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Influence of Acute Back Muscle Fatigue on Repositioning Accuracy of the Knee Joint In healthy subjects

Authors

Amira H. Draz , Azza M. Atya, Ahmed M. Aboeleneen, Mohamed H. Elgendy

Department of Basic Sciences, Faculty of Physical Therapy, Cairo University

Corresponding Author

Amira H. Draz

Department of Basic Sciences, Faculty of Physical Therapy, Cairo University

Tel.: 0226705599. Mob: 0149411373

Email: *amira.draz@pt.cu.edu.eg*

Abstract

Background: *The proprioceptive system is responsible for the body coordination and stability; it is a major component of function and performance in the functional activity.* ***Purpose:*** *To investigate the effect of acute back muscle fatigue on repositioning accuracy of the knee joint in healthy subjects.* ***Design:*** *A pre test post test design* ***Methods:*** *100 healthy subjects of both genders aging from 18 – 22 years and body mass index from 20-25 kg/ m² participated in this study. Active angle repositioning test was used to assess the proprioceptive accuracy of the non-dominant knee joint at 45 degree knee flexion by Biodex system 3 pro isokinetic dynamometer pre and immediately after back muscle fatigue protocol used by biodex system.* ***Results:*** *The statistical analysis revealed that repositioning accuracy of the knee joint was significantly decreased ($p<0.05$) after fatigue protocol of the back muscle* ***Conclusion:*** *acute back muscle fatigue reduces repositioning accuracy of the knee joint.*

Key words: *acute back muscle fatigue, biodex isokinetic system, knee repositioning accuracy*

INTRODUCTION

Proprioception refers to neural cumulative input to the central nervous system (CNS) proceeding from specialized nerve endings called mechanoreceptors [(1)]. Information regarding limb awareness, position, force, and heaviness is provided by input which is received from the peripheral afferents (muscle spindles, joint receptors, cutaneous receptors, and Golgi tendon organs) and this refers to a proprioceptive mechanism[(2)].

The body can maintain stability and orientation during both static and dynamic activities by proprioception and also it is the process by which the body can vary muscle contraction in immediate response to incoming information regarding external force [3] Thus, proprioception correctly describes afferent information arising from internal peripheral areas of the body that contribute to postural control, joint stability, and several conscious sensations [4]

Proprioception plays a major role in muscular control, the precision of motion and the stability in joints. The skin, muscles, tendons, menisci, capsule and ligaments, in and around the knee joint contain several receptors, which contribute to perception of movement and position. Due to this control mechanism it is possible to adjust muscle tension and therefore improve joint stability [5]. Proprioceptive information can be used to correct velocity and timing errors induced by sudden perturbations of resistance during multijoint movement [6].

Fatigue may arise due to peripheral changes at the level of the muscle action, or failure of CNS to drive the motorneurons adequately [7]. Basically it is a protective mechanism that prevents us from exhausting metabolic reserves within muscle and limits the buildup of harmful metabolic products. It also reduces continual generation of high forces, which may cause damage to the contractile elements[8].

Fatigue also alters central processing of proprioception. With fatigue, cortico-motor neuronal cells firing rates decrease and motor-evoked potentials increase suggesting inadequate cortical output. Besides, central fatigue may induce deterioration of cognitive functions. For example, following mental fatigue, subjects are still able to perform automated tasks but performance in complex tasks deteriorates .Also, when producing submaximal contractions at the elbow, a constant force production can be obtained at the cost of increasing central command intensity. This process is not automatic and it was suggested the presence of a mutual interaction between cognitive functions and the central mechanisms driving motor behavior during fatigue [9,10].

Impaired joint proprioception at the same joint where fatigue was induced has been reported for numerous joints. Joint position and motion is sensed through various mechanoreceptors, including GTOs, muscle spindles, and cutaneous receptors. Several reports have demonstrated that muscle spindle and GTO activity may be decreased with fatigue [11]. Similarly, it was outlined that a fatigue-mediated alteration in joint proprioception, pointing to changes in afferent output from joint and muscle receptors as the cause for impairment. [12]

Fatigue may impair the proprioceptive and kinesthetic properties of joints. It increases the threshold of muscle spindle discharge, which disrupts afferent feedback, subsequently altering joint awareness [13].

Many authors have studied the relationship between muscle fatigue and proprioception. It was reported that impairment in the ability to sense a change in lumbar position following lumbar fatigue for both low back trouble patients and control subjects and found that the proprioceptive accuracy of the lumbar was decreased, but patients with low back trouble had poorer ability to sense a change in lumbar position than control subjects even when the subjects were not fatigued. As such, a loss of proprioceptive acuity in the lumbar extensors with fatigue may result in larger movements at the lumbar spine during quiet standing, and a concomitant increase in postural sway. [14]

Lumbar extensor fatigue impairs ankle proprioceptive acuity as quantified by ankle joint motion sense (JMS), which may help explain observed increases in postural sway subsequent to lumbar extensor fatigue. [11]

When a muscle is fatigued, fewer motor units are available to call on during muscle contractions [15].

Lumbar muscle fatigue causes biomechanical adaptations during lifting tasks [16] and reduces trunk proprioception [14].

Persons with chronic LBP commonly show weak or unbalanced trunk muscles and tend to experience a quicker rate of fatigue during sustained lumbar extension exercise. This muscular deficiency may impose lower extremity muscular adaptations during fatiguing exercise to maintain stability and preserve normal function. Recently, more QI was observed after fatiguing lumbar extension exercise in persons with healthy knees, indicating that the quadriceps may be adapting in response to lumbar paraspinal fatigue [17].

The effect of lumbar paraspinal muscle fatigue on the knee joint proprioception has not been clearly established. If this effect can be reliably established, rehabilitation protocols could be altered to include proprioceptive training of the knee joints in cases that excessive fatigability of the back extensor muscles is common as in patients with chronic low back trouble. Also the effect of gender has to be investigated as some investigators had found no effect of gender on fatigue [18]

Materials and Methods

Subjects

One hundred normal subjects of both sexes were participated in this study. Subjects were recruited in voluntary base from the students of faculty of physical therapy, Cairo University. They had an age ranged from 18 to 22 years and their body mass index ranged from 20 to 25 kg/m². All volunteers provided written consent for participation

Instrumentation:

Biodex system 3 pro Isokinetic dynamometer (Biodex Medical INC., Shirley, New York, USA), equipped with a special forward reclined back attachment was used to measure the reposition accuracy of the knee joint and to induce lumbar paraspinal muscle fatigue

Procedures:

Pre fatigue reposition accuracy of non dominant knee was measured and immediately after lumbar paraspinal muscle fatigue.

Knee repositioning accuracy:

Proprioception accuracy as represented by repositioning accuracy was assessed for non dominant knee by the Biodex system 3 Pro Multijoint system isokinetic dynamometer (Biodex Medical Inc., Shirley, NY) through active repositioning test by examining the ability of subjects to reproduce actively an angle at which the joint had been placed before in non weight-bearing position. Leg dominance was established by asking the subject which leg they preferred to use to kick a ball [19].

Measurement procedure

Each subject was asked to sit on the chair of the Biodex system with the knee of the tested leg aligned with the axis of the dynamometer and positioned in 90° flexion (starting position), the subject was stabilized in the test position by straps around the trunk, pelvis and thigh and was blind folded to eliminate visual input during testing, the tibial pad was secured to the shank 3 cm superior to the lateral malleolus [20]. Type of test was chosen (active repositioning test with speed 30°/s) with three repetitions for each test. Prior to testing each subject performed 2 tests to be familiarized with the procedures [21].

Initially the anatomical reference angle was set at 45° then the subject leg was returned to the starting position [20].

For standardization, the tested limb was allowed to move to target angle (45°) actively [22] then was held for 10 seconds as a teaching process for the subject so the subject could memorize the position, and then the limb was allowed to return to the starting position by the apparatus [20].

After a 5-second rest, the subject was asked to move his limb to the target angle (45°) actively, when the subject felt that he/she reached the target angle actively he would stop the apparatus using the Hold/Release button. Subjects were not permitted to correct the angle [22,20]

Three trials were done with rest period of 30 seconds between each trial [23].

The mean angular differences of the 3 trials, between the target angle position and the subject perceived end range position (absolute error) was recorded in degrees as the deficit in repositioning accuracy and was used in the statistical analysis [(19)].

Lumbar fatigue exercise

The examiner set the parameters of the isokinetic dynamometer on the fatigue model. The subject was seated on the trunk flexion/extension unit of the Biodex system. Knee block position was individually adjusted by two curved anterior leg pads, the feet were held in a position with no contact with the floor, both thighs were stabilized by two straps, the pelvic brace was then applied and positioned as far down as possible to press firmly but comfortably against the superior aspect of the proximal thighs.

In addition, lumbar pad was located against the lower lumbar spine. The head was stabilized neutrally on adjustable head rest

Each subject was positioned into an upright neutral starting position. This position was such that the anterior superior iliac spine and the posterior superior iliac spine were aligned in the horizontal plane [(24)]. The spinal range of motion (ROM) was adjusted between 80 degree flexion and 10 degree hyperextension as recorded through the Biodex system. The subject would perform isokinetic lumbar flexion and extension at a speed of 60°/s [(25)]. The subject was instructed to perform maximal effort. The mean value of maximal voluntary contraction (Peak torque) of the lumbar extensor was obtained, the subject continued in exercise until the lumbar extensor peak torque dropped below 50% for 3 consecutive repetitions [(26)]

Post fatigue knee repositioning accuracy:

Immediately after lumbar paraspinal muscle fatigue, the knee reposition accuracy test was performed with the same previous procedures.

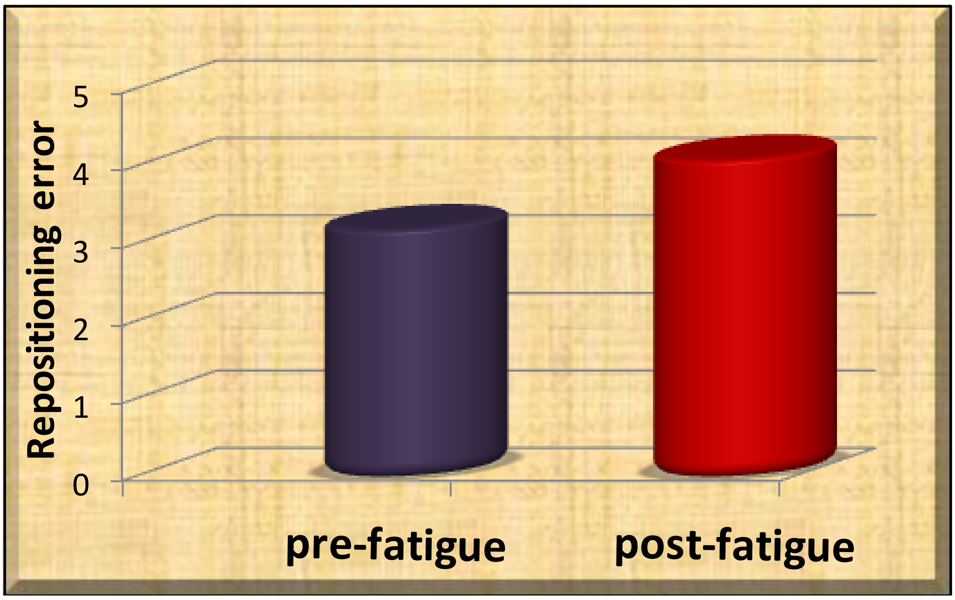

Fig.1. Comparison between knee joint repositioning error pre and post lumbar paraspinal muscle fatigue

RESULTS

One hundred healthy subjects aged from 18 to 22 years who fulfilled the inclusion criteria participated in the study. Demographic characteristics are clarified in Table (1).

Table 1.Demographic Data of 100 healthy subjects

Characteristics Mean ± SD	Mean ± SD
Age (years)	19.18 ±.7
Weight (kg)	67.61 ±4.1
Height (cm)	170.8 ±3.9
Body mass index(BMI)	23.3 ±1.1

Knee joint repositioning error	Pre paraspinal muscles fatigue	Post paraspinal muscles fatigue
Mean	3.2	4.1
±SD	±1.12	±2.11
Mean difference	-.985	
Stander error	0.183	
DF	99	
t-value	-5.3	
P-value	0.0001	
S	S	

*SD: standard deviation, P: probability, S: significant, DF: degree of freedom. $P < 0.05$

Table (2) demonstrated the knee joint repositioning error pre and post lumbar paraspinal muscle fatigue for 100 subjects. There was a significant difference in the paired t-test between knee joint repositioning error pre and post lumbar paraspinal muscle fatigue as the mean value of pre lumbar paraspinal muscle fatigue was (3.2±1.12) and for post lumbar paraspinal muscle fatigue was (4.1±2.11) where the t-value was (5.3) and P-value was (0.0001).

DISCUSSION

This study was conducted to investigate the effect of lumbar paraspinal muscle fatigue on knee proprioception in 100 healthy subjects. The active repositioning test or active angle reproduction test was used to measure the proprioceptive accuracy of the knee joint by Biodex system 3 pro isokinetic dynamometer pre and immediately after lumbar paraspinal muscle fatigue. The proprioception accuracy was measured on the non-dominant leg which was determined by asking the subjects to kick a ball and this was to avoid the effect of limb dominance on proprioception, also fatigue was determined according to the fatigue model of the isokinetic dynamometer where the mean value of maximal voluntary contraction (Peak torque) of the lumbar extensor was obtained and then the subject continued in exercise until the lumbar extensor peak torque dropped below 50% for 3 consecutive repetitions. The results of the current study showed that the proprioceptive accuracy of the knee joint was significantly decreased after fatiguing exercise of the lumbar paraspinal muscle at 45 degree of knee flexion ($p<0.05$).

The reduction of the knee proprioceptive accuracy after lumbar paraspinal muscle fatigue may be explained by one of the following mechanisms: first, during local muscle fatigue' nociceptors are activated by metabolic products of muscular contraction including bradykinin , arachidonic acid , prostaglandin E2 , potassium, and lactic acid ,these metabolites have a direct impact on the discharge pattern of muscle spindles which represent the peripheral component of fatigue [(27)].

Second, the lower extremity motor neuron excitability altered as a result of change in afferent information from the sacroiliac joint capsule. Similarly, changes in afferent information from the muscle and joint mechanoreceptors and proprioceptors in the lumbar spine due to prolonged intense fatiguing exercise may affect quadriceps motor neuron excitability. Difficulty maintaining appropriate positioning and stability of the trunk as a result of excessive fatigue may affect lower extremity joints during activities and may help to describe lower extremity injury risk in persons with poor core and trunk stability[(28)].

Sharpe and Miles, 1993 reported changes in proprioception at the elbow resulting from fatigue at either the ipsilateral or contralateral elbow. In an attempt to explain changes in proprioception with contralateral elbow fatigue, they hypothesized that the proprioceptive signals remained unchanged, but the central processing of these signals suffered from fatigue induced changes. In the present study, it is possible that lumbar extensor fatigue, though localized, induced central fatigue which contributed to a general decrease in processing of proprioceptive signals and thus a decrease in proprioception[(29)].

The findings of this study were in line with the findings of **Pline et al., 2005** who investigated the effect lumbar extensor fatigue and circumferential ankle pressure on ankle joint motion sense and they concluded that muscle fatigue of the lumbar extensors decreased ankle JMS[(30)].

The results were supported by a study of **Olmedo and Rodríguez , 2009** who study the immediate effects of an upper body fatigue protocol on knee joint position sense, measured by a position matching technique and the results showed a significant increase in absolute angle error (AAE) for the angles measured from pretest to posttest in the fatigue group and no significant differences from pretest to posttest in the control group[(31)].

Also the findings of the current study were in agreement with **Voight et al., 1996** who studied the effect of muscle fatigue on shoulder proprioception and it was found that there was a significant decrease in proprioception ability with fatigue, at the same time no significant difference between dominant and non dominant extremities was found [(32)].

Furthermore the results were consistent with **Taimela et al., 1999** who reported impairment in the ability to sense a change in lumbar position following lumbar fatigue for both low back trouble patients and control subjects and found that the proprioceptive accuracy of the lumbar was decreased, but patients with low back trouble had poorer ability to sense a change in lumbar position than control subjects even when the subjects were not fatigued. So a loss of proprioceptive acuity in the lumbar extensors with fatigue may result in larger movements at the lumbar spine during quiet standing, and a concomitant increase in postural sway [(33)].

Miura et al., 2004 studied the effect of local and general fatigue on knee proprioception by measuring AAE at matching defined index angles before and after local and general fatigue protocols and they found significant increase of AAE after general fatigue and they suggest that decreased reproduction ability after general load is not due to the loss of peripheral afferent signals, but to other factors, especially deficiency of central processing of proprioceptive signals [(34)].

On the other hand the results of this study were disagreement with the results of other studies for the knee **(Marks and Quinney 1993)[(35)]**, elbow **(Sharpe and Miles 1993)[(29)]** and shoulder joint **(Sterner et al. 1998)[(36)]** that revealed no effect and this may be due to the difference in fatiguing protocol and proprioception assessment methods used.

CONCLUSION

Based on the finding of this study, it was concluded that Fatigue of lumbar paraspinal muscles decreased knee proprioception accuracy in health subjects.

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