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RELATIVE ERROR ANALYSIS DURING REPRODUCTION OF ISOMETRIC FORCE OF KNEE EXTENSORS IN YOUNG ADULTS

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This study compared the force reproduction of isometric knee extension at 60°, between the target forces at 30%, 50% and 70% of the maximum voluntary isometric force (MVIF) in young adults. Twenty young males took part in the study. The trials were performed on an instrumented chair developed for the study. Feedback was given to the participants during three trials prior the beginning of data collection in each analyzed target force. Participants performed 10 trials without any feedback for the target force at 30% and 50% of the MVIF and 3 trials for the target force at 70% of MVIF. The relative error decreased as the target force increased. The differences were significant between 30% and 70% ($p=0.01$) and between 50% and 70% ($p=0.03$). The reproduction of higher forces during isometric extension of the knee will produce lower relative errors for this specific task.

KEYWORDS: proprioception, force sense, muscle force.

INTRODUCTION: Proprioception is related to any afferent information coming from peripheral areas of the body that contribute to postural control, joint stability and conscious sensation (Gandevia, 1996; Riemann & Lephart, 2002a). This information is processed in the Central Nervous System (CNS) and transformed into movements that can correct positions and prevent injuries (Jong et al. 2005; Payne, Berg, & Latin, 1997; Riemann & Lephart, 2002b).
Proprioception is usually analyzed by tests such as sense of joint position and perception of movement velocity (Deshpande et al., 2003; Ribeiro & Oliveira, 2008), however little attention has been given to force sense. When considering function, force sense can be as important as position sense, because many sports and daily living activities involve force sense as well as accurate joint positioning.
The force sense can be analyzed through the reproduction of a target force, which is generally determined considering a percentage of the maximum voluntary contraction; the force sense is then evaluated based on the relative error between the target and the force generated by the individual (Dover & Power, 2003; Proske et al., 2004).
The individual's capacity of reproducing a target force is related to the motor control during the performance of a specific task. In addition, the identification of the percentage in which the individual presents the highest relative error could provide useful information to better support an intervention to prevent injuries during the sportive or daily activities.
Therefore, the present study aimed to compare the force reproduction of isometric knee extension at 60° between target forces of 30%, 50% and 70% of the maximum voluntary isometric force (MVIF) in young adults.

METHODS: Twenty young males with a mean height of 1.79 ± 0.07 m, body mass of 76.8 ± 8.4 kg and age of 23.2 ± 3.0 years took part in the study. The inclusion criteria were age between 18 and 30 years and absence of muscle or ligament injury in lower limbs during the six months prior to data collection. Written consent was gained from participants through a consent form previously approved by the Ethical Committee for Research on Humans of the Institution.
Analyzed variable: Relative error, which is the difference between the requested force (target force) and the mean force actually achieved by the participant. We used 5 s of force generation to calculate the achieved force, and the calculation started only after the force

generation (contraction) could be considered stable, which was approximately 2 s after the beginning of the task (Figure 1).

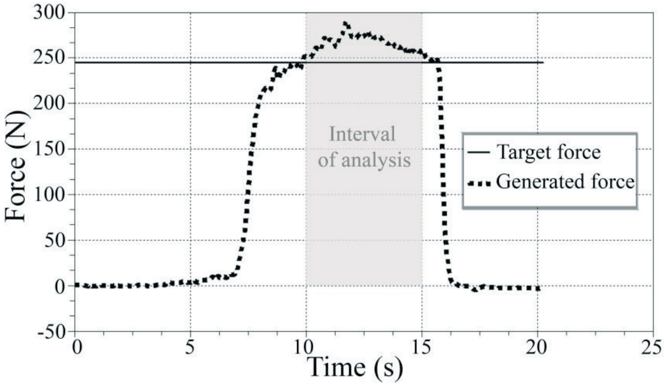

Figure 1: Sample of the curve generated during force reproduction. The contiguous line represents the target force; the dotted line represents the force generated during the task by the participant and the grey area represents the 5 s used to calculate the difference between the target force and the force generated by the participant, that is, the relative error.

Instruments: A ring load cell (sensitivity of 2 N and error below 1%) was adapted to a chair specifically designed to perform knee extension. Data were acquired and processed through the use of the ADS2000-IP System (Lynx Tecnologia Eletrônica LTDA, São Paulo, SP, Brazil). The sampling rate and gain were set at 50 Hz and 2000, respectively.
Data collection procedures: After the anthropometrical measurements, the participants were positioned on the instrumented chair with 60° of knee flexion, hip between 110° and 120° and a belt restricting trunk movement. The participants were instructed to perform only knee extension, using their right lower limb and avoiding other movements. After positioning, the participants were instructed to perform four sub-maximal contractions at different intensities, to become familiar with the procedures. Data collection started right after familiarization, by requiring the participants to perform a MVIF. Then, participants were required to produce contractions at three target forces: 30%, 50% and 70% of the MVIF. The sequence in which each target force was performed was decided at random. The first three executions (which were not considered for analysis) were performed with visual feedback (computer screen) and verbal feedback for each target force. Following this training, ten trials were performed for the target forces 30% and 50%, and three trials for the target force 70%, in order to avoid fatigue (Proske et al., 2004). Participants were instructed to maintain the contractions for 5 s in each trial and a rest period of 30 s was given between trials for the target forces 30% and 50% and 2 min for the target force 70%.
Data processing: All curves were exported and analyzed through a processing routine created with the Scilab 4.1.2 software (Institut Nationale de Recherche en Informatique et en Automatique, Ecole Nationale des Ponts et Chauss, France), which consisted of the following phases: (1) offset correction and filtering (Butterworth low-pass filtering with a cut-off frequency of 10 Hz); (2) calculation of the relative error, based on root mean square values; and (3) calculation of the mean relative error for each participant in each target force (30, 50 and 70% of MVIF).
Statistics: SPSS software version 17.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data. Mean and 95% confidence intervals (CI) were calculated and repeated measures ANOVA was used to compare the relative error between the three target forces. Multiple comparisons were performed with the LSD test. An alpha level of $p<0.05$ was used for all statistical tests.

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RESULTS: Table 1 shows the mean and CI of the relative error for each target force and the P-value resulted from the comparison between the conditions.

Table 1
Mean (95% Confidence Interval) of the relative error for each target force and P-values resulted from the comparison between the conditions.

% of MVIF	Relative Error
30 (N)	24.6 (14.4–34.7)[a]
50 (N)	15.9 (11.6–20.2)[a]
70 (N)	11.2 (7.6–14.8)[b]
	***p* = 0.03**

MVIF: maximum voluntary isometric force; Lowercase letters (a, b) indicate LSD multiple comparisons between the conditions. Equal letters mean non-statistical difference ($p > 0.05$).

There was an increase in the relative error as the percentage of the target force decreased. There were significant differences between the target forces 30% and 70%, (95% CI=2.48-24.35, p= 0.01) and between the target forces 50% and 70% (95% CI=0.41-9.11, p=0.03). No significant difference was found between the target forces 30% and 50% (95% CI=-2.64-19.89, p=0.12).

DISCUSSION: According to our results, the higher the target force, the lower the relative error for the reproduction of isometric force of knee extensors at 60° of flexion. Maintaining a sub-maximal isometric contraction is a task that can be considered more difficult than performing a MVIF because it requires constant adjustments involving feedback and feedforward from the CNS (Kroemer & Marras, 1981). These constant force adjustments are likely to be achieved by a synchronization of the motor units, and these synchronizations could be of greater magnitude for the less intense isometric contractions (Salonikidis et al., 2009).
In a MVIF, the CNS generates efferent impulses to achieve maximal muscular fiber recruitment, resulting in a less complex task (Jones & Hunter, 1982). In the present study, the participants had less difficulty reproducing the target forces that where the most similar to a MVIF, corroborating the cited theory and other studies that investigated other muscle groups (Salonikidis et al., 2009). Activities of daily living and most athletic activities require a contraction of small intensity. When we analyzed the contractions with small intensities, the relative error was higher; therefore, it should be determined whether people with less athletic ability have a poorer performance in the force reproduction task when compared to those with high athletic ability. If that is the case, a higher level of relative error could be associated with flaws in the sports movement or the lack of capacity to correct a movement error and therefore an increase in the risk of injury. From that point of view, the capacity to reproduce force could be used as a tool for professionals who aim to improve performance in sports and prevent injuries.
The findings of other studies differ from those presented in the current study. Some studies reported a smaller variation when force reproduction was performed at target forces around 50% of MVIF (Jackson & Dishman, 2000; Jones & Hunter, 1982) and others reported smaller relative errors for the smaller target forces (Schiffman, Luchies, Richards, & Zebas, 2002). Therefore comparisons between studies should be analyzed with caution and should be performed when there is homogeneity among participants, muscle groups and target forces. According to the present study, if the objective is to analyze force reproduction in young male adults, focusing on knee extensors, with knee flexion of 60° and isometrical performance, the target force of 70% of MVIF would be the most appropriate to detect deficits because it was the target force that presented the least relative error in a sample of healthy adults.

CONCLUSION: The higher the force to be reproduced in an isometric contraction of the knee extensors, the smaller the relative error will be. This may be due to the significant differences found between the target force at 70% and the other two target forces at smaller percentages. Future studies should be performed to clarify the pattern of error in force reproduction tasks for healthy people. Also, future studies should analyze the relationship between force reproduction error, athletics performance and varied motor tasks. The capacity to reproduce force could also be investigated as a measure to predict injuries.

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