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Research Article

THE EFFECT OF QUADRICEP'S FATIGUE FOLLOWING ECCENTRIC AND CONCENTRIC CONTRACTIONS ON FORCE PERCEPTION IN KNEE JOINT

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ABSTRACT
Force perception, as one of the main components of proprioception in neural units of muscles, plays a key part. Considering the spreading trend of sports related injuries in knee joint at times of fatigue, and the differing characteristics of eccentric and concentric contractions of muscles, the purpose of this study is to look into the effects of fatigue after strenuous exercises on the discrepancies that occur in the level of accuracy in perceiving the employed force on knee joint. This research was a quasi-experimental study which was conducted on 20 healthy men with the age range of 18 to 28. In order to measure the maximum voluntary isometric force and certain reproduced amount of it, we used a specially designed dynamometer. The measurements were carried out in two stages with one week interval between them. In the first stage, the muscle's maximal isometric force (MVIC) and then the accuracy level in producing the target force (MVIC 50%) were recorded. Later, by the protocol of repeated walking up some stairs (repeated concentric contractions), the needed fatigue was achieved. Right after the fatigue, the muscle's maximum isometric force and the accuracy in producing the target force were measured. In the next stage of our study, the same procedures went on with this difference that implementing the fatigue was done by the protocol of walking down the stairs(eccentric contractions).the data were analyzed in the Even-T system and $p<0.05$ was adopted. The maximal isometric force in the muscle under examination after eccentric and concentric fatigue dramatically dropped in comparison to the figures before fatigue. The produced MVIC after eccentric contractions, compared with the one after concentric types, was marginally less. The average error rate after both kinds of contraction fatigue was notably high. In addition, the average absolute error in producing the target force in eccentric contractions was higher than in concentric ones. The accuracy in perceiving force is then reduced; consequently, this drop is more obvious in eccentric contractions. Disruption in sense of force might have a role in sports related injuries.

Keywords: *Knee, Quadriceps, Fatigue, Sense of Force*

INTRODUCTION
The dynamic stability of knee is complicated matter which functions through the coordination of different systems including mechanical hindrances of joints, proprioception, muscle's properties (strength, stamina, reactive response etc.) with central neural unit (William *et al.*, 2001). Proprioception is comprised of data carriers from skin receivers, joint receivers and, in particular, mechanical receivers of muscles that transfer such important information as joint position, the pace and acceleration of the movement, length and the strength of muscles to the central neural unit. And this unit utilizes the received data to control the muscles surrounding the joint (Riemann and Lephart, 2002; Proske and Gandevia, 1697). Accordingly, any defect or disruption in the Proprioception may cause physical injuries during exercises (Adachi and Uchio, 2002).
Proprioception includes sense of position, kinesthesia, and sense of force. Nowadays, researchers have focused their attention on the role and variations of sense of force at times of pain, swelling, fatigue, injury and disease. Sense of force is defined as the conscious perception of produced force in skeleton muscles, which is achieved through the proprioception and too the central mechanism of force perception (Proske and Gandevia, 1697; Jones and Hunter, 1983). The assessment of sense of force is made by

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reproducing a certain level of a muscle's maximum isometric contraction in both directions (Cafarelli *et al.,* 1995; Weerakkody *et al.,* 2003). In the measurement of sense of force, the individual is asked to produce maximal isometric contraction in the certain muscle at a determined angle of knee. Then, he is asked to reproduce a certain level with open eyes along with the examiners feedback. Finally, in the most important part of the test, he is expected to reproduce the target force (usually 50% of max isometric contraction) with closed eyes in both directions. Ipsilateral Remembered is referred to as production of a certain level of isometric contraction with the use of feedback and then remaking the target force in the same muscle without feedback (after an interval of time). This method has been used to evaluate the sense of force in this study.

Muscle fatigue is identified as a restricting factor in long lasting competitions and a major cause of injuries; in such a way that most sports related injuries take place in the final minutes of athletic competitions (McHugh *et al.*, 2007). Jones *et al.,* (1983), Brockett *et al.,* (1997) have reported that fatigue in upper organs can have a detrimental effect on perception of force in healthy individuals. Proske *et al.*, (2004) have indicated that fatigue due to both eccentric and concentric exercises increases the probability of error in reproducing force at elbow muscles. The absolute error in concentric contractions was higher and kept on this trend by the end of the exercises. They also reported that on painful joints, the force in the aching arm is measured lower.

Hortobagyi *et al.,* (2001) asserted that the force accuracy, and stability in maintaining it, did not have a meaningful relevance to the isometric force of muscle before and after strenuous exercises. Maximum error in measurement of force was observed in eccentric contractions, concentric contractions and isometric contractions respectively. Furthermore, the young individuals attained more accuracy than the older ones.

Some researchers also reported that due to fatigue in the ankle muscle, individuals under examination experienced difficulty in producing the target force and sense of force was decreased (Vuillerme and Biosgontier, 2008). Song *et al.,* (2006) propounded that with the increase in fatigue caused by isometric activity in knee area, there was a meaningful error in force reproduction that the individuals estimated the force larger than it really was.

In essence, eccentric and concentric exercises are different and research has shown that after intense eccentric exercise, it is more likely to inflict pain and injury to the muscle (Jones *et al.,* 1989). The knee joint is the most commonly vulnerable joint in sports related injuries and the role of fatigue is considered of key importance. The effect of fatigue after eccentric and concentric contractions during walking up and down stairs on sense of force has not been studied yet. Therefore, research in this area helps us understand more about the mechanisms in place for possible injuries. So the purpose of this study is to look into fluctuations in maximum force implemented by the quadriceps muscle doing eccentric and concentric contractions by walking up and down stairs.

MATERIALS AND METHODS

Methodology

Sample

In this semi experimental study, 20 healthy young men, ranging in age from 18 to 28, participated. The participants were chosen randomly; conditions to enter this study were: no surgical history in lower organs, no pain, swelling, weakness in knee muscles, no fractured or broken bone or any neural injury in knee muscles, no heart, respiratory disease, no use of painkillers, no addiction to alcoholic drinks or narcotics, no history of balance disorder or neurological diseases. The study samples consciously and voluntarily entered this study after filling out a consent form.

Measurement Tools

We used a specially designed dynamometer to precisely evaluate the target force. The sensors used to measure the forces are load cells manufactured in Korea whose technical properties are accessible in www.decell.com. The capacity to repeat the procedures has been assured of in preliminary examination.

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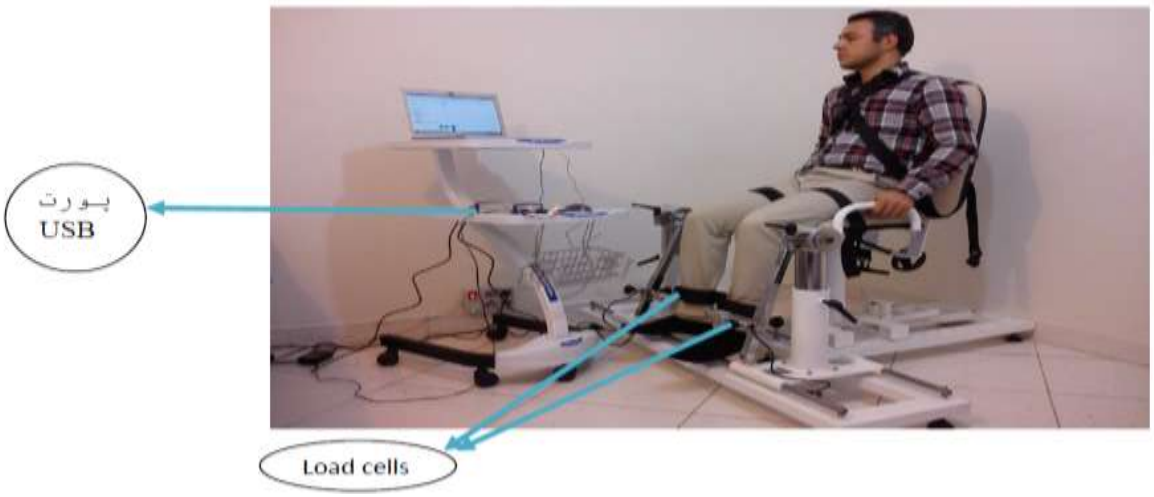

Figure 1: Measurement of Maximal Isometric Contractions and Reproducing the Target Force with the use of Dynamometer

All measurements are carried out on the right foot; all the records have been jutted down in two stages before and after concentric contractions and before and after eccentric contractions (one week later). The voluntary maximum isometric contractions were implemented while the case study was sitting on a chair observing the 70 degrees angle of knee. To prevent extra and unnecessary movements, the individual's body and thighs were fastened to the chair by a rubber strap. The maximum isometric attempt lasted for 5 seconds (with a 15 second rest time) and the highest amount was selected as the maximum isometric contractions. To measure the accuracy of force perception, at first, a familiarization process in which the participant produced the target force (50% of the maximum isometric contraction) was conducted. In this process, the participant was asked to reproduce 50% of the maximum isometric contraction along with visual feedback for 8 seconds. The individual repeated this work three times, and finally, after a 5 second interval, he does it without visual feedback. The latter contractions, without any visual feedback, are implemented three times as well each one lasting 8 seconds. The average of these three part processes is determined as the final measurement. All evaluations, after and before eccentric and concentric contractions, were written down in this way.

Creating Muscle Fatigue

For all participants, the quadriceps muscle was exposed to fatigue on the right foot. To create fatigue in concentric contractions, participants walked up some stairs on their prevalent foot. On each step, they pulled themselves up by putting their right foot on the next step; accordingly, the concentric contraction was achieved. On ascending to the next step, the left foot did relatively nothing at all and was just there to support the weight. While walking down the stairs, the right foot did not experience eccentric contractions and this cycle of walking continues until the individual is tired.

After a week of resting, eccentric contraction fatigue was put to test. To do this, participants were asked to repeat walking up the stairs on their left foot, so in ascending the stairs, the right foot was literally inactive. While descending the stairs, the individuals used their left foot and consequently the eccentric contractions were achieved.

This cycle kept on going until the individual feels fatigued in his right foot muscle. Right after the fatigue was observed all records were taken in producing the maximum isometric contraction and accuracy level in recreating the target force.

Data Analysis

In order to descriptively analyze the average, standard deviation max and min were used. Even-T system was used to assess the discrepancies in average data in dealing with both concentric and eccentric contractions ($P<0.05$).

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RESULTS AND DISCUSSION

Findings of the Study

The results of comparison between the max isometric contractions before and after fatigue are listed in table 1. The findings demonstrate that the max contractions dramatically dropped after muscle fatigue for both types (eccentric and concentric). The maximum eccentric contraction after fatigue was less than the max amount for concentric contractions.

Table 1: Comparison of maximal voluntary isometric contractions before and after fatigue

Sig.	SD	Mean	Variable
Comparison before and after concentric contractions(P<0.05)	8.25	14.304	Concentric contractions Mvc before fatigue
Comparison before and after eccentric contractions(P<0.0)	69.25	87.303	Eccentric contractions
Comparison before and after eccentric contractions(P<0.05)	87.26	86.283	Eccentric contractions Mvc after fatigue
Comparison before and after eccentric contractions(P<0.05)	83.25	36.269	Eccentric contractions

MVC: Maximal Voluntary Isometric Contraction, based on Newton

Results related to the comparison between the error in reproducing target force before and after fatigue are listed in table 2. The findings clearly demonstrate the fact that the error in recreating the target force was much larger after fatigue than before it. The error in eccentric contractions was larger than in concentric ones.

Table 2: Comparison of average absolute error in reproducing the target force

Sig.	SD	Mean	Variable
Comparison before and after concentric contractions(P<0.05)	24.3	14.5	Concentric contractions AE-MF before fatigue
Comparison before and after eccentric contractions(P<0.05)	9.2	5	Eccentric contractions
Comparison before and after eccentric contractions(P<0.05)	54.3	14.9	Concentric contractions
Comparison before and after eccentric contractions(P<0.05)	5.5	43.16	Eccentric contractions AE-MF after fatigue

AE-MF :Absolute Error in Matching Force

Discussion

The maximal voluntary isometric force and the average error level in reproducing the target force before implementation of fatigue in concentric contractions and a week later before eccentric contractions were

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almost the same (table 1 and 2). Therefore, the fatigue caused by the first stage of the study (concentric contractions) had no impact on the findings in the next stage, meaning, the fatigue completed faded away.
The results of this examination signify that the maximal force after fatigue dropped dramatically. All these results are in line with the findings of other researchers (Deeb, 1997; Skurvydas *et al.*, 2000) mainly because fatigue causes secondary factors to prevent muscles from producing the maximal force. The factors are: disruption in cross area of muscular and neural units, disruption in the mechanism of contraction and stimulation, disruption in the mechanism of calcium release, drop in energy sources, hydrogen ion accumulation and increase in PH (Fitts, 1996; Allen *et al.*, 1992). The reason behind the higher drop in eccentric contractions than the concentric ones may be due to some level of tissue damage; it is because muscle injury in eccentric contractions is more likely (Jones *et al.*, 1989).
Findings of this study showed that the average error in recreating target force both in eccentric and concentric contractions went up, and this means fatigue has tremendously negative effect on the accuracy of force perception. Perhaps it is because the sent data from proprioception or central perception mechanism get hindered (Brockett *et al.*, 1997; Proske *et al.*, 2004; Song *et al.*, 2006). As mentioned above, muscle fatigue after eccentric contractions has larger effect than concentric ones on the decrease of sense of force and growth of error.
Researchers propose that fatigue and injury lessen the capability of producing the necessary force; therefore, only the same amount of force is created with more and more attempt. It has also been argued that chemical changes inside muscles could have detrimental effect on muscle neural receivers (III, IV) that are sensitive to tension increase in muscles (Plaskett and Cafarelli, 2001).
Torres *et al.*, (2010) suggest that eccentric workout to the fatigue limit cause muscle injury and result in a change in proprioception and it is indicative of the fact that there may be disruptions in inner muscle fibers. As Weerokkody (2003) believes, pain increases the error in force perception and this is because data relating to pain may travel in such a way that it hinders motion neuron's function. Fatigue as a factor of growing error rate could cause failure in some athletic maneuvers. Interestingly enough, success in some fields like dart and basketball does not only depend on the power muscles produce but on the accuracy of desired force, which is achieved by an accurate contraction (Carson *et al.*, 2002). Failure in such sports could potentially stem from higher error rate and defect in proprioception force, and this is more intense in eccentric contractions. It is suggested that on individuals with joint injury, the effects of kinds of strenuous exercises, stamina exercises and controlled ones on the accuracy of force perception in knee joint be thoroughly studied.

Conclusion

Muscle fatigue, after eccentric contractions in particular, lessen the accuracy in reproducing a certain level of contractive force and force perception defect may be a major contributing factor of failure in some athletic performances and may lead to sports related injuries.

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