Massage and recovery: An electromyographical and biomechanical approach

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Since antiquity massage has been used to bolster performance and to help recovery after strenuous exercise (Harris, 1964). However, in spite of such a long history, few scientific results have been published proving its effectiveness (Cafarelli & Flint, 1992). Numerous techniques are described (Prentice, 1994) and the beneficial effects of massage are attributed to physiological response caused by the mechanical stimuli of the procedure. Three kinds of response are usually describes:

- an increase in the permeability of the cellular membrane due to noxious substances gathering inside the cells;
- an increase in the blood flow helping the reshaping of such substances and the delivery of oxygen;
- action on the intramuscular sensors.

Massaging could reduce those sensors' contribution to muscular stiffness (tension) or cause an analgesic response calming the discomfort often associated with intense physical exercise.
In spite of the abundance of anecdotes supporting such claims, there is no data to identify the mechanisms responsible for the described or purported effects. The only exception to this lack of data is a slight increase in the temperature observed during and after the massage. However, such rise is of the same magnitude as that occurring during a low intensity contraction but without activation of the contraction metabolism. The massage induced hyperemia could accelerate the elimination of the contraction metabolites, thus facilitating recovery. The "gross" result should be the capability of carrying out a higher intensity exercise for a longer time. The recovery from physical exercise implies a progressive loss of the functional capacity which can be reversed by a change in activity (in various forms) or by resting. This matches the definition of fatigue and more specifically of muscular fatigue.
The notion of muscular fatigue is a theme on which research has been done. It covers a wide range of physiopathological conditions: diminished physical capacity reduction due to illnesses (cardiovascular, muscular) (Radda & al., 1982), but also to intense training or exhausting physical exercise, whether of short or long duration.

Various definitions of local muscular fatigue have been offered; let us consider the one offered by Edwards (1981): "inability of the muscle to maintain a given level of strength or power during a sustained contraction or series of contractions".
It is within the very precise scope of this definition that the etiology of muscular fatigue has generally been studiedin the last ten years (Mac Laren & al., 1989).
Muscular contraction is the outcome of a chain of physiological events and each link in that chain is a potential "fatigue site". We distinguish two types of fatigue:

- central fatigue, the cause of which lies in the central nervous system (CNS) and which is based on an impairment of motivation, a change in the transmission of CNS commands, or in demand for the motoneurones. This central fatigue should have little impact on performance with highly motivated subjects (Gibson & Edwards, 1986).
- Peripheral fatigue encompasses the totality of mechanisms located within the muscle. Various studies (Vollestad & Sejersted, 1988; Westerblad & al. , 1991; Enoka & Stuart, 1992) describe the keys and the factors involved.

Metabolic acidosis is one of the factors implicated in the onset of muscular fatigue. The muscular pH decreases from a resting value of 7 to 6.4-6.6 after stenuous exercise carried to the point of exhaustion. This decrease of pH is due mainly to the increased proton load connected to the accumulation of lactic acid. Such a decrease in the intramuscular pH can change the cellular metabolism at many ways, particularly in the area of enzyme activities including that of the Na-K ATPase which regulates trans-membrane ionic movements, thus affecting the excitability of the muscular fibre's external membrane.
A non-invasive electro-physiological approach to this problem is feasible, using the surface EMG signal, and especially through the spectral analysis of that signal. In fact, the spectral reshaping observed during the isometric fatigue test, the energy increase and the mean frequency decrease of

MPF (mean power frequency) (De Luca, 1984; Duchêne & Goupel, 1990; Kadefors & al., 1968) could be tied to the reduced propagation speed of the action potentials along the muscular fibre (Mortimer & al., 1970) due to the accumulation of metabolites within the fatigued muscle. Incidentally, a connection between intramuscular pH and the MPH was brought to light during an isometric fatigue test (Laurent & al., 1993). Furthermore, the local ischemia caused by the isometric contraction, by reinforcing the setting in of acidosis, is considered one of the factors causing fatigue (Sjogaard & al., 1986).
The purpose of this study is to determine the effects of a new technique called "LPG technique", which synergetically uses suction and the cutaneous rolled fold method. Acting locally on the conjunctive tissue by improving local vascularisation and increasing drainage could thus help eliminate the metabolites produced during exercise. It should therefore be able either to improve recovery or to decrease muscular or to decrease muscular fatigability by improving the elimination of blood catabolites.
The object of this study id to evaluate the effectiveness of a technique called "LPG technique" on the muscular endurance capacity of healthy subjects. The approach shall be multi-parametrical based on the biomechanical, electromyographical and subjective of muscular fatigability.

MATERIAL AND METHOD

Population

It is made up of 10 male subjects (age: 28.2 $\pm$ 8.05 years; weight: 68.1 $\pm$ 9.23 kg; height: 179.2 $\pm$ 6.86 cm) who, after being briefed, gave their informed consent to take part in the study. The subjects presented no declared chronic or acute pathology affecting either the limb to be tested or the whole of the locomotor system's muscular network.

Material

The massaging machine used is type S70. This can be assimilated to a vacuum generator allowing the instantaneous formation and mobilization of the cutaneous fold. Linked to a real time suction control system, it guarantees the accuracy and safety essential to the use of such a technique in the health field.
The mechanical parameters are measured with a Cyber 330-type isokinetic dynamometer.
The EMG recordings are made by Beckman-type surface electrodes and a Gould amplifier-signal conditioner connected to a TEAC R 71 magnetic recorder.

Protocol

Physical trials

Under consideration are 3 trials, separated from each other by 7 days (Figure 1 - *see original French version*); they shall be carried out in random order. Each subject shall undergo the trials at the same time of day and exercise shall be performed on the right knee.

- *First trial called "reference" or "control"*
- Isometric gauging of the maximum voluntary strength (MVS1) of the quadriceps on a Cybex 330 dynamometer-three tests
- 5-minute rest period
- Isometric fatigue trial at 66% of MVS1 (contraction held of the quadriceps) and measurement of the holding time.
- 1-minute rest period
- Gauging of MVS (MVS2) – three tests

- *Second trial*
- Gauging of the MVS1 – three tests
- 5-minute rest period
- Local exhaustion trial consisting of 30 successive flexion-extensions of the knee at a speed of 180°s, with maximum exertion demanded.
- 1-minute rest period
- gauging of MVS2 – three tests
- 15-minute rest period, the time required for return to a resting pH being 45 minutes (Allsop & al., 1990)
- Isometric fatigue trial (as in the first trial)
- 1-minute rest period
- gauging of the MVS (MVS3) – three tests

- *Third trial*

It has the same characteristics as the second trial except for the 15 minute period where the LPG Technique will be applied (during 8 minutes) to the front part of the right thigh. The fatigue trials are performed under conditions of isometric, rather than dynamic, contractions because:
- during isometric contraction the kinetics of the MPF are more readily usable;
- the demand on motor units is more stable due to the very force constant, as dynamic contractions cause variations in tension and muscle length.

During the fatigue trials, the strength torque requirements shall de presented to the subject by means of the Cybex 330 control screen. The EMG surface signals will be sensed by surface electrodes in bi-polar mode, amplified and recorded in a conventional manner. The processing of the EMG signals will consist of a spectral analysis using a rapid calculus board installed in a PC and driven by a specific software, computing the total energy and MPF among others. The spectral changes will be quantified in terms of MPF evolution.

In parallel, an analog scale (referenced from 0 to 10 (Borg, 1982) filled in by the subjects, will help evaluate the exertion produced (RPE: rate of perceived exertion)

The massage

The "LPG" Technique will be applied by an investigator with prior training in this new massaging method. The application will take place on the front of the right thigh. The manipulation shall be performed in the disto-proximal direction, from the peripatellar insertions to the root of the limb avoiding the Scarpa triangle. The treatment will last 8 minutes, included in the rest period, and will start 2 minutes after the VMS2 measurements. The suction intensity shall be shown as 5 on a scale graduated from 0 to 10 (10 corresponding to a depression of 500 mbar).

Statistical analysis

The statistic study presents the +/- SD averages (typical gap) of the different parameters measured. A Student test in matched series makes it possible to quantify the conditioning's specific effect on a given variable, thus perhaps making it possible to detect a de-fatiguing effect of this technique. The significance threshold has been established at $P<0.05$.

RESULTS

The results presented show the modifications in the different criteria during the three different trials (reference or control, without LPG and with LPG):

- comparison of the isometric force torque variations (MVS) measured before each trial and after each isometric fatigue test. The comparison of these percentage averages was made by using the conversion of each value into *arc sin x*;
- comparison of the isometric contraction holding times up to exhaustion (endurance time) of each isometric fatigue test;
- comparison of the MPF flows calculated at the end of each isometric fatigue trial;
- comparison of the indexes of perceived exertion (RPE) at the end of the isometric fatigue test.

The main results are shown on figures 2, 3 and 4 *(see original French version).*

Figure 1: Chronology of the trials and tests
Figure 2: MVS decrease at the end of the isometric fatigue trial
Figure 3: MPF flow of the Vastus Lateralis muscle during the isometric fatigue trial

Figure 2 shows the decrease in MVS at the end of the isometric fatigue test (expressed as a percentage of the initial value). The values are: -3.48 ± 7.53 % (ref), -10.85 ± 5.78 % (without LPG) and –5.29 ± 6.6 % (with LPG). The variations are significant between (ref) and (without LPG) (p0.01, on one hand, and between (without LPG) and (with LPG) ($p<0.03$), on the other.

Figure 3 shows the endurance time variation (in seconds) during the isometric fatigue test. The values are: 63.9 ± 12.25 s (ref), 52.1 ± 9.17 s (without LPG) and 58.2 ± 8.16 s (with LPG). The variations are significant between (ref) and (without LPG) ($p<0.01$), and they are indicative ($p=0.10$) between (ref) and (with LPG) on one hand, and between (without LPG) and (with LPG), on the other.

Figure 4 shows the MPF flow shifts (as a percentage decrease of the initial values) during the isometric fatigue test. The values are 18.41 ± 8.51 (ref), 25.24 ± 8.31 (without LPG), and 20.03 ± 9.21 (with LPG). The variations are significant between (ref) and (without LPG) ($p<0.01$) on one hand, and (without LPG) and (with LPG) ($p<0.03$) on the other.

Finally, the RPE values are 8.9 ± 1.01 (ref), 9.03 ± 1.03 (without LPG) and 8.96 ± 1.2 (with LPG). The variations are not significant.

DISCUSSION

Massage is often used thought different techniques to decrease the feeling of discomfort resulting from a violent effort and to help recovery (Wakim, 1985; Wood, 1974). However, the real effectiveness of massage to hasten the recovery of the function has not been demonstrated and the nature of the mechanisms activated during such recovery process is not known. This is probably due to the fact that muscular fatigue is a phenomenon the causes of which have not yet been clearly established (Edwards, 1981; Westerblad & al., 1991). However, and in all cases, muscular fatigue is a disruption of the muscle's homeostatic factors. It is therefore reasonable to study ways of easing the return to basic homeostatic levels allowing the restoration of he functions leading to performance. The results of this study show that the massage by rolled fold (done by suction – LPG) has an effect which helps the recovery within the scope of this protocol. As a result, we shall consider on one hand the possible causes of fatigue and the conditions of our experimentation, and on the other the physiological consequences of massage and the reasons for its results.

Restricted blood flow is one of the causes of muscular fatigue often suggested in literature (Sjogaard, 1987; Sjogaard & al., 1986) and the control of the blood flow is related to the muscular metabolic demand level. The blood circulation in the muscle is probably interrupted when the muscular contraction level is between 20% and 40% of the maximum voluntary strength (Zwarts & Arendt-Nielsen, 1988). During movement, the blood flow required for muscular functioning can only occur between contractions. Without such flow, the input of substrates and oxygen and the elimination of catabolites are insufficient.

During the isokinetic fatigue test, described by Baltzopoulos & al. (1988) and modified, the fatigue indexes were 63.9 $\pm$ 8.18 % for the situation without LPG and were 64.92 $\pm$ 9.16 % for the LPG situation. These results show, on one hand, that these two tests were of equal intensity and, on the other, that such intensity was at a high level since these indexes correspond to a decrease in the production of work of 35 % over 30 seconds. This anaerobic-type demand thus creates a high metabolic load which will disrupt the isometric fatigue test, the passive 15 minute rest period probably being insufficient to recover the resting metabolic balance and, in particular, the intramuscular pH (Allsop & al., 1990). Without LPG, the isometric fatigue test, following the isokinetic test, will take place in a perturbed metabolic field. Furthermore, the type of isometric exercise used (66 % MVS) creates a very high metabolic constraint, the pH plunging to 6.6 (Sahlin & al., 1975); this constraint is added to that generated by the isokinetic test. This explains the greater strength decrease, the shorter endurance time and, finally, a higher MPF flow. The latter parameter, which interprets the spectral modifications of the EMG signals, is, on one hand, a good index of muscular fatigability and, on the other, an indicator of the metabolic processes and of the involvement of the underlying muscle. In fact, the MPF evolution was correlated with the proton H^+ concentration and with that of inorganic phosphate in two proton form (H_2 PO_4) (Laurent & al., 1993), as also with changes in the selection order of the motor units (Stuart & Enoka, 1990).

The massage (applied to the muscular region), by acting on the local blood flow, is supposed to help recovery, thanks mainly to its mechanical effect and, to a lesser extent, due to the thermal effect (Cafarelli & Flint, 1992). Be that as it may, the observed effects are significant since the values of the main parameters in the cases involving LPG are close to the Ref case, in particular the MPF flow, which could reflect the fact that massage has contributed to the elimination of the anaerobic metabolism products. This association of massage and rest thus seems effective in optimising the recovery process. Finally, it should be noted that the parameter quantifying the exertion perception (RPE) does not change according to the different cases. This phenomenon can be explained by the fact that, in every case, the subjects are exerting a maximum effort.

CONCLUSION

The results of this study point to the definite effectiveness of the LPG technique in muscular function recovery after a local fatigue trial. The effects were demonstrated mainly thanks to electrophysiological parameters representative of the muscular fatigue condition. Although the mechanisms brought into play are not clearly established, it would seem that the rolled fold massage technique, carried out with an LPG systems, favorably affected the post-exercise muscular recovery. The mechanical demands on the cutaneous and sub-cutaneous tissues is certainly the site of circulatory and thermal shifts helping the elimination of anaerobic metabolism products. Such encouraging results open up other prospects for the use of this technique, both as regards treatment duration and application modes and their prescription.

REFERENCES

See original French version