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Submaximal aerobic exercise with mechanical vibrations improves the functional status of patients with chronic fatigue syndrome

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***Aim*. Chronic fatigue syndrome (CFS) is an illness characterised by disabling fatigue of uncertain aetiology and other nonspecific symptoms. Typically CFS patients complain of a severe fatigue made worse by exercise, with a consistent reduction of working activity. A physical deconditioning could explain CFS features as well as a neuromuscular dysfunction, of central or peripheric origin.**
***Methods*. Ten CFS patients were enrolled in a protocol of a rehabilitative treatment over a six-month period: they underwent a submaximal and predominantly aerobic exercise with a reduced O_2 consumption using a Galileo 2000 system that provides mechanical vibrations characterised by sinusoid vertical sollecitations. Before and after such treatment, all patients underwent a pressure pain thresholds profile, an evaluation of physical and psychosocial parameters using the visual analogue scale (VAS) of Scott-Huskisson, and a muscle performance analysis by the CIBEX 6000 dynamometer.**
***Results*. After the six-month period of study there was an overall improvement of the above described parameters as compared to the basal determinations.**
***Conclusion*. We conclude that the rehabilitative exertion provides an useful treatment for CFS patients particularly to realize an effective training of the explosive strength.**

Key words: **Fatigue syndrome, chronic - Work capacity evaluation - Rehabilitation - Exercise.**

Chronic fatigue syndrome (CFS) is a disabling illness of unknown cause.[1] About 0.5% of patients attending general practice are identified as having CFS.[2] The age at presentation is usually between 20 and 50 years, presenting more frequently in females.[3] The most characteristic and debilitating feature of CFS is a fatigue producing a reduction of the working activity and lasting for more than 6 months. The diagnosis of CFS is confirmed only when all the other well known pathologies that usually cause fatigue are excluded, particularly psychiatric disorders such as major depression [4] (Table I). Patients typically complain of several infectious, rheumatologic and neuropsychological symptoms. Furthermore, they often show a reduced tolerance to exercise [5, 6] with a more easy and quick exhaustibility than controls.[7, 8]

The hypothesis of a deconditioning due to the absence of physical exercise [5] could explain CFS features as well as the hypothesis of a neuromuscular dysfunction, of central or peripheric origin, which is supported by many experimental findings,[9, 10] including the several ones reported by our group.[11, 12]

The reduced tolerance to exercise and the easy exhaustibility, independently from the potential causes, and the gait abnormalities found during the walking [13, 14] represent the main problem to realize a rehabilitative therapy in these patients with beneficial effects, even though it was recently suggested that

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TABLE I.—*Exclusion criteria for chronic fatigue syndrome case definition (CDC, 1994).*

a) Any active medical condition that may explain the presence of chronic fatigue, such as:
   1) untreated hypothyroidism
   2) sleep apnea
   3) narcolepsy
b) Any previously diagnosed medical condition whose resolution has not been documented beyond reasonable clinical doubt and whose continued activity may explain the chronic fatiguing illness, such as:
   1) previously treated malignancies
   2) unresolved cases of hepatitis B or C virus infection
c) Any past or current diagnosis of a major depressive disorder with psychotic or melancholic features; bipolar affective disorders; schizophrenia of any subtype; delusional disorders of any subtype; dementias of any subtype; anorexia nervosa; bulimia nervosa
d) Alcohol or other substance abuse within 2 years before the onset of the chronic fatigue and at any time afterward
e) Severe obesity as defined by a body mass index equal to or greater than 45

TABLE II.—*CDC criteria for chronic fatigue syndrome case definition.*

a) Persistent or recurrent fatigue (lasting >6 months):
   1) recent and/or well defined onset;
   2) not secondary to excessive physical activity;
   3) not resolved by rest;
   4) inducing important reduction of previous levels of physical and mental activities.
b) Presence of more than 4 of the following symptoms (lasting >6 months), not previous to fatigue onset:
   1) impaired memory or concentration;
   2) sore throat;
   3) tender cervical or axillary lymph nodes;
   4) muscle pain;
   5) multijoint pain;
   6) new headaches;
   7) unrefreshing sleep;
   8) postexertion malaise.

Chronic fatigue syndrome (CFS) = a + b (≥4).

fatigue, functional capacity and fitness were significantly better after graded aerobic exercise than after flexibility treatment and relaxation therapy.[15] However, a flexibility treatment further increases the improvement reached with a graded aerobic exercise.[15] On the other hand, an exhaustive exercise determines in CFS subjects impaired cognitive processing compared with healthy controls.[16]

It is known that training is based on exercises characterized by variations of gravitational acceleration [17] and that changes in gravitational conditions can also be induced by mechanical vibrations applied to the total structure of the human body. It is also known that the reply to training is mediated by neurogenetic [18] and myogenetic [19] factors: the first phase of muscle adaptation is characterized by an improvement of neural factors, while myogenetic factors become more considerable when the incentives of muscle adaptation last for more long time (*e.g.* some months).

So, we submitted CFS patients to a protocol of rehabilitative therapy based on these biodynamic features where our patients underwent a submaximal, low grade and predominantly aerobic exercise in which O_2 consumption was reduced. This modality agrees with previous personal reports which characterize CFS patients as subjects with a reduced capacity of O_2 consumption during exercise as measured by K4 test [20] (personal unpublished data).

In a previous report [21] we already described the diagnostic usefulness of the pressure pain thresholds to study CFS, as well as the evaluation of electrical muscle pain thresholds which resulted characteristic when compared to cutis and subcutis pain thresholds in the comparative study of other syndromes with similar symptoms such as fibromyalgia and myofascial syndrome.[21-23] So we evaluated results before and after treatment by a muscle performance analysis and a comparative evaluation of pressure pain thresholds. Furthermore we applied a visuo analogue scale (VAS) [24] to study the most often alterated parameters of CFS patients (fatigue, muscle pain, and their interference with mood tone, quality of life, and working capability).

The interesting results observed in the first 10 treated patients encourage us to make this preliminary report.

Materials and methods

Ten patients (6 females and 4 males, aged between 20 and 49 years, mean age: 34.5±11 years) who met CDC criteria for CFS case definition [4] (Table II) underwent the protocol yet. Before starting the therapy they were submitted to stretching and relaxations therapies for 6 months without any clinical improvement and later to a break of any rehabilitative therapies for following 3 months. All patients were free from therapies (*e.g.* NSAIs, antidepressant therapies etc.) under this study both during the first and the

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TABLE III.—*Demographic and clinical features of all patients.*

Sex	
F	6
M	4
Mean age (years)	34.5±11
High educational level	7
Acute onset	4
Mean duration of symptoms (months)	43.7±53.7
Body mass index (BMI)	21.2±11.7
Body weight (kg)	68.5±15.7

second evaluation. The patients were informed both on aim and execution modality of the protocol.

Subjects underwent a set of sinusoidal vertical vibrations of all the body by the Galileo 2000 instrument (NOVATEC, Pforzheim, Germany).[23] During the vibration, the human skeletal muscle are submitted to short modifications concerning the muscle lenght. The frequency of the vibrations applied to this study was 18 Hz (shift:10 mm; acceleration: 27 m/s) for the first 2 months and then 22 Hz for the next 4 months. The procedure was initially repeated every 48 h for a total amount of 8 min (2 min for each position), with an increase of 20 s every month until a total amount of 4 min for each position in the next 5 months. The global time of the rehabilitative therapy was 6 months.

The first treatment was executed in the upright position with the feet tip on the vibrating platform. The second treatment was performed in a position of 1/2 squat with the feet rested in extrarotation against the platform. The third treatment was realized putting the subject with only the right foot rested against the right side of the platform and the knee in a position of 60°, while the fourth treatment with only the left foot rested against the left side of the platform and the knee at an angle of 60°.

After each exercise 2 static stretches were performed by the gastrosoleus, ischiocrural and quadriceps muscles for a time of 15 s each one.

During each exercise subjects wore gym socks to avoid wound and to reach a full feet contact of the platform.

Before and after the rehabilitative treatment subjects underwent an algology evaluation with the determination of pain threshold to pressure of quadriceps, trapezius and deltoid muscles bilaterally using the algometer of Fischer.[25] The patients were asked a very detailed account of how they felt and whether or not improvement had occurred after therapy relating to fatigue status, muscle pain and their interference with mood tone, quality of life and working activity. This evaluation was realized using the VAS of Scott-Huskisson with anchor points ranged from 0 (no symptom) to 10 cm (highest imaginable intensity of the symptom).[24]

Statistical analysis

of baseline and after treatment values of pressure pain threshold for each muscle group was performed using the paired t-test (two-sided). Comparison of the VAS values was performed using the Wilcoxon test.

Moreover, subjects underwent a muscle performance analysis using the CIBEX 6000 dynamometer of LUMEX Inc.[26] This test consisted of the evaluation of the best performance of the maximum peak of torque reached during 4 trials by the extensor quadriceps muscle with an extension movement of the knee at 90°/s. After the rehabilitative therapy subjects underwent a second evaluation and collected data were statistically analyzed (Student t-test).

Results

The epidemiological and clinical features of all patients are reported in Table III. For all subjects well defined pathologies were excluded and any kind of therapy was avoided.

All subjects initially referred a worsening of symptoms with the highest intensity during the 24 h immediately after the beginning of therapy, and a progressive resolution of symptomatology from the second week of treatment on.

After the rehabilitative therapy lasting 6 months interesting variations of the examined parameters were reported. We observed a significant decrease of both BMI and body weight (21.2 *vs* 18.4 and 68.5 kg vs 61.4 kg, respectively; $P<0.05$).

The pain thresholds to pressure stimulation were found significantly higher than those of the basal evaluation for quadriceps muscle ($P<0.01$ for the left side with mean difference -3.408, $P< 0.05$ for the right side with mean difference -3.922); no significant differences were reported for trapezius and deltoid muscles ($P<0.4930$ and $P<0.2021$ for the left side and $P<0.6718$ and $P<0.4267$ for the right side, respectively) (Figure 1).

All the parameters evaluated by the VAS showed a decrease, particularly significant for the fatigue status ($P<0.05$), muscle pain ($P<0.05$) and highly significant for the interference with mood tone ($P< 0.01$),

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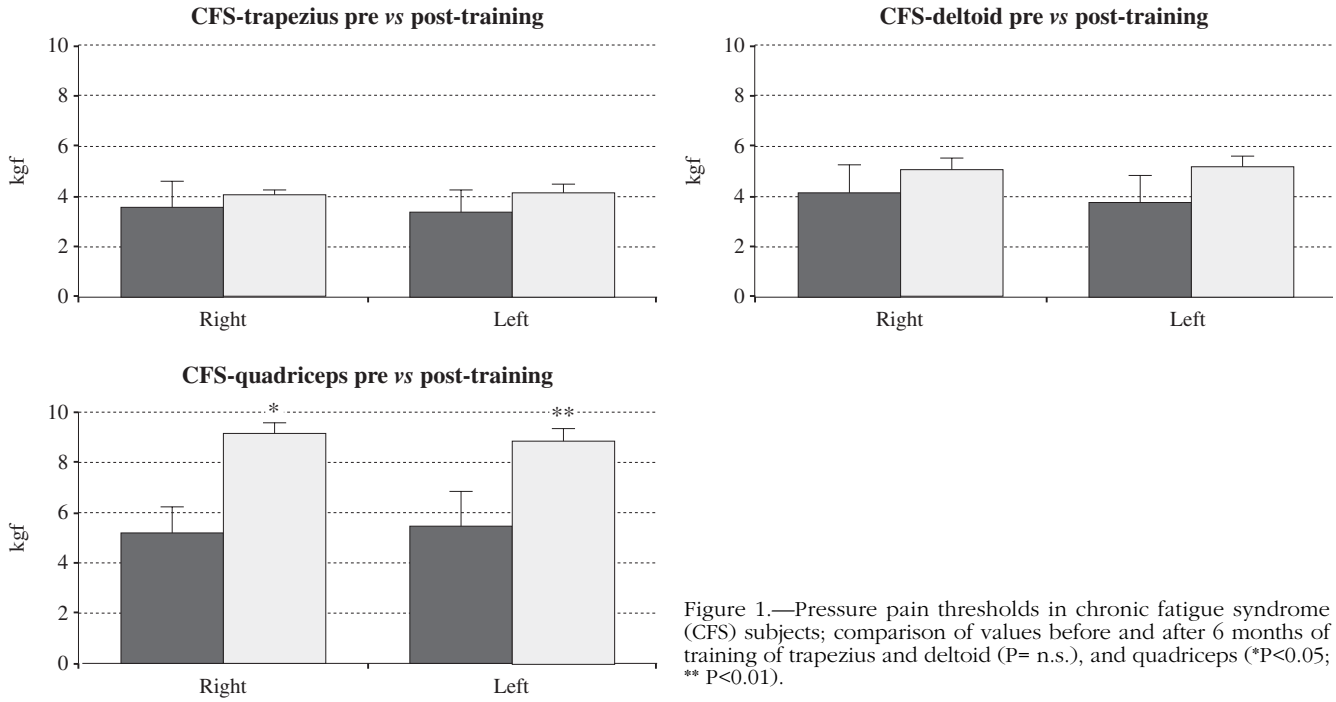

Figure 1.—Pressure pain thresholds in chronic fatigue syndrome (CFS) subjects; comparison of values before and after 6 months of training of trapezius and deltoid (P= n.s.), and quadriceps (*P<0.05; ** P<0.01).

quality of life (P< 0.01) and working activity (P< 0.01) (Figure 2).

The strength parameter that was the peak of Torque showed a significant increase of 18% compared to the basal performance at the end of treatment (P< 0.006).

Discussion and conclusions

In literature few reports describe a clinical improvement of CFS patients after a rehabilitative therapy. Physical exercise often determines a symptom exacerbation, including worsening of cognitive function after exertion.[16, 27-30] The only other treatment of CFS to show promise is cognitive behaviour therapy, which improves functional capacity and symptoms more than both standard medical care and relaxation therapy.[31, 32] More recently, Fulcher and White [15] reported that graded exercise treatment was more effective than relaxation and stretching exercises, suggesting that the amount of therapists' attention was not responsible for the difference in outcome. Overall improvement was accompanied by improvements in fatigue and physical function but seems independent of the improved strength and peak aerobic capacity produced by exercise which is increased of a mean of 13% and which is consistent with an increase of between 5% and 10% found in healthy but sedentary people performing a similar training program.[33]

Our results suggest that it is possible to reach an improvement of functional status of CFS patients that underwent a submaximal and predominantly aerobic exercise with a reduced O_2 consumption using a Galileo 2000 system providing mechanical vibrations characterized by sinusoidal vertical sollecitations.

By the application of the VAS we reported statistically significant variations in the perception of fatigue, muscle pain, mood tone, quality of life and resumption of working activity. In addition we found an interesting and significant increase of the pain threshold of quadriceps muscle which probably is correlated to the changes of the body and skeletal muscle secondary to little variations of muscle length. These variations induce changes of those neuromuscular functions and properties that control the quadriceps stiffness. In fact our treatment procedure provided that this muscle underwent a work at closed kinematic chain, while trapezius and deltoid muscles underwent vibrations at open kinematic chain.[34] Even

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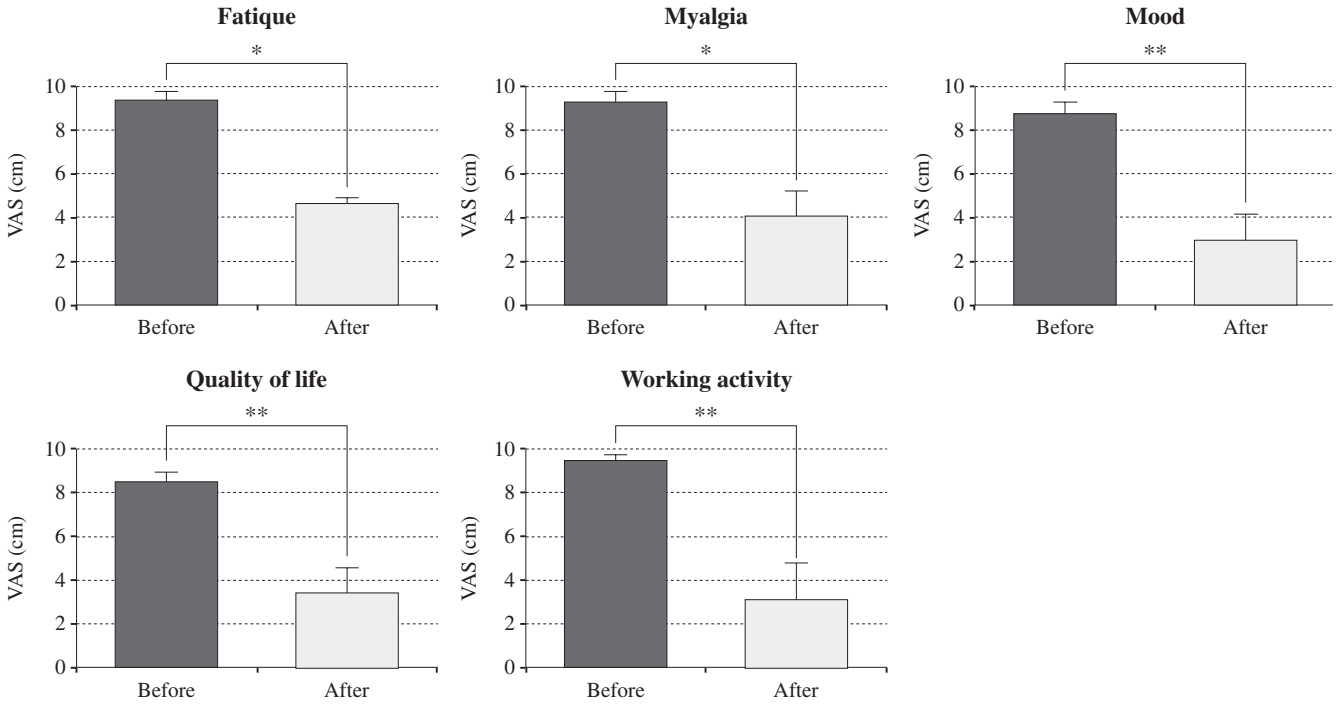

Figure 2.—Visuo analogical scale (VAS) in chronic fatigue syndrome (CFS) subjects; comparison of values before and after 6 months of training. * P<0.05; ** P<0.01.

though no other studies evaluated such parameters using the VAS, these data are very interesting because they suggest a local effect of training on pain thresholds as reported by other authors.[35]

The highly statistically significant improvement of the quantitave values of the pressure pain treshold induced by the mechanical vibration rehabilitation (graded exercise) program seen in the quadriceps and deltoid (to a lesser extent) could be explained by the improvement of neuromuscular proprioception and the increased muscular vascularization (induced by physical exercise) resulting in modifications of muscular trophism. These variations induce changes of neuromuscular functions and properties that control the quadriceps stiffness. In fact, our treatment procedure provided that this muscle underwent work at a closed kinematic chain, while trapezius and deltoid muscles underwent vibrations at an open kinematic chain. Furthermore, our results could be correlated to a chronic stimulation of endorphine system secondary to physical exercise. In fact, endorphins are well known to induce an antalgic effect on subjective pain perception and mood [36] and, interestengly, we found decreased concentrations of beta-endorphins in CFS patients when compared to depressed patients and healthy subjects.[37] For this reason, we included trapezius and deltoid muscles in the algology evaluation of our patients to search for a global and not only local clinical improvement after the submaximal aerobic exercise.

So we suggest that the rehabilitative exertion could characterize:

a) an increase of the synchronization activity of the motor units;

b) an improvement of the cocontraction muscle synergy also due to an increased inhibition of the antagonist muscles;

c) an increase of the mechanism of propioceptive feedback, too.

However the strength parameter also showed an interesting positive increase of 18% of the basal performance at the end of treatment. This increase resulted higher than that reported by other authors [15] after a graded aerobic exercise. This data further confirms that the training of the explosive strength can be realized not only by body exertions characterized by

quick and violent variations of the acceleration of gravity [38] but also by mechanical vibrations applied to the whole structure of human body so to modify the gravitational status of the body itself.

These interesting data need to be confirmed by studies on a largest number of CFS patients compared with a well sex and aged matched group of controls. In fact, a real benefit on CFS symptomatology after this rehabilitative protocol seems to really exist, while our previous observations on stretching and relaxation therapies performed by CFS patients did not show any clinical improvement.

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