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Enhancement of rowing performance in athletes after focal muscle vibration

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Abstract

Muscle vibration has been reported to induce positive long lasting effects on proprioception when applied on specific body segment. The aim of this study was to evaluate the effect of focal muscle vibration applied on quadriceps and latissimus dorsi muscles in athletes evaluated during rowing test. Sixteen volunteered national level sculling stroke rowers were randomized in a study group and in a control group (treated with sham vibration). The overall kinematics consistency, joints angular acceleration patterns and performance test were used for evaluation. Results showed statistical significant differences for angular accelerations at the knee and shoulder joints and muscles timings. Vibration treatment seems to be a useful proprioceptive stimulation in sport activities to improve muscle control and performance.

Keywords: *muscle vibration, proprioception, rowing, sport activities, strength.*

Introduction

Muscle vibration has been reported to induce positive long lasting effects on proprioception when applied on specific body segment (the muscle belly), at small amplitudes (0.2-0.5 mm), at a specific frequency (100 Hz) and with a specific application time (30 minutes) [1]. These effects can be attributed to adaptive changes in motor control and not to vascular or metabolic modifications of the treated muscles [2-4].

In the last years different papers have evaluated the role of muscle vibration in different pathologies [5-10] and in particular the influence of localized muscle vibration on proprioception [11] and motor performance, reporting improvement of endurance, enhancement of motor control and increase of rate of force development, without effects on maximal force [12].

Given the results of these studies, it can be expected that muscle vibration have maximal effects on the performance of motor tasks requiring a combination of coordination, proprioception, strength (at a sub-maximal level) and endurance. Hence, muscle vibration may represent a potential tool for sports training. However, to our knowledge no study has been conducted to evaluate the effects of focal muscle vibration on the execution of sport-specific motor tasks.

Rowing requires to carry out a series of strokes at constant, high levels of performance and to maintain coordination of joints kinematics to perform an effective and harmonious whole-body motion. Moreover, high rates of force development are required, in particular for knee extension and shoulder horizontal abduction, in order to deliver adequate energy for propulsion.

The rowing task has been thoroughly investigated by energetic, kinematic and kinetic point of views, thanks to the high reliability of well-trained rowers performances on ergometers [13]. In particular, 2,000 meters rowing trials are commonly used to provide a controllable and repeatable assessment of the rower's performance [14;15].

A critical role for crew's rowing performance has been attributed to the synchrony between partners [16]. Hence, a high consistency of the force and kinematic output throughout the race may also play a critical role, allowing the rowers to adapt each other and maintain this coordination as long as possible [17], as demonstrated by the effectiveness of kinetic feedback in improving rowing performance [18]. However, the individual consistency across different rowing cycle can be affected by poor technique and muscle fatigue, with detrimental effects on the crew's overall performance [19; 20].

Thus, the effects demonstrated by focal muscle vibration during non-specific motor tasks – i.e., improvement of endurance, enhancement of motor control and increase of rate of force development – may have a beneficial effect on rowing performance.

The purpose of this study was to evaluate the effects of the bilateral administration of focal vibration on quadriceps and latissimus dorsi muscles on:

- consistency of the overall rowing pattern;
- angular acceleration pattern at knee and shoulder joints;
- performance,

during a 2000 meters rowing test.

Materials and Methods

Subjects

Sixteen volunteered national level sculling stroke rowers from two different crews were recruited, and a written informed consent was obtained. The study was approved by local Ethic Committee. The exclusion criteria were musculoskeletal injuries in the year preceding the study and the presence of any musculoskeletal pain at the time of the assessments. All subjects participating in the study were in a pre-race period.

Eight rowers (4 from each of the crew) were randomly assigned to the study group and eight to the control group. No significant differences concerning age, height and weight were observed between the two groups.

Vibration therapy

Mechanical perturbation was applied by a device (CRO®SYSTEM, international patent by NEMOCO srl, Italy) consisting of an electromechanical transducer, a specific mechanical support and an electronic control device. The transducer can develop a sinusoidal time modulated (100 Hz) , with a minimal displacement (0,2-0,5 mm peak to peak).

The rowers in the study group underwent three applications of mechanical vibration (duration of each application 10 minutes, time interval between two consecutive applications about 30 sec) over three consecutive days. The administration technique consisted of applying vibratory stimulation bilaterally on the skin overlying the distal part of the quadriceps, and in correspondence of the intermediate fibers of the latissimus dorsi muscle. During application of the stimulation, the subject was asked to maintain an isometric contraction of the treated muscles, by setting the contraction level at about 10% of his MVC. The rowers in the control group underwent the same protocol, but the electromechanical transducer was disconnected from the mechanical support, so that no mechanical perturbation was applied to the muscle.

The rowers of both study and control group performed their usual training sessions in the course of the study.

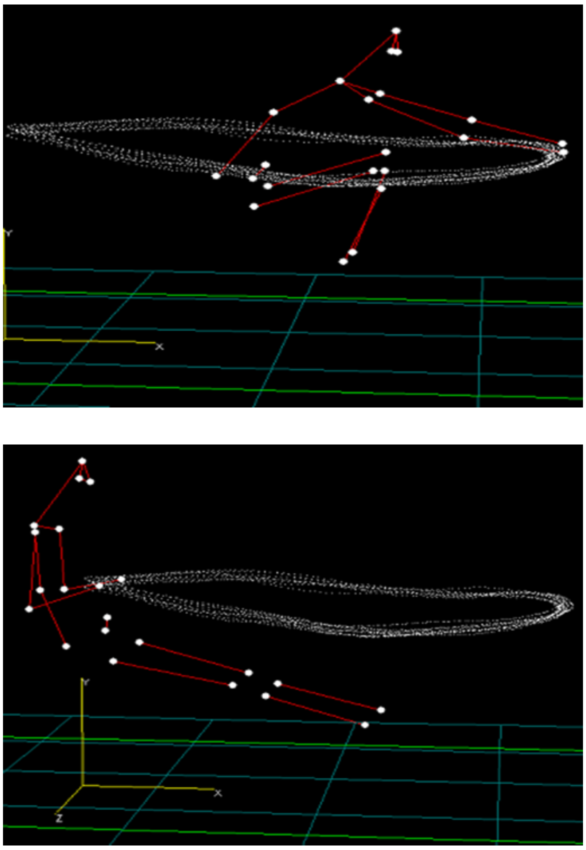
Testing procedures

All subjects has been evaluated 3 days before treatment and after 14 days from vibratory application.

The subjects completed an all-out 2000-meters row on an ergometer (Concept II model C, Indoor Rowing, Castelnuovo di Porto, Roma, Italy) designed to simulate an actual race on the water. Intermediate (over 500 meters intervals) and final times necessary to cover the distance were recorded.

During the rowing trial, a kinematic study was performed using ELITE stereophotogrammetric system (BTS SpA, Milan, Italy) with 8 infrared video cameras with an acquisition frequency of 100 Hz. Spherical reflecting markers (15 mm in diameter) were placed upon bony prominences of the upper [21] and lower limbs [22] of the dominant side to allow the calculation of knee and shoulder joints angular displacements. One additional marker was applied at the ergometer handle (**see figure** 1).

Figure 1: The kinematic study of rowing trial.



Data management and analysis

For each subject, we analyzed 20 strokes, collected at 100 meters distance intervals. Collecting data at regular intervals allowed to determine each rower's mean kinematic patterns taking into account changes occurring throughout the duration of the test. We evaluated the drive phase of each stroke, because it represents the power phase of the stroke. The onset and offset of the drive phase were identified by the shift of the handle marker motion from backward to forward and *vice versa*. Data from each drive phase were reduced to 100 samples in order to allow for comparison between strokes of different duration. Data were then averaged to obtain each subject's mean parameters relative to the whole test and to 500 meters distance intervals.

The coefficient of multiple correlation (CMC) was used to look at the closeness in the shape of the curves describing handle marker velocity in the collected strokes of each subject. CMCs were calculated for the whole test and for the 500 meters intervals. The mean of the trials being compared was used as reference.

The angular excursion at the shoulder and knee joint, calculated by validated methods [21-22] were used to derivate angular accelerations. We identified the peak of acceleration and calculated the time to peak (t_p) as the time from the sample in which the angular acceleration exceeded 10°/s^2 and the sample were the peak of angular acceleration was observed. Furthermore, we calculated the values of angular acceleration at 25%, 50% and 75% of t_p.

Statistical Analysis

Statistical analysis were performed using the SAS 8.2 (SAS Institute Inc., Cary, NC, USA).
The Shapiro-Wilkes test was performed to assess data normality. Hence, all variables relative to the whole rowing test were analyzed with either two-way analysis of variance (ANOVA) (no evidence against normality) or Kruskal-Wallis two-way ANOVA (evidence against normality) to investigate the effects of group belonging (study *vs* control), time (pre- *vs* post-treatment assessment) and interaction effects.

The same analysis were performed within each group to detect the effects of the time course of the test (500 meters intervals) and the time of the assessment (pre- *vs* post-treatment assessment) on CMCs and whole and intermediate time to race.
The significance level alfa was set to 0,05.

Results

The subjects, all males, had a mean age of 24±3 years (range 20-26 years), mean height 177±5 cm (range 170-183 cm), mean weight 69±4 Kg (range 62-74 Kg).

Overall kinematic consistency (Table 1)

Kruskal-Wallis two-way ANOVA detected significant group belonging and interaction effects ($p<0.01$). Post-hoc analysis revealed a significant differences between study and control group at the post-treatment assessment, with study group showing greater values of the CMC calculated in the whole trial ($p<0.001$). Furthermore, in the study group it was observed a significant increase of the CMC calculated in the whole trial ($p<0.005$).

A significant effect of the time course of the trial on the CMC was detected at the pre-treatment assessment by Kruskal-Wallis two-way ANOVA ($p<0.01$) in both study and control group, with significantly lower values observed in the 1500-2000m interval compared to the other intervals in the post-hoc analysis (all $p<0.001$). The same effect was observed in the control group at the post-treatment assessment (ANOVA, $p<0.05$; post-hoc, $p<0.01$), but not in the study group. In the study group, a significant increase was observed in the CMC calculated in the 1500-2000 meters interval at the pre-treatment assessment compared to the post-treatment assessment ($p<0.001$).

Table 1: Results of the the time course of the trial on the CMC in the study and in the control group.

Race interval	Study group		Control group	
	pre	post	pre	post
0-500m	0.953 (0.031)	0.969 (0.033)	0.960 (0.029)	0.957 (0.031)
500-1000m	0.961 (0.028)	0.972 (0.031)	0.964 (0.032)	0.966 (0.035)
1000-1500m	0.960 (0.027)	0.971 (0.034)	0.962 (0.030)	0.968 (0.036)
1500-2000m	0.925 (0.047)	0.968 (0.039)	0.930 (0.044)	0.941 (0.046)
0-2000m	0.861 (0.085)	0.951 (0.053)	0.868 (0.090)	0.875 (0.086)

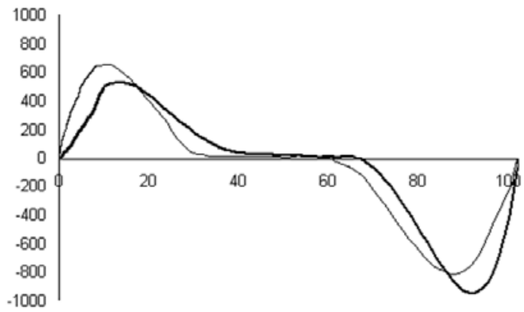
Joints angular acceleration pattern (Table 2)

Kruskal-Wallis two-way ANOVA detected significant group belonging and interaction effects ($p<0.01$). Post-hoc analysis revealed a significant differences between study and control group at the post-treatment assessment, with study group showing greater values of the peaks and intermediate values of angular accelerations at the knee and shoulder joints, and lower values of time to peak acceleration ($p<0.001$). Furthermore, in the study group it was observed a significant increase of the acceleration values and a decrease of time to peak for both knee and shoulder joints ($p<0.001$) (see **Figure 2**).

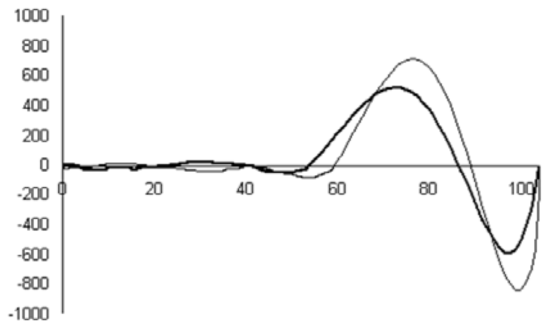
Table 2 Results of the knee and shoulder acceleration patterns in the study and control group.

Race interval	Study group		Control group	
	pre	post	pre	post
Knee Acceleration pattern				
Peak (°/s2)	527 (74)	608 (87)	539 (71)	556 (75)
Time to peak (s)	0.17 (0.03)	0.10 (0.02)	0.16 (0.03)	0.15 (0.03)
Acc 25% tp (°/s2)	117 (21)	156 (22)	123 (23)	132 (27)
Acc 50% tp (°/s2)	241 (36)	315 (35)	249 (34)	262 (39)
Acc 75% tp (°/s2)	410 (61)	478 (56)	417 (55)	443 (60)
Shoulder Acceleration pattern				
Peak (°/s2)	557 (93)	728 (104)	542 (89)	570 (85)
Time to peak (s)	0.24 (0.05)	0.15 (0.04)	0.25 (0.06)	0.23 (0.05)
Acc 25% tp (°/s2)	145 (36)	185 (41)	138 (37)	143 (39)
Acc 50% tp (°/s2)	312 (71)	392 (80)	318 (64)	326 (61)
Acc 75% tp (°/s2)	496 (88)	583 (96)	487 (79)	497 (81)

Figure 2 : Diagramme of linear knee (a) and shoulder (b) acceleration before (thick line) and after (thin line) treatment.



a)



b)

Performance (Table 3)

Kruskal-Wallis two-way ANOVA detected significant group belonging and interaction effects ($p<0.01$). Post-hoc analysis revealed a significant differences between study and control group at the post-treatment assessment, with study group showing lower time to race ($p<0.001$). Furthermore, in both the study and control groups it was observed a significant increase of the time to race ($p<0.001$ and $p<0.005$, respectively).

A significant effect of the time course of the trial on the intermediate times was detected at the pre-treatment and post-treatment assessment by Kruskal-Wallis two-way ANOVA ($p<0.01$) in both study and control group, with significantly lower values observed in the 1500-2000 meters interval compared to the other intervals in the post-hoc analysis (all $p<0.01$). In the study group, a significant increase was observed in the 0-500 meters and 1500-2000 meters intermediate times and in the overall time to race ($p<0.005$), whereas in the control group a significant increase was observed in the overall time to race ($p<0.01$) but not in the intermediate times.

Table 3: Results of the time course of the trial in the study and control group.

Race interval	Study group		Control group	
	pre	post	pre	post
0-500m	100.92 (3.09)	100.68 (3.01)	100.88 (3.06)	100.77 (2.97)
500-1000m	100.99 (3.15)	100.79 (3.10)	100.85 (3.14)	100.71 (3.02)
1000-1500m	101.00 (3.15)	100.81 (3.09)	100.92 (3.09)	100.78 (3.05)
1500-2000m	100.37 (2.98)	100.07 (2.92)	100.51 (2.93)	100.35 (2.90)
0-2000m	403.28 (12.34)	402.34 (12.07)	403.16 (11.93)	402.61 (11.75)

Discussion

At our knowledge, this is the first study investigating the effects of small-amplitude segmental muscle vibration on a sport-specific motor task requiring a combination of power, coordination and endurance. Our results indicate that administration of small-amplitude vibration on the muscles mainly involved in a specific motor task allows not only to improve segmental function, but also the performance in that specific motor task and the reliability of the motor task. Hence, by this point of view focal muscle vibration can be considered as a specific training procedure.

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