Influence of Unilateral Fatigue of Lower Limbs on the Bilateral Vertical Jump

ABSTRACT

It is common to observe bilateral strength deficit during the vertical jump. This is characterized by lower strength produced during bilateral contractions, when compared to the sum of the unilateral contractions of similar muscles. There is not much scientific knowledge about the effect of unilateral fatigue on bilateral activities. The aim of this study was to investigate the effect of unilateral fatigue on bilateral deficit performance during bipedal vertical jump. Ten sedentary young adults unilaterally fatigued each lower limb and performed vertical jumps (bipedal and unipedal). We measured the vertical ground reaction force and myoelectrical activity to each lower limb and conditions (pre-fatigue, fatigue of the dominant limb (DF) and non dominant limb (NDF)) were measured. Differences between tasks and conditions only on the pre-fatigue (p=0.030) were observed. Differences were observed for the bipedal vertical jump between pre-fatigue and DF (p=0.005), and unipedal vertical jump between pre-fatigue and DF (p<0.001) and NDF (p<0.001). We only observed change on the performance of bipedal vertical jump during the DF condition. We observed a trend to the asymmetry index decrease for the muscular action of the fatigued contralateral lower limb by electromyography. The results suggest that there is a common command where the nervous system considers the muscles simultaneously activated as a unit, except in conditions of unilateral lower limb fatigue.

Keywords: fatigue, countermovement jump, bilateral strength deficit.

INTRODUCTION

Bilateral strength deficit is a commonly verified phenomenon when the voluntary maximal strength levels produced during bilateral contractions are lower than during unilateral contractions of the same muscles, when they are added being is description firstly published in 1961 by Henry and Smith. Deficit in bilateral strength has been observed in lower limbs and upper limbs; however, its magnitude is usually lower in upper limbs compared to lower limbs (13%-25%).

The mechanisms responsible for the bilateral deficit are currently little known, partly for being a non-visible phenomenon in all experimental conditions. However, there are many theories related to deficit of bilateral strength such as: spinal inhibitory reflex, reduction of motoneurones excitability, inter-hemispheric inhibition, influence of postural instability, influence of the strength-velocity curve of the active muscles, differences in the neuromuscular control between unilateral and bilateral contractions.

Several studies have reported that during bilateral jumps, the individuals reach lower height in maximal vertical jump compared to the maximal height reached in unilateral jumps, when the leg is bent. The implication that the amount of work produced by one leg in a bilateral jump is lower than in unilateral jumps is confirmed by inverse dynamics analysis.

During the sustained muscular contraction or the performance of repetitions, the muscle may face exhaustion and fail to maintain the desired strength, power or work. Therefore, muscular fatigue is considered progressive loss in the generation of muscular strength, or decline in the development of strength through progression of the number of repetitions and can also affect many other factors related to human performance: movement coordination, accuracy, reaction time and proprioceptive capacities.

Several studies report the effect of unilateral or bilateral fatigue in tasks of same characteristic (e.g. unilateral fatigue with unilateral jump); however, little is known about the effect of unilateral fatigue on bilateral activities. Thus, the aim of this study was to verify the effect of unilateral fatigue, dominant and non-dominant sides over performance and bilateral deficit during the bilateral vertical jump.

MATERIALS AND METHODS

Subjects

The sample was composed of 10 sedentary, healthy, male young adults (age: 25 ± 4 years; height: 176 ± 8cm, weight: 73 ± 12kg), thigh and lg circumferences were not different between right and left sides (table 1). The subjects were selected and included after having been confirmed they did not present injuries which could compromise performance, or even peripheral and /or central neurological disorders. The subjects were informed about the experimental procedures and signed the Free and Clarified Consent Form, approved by the Ethics in Research Committee of the Physical Education and Sports College of the University of São Paulo.

Procedures

Initially, the dominant lower limb was determined through the kick a ball test. Prior to the jump tasks, the subjects performed unilateral one-repetition maximum test (IRM) in the leg press exercise (Cybex, Int, USA). Subsequently to the procedures...
mentioned above, they performed bilateral and unilateral jump
with maximal contra movement (CMJ) (dominant limb (Dom) and
non-dominant limb (Ndom)). The forces to ground reaction were
measured by a strength platform (OR6, AMTI Inc., USA), and the
myoelectric activity (EMG) of the vastus lateralis muscle (in each
limb) was measured through an electromyographer (Noraxon USA,
Scottsdale, AZ). The body hair was removed from the region of the
electrodes placement, and light skin abrasion was performed for
dead cells removal and reduction of impedance for the EMG. Pairs of
Ag/AgCl round self-adhesive passive surface electrodes, with
1-cm diameter and 2-cm spacing from center to center between
electrodes, associated to a conducting gel were used. The
electrodes were placed on the skin surface on the vastus lateralis
muscle, specifically at 2/3 between the antero superior iliac spine
and lateral of the patellar lateral line following the muscle fibers
orientation and placed in the muscle venter (SENIAN, 2010). The
1-cm Ag/AgCl self-adhesive reference electrode associated to a
conduction gel, was placed on the clavicle bone prominence.
The data acquisition was done at 1,080Hz frequency and data
were processed through a written routine on the Matlab software
(Mathworks Inc., USA).

The bilateral vertical jump with contra movement (CMJ) was
performed with subjects standing still on a strength platform, with
feet apart at hip width and upper limbs front crossed at chest level.
Unilateral CMJ followed the same orientation; however, only one
limb remained in contact with the strength platform (dominant or
non-dominant). The subjects were told to perform here maximal
jumps and keep their knees extended during the flying phase; the
velocity peak (defined by the double integration of the vertical
reaction force of the ground) in the propulsive phase of the CMJ
was calculated for the bilateral and unilateral CMJ. The following
formula was used:

$$V^{2}_{\text{takeoff}}/(2g)$$

Where $g$ is the gravity force ($g = 9.8m/s^2$).

Specifically to the unilateral CMJ, the sum of the maximal heights
each limb was calculated during all conditions: pre-fatigue,
dominant fatigue (fatigued dominant limb + non-fatigued non-
dominant limb) and non-dominant fatigue (fatigued non-dominant
limb + non-fatigued dominant limb).

Processing of the EMG signal followed this order: the EMG
signals were filtered with a fourth order passband filter between
20-400Hz, and delay of zero phase, the root-mean square with a
movable window of 50ms was used, being normalized by the
activation peak during the propulsive phase of the jumps. The EMG
data were defined by the beginning and end of the CMJ propulsive
phase and the integral of the myoelectrical activation defined by
the activation time (IEMG) of the vastus lateralis muscle of each limb.

An asymmetry index (AI) between the dominant limb (Vd) and the
non-dominant limb (Vnd) was hence calculated as follows:

$$AI = 100 * \frac{(V_d - V_{nd})}{(V_d + V_{nd})/2}$$

**STATISTICAL ANALYSIS**

The descriptive analysis involved measurements of central
tendency and variability. All data were reported through the mean
and standard deviation (SD) of the mean. Normality and homogeneity
of the variances were verified using the Kolmogorov-Smirnov
and Levene test, respectively. Paired Student’s $t$ test was used to verify
the differences (bilateral deficit) between the maximal heights of
the jumps between the unilateral tasks and the myoelectric activity
of the vastus lateralis muscle at the fatigue conditions. 2x3 ANOVA
was used for the maximal height of the bilateral jumps, having as
factor the task (bilateral and unilateral) and the fatigue condition
(lack of fatigue, fatigue of the dominant limb and fatigue of the
non-dominant limb), being the last measurements repeated. Sidak
post hoc was used. Significance level ($\alpha$) of 0.05 was used for all
statistical tests, through the SPSS software, version 15.0.

**RESULTS**

Initially, unilateral jumps were used to certify that the unilateral
fatigue was really induced (height of the unilateral jumps after
unilateral fatigue was significantly lower for the two legs; dominant
leg: $t(9) = 7.13$, $p < 0.001$; non-dominant leg: $t(9) = 7.65$, $p < 0.001$)
(figure 1). The decrease in the unilateral jumps after fatigue induction was of 28.9% and 31%, dominant and non-dominant leg, respectively.

Figure 2 shows the mean and standard deviation values of the height of the jump with bilateral and unilateral contra movement, at the lack of fatigue and unilateral fatigue conditions (dominant and non-dominant). Statistical analysis (ANOVA) showed interaction between tasks and fatigue conditions ($F(2.18) = 11.34, p = 0.001$); the post hoc presented differences only between the tasks at the lack of fatigue condition ($p = 0.030$). The main effect between the fatigue conditions ($F(2.18) = 27.42, p < 0.001$) was also presented; the post hoc presented significant differences for the bilateral task at the pre-fatigue and fatigue of dominant limb conditions ($p = 0.005$) and for the unilateral task at the pre-fatigue and fatigue of dominant limb ($p < 0.001$) and non-dominant limb ($p < 0.001$).

Figure 3 presents the mean and SD values for the asymmetry index by the difference between the dominant limb and non-dominant limb in EMG of the vastus lateralis muscle. This index was calculated for the pre-fatigue and post-fatigue conditions (dominant and non-dominant limbs). It represents the tendency of participation of one limb over the contralateral, meaning that the positive values show higher participation of the dominant limb compared to the non-dominant limb, while negative values show higher participation of the non-dominant limb compared to the dominant one. There were not significant differences for the asymmetry indices for the fatigue conditions.

**DISCUSSION**

The aim of the present study was to verify the unilateral fatigue effect, dominant and non-dominant sides, over performance and bilateral deficit during the bilateral vertical jump. Initially, similar decrease was observed in performance of the unilateral maximal jumps in both limbs (dominant and non-dominant), which does not corroborate other studies which point higher susceptibility to fatigue of the non-dominant limb compared to the dominant one(26). However, the studies mentioned analyzed muscles of upper limbs, which presented differences in their muscle fibers composition between the right and left limbs, a factor which could have influenced on the level of fatigue reached. It is known that muscles with higher percentages of fast contraction fibers (type II) are more prone to fatigue(27). In the case of lower limbs, there is evidence that there is higher percentage of type II fibers in the vastus lateralis muscle(27); hence, lower resistance to fatigue is expected. However, evidence on the differences in the composition of muscle fibers between limbs, as well as which factor could directly affect performance of jumps is scarce(21).

Considering that the level of fatigue reached by both limbs is similar, and supposing that such fatiguing condition equally affects performance during bilateral tasks, it was curiously verified that only during the fatigue condition of the dominant limb there was alteration in performance of bilateral jumps. Therefore, it seems that the dominant limb has greater influence than the non-dominant one at maximal height of the bilateral jumps. Such results above also corroborate the electromyographic findings of the present study, which present tendency to decrease in the participation of the vastus lateralis muscle during the propulsive phase of the bilateral jumps when the ipsilateral limb is fatigued(26).

Electromyography is the result of central commands to the muscles, and can provide information of the neural mechanisms related to the bilateral deficit(5). The amplitude of the myoelectric signal depends on the membrane properties of the muscle fibers and the timing of the action potential of the motor units, reflecting central and peripheral properties of the neuromuscular system, both at normal and fatigue conditions(5,28). At the lack of fatigue condition, both limbs reached similar muscular activation values; however, when fatigue is present in one of the limbs, higher activation of the contralateral limb can be verified. In the specific case of the bilateral jump with fatigue in the dominant limb,
increase of the electromyographic activation was not sufficient to maximize the jump and produce maximal Heights similar to the lack of fatigue condition, a fact occurred only when the non-dominant limb was fatigued.

Many studies show that maximal bilateral voluntary contractions reach lower values than the sum of the unilateral strength, a phenomenon named bilateral strength deficit(23,24). During the study, the presence of bilateral deficit only at the lack of neuromuscular fatigue condition was observed, which does not corroborate the findings by Yoshioka et al.(29).

It can be speculated that there is a common command(26) which may indicate that the muscles simultaneously activated, in order to generate maximal strength, are seen by the nervous system as an unit and control them in a similar way(1). However, it seems that fatigue of only one of the limbs alters this common command and dissociating the command for both limbs(1).

In practical terms, training, as well as the familiarization to tasks, may reduce the bilateral strength deficit minimizing the asymmetry, especially at fatiguing conditions, in which the control dissociation may modify the overload between limbs, since tasks which present asymmetry between limbs are more prone to injuries during physical performance(30-36).

CONCLUSION

Previous unilateral exercise with dominant lower limb until exhaustion resulted in subsequent decrease in bilateral vertical jump performance. This is interesting information for physical preparators and coaches, which may guide their athletes from training prescription to sports conduct. Associated to this performance response, there was a tendency to decrease in participation of the vastus lateralis muscle during the propulsive phase of the bilateral jumps when submitted to ipsilateral fatigue, especially for the dominant side.

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REFERENCES