SHORT REPORT

Effects of neuromuscular electrical stimulation of the knee extensor muscles on muscle soreness and different serum parameters in young male athletes: preliminary data

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Aim: To evaluate the effects of neuromuscular electrical stimulation (NMES) on muscle soreness and on a variety of serum parameters during and after NMES of knee extensor muscles of young, well trained subjects over a study period of 96 h.

Methods: Five male cyclists were included in this clinical observation. NMES (biphasic, asymmetric impulses) was applied through surface electrodes to both knee extensor muscles of each subject for 30 min. To determine changes in serum concentration of muscle proteins, blood samples were drawn at defined measure points before and after NMES. Muscle soreness was evaluated using a visual analogue scale at all measure points.

Results: There was a maximum ($p<0.05$) for ''muscle pain'' during stimulation but no significant changes could be detected after the stimulation period. Serum creatine kinase showed a peak with a significant increase ($p<0.05$) 24 h after NMES. Serum lactate levels only increased slightly ($p=0.08$) during NMES.

Conclusions: Although the changes of blood parameters measured in the present work correspond to those reported in the literature on eccentric strength training, no delayed onset muscle pain could be detected. Further studies should be carried out, also investigating different stimulation protocols in non-trained healthy subjects and in patients with less muscle mass.

Neuromuscular electrical stimulation (NMES), as well as eccentric strength training, provokes muscle soreness in healthy people and patients.[1–12] Only a small amount of data are available that document the influence of NMES on serum parameters, and discuss different possible mechanisms of muscle damage.[8] Therefore, the present work aimed to describe the effects of NMES on muscle soreness and on a variety of serum parameters.

MATERIALS AND METHODS

Five male, healthy, well trained cyclists (mean (SD) age 26(7) years, 24(1) body mass index) gave their written, informed consent to participate in this trial. NMES was applied through surface electrodes to both knee extensor muscles of each subject for 30 min. The subjects were seated in a sitting position, hips and knees flexed at 90°. Two electrodes (7×12 cm) were applied to each quadriceps muscle, i.e. over the motor point of the vastus medialis and lateralis or the proximal insertion of the muscle respectively. The NMES protocol consisted of biphasic, asymmetric impulses (63,3 Hz, 0.3/0.1 ms; pulse width: 400 μs; 3.5 s on, 4.5 s off), which is the standard protocol for the NMES device used (see below). The intensity of stimulation was as high as to provoke a visible strong tetanic contraction, and was limited by pain (100 on a visual analogue scale (VAS)) or by the maximum output intensity of the device (= 128 mA; Stimulette® CX, Dr G. Schuhfried GmbH, Mödling, Austria).

To assess serum lactate level, blood samples were drawn from the ear lobe before (1a), after 15 min (2a) and after 30 min (3a) of NMES. Lactate concentration was measured using the Ebio® plus (Eppendorf AG, Hamburg, Germany).

Further, to determine changes in serum concentration of creatine kinase (CK), creatine kinase isoenzyme μB (CK-MB), lactate dehydrogenase (LDH), hydroxybutyrate dehydrogenase (HBDH), myoglobin, troponin, c-reactive protein (CRP), erythrocyte sedimentation rate (ESR), fibrinogen, red and white blood cell count, blood samples were drawn from the antecubital vein before (1b), immediately after (2b), 24 h (3b), 48 h (4b), 72 h (5b), and 96 h (6b) after NMES.

The extent of ''muscle pain'' was evaluated using a 10-point VAS at all measurement points.[6 9 10] Furthermore, to avoid misinterpretation of simple electrical sensations, ''skin pain'' was assessed using a VAS. The training habits of the athletes remained unchanged for the whole study period.

Statistical analysis was performed using a Wilcoxon test. The significance level was set at $p<0.05$.

RESULTS

In every subject, strong tetanic muscle contractions were achieved. All subjects tolerated a 30-min stimulation up to the output maximum of the stimulation device. There was a maximum ($p<0.05$) for ''immediate onset muscle pain'' during stimulation (2a). Surprisingly, no significant ''delayed onset muscle soreness'' could be detected after the stimulation period (fig. 1). ''Skin pain'' was 0 on the 10-point VAS at all measure points. Serum CK showed a peak with a significant increase ($p<0.05$) 24 h after NMES (3b; fig. 2). A slight increase of serum lactate level ($p = 0.08$) was seen during NMES (2a), but a significant peak could not be detected (fig. 3). There were no other changes in serum parameters.

DISCUSSION

Strength training using NMES in comparison to eccentric strength training is thought to have the same effects with regard to muscular damage, hypertrophy and increase of serum parameters, but little data investigating those effects as caused by NMES exist.[7 8]

To demonstrate an expected analogy between NMES and eccentric strength training, the investigated parameters were chosen in accordance with the literature on the latter.

Abbreviations: CK, creatine kinase; NMES, neuromuscular electrical stimulation; VAS, visual analogue scale

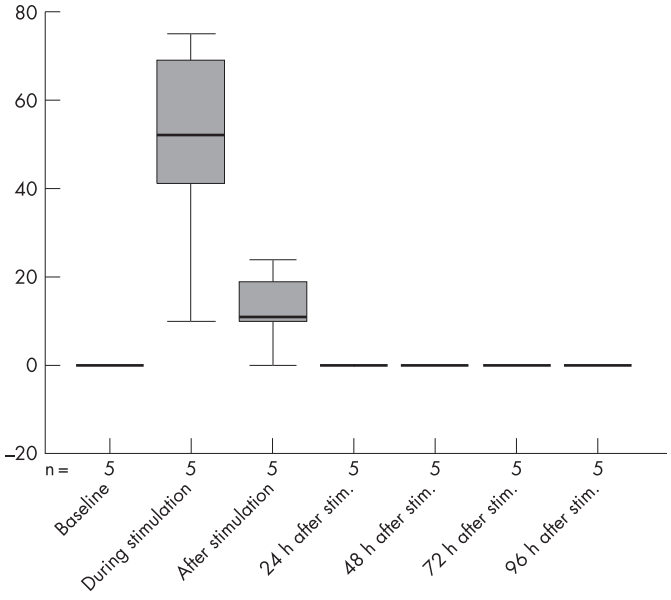

Figure 1 Boxplot showing muscle pain measured by 10-point visual analogue scale: a significant peak for immediate onset muscle pain during stimulation ($p<0.05$) was recorded, no delayed onset muscle soreness. The box represents the interquartile range with the median as the centre line, the whiskers represent the non-outlier minimum and maximum values.

Eccentric actions have been shown to produce muscle damage.[1–12] Indirect evidence is the appearance of muscle proteins in the blood.[1–12] The plasma activities of specific muscle enzymes such as CK and LDH are such markers of muscle tissue damage; their release is a result of a change in fibre membrane permeability reflecting necrosis of focal areas on the muscle fibre.[2 8] CK activity is said to be a good indicator of the rate of muscular recuperation of the muscle and its work capacity.[12] As hypothesized, serum CK responded to NMES with a significant peak after 24 h, as reported in the literature.[3 12]

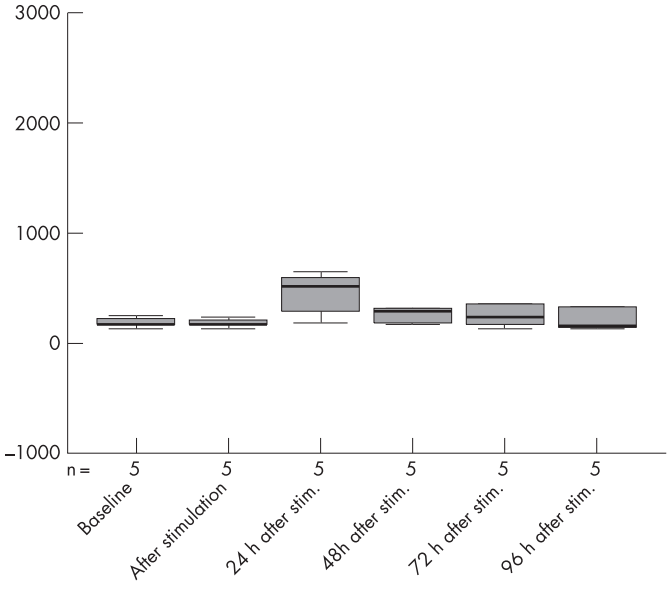

Figure 2 Boxplot showing CK concentration in U/litre: a significant peak 24 h after stimulation ($p<0.05$) was recorded. The box represents the interquartile range with the median as the centre line, the whiskers represent the non-outlier minimum and maximum values.

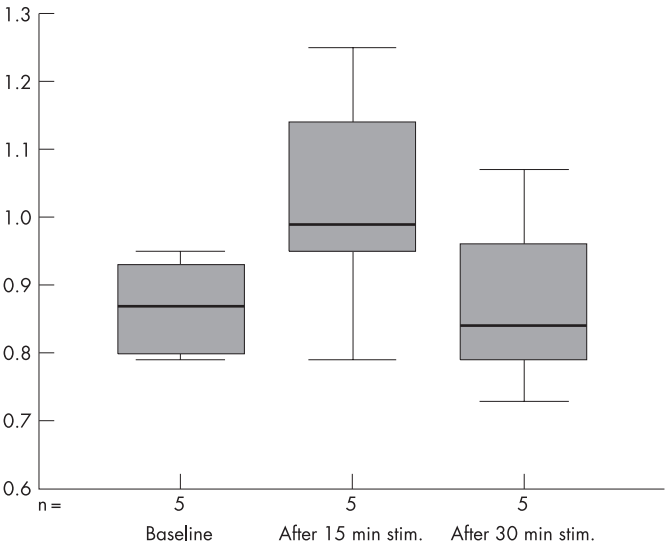

Figure 3 Boxplot showing lactate concentration in mmol/litre: small increase after 15 min of stimulation ($p=0.08$). The box represents the interquartile range with the median as the centre line, the whiskers represent the non-outlier minimum and maximum values.

No significant increase of serum LDH could be seen in the present work.

A slight but not significant increase of serum lactate level could be observed during NMES application ($p = 0.08$). These findings are in accordance with the study results of Nosaka *et al*.[9]

In the present work, immediate onset muscle pain could be seen during NMES, showing a decrease at the end of stimulation. Delayed onset muscle soreness was not reported by the subjects. Enoka states that NMES exercise-induced soreness is dependent on the intensity of stimulation and the duration and rate of the impulse.[4] The lack of typical delayed muscle soreness in the present observation could be a consequence of the fact that all

What is already known on this topic

- Eccentric strength exercises can produce muscle damage, muscle soreness, and changes of serum parameters.
- NMES, as a passive option with the intention to avoid loss of skeletal muscle and/or to increase muscle mass, can also cause muscle pain.
- Muscle soreness and serum parameters during and after NMES of thigh muscles have not been described in detail to date.

What this study adds

- This is the first description of effects of NMES of knee extensor muscles on muscle soreness and different serum parameters in young male athletes (cyclists).
- Changes of blood parameters measured correspond to those reported in the literature on eccentric strength training, but no delayed onset muscle pain could be detected.

included subjects were athletes with well trained thigh muscles. The stimulation protocol and/or the intensity of the applied current were able to reach strong tetanic contractions, but did not seem to be able to provoke adequate muscle damage. This might be because of the intensity (128 mA) deliverable by the stimulation device used in this study, which has the highest output intensity allowed in Austria.

Applying NMES on less well trained muscles or atrophic muscles could give completely different findings. The lesser the muscle mass, the more muscle fibres can be affected; this would result in greater muscle damage and therefore provoke delayed onset muscle soreness.

CONCLUSIONS

This work is the first description of the effects of NMES of the knee extensor muscles on muscle soreness and different serum parameters in young male athletes.

Although changes of blood parameters measured in the present work correspond to those reported in the literature on eccentric strength training, no delayed onset muscle pain could be detected. Further studies, carried out in larger study populations using different stimulation protocols and current intensities, are urgently needed. In addition, the effects in non-trained healthy subjects and in patients with different kinds of diseases and less muscle mass should be investigated.

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REFERENCES

1 **Clarkson PM**, Litchfield P, Graves J, *et al*. Serum creatine kinase activity following forearm flexion isometric exercise. *Eur J Appl Physiol* 1985;**534**:368–71.
2 **Clarkson PM**, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Med Sci Sports Exer* 1992;**24**:512–20.
3 **Ebbeling CB**, Clarkson PM. Exercise-induced muscle damage and adaptation: A review. *Sports Med* 1989;**7**:207–34.
4 **Enoka RM**. Muscle strength and its development: New perspectives. *Sports Med* 1988;**6**:146–68.
5 **Juel C**, Klarskov C, Nielsen JJ, *et al*. Effect of high-intensity intermittent training on lactate and H+ release from human skeletal muscle. *Am J Physiol Endocrinol Metab* 2004;**286**:E245–51.
6 **Kauranen K**, Siira P, Vanharanta H. Delayed-onset muscle soreness and motor performance of the upper extremity. *Eur J Appl Physiol* 2001;**84**:302–9.
7 **Maffiuletti NA**, Zory R, Miotti D, *et al*. Neuromuscular adaptations to electrostimulation resistance training. *Am J Phys Med Rehabil* 2006;**85**:167–75.
8 **Moreau D**, DubotsP, Boggio V, et al. Effects of electromyostimulation and strength training on muscle soreness, muscle damage and sympathetic activation. *J Sports Sci* 1995;**13**:95–100.
9 **Nosaka K**, Newton M, Sacco P. Muscle damage and soreness after endurance exercise of the elbow flexors. *Med Sci Sports Exer* 2002;**34**:920–7.
10 **Vincent HK**, Vincent KR. The effect of training status on the serum creatine kinase response, soreness and muscle function following resistance exercise. *Int J Sports Med* 1997;**18**:431–7.
11 **Zainuddin Z**, Sacco P, Newton M, *et al*. Light concentric exercise has a temporarily analgesic effect on delayed-onset muscle soreness, but no effect on recovery from eccentric exercise. *Appl Physiol Nutr Metab* 2006;**31**:126–34.
12 **Zając A**, Waśkiewicz Z, Pilis W. Anaerobic power, creatine kinase activity, lactate concentration, and acid–base equilibrium changes following bouts of exhaustive strength exercises. *J Strength Cond Res* 2001;**15**:357–61.