Effect of Intermittent Sequential Pneumatic Compression of Legs on Recovery of Fatigued Muscles

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Introduction: Muscle fatigue is defined as failure to maintain the required or expected force (Edwards 1981) and is characterized by the accumulation of metabolic waste inside and outside the cells (Mainwood and Renaud 1985). Muscle recovery depends on the elimination rate of this metabolic waste (Vollestad and Sejersted 1988). Active recovery is more effective than passive recovery (Belcastro and Bonen 1975, Boileau et al., 1983). An example of active recovery is the application of Intermittent Sequential Pneumatic Compression (ISPC) on the legs, which accelerates venous return from the lower limbs (Zelikovski et al., 1993). A well-established fatigue indicator is the mean power frequency (MPF) of the myoelectric signals, as recorded by EMG (Moritani et al., 1982). In this study we quantified the effect of IPSC on Tibialis Anterior (TA) recovery after a fatiguing sustained effort bout by making use of EMG fatigue indicators. We postulated that enhancing venous return in the veins of the lower limbs by ISPC would result in a faster TA recovery.

Methods: The protocol design is depicted in Figure 1. Eight young healthy male subjects having right leg dominancy participated in this study. The test included: (a) ten min of ‘fast walking’ on a treadmill; (b) 2 min of sustained effort, referred to as ‘load A’, (c) 3 min ‘recovery’ (active or passive); and (d) 2 min of a second sustained effort, referred to as ‘load B’. The above procedure was repeated after a period of one week, (‘repeat set’). The sustained effort tests consisted of holding dead weights of 10 kg by the feet for 2 min in a seated position, while maintaining the ankle angles at the 90 deg. Immediately after ‘load A’ the weights were removed, and the subjects were asked to sit on a reclining chair with the lower limbs extending forward. In this position the muscles of the legs were allowed to recover for a period of 3 min. In one leg active recovery was accomplished by ISPC. In the other leg recovery was passive. In the ‘first set’ of measurements the right leg was in active recovery and the left one was in passive recovery and in the ‘repeat set’ the sides were interchanged. The ISPC device used in this study was a Lympha Wave (model 301 ET, Mego Afek, Israel) and consisted of a sleeve worn on the treated leg. The part of the sleeve used included 8 annular overlapping cells covering the foot and shank and fed separately from a compressor and distributor, which provided continuous cycles of ascending pressure waves reaching the level of 80 mm Hg. There were two compression cycles per min and each cycle was divided into two phases: 21s inflation followed by a deflation period of 9s. Thus, for the 3 min active recovery six cycles of “milking” of the leg were completed. Immediately after the recovery period each subject returned to the seated position to perform the second sustained effort (‘load B’) in a similar way as described for the sustained effort (‘load A’). Surface EMG of the TA muscles was used to monitor muscle fatigue and recovery. The mean power frequency (MPF) of the signals was calculated. Differences were tested using within-subject repeated-measures analysis of variance (ANOVA), with a significance level of p < 0.05.

Results and discussion: Averages for all the subjects of the MPF of the TA EMG are summarized in Figure 1. At the end of the ‘fast walking’ session there was a significant decrease in MPF of the EMG signal. Thereafter, following the first sustained load (‘load A’), the TA underwent a much higher degree of fatigue, as reflected by the additional decrease in the MPF. It can thus be concluded that in our experimental protocol the TA muscles reached substantial levels of muscular fatigue. Fatigue is characterized by the accumulation of water and catabolites in both the intra- and extra-cellular compartments of the muscular tissue (Hultman et al, 1986). Therefore, the active recovery of the fatigued
Figure 1 Average MPF (Mean (SD)) of the TA muscle under sustained loads. # sustained quasi-isometric effort (Loads A&B); Significant difference (p<0.05): * initial and end of pre-load; ** left and right legs, within each set; *** end time of 'load A' and initial time of 'load B'.
muscle yielded, by enhancing water removal out of the muscle tissue, better muscle performance than passive recovery (Zelikovski et al, 1993), as shown in the rightmost part of the Figure. The results of the present study showed that the application of ISPC to the lower limbs yielded a significant enhancement of performance, presumably by increasing the venous return rate in the major veins of the legs. In the initial part of ‘load B’ the degree of muscular recovery of the ISPC treated leg was significantly more effective in comparison to the untreated leg. This finding was reconfirmed independently of the dominance of the treated lower limb. Moreover, at the end of ‘load B’ the TA of the ISPC treated leg achieved higher levels of muscular power than the opposite, passively recovering leg. This clearly indicates that the enhancement of venous return from the lower limbs yielded rapid recovery of the fatigued muscles. Enhancement of venous return improves the perfusion of the tissue. According the laws of Starling, this is attributed to a decrement in the hydrostatic pressure at the post-capillary vein, yielding a higher difference in pressures between the pre-, and post-capillary vessels (Ingram and Braunwald, 1998). Improved oxygenation of the muscular cells might accelerate recovery in cases where the muscle cell shifts to anaerobic metabolism. Levy et al (1993) described a progressive intracellular pH decrement and inorganic phosphate increment in muscle fatigue induced by functional electrical stimulation (FES). These biochemical changes represented depletion in the energy storing molecules, such as creatine phosphate CrP and ATP. It is thus clear that muscular fatigue is a complex phenomenon, characterized by intracellular changes accompanied by a gradual deterioration of the muscle performance. Future studies would have to incorporate intracellular measures of fatigue and recovery to gain more specific information on the process taking place by the application of ISPC.

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