A Psychophysical Study of Muscle Fatigue and Post-exercise Muscle Soreness of First Dorsal Interosseous Muscle of Hand

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Abstract

Eleven males, aged, 23.6 ± 0.61 years (mean ± sem) were studied at before, immediately after, 24 and 48 hours after eccentric exercise. Post-exercise muscle soreness (PEMS) was induced in the first dorsal interosseous (FDI) muscle of the dominant hand by a standardised eccentric exercise. Effort score during the eccentric exercise was scored on a verbal numerical scale. Pain and heaviness sensations were assessed on a visual analogue scale (VAS) in response to 0.936 kg load on the FDI. In addition PEMS was measured on VAS after 10 unloaded abductions of the finger. Heaviness and pain correlated at 24 hours (Pearson R = 0.622, P < 0.04) at the time when PEMS was most significant (P<0.05). The stretching of index finger with a load of 0.936 kg weight without any voluntary contraction or by one maximal contraction resulted in a significant pain at 24 to 48 hours (P < 0.05), but the pain during these two experiments did not differ from each other. It is concluded that the PEMS is not simply the result of activation of sensitized mechanoreceptors alone, but is the result from the interactions between different sensations from the FDI and the brain.

Keywords: *Muscle Fatigue, Heaviness, Post-exercise muscle soreness, Eccentric exercise*

1 Introduction

Physiologically the fatigue is described as a reduced capacity to sustain force or power output [8;19]. Repetitive eccentric contractions result in reduced force production by the muscles [14;10]. It is suggested that during fatigue the motor units originally chosen for the task will become unable to sustain the original mechanical power output [20]. Both lower and upper limb muscle EMG characteristics are similar during fatigue and are associated with loss of force [21]. The clinical utility of this study can be judged from the difficulties encountered due to the fatigue associated with sports involving eccentric actions on the hand muscles, such as in baseball. The inability of the hand muscles to handle the force loads on the base of index finger and on the lower hypothenar eminence created by high velocities of the tennis ball may predispose the hand muscle to injury [9]. The sense of force, as well as the sensations of position and movement, is thought to constitute the complete kinesthetic sense [12;17]. The interaction between post-exercise muscle soreness (PEMS) and kinesthetic senses is not fully understood [3;20] and has not been studied in eccentric exercise by psychophysical methods.

2. Material and methods

2.1 Subjects:
Eleven healthy right-handed males, aged, 23.6 ± 0.61 years; height 176.5 ± 2.8 cm; weight 72.1 ± 4.3 kg, and hand length 18.79 ± 0.2 cm (mean ± SE) were examined at before, immediately, 24 and 48 hours after eccentric exercise. Before participation in the testing procedures, all subjects signed an informed consent form and the study was conducted in accordance to the declaration of Helsinki.

2.3 Hand exercise apparatus:
By resisting 125% concentric maximum voluntary contraction (MVC) weight, the right index finger performed six bouts of standardized eccentric exercises till the FDI had fatigued. The design of the apparatus ensured that the experimental eccentric exercise involved primarily the FDI muscle of the right hand [2].

2.4 Assessment of pain after 10 unloaded abductions:
Subjects rated pain on a VAS (0-10 cm) after carrying out ten maximal abductions with an unloaded index finger at the maximum speed in the test and contralateral hands. Post-exercise relative changes between the test and the control hands were calculated at all times before and after the eccentric exercise.

2.5 Sense of effort:
'Sense of effort' was defined, as the sensation perceived by the subject during the eccentric exercise. Subjects reported effort on a verbal numerical rating scale (0 – 4).

The 0 = “no effort”, 1 = “mild effort”, 2 = “moderate effort”, 3 = “severe effort” and 4 = “extreme effort”. Effort bout score was calculated as mean of effort rated for each eccentric contraction.

2.6 Sensation of heaviness and pain:
Heaviness and pain were scored separately on the VAS (0-10 cm) scales after the finger was loaded with 0.936 kg for 5 seconds. Subjects were instructed to keep their finger muscles relaxed and not to make any voluntary effort to contract their muscles. In other words, heaviness was being generated from the process of cognition.

2.7 Pain on one maximum abduction movement:
Subject was instructed to make one-maximum FDI abduction with 0.936 kg. Subjects reported pain on VAS (0-10 cm) immediately after this procedure.

3. Statistical analysis

The data were expressed as means ± standard error of the mean (SE). It was evaluated by 1 & 2 – way analysis of variance with repeated measures (RM ANOVA). The post-hoc analysis by a Student-Newman-Keuls test (SNK) for multiple comparisons was carried out if a significant main effect was revealed. Pearson’s correlation test was applied to measure the strength of correlation between variables. Significance was accepted at $P \leq 0.05$.

4 Results:

4.1 Number of eccentric contractions and the effort score:
Although the number of abductions significantly reduced in bouts 2-6 as compared to bout 1 (SNK, P <0.05), the mean effort score perceived during eccentric exercise was insignificantly different in all bouts (see figure 1).

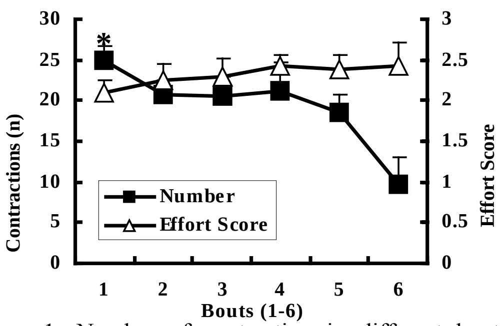

Figure 1: Number of contraction in different bouts of eccentric exercise were significantly higher in bout 1 as compared to bouts 2 to 6, while the effort score remained constant. *: SNK, P < 0.01.

4.2 Pain after 10 unloaded abductions:
There was a significant effect of time, hand and interaction between time and hand together (P < 0.04). Significant pain was found only in the test hand at 24 and 48 hours (SNK, P < 0.05) (see figure 2).

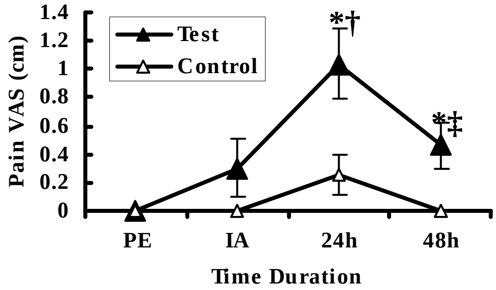

Figure 2: * indicates significant increased pain at 24 and 48 hours after exercise as compared to the control hand (P < 0.05). †indicates significant pain at 24 hours as compared to before, immediately after and 48 hours after exercise (P< 0.05). ‡indicates significant pain at 48 hours as compared to before exercise (P < 0.05).

4.3 Heaviness during loading on the index finger in a relaxed position:
The time course of change in heaviness with 0.936 kg showed no significant change at all times before or after the exercise (SNK, P = 0.23) (see figure 3).

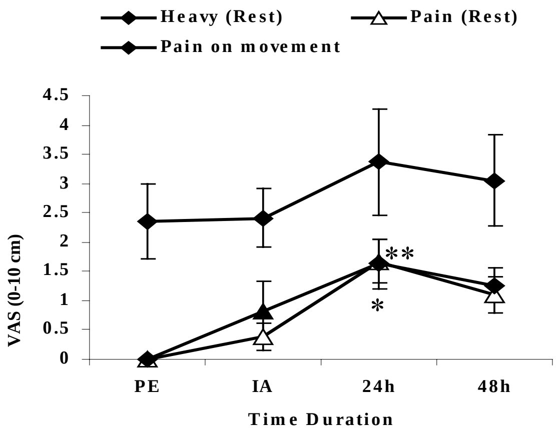

Figure 3: Showing time course changes in heaviness with 0.936 kg (1-RM ANOVA) and pain at rest or after one maximum abduction with 0.936 kg after the eccentric exercise (2-way RMANOVA). *indicate pain at rest SNK P <0.05 as compared to before and immediate after. ** indicates pain during movement SNK P <0.05 as compared to before exercise.

4.4 Pain on loading the index finger with 0.936 kg in a relaxed position and during movement:
There was a significant effect of time (SNK, P < 0.05) but not between rest or motion (SNK, P < 0.48) (see figure 3). Heaviness report from 0.936 kg weight correlated significantly with the pain report from the same weight at 24 hours after the exercise (Pearson’s R=0.622, P<0.04) (see figure 4).

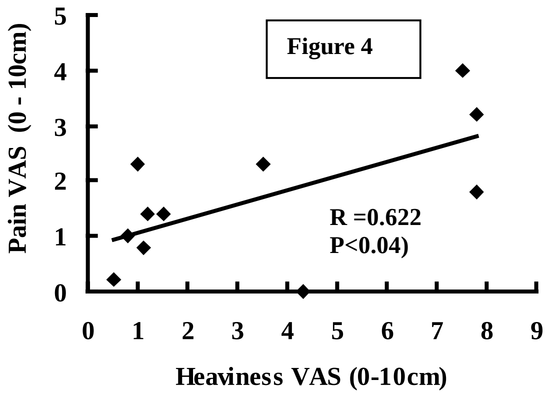

Figure 4 Correlation at 24 hours between heaviness and pain report with a load of 0.936 kg on a relaxed index finger in neutral position (Pearson's correlation coefficient = 0.622, P < 0.04).

5 Discussion

PEMS was maximum at 24 hours and was still present at 48 hours after exercise. Sensation of pain and heaviness reported during loading of 0.936 kg weight on the index finger at 24 hours was correlated.

5.1 Effort Score:
During the first bout the muscle was fresh and the sensation of effort was mainly due to the metabolic demand imposed on the muscle due to the rate and force of contraction of FDI. During the sixth bout the muscle fatigued and then probably the increased central drive resulted in an additive effect on the sense of effort, suggesting that this is a central fatigue.

5.2 Heaviness and Pain:
During heaviness report in a relaxed state, the mechanoreceptors from the skin and the joint may only contribute to a report of heaviness rather than the muscle spindles [4;11]. Others suggest that sensation of heaviness is a cognitive phenomenon and is derived from neural correlates (corollary discharges) of the descending efferent command [7]. The increase in muscle spindle activity during movement of the loaded finger and increased firing from the damaged muscle tissues did not change the pain intensity felt at 24 and 48 hours after the exercise as compared to pain report during the relaxed resting state. The group III afferents are easily activated by contractions of their parent muscles [16]. Background firing in the spinal neurons increase after induction of muscle soreness in animal experiments [5;6]. Eccentric exercise is associated with increased swelling in the tissues and the reduced range of movement of the joint [15]. Muscle injury due to eccentric exercise changes the chemical milieu of the injured muscle [1;18]. Stretching of eccentrically damaged FDI by moving the load attached to the finger might increase the discharge from the sensitized afferents, as shown in the experimental studies [13]. In the present study it appears that the sensitization of the tissues induced by the eccentric exercise damage is such that it might have saturated the background firing of spinal neurons by a simple stretch with 0.936 kg at rest. The other possibility is that the contributions of cognitive mechanisms in the form of central commands are contributing to the pain rather than the peripheral sensitization.

6 Conclusion

It is concluded that the PEMS is not simply the result of activation of sensitized mechanoreceptors alone, but is rather the result of the interactions between different sensations from the FDI in the brain. Further studies with a combined use of microneurography and central nervous system investigations may be undertaken to prove the findings of this psychophysical study.

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