STRENGTH SYMMETRY AND IMPRECISE SENSE OF EFFORT IN KNEE EXTENSION

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Abstract:

To verify the asymmetry in strength and the sense of effort between the preferred and non-preferred leg as well as differences between perceived and real workload achieved during trials for a maximal one-repetition knee extension, 32 subjects, all physically active (24 males and 8 females) performed one-repetition tests for knee extension (1 RM) with their preferred and non-preferred leg. The subjects reported the sense of effort by means of the Borg's scale for subjective perceived effort. Asymmetry was quantified for the workload and the sense of effort. We found similar strength and sense of effort for both legs. There were differences between the perceived and real workload when normalized by the maximal effort, mostly for higher intensities. Similar strength could be achieved between the preferred and non-preferred leg; however, the subjects' perception about the workload can be imprecise, which may lead to mistakes when controlling training overload by means of the sense of effort.

Key words: *functional laterality, knee force, sense of effort, one-repetition test, laterality.*

Introduction

A common way of interaction between the coach or therapist and the athlete or patient is the assessment of the subject's perception of exercise intensity. In this regard, *sense of effort* and *sense of force* are two interacting concepts when regulating the necessary force for accomplishment of a given task (Schmidt & Lee, 1999).

The sense of effort relates to the ability to judge the force necessary to perform a task successfully. It is based on the descending motor commands (*feedforward mechanisms*) of the central nervous system (CNS) (McCloskey, Ebeling, & Goodwin, 1974). On the other hand, the sense of force concerns the regulation of force output by using information transmitted by proprioceptive organs such as Golgi organs and cutaneous receptors (Gandevia & McCloskey, 1978; Roland & Ladegaard-Pedersen, 1977).

There is a relationship between force production and a sense of effort in healthy subjects (Simon, Kelly, & Ferris, 2009); however, loss of stability in the articular system induces errors in force sense resulting in increased muscle stiffness (Docherty & Arnold, 2008). Despite improvements in effort perception after training in the healthy subjects (Docherty, Arnold, Zinder, Granata, & Gansneder, 2004), training does not ensure a proper effort perception for people who experience joint instability (Docherty & Arnold, 2008). Additionally, the perceived workload may not correspond to the real workload, while the sense of effort for concentric knee extension strength can also differ between lower limbs when considering different workloads (Vagenas & Hoshizaki, 1991).

In this regard, lower limb asymmetries are thought to be dependent on neural factors rather than mechanical capability (Simon & Ferris, 2008). In cyclic activities involving constant cooperation and a coordination pattern between the legs, such as cycling (Carpes, Rossato, Faria, & Mota, 2007a, 2007b; Sanderson, 1990) and running (Vagenas & Hoshizaki, 1991, 1992), asymmetries were related to the effort level depicted by the exercise intensity. Therefore, an inappropriate judgment of the sense of effort could contribute to an overload of the joint system. Therefore, as observed for force output, lower limbs may present asymmetries in the sense of effort, which may lead to mismatches in training programs.

To the best of our knowledge, no previous study has addressed bilateral asymmetries and differences in the sense of effort between the preferred and non-preferred leg during maximal efforts. The aim of this study was to verify maximal strength and sense of effort asymmetries, as well as differences between a perceived workload and a real workload, during trials for maximal one-repetition knee extension in healthy subjects. From previous studies we hypothesized that the preferred leg would have a higher capability to match the sense of effort with the real workload, and that maximal effort could be symmetric in both legs.

Methods

Subjects

Thirty-two healthy subjects (24 males and 8 females) volunteered for this study. The mean ± SD for age was 22 ± 2 years, for body mass 74.1 ± 13 kg, and for height 1.76 ± .09 m. The subjects were active during the time of the study with an average weight-lifting experience of one year and seven months. None of the subjects reported any lower limb neurological and/or musculo-skeletal condition that might impair the task performance. The subjects demonstrated full lower limb range of motion for knee flexion and extension. All subjects signed an informed consent approved by the local institutional review board and according to the Declaration of Helsinki.

Experimental design

Each subject completed the experimental tests in one day. Trials of unilateral progressive load were performed to define the maximal knee extension concentric force obtained in one maximal repetition (1 RM) as described elsewhere (Ploutz-Snyder & Giamis, 2001). Three to five minutes of rest were permitted between the trials to minimize the effects of fatigue (Ratamess, et al., 2007). The preferred and non-preferred leg were tested alternately between the subjects. Any influence in terms of muscle contraction type was not present in the study (Hollander, et al., 2008), as all subjects performed the same exercise.

All subjects performed the test using the same exercise machine, which was a general knee extensor gym machine similar to those used elsewhere (Perry, Morrissey, King, Morrissey, & Earnshaw, 2005) that permitted to execute movements either unilaterally or bilaterally. The machine was properly fitted for each subject. Subjects were comfortably seated on the machine with their right and left knee flexed at the angle of approximately 90º, and their ankle supported in a position of approximately 90º of plantar-flexion. During all tests, subjects were verbally encouraged to perform their very best and the maximal workload achieved was assigned as the maximal effort perceived (100%).

Leg preference was assessed using the Waterloo inventory (Elias, Bryden, & Bulman-Fleming, 1998). Data were organized considering four intensity zones related to the maximal effort: 50 to 70%, 70 to 80%, 80 to 90% and 90 to 100% of the 1 RM test. Real workload and perceived workload (sense of effort assessment) were recorded for each leg and subject.

Index of asymmetry and sense of effort assessment

Asymmetry index (AI, %) was determined for knee strength from the maximal load achieved for the preferred and non-preferred leg in the unilateral knee extension following the equation of Chavet, Lafortune, & Gray (1997). For the sense of effort assessment, the Borg's scale for subjective perceived effort was applied for each trial of the 1 RM as described elsewhere (Tiggemann, et al, 2010).

Statistical analysis

Descriptive statistics in terms of means and standard deviations was calculated. The normality of distribution was verified by Shapiro-Wilk's test; data sphericity was checked by Mauchly's test. The maximal knee extension strength as measured by the unilateral 1 RM test and the workloads correspondent to the effort zone indicated by the subjects were compared between the preferred and non-preferred limbs using Student's independent *t*-test. For all statistical procedures the significance level was $p \leq .05$ (SPSS 13, Statistical Package for Social Sciences Inc., Chicago, IL, USA).

Results

The maximal knee extension strength measured by the 1 RM test was not significantly different between the preferred and non-preferred leg [$t(64)=.465$; $p=.64$] (73±22 kg and 70±20 kg for the preferred and non-preferred leg, respectively). The average asymmetry index for the maximal knee extension strength in the 1 RM test was 4.07±6%. There were no statistically significant differences between the legs for the relative workload (% of 1 RM) corresponding to different senses of effort (50-70%, 70-80%, 80-90% and 90-100% of maximal effort). In Figure 1 the black bars represent the real workload (in kg and % of 1 RM) and the gray boxes depict the expected workload (in % of 1 RM according to the sense of effort reported by the subjects).

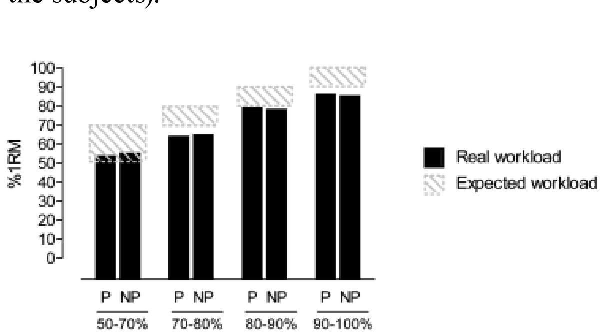

Figure 1. Real workload (in kg) and expected workload (% of 1 RM according to the sense of effort reported by the subject) in the different effort zones analysed.

When the real workload and the expected workload were compared, the 50-70% effort zone was the only zone at which real workload and sense of effort did not differ statistically. For the three other effort zones, the subjects felt they were producing more force than they actually were.

Discussion and conclusions

The successful monitoring of training or rehabilitation based on subjective perception is dependent on the accuracy of information provided by the athletes or patients. The aim of this study was to verify lower limb strength and sense of effort asymmetries, as well as the differences between perceived workload and real workload during trials for maximal one-repetition of knee extension in healthy subjects. Our results demonstrate symmetry between the preferred and non-preferred leg in maximal knee extension strength as measured by the 1 RM test as well as in different effort zones. In contrast, there was disagreement between the sense of effort reported at different levels of force matching according to the maximal capability in three of the four effort zones assessed, and agreement in only the 50-70% of 1 RM effort zone.

The sense of effort observed for higher effort zones (> 70% of 1 RM) did not correspond to the real workload experienced. One reason for this result could be the inexperience of the subjects in performing 1 RM test (Hampson, St Clair Gibson, Lambert, & Noakes, 2001). Another plausible explanation for this observation is that a sense of effort is dependent on sensory processing rather than the magnitude of the motor drive produced during the tests (de Graaf, et al., 2004).

Fatigue may be related to mismatches in the sense of effort and higher intensity workloads; however, in this study the effects of fatigue on the sense of effort were minimized by allowing resting periods between submaximal contraction trials (Walsh, Hesse, Morgan, & Proske, 2004; Winter, Allen, & Proske, 2005). Alternatively, the relationship between higher intensity workloads and mismatches in the sense of effort may be explained by the short duration of afferent feedback during the contraction. A short period of afferent feedback may not provide enough time to reach a steady state and to adjust the sense of effort appropriately with the exercise intensity (Ulmer, 1996).

On the other hand, our results could not be stated as dependent on fatigue effects. The increase in the amount of information conducted towards the motor cortex observed during fatigue increases the ability for the regulation of the sense of effort (Gandevia, 2001) and sense of position (Allen & Proske, 2006). Indeed, our results are consistent with findings obtained from cyclic activities where increases in workload were related to symmetry during a simulated cycling race (Carpes, et al., 2007a), in incremental maximal (Carpes, et al., 2007b) and submaximal cycling tests (Sanderson, 1990).

In contrast to our results, the magnitude of asymmetry in concentric knee extension strength found between the preferred and non-preferred leg had magnitudes of up to 10% in long distance runners (Vagenas & Hoshizaki, 1991). In agreement, Kawakami, Sale, MacDougall, & Moroz (1998) showed that the bilateral deficits in plantar flexor muscles can be related with a reduction on the motoneuron excitability, decreasing the capability of voluntary activation of the muscle. In our study, the lack of strength asymmetries in the legs paired with the asymmetries in the sense of effort denotes that different pathways are involved in the control of force generation and perception of effort.

The inexperience of the subjects in performing maximal contractions could be a limitation of our study, as our subjects had experienced only one year and seven months of resistance training. Additionally, no 1 RM test had been completed before these evaluations. Nevertheless, understanding how the sense of effort is generated and interpreted by the brain during exercise is an attractive topic for further investigations. The practical implication of the present study is that the use of the sense of effort at higher intensities of workload, especially short-duration exercises performed by untrained subjects, is not the best way to program or assess the intensity of training.

The evaluation of strength by the 1RM test for knee extension did not reveal significant strength asymmetries in healthy young subjects as well as for the sense of effort between the preferred and non-preferred leg. There were differences between the perceived and the real workload experienced, especially when the effort level increase. Exercise program based only on the sense of effort may be imprecise at intensities zones above 70% of the 1 RM load. Therefore, they can contribute to overload of the joint system and mismatches in training program based on individual effort perception.

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SIMETRIJA SNAGE I NEPRECIZAN SUBJEKTIVNI OSJEĆAJ OPTEREĆENJA PRI ISPRUŽANJU POTKOLJENICE

Istraživanje je provedeno radi utvrđivanja postoji li asimetrija u snazi te razlika u subjektivnom osjećaju opterećenja između preferirane i nepreferirane noge, kao i razlika između doživljenoga i stvarnoga opterećenja postignutoga tijekom testiranja maksimalne izvedbe ispružanja potkoljenice. 32 fizički aktivna ispitanika (24 muškarca i 8 žena) izvodila su test maksimalnog opterećenja (1 RM) tijekom ispružanja potkoljenice preferirane i nepreferirane noge. Ispitanici su na Borgovoj skali za subjektivnu procjenu opterećenja ocijenili osjećaj opterećenja tijekom obje izvedbe. Asimetrija je kvantificirana za opterećenje te za osjećaj opterećenja. Istraživanjem su dobiveni slični rezultati za jakost i osjećaj opterećenja za obje noge. Nakon normalizacije maksimalnim opterećenjem, u istraživanju su utvrđene razlike između doživljenoga i stvarnoga opterećenja, najviše za pokušaje pri višem intenzitetu. Slična se jakost može postići između preferirane i nepreferirane noge, ali samopercepcija opterećenja ipak može biti neprecizna, što može dovesti do pogrešaka u kontroli trenažnoga opterećenja subjektivnim osjećajem opterećenja.

Ključne riječi: *funkcionalna lateralnost, sila u koljenom zglobu, subjektivni osjećaj opterećenja, test maksimalnog ponavljanja, lateralnost.*

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