based on monopedal postural tasks, especially when the athletes are evaluated in a lessened physiological condition (e.g., immediately after strenuous exercise and/or a sports competition).

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