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学位論文の要旨

The prevalence of work-related muscle pain is large in the general population, especially in the caregivers working in elderly institutions. Despite significant advances over recent years in some research areas, the mechanisms of why work-related muscle pain occurs and the pathophysiological mechanisms behind the disorders are still unclear. One suggested explanation is that such pain is caused initially by a limitation of the local muscle circulation, oxidative metabolism and fatigue. There is a lack of objective methods to measure the development and diagnosis of muscle fatigue and necessary recovery time. Low back muscles with their relatively small moment arms in relation to external forces contribute significantly to loading across intervertebral joints. These loads can challenge both tissue and structural tolerance of the spine. Not surprisingly, mechanical factors are often identified as the primary cause in a large proportion of low back disorders.

(1) Oxidative metabolism in muscle with Near-infrared spectroscopy (NIRS)

Since the end of the 1980s, NIRS has been used to investigate local muscle oxidative metabolism at rest and during different exercise modalities. NIRS is a non-invasive technique that allows for determination of oxygenation and blood flow. The parameters commonly measured by NIRS are oxyhemoglobin/myoglobin (Hb/MbO2), deoxyhemoglobin/myoglobin (Hb/MbR), and total hemoglobin/myoglobin (THb/Mb). Using NIRS, Chance et al (1992) reported that recovery time is the balance between oxygen supply and oxygen demand as the bioenergetic resources are restored following determined exercise. On the other hand, it can be interpreted as a measure of the time needed for replenishment of oxygen and energy deficits occurring during exercise by tissue respiration under adenosine diphosphate control.

The purpose of this thesis was to evaluate NIRS (1) as a method for measuring muscle oxygenation recovery time and hemodynamics for the erector spinae muscle (ESM), and (2) to investigate whether

variables measured by NIRS differed between isometric and isotonic contraction in healthy subjects.

(2) Analysis of the recovery time based on reoxygenation period from incremental test after sustained isometric exercise.

The aim was to calculate the half time to recovery (hTR), along with its predictors, based on an incremental test using NIRS. As well as, to attempted to examine the interrelationship between the NIRS and EMG variables assessing the metabolic and electrophysiological condition of the ESM during and after isometric task. All subjects performed six incremental static trials over time randomly as follows: 10, 20, 30, 40, 50, and 60s, with 15 min rest between each trial. A fast linear decreasing phase of oxygenation index at the beginning and a constant decreasing until the end of exercise. The recovery period was followed by systematic increase of oxygenation index with the values being at or near baseline during the final 2 minutes. There were progressive and significant increases in the hTR of ESM related to the incremental time. There was a negative trend for a relationship between MF slope during the BSME test and an increase in hTR after the test (right r=-0.59, p=.001; left r=-0.77, p=.001). The regression equation developed to predict hTR for the right ESM was:

hTR (s) = 7.699 + .518 Incremental time (s)

The second objective was to assess ESM during isometric task until fatigue by EMG and measuring the hTR by NIRS. All subjects performed one single static task. Two min was measured as a baseline following by an endurance test until volitional exhaustion and subsequently 5 min of recovery period. Fast linear decreasing phase of TOI at the beginning and a constant decreasing until the end of exercise (from 100% to 84.8% with right and left side pooled). Mean BSME time was 155.5±33.0 s. The half time to recovery (hTR) demonstrated to be between about 21 s and 35 s (right and left side pooled). Mean EMG MF decreased progressively to nearly 70% of resting value in both sides.

The third objective was to estimate the low back joint moment and calculate the hTR during an isotonic muscle task by simulating patient-handling task. The study subjects were required to perform two distinct transfer tasks: 1) Elevation of the patient from a supine position in bed to a sitting position (SS), and 2) Transferring of the patient from sitting on the bed to sitting in a wheelchair (SW). An additional third task, namely, continuous performance of SS and SW (SS+SW) was also performed. The forces and moments of the L3/L4 joint, hip joints, knee joints, and ankle joints were estimated using the kinematic and inertial properties of the body, together with the process of inverse dynamics and the developed free body diagram (FBD) for motion analysis, based on the kinetics of the lower limb muscles and bone joints. There was no statistically significant difference with L3/L4 joint moment between SW and SS+SW ($p = 0.968$). Simple main effect analysis showed that the hTR for SS+SW was significantly higher than those for SS and SW ($p < 0.05$), but there were no differences between the right and left lumbar during SS and SW.

The slight interruption of oxygenation during the isometric exercise by increased intramuscular pressure was observed. Considering that ischemic muscular activity occurs in this muscle, these results provide information about muscle aerobic function. The recent advanced of NIRS would help to refine the understanding of skeletal muscle oxygenation in more different pathophysiology conditions. The findings of this study have implications for future investigations on the mechanism of action of the low back muscles. A reduction in the strength (i.e., EMG), endurance, and oxygenation levels (i.e., NIRS) of the low back muscles has been implicated as a contributory factor to fatigue. Adequate blood supply is obviously the most essential component to withstand fatigue and prevent the loss of lumbar muscle function. Furthermore, prolonged static posture might diminish oxygenation level and MF, increasing

susceptibility to fatigue.