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Original articles

The Influence of Hand Muscle Fatigue and Fatigue Recovery on Joint Position Sense in Healthy Subjects

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Purpose: The first purpose of this study was to evaluate whether hand muscle fatigue alters sensorimotor control of the hand in healthy subjects, using hand position sense. The second objective was to assess the repositioning variables during a 7.5-min period after the fatigue protocol.

Methods: Participants performed a repeated handgrip movement to induce the fatigue condition as fast as possible, until they could no longer continue. Recordings were performed before (pre-fatigue) and after the completion of the fatigue exercises (immediately: post-fatigue, after a 2.5 min recovery, after a 5 min recovery and after a 7.5 min recovery).

Results: The joint reposition test of the MP joint in the post-fatigue condition showed higher reposition errors than the pre-fatigue condition ($p<0.05$). Additionally, there was a significant difference in recovery of joint reposition errors after fatiguing exercises of the hand muscle, among groups ($p<0.05$).

Conclusion: The fatigue of the hand muscles affected joint position sense by an alteration of somatosensory and proprioceptive information. Nonetheless, the effect of hand muscle fatigue was short-lived, since joint reposition errors decreased to post-fatigue values after 7.5 min of recovery.

Key Words: Hand function, Joint position sense, Muscle fatigue

I. Introduction

Muscle fatigue is a progressive loss of maximal force capacity and muscle strength during a sustained contraction.[1,2] Proprioceptive sense is defined as the ability to sense actions of own body and the cumulative neural input to the central nervous system from specialized nerve endings called mechanoreceptors.[3–6] It is the relationship between muscle fatigue and proprioceptive sense.

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Muscle fatigue has been shown to negatively influence proprioceptive sense. Several studies investigated the effects of muscle fatigue on the ability to reproduce movement in reposition sense.[7–9] Muscle fatigue impairs reposition sense of various joints, such as shoulder, elbow, knee, and ankle.[10–13] Allen et al.,(2007) reported that position sense at the elbow joint and exercise of elbow flexor muscle produced position errors, where the exercised was perceived as more extended than the non–exercise.[10] These studies used the assessment method of position sense or reposition errors for the evaluation of change in proprioceptive sense after muscle fatigue. Even though a diminished proprioceptive sense can be expected in healthy participants after a fatigue protocol, it is still unknown whether these alterations affect a short adaptation to acute muscle fatigue or a phenomenon which lasts over a long period.

Furthermore, hand function especially, is the essential kinesiology of many work– and sport–related activities.[14] To our knowledge, however, few studies have explored the influence of hand muscle fatigue on reposition sense of proprioception after the fatigue protocol in hand flexion (finger flexion). Therefore, the first purpose of this study was to evaluate whether hand muscle fatigue altered sensorimotor function control the hand in the healthy subject, using a hand position sense. The second objective was to assess to repositioning variables during a 7.5–min period after the fatigue protocol.

II. Methods

1. Subjects

Twenty one healthy subjects, without known neuromuscular impairment, volunteered to this study. All of the subjects were right–handed, according to the modified Edinburg Handedness Inventory. Subjects who reported symptoms in the neck, shoulders or arms within the previous year, or had a history of musculoskeletal disorders in the upper limb, were excluded from the study. All included subjects understood the purpose of this study and provided their written informed consent prior to participation. This study was approved by the local Institutional Review Board and was in accordance with the ethical standards of the Declaration of Helsinki.

2. Experimental methods

Subjects sat on a chair without armrests (back against the chair back, with hips and knees flexed at 90°, shoulders adducted and neutrally rotated, elbows flexed at 90°, forearm in 0 rotation and wrist in 0–30° of dorsiflexion). Hand muscle fatigue was achieved by performing handgrip until subjects insisted on stopping. The fatigue protocol was stopped when the participant indicated that he was unable to continue, when the movement frequency fell below. This fatigue protocol has been proven in previous.[15–17] Verbal encouragement was given to ensure maximal effort. Joint position sense test was measured before (pre–fatigue for PRE condition) and after the completion of the muscle fatiguing exercises (immediately: post–fatigue or POST condition). Additionally, the recovery of joint position sense test was evaluated 2.5 min after the fatiguing exercise (POST2.5), 5 min after the fatiguing exercise (POST5) and 7.5 min after the fatiguing exercise (POST7.5).

MP (metacarpal phalangeal) joint position sense: MP joint position sense was evaluated by a repositioning test. Participants were seated in front of a table, of which the height was adjusted to the level of their xiphoid process. The rested elbow on the table was flexed approximately 90°, and the forearm was supported on comfortably foam. Participants held a custom–made rotator machine with a built–in potentiometer on the table using their dominant upper limb, which was allowed to rotate at the horizontal axis. The experimental apparatus for the MP joint position tests included a custom–made button (7×5 cm), a plastic–made frame for restriction of metacarpal and carpal joints, and analog–to–digital data acquisition software using SuperLap Pro Ver 2.0. The digital potentiometer signal was transferred to a personal laptop computer (IBM T41, USA), and the signal was changed to angular degrees. The subject's limb was situated passively at an angle by an evaluator and held in place for 3 s. The MP joint was then returned to the flexion position. Participants were instructed to actively reproduce the MP joint extension and flexion on the vertical axis that was passively positioned by the evaluator. The subjects wore a blindfold to eliminate visual feedback. The joint reposition error was measured between the passively positioned angle and actively repositioned angle. The mean value from 2 trials was adopted.

Data were analyzed with SPSS version18. Pre– and post–data of the fatiguing exercise were examined using the within group paired t–test; and analysis of variance (ANOVA) was conducted to determine the effects of upper limb fatigue on recovery of joint position sense. The alpha was set at 0.05 with LSD adjustments for multiple comparisons.

III. Result

The mean age of the 21 healthy subjects (9 men and 12 women) was 25.50± 3.42 years. The mean ± SD for the joint reposition test of pre– and post– muscle fatigue

Table 1. The comparison of Joint reposition error at pre-test and post-test

	PRE	POST	P
Reposition error(°)	3.17 ± 1.45	8.83 ± 1.28	0.000*

Mean ± S.D
* significant difference (p<.05).

Table 2. Mean and SD of the joint reposition error before and after fatigue exercises

	POST	POST (2.5)	POST (5)	POST (7.5)	P
Reposition error(°)	8.83 ± 1.28	5.33 ± 1.61 †	4.31 ± 1.37 ‡	3.39 ± 1.34 §	0.000*

Mean ± S.D
* significant difference (p<.05).
† significant difference compared with the POST (p<.05).
‡ significant difference compared with the POST 2.5 (p<.05).
§ significant difference compared with the POST 5 (p<.05).

condition were shown in Table 1. The joint reposition test in the POST condition showed higher reposition errors than the PRE condition ($p<0.05$).

There was a significant difference among groups in recovery of joint reposition errors after the fatiguing exercises ($p<0.05$) (Table 2). The POST condition was significant increased as compared to POST2.5, POST5 and POST7.5 conditions, according to the post-hoc test. Additionally, POST2.5 was significantly increased as compared to POST5 and POST7.5 conditions. Finally, POST5 was significant increased than the POST7.5 condition.

IV. Discussion

We investigated the effects of hand muscle fatigue on joint position sense in healthy subjects, in the current study. The results of our study showed that joint reposition errors increased post-fatigue, as compared to pre-fatigue. Additionally, decreased joint reposition errors occurred between 2.5 and 7.5 min after the fatiguing exercise as compared with post-fatigue. Therefore, fatigue of the hand muscles affected joint position sense because it induced an alteration of somatosensory and proprioceptive information. Nonetheless, the effect of hand muscle fatigue was short-lived since joint reposition errors decreased to post-fatigue values after 7.5 min of recovery.

Our results we stemmed from the observation that the fatigue protocol of a particular muscle group led to significant position-matching errors at the joint reposition sense. Similar observations were made in previous studies.[3,18-21] A previous study measure in shoulder position sense before and after a fatiguing task involving the internal or external rotator muscles by repeated shoulder joint rotation. The reported finding was that joint reposition error increased significantly after the fatigue task.[7] Our finding that fatigue of the hand muscle led to perception of a higher joint reposition error indicated that the tiring hand tends to overextend hand movement. Search for an explanation for the effects of fatigue on position sense, led us to speculate that subjects who exercised the fatigue protocol perceived the exercised muscle as shorter or longer than in actuality.

The mechanism behind the relatively changes in conscious hand motor control after exercise of the hand fatigue protocol is unclear, despite the well established concept that proprioceptive sense is mediated through joint and muscle receptors.[22] Furthermore, it is known that joint and muscle receptors mediate change in efferent output of muscle which control the joint.[23] It seems that neuromuscular control is interrupted for a short period, because muscle fatigue may lead to an increased threshold of muscle spindle discharge. Therefore, it provides preliminary evidence that hand muscle fatigue and hand motor control parameters during muscle fatigue may be interrelated.

Additionally, our study was the first to assess the recovery of motor control parameter of the hand after a muscle fatigue protocol. Joint position errors were the highest immediately after the muscle fatigue protocol, and disrupted proprioceptive sense due to muscle fatigue gradually recovered over a period of time. Thus the effects of muscle fatigue on proprioceptive sense were limited and seemed to be closely related in time to the neuromuscular effects of fatigue. A previous study reported that a rest interval as short as 10 min was sufficient for trunk extensor muscles to recover completely from a static trunk extension fatigue protocol.[21] This study which was conducted on muscle recovery from a short fatigue test was consistent with the results of our study.

In summary, the results of our study suggested that fatigue of any limb muscle can lead to a change in perceived position of a particular joint that gradually recovers as a function of the time. Several limitation should be taken into account when interpreting the data. We performed concentric exercise alone, to fatigue the flexion muscle of the hand and did not consider hand extension. The fatigue of both intrinsic and extrinsic muscle would be induced by muscle fatigue protocol through hand flexion. However, we did not consider to a specific fatigue protocol for the MP joint. Our study evaluated joint position sense over flexion of MP joint which instrinsic muscle is mainly acting. Additionally, we only measured 7.5 min of fatigue recovery after the fatiguing exercise. However, our study was valuable to elucidate the effect of acute hand muscle fatigue and fatigue recovery after the fatiguing exercise. We expect that the effect of muscle fatigue will be clarified by further study considers control variables, which can affect muscle fatigue on proprioceptive sense.

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