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The Efficacy of Farabloc, An Electromagnetic Shield, in Attenuating Delayed-Onset Muscle Soreness

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Objective: To assess the hypothesis that Farabloc, a fabric with electromagnetic shielding properties, would attenuate the symptoms, signs, and muscular strength deficit secondary to delayed-onset muscle soreness (DOMS) induced by two exposures to eccentric exercise in humans.

Design: Randomized, single-blind, placebo-controlled, crossover trial with two testing stages of 5 days duration separated by a washout period of more than 8 weeks.

Setting: University-based sports medicine center.

Participants: Twenty volunteers equally representing untrained male and female subjects.

Interventions: 20 sets of 10 repetitions of single-leg eccentric knee extensions for 37 minutes with the Biodex dynamometer set at 30 degrees per second were performed on the first day of stage one and stage two to induce DOMS in the quadriceps muscle. Double layers of fabric, either Farabloc or placebo, were wrapped around the thigh of each participant during each stage for 5 days.

Main Outcome Measures: Perception of muscle pain, as measured by a visual analog scale (VAS), and strength, as measured by knee extensor torque (EST) with the Biodex dynamometer, were evaluated at 0, 24, 48, 72, and 96 hours. Serum inflammatory markers of muscle damage, including malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils, were assayed at 0, 2, 6, 24, and 48 hours.

Results: Repeated-measures analysis of variance was carried out for each of the seven variables to assess differences for fabric, order of treatment, time, and all combinations. Results of VAS and EST and levels of malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils all showed a highly significant effect of Farabloc compared with placebo. This analysis shows that the order of Farabloc or placebo fabric use in stage 1 and 2 produces different results. This may be caused by a learning effect, but did not alter the overall influence of Farabloc.

Conclusion: The data indicate that double layers of Farabloc fabric wrapped around the thigh reduces pain and strength loss and serum levels of malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils when untrained human subjects are exposed to eccentric exercise to produce DOMS in the quadriceps. Farabloc shields high-frequency electromagnetic fields, although the results do not indicate how these changes are mediated. Further research is needed to determine the mechanism.

Key Words: Creatine phosphokinase—Delayed-onset muscle soreness—Eccentric exercise—Farabloc—Malondialdehyde—Myoglobin.

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The purpose of this study was to determine the effect of Farabloc (Farabloc Development Corp., Coquitlam, BC, Canada) in attenuating the pain, strength changes, and serum biochemical markers of muscle damage caused by delayed-onset muscle soreness (DOMS) induced by two exposures to eccentric exercise in humans. It was hypothesized that Farabloc would reduce the inflammatory response after exposure to exercised-induced quadriceps muscle damage. This reduction would be demonstrated by less pain and strength loss combined with reduced levels of inflammatory markers in the blood.

We speculated that the use of Farabloc would alter the balance of frequencies of electromagnetic fields to which the DOMS-perturbed muscle cells will be exposed. Farabloc will permit continued exposure to extremely low-frequency (ELF), very low-frequency (VLF), and low-frequency (LF) electromagnetic fields, but effectively block high-frequency (HF) electromagnetic fields and most frequencies associated with radiofrequency. This could increase the cells' resistance to perturbation by DOMS. Specific electromagnetic field frequencies may reduce cellular excitability by increasing cell membrane potential while reducing ionic pore activity, hence limiting the damage created by noxious stimuli. Changing the balance of the electromagnetic field toward lower frequencies may suppress free radical formation by inhibition of iron-containing enzymes, limiting the potential cascade of lipid peroxidation that is characteristic of inflammation in DOMS.

The goal of this study was to evaluate the use of Farabloc on a muscle injury model. DOMS, the muscle injury model selected, is a result of strenuous eccentric

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work to which the subject is unaccustomed, causing severe muscular discomfort 24 to 48 hours after exposure.[1] DOMS is characterized by pain and loss of muscle strength in the specific muscle exposed to the eccentric work, and by an increase in the serum levels of biochemical substances indicating muscle damage.[2] DOMS provides a model of muscle injury and tissue inflammation in humans for evaluating experimental interventions.

When the microcirculation is damaged, free radical formation[3] may activate proteolytic enzymes.[4] Reactive oxygen species also are activated during ischemia/hypoxia and subsequent reperfusion/oxygenation in skeletal muscle. Degradation of adenosine triphosphate forms xanthine, which leads to a cascade effect on xanthine dehydrogenase, xanthine oxidase, and uric acid, causing malfunctioning of the ion pumps and increasing intracellular levels of calcium.[5] The end result will generate oxygen free radicals, which induce disruption of phospholipid layers and lipid peroxidation.[6]

Farabloc is a fabric made of a woven mesh of stainless steel and nylon thread, and has been proven to have electromagnetic shielding properties (McDiarmid S, Trudeau M, unpublished data). 9.5% of the fabric is made of steel wire, which consists of iron, nickel, and chromium. A recent study has shown that the magnetostatic shielding ability of Farabloc is indistinguishable from that of placebo using as many as eight layers of fabric (McDiarmid S, Trudeau M, unpublished data). However, Farabloc was found to block electrostatic fields four times more effectively than placebo fabric. Farabloc was found to be an effective electromagnetic shield at frequencies greater than 1 MHz. It has been suggested that Farabloc has a limited shielding effect on electromagnetic radiation in the LF electromagnetic field, particularly the VLF (< 10 KHz) and ELF, and also super and extremely HF (> 10,000 MHz). Farabloc is most effective in shielding against electromagnetic fields in the HF to ultra HF range characteristic of radiofrequency.

Farabloc was devised by Frieder Kempe in 1978 in an effort to relieve phantom limb pain. Initial work by Bach (Bach GL, unpublished data) reported beneficial effects on phantom limb pain and later suggested that Farabloc also may reduce rheumatic pain. Results of a double-blind crossover study demonstrated that Farabloc was effective in the control of phantom limb pain.[7] Investigation of the effects of Farabloc on deep somatic pain has not been undertaken in the past.

A variety of studies have proposed that the alteration of electromagnetic field has an effect on biologic systems.[8,9] Grundler et al.[10] and Eichwald and Walleczek[11] suggested that enzyme systems that are sensitive to electromagnetic fields may be activated, which in turn modulates calcium dynamics. Sandyk[12] performed a study in which patients with Parkinsonian symptoms experienced an increase in central dopamine levels secondary to extracerebral exposure to LF electromagnetic fields. Detlavs et al.[13] demonstrated a greater inflammatory response in rats with full-thickness dermal wounds after exposure to modulated nonthermal electromagnetic fields. Valberg et al.[14] postulated a variety of mechanisms in which electromagnetic fields may produce biologic effects. It is suggested that energy transfer by acceleration of ions and charged proteins modifies cell membranes and receptor proteins. Electric fields induced inside the body exert force on electric charges and electric moments. The magnetic moments of ferromagnetic particles and free radical molecules interact with magnetic fields.[15] Research has been conducted using electromagnetic stimulation in the ELF range of healing bone fractures and cell metabolism.[16–18]

SUBJECTS AND METHODS

Subjects

Twenty untrained volunteers (10 men and 10 women) ranging from 20 to 38 years of age were included in the study. Equal numbers of men and women were assigned to the experimental and control groups. Results were analyzed by treatment group but not by sex. All participants exercised less than once per week.

Individuals who participated regularly in weight training, running, team sports, skiing, or other activities that involved repetitive eccentric loading of the quadriceps muscle were excluded. Other exclusion criteria included experiencing DOMS in the past 3 months, a history of joint disorders, chronic illness, or use of analgesics, nonsteroidal antiinflammatory drugs, or other prescription drugs. The research protocol was approved by the University of British Columbia Clinical Screening Committee for Research Involving Human Subjects.

Procedures

All 20 participants were divided equally into two groups (group A and group B) that alternately were treated as the experimental and control group during two study stages (stage 1 and stage 2). Each stage lasted 5 days and was separated by a washout period of 8 to 12 weeks. After exposure to the eccentric work, participants had their right thigh wrapped in a double layer of fabric for 5 days. In the experimental group, the thigh was wrapped with Farabloc fabric, and in the control group, the thigh was wrapped with a placebo fabric that was identical in appearance to the Farabloc fabric. This study followed a single-blind, randomized, crossover design (Figure 1).

The DOMS of the right quadriceps muscle was created by exercise using a Biodex dynamometer (Biodex Medical Systems, Shirley, NY, U.S.A.). Each session included force adjustment, preexercise eccentric strength test, and 20 sets of 10 repetitions of eccentric muscle work. Participants performed three submaximal and one maximal contraction, followed by four maximal contractions with the Biodex adjusted to 30 degrees per second through a 60-degree range at a long muscle length (105–45 degrees). Average knee extensor eccentric torque (EST) was established after controlled warm-up by averaging the last three of four maximal contractions. The DOMS then was created by just under 37 minutes of eccentric knee extension. Each of the 20 sets lasted approximately

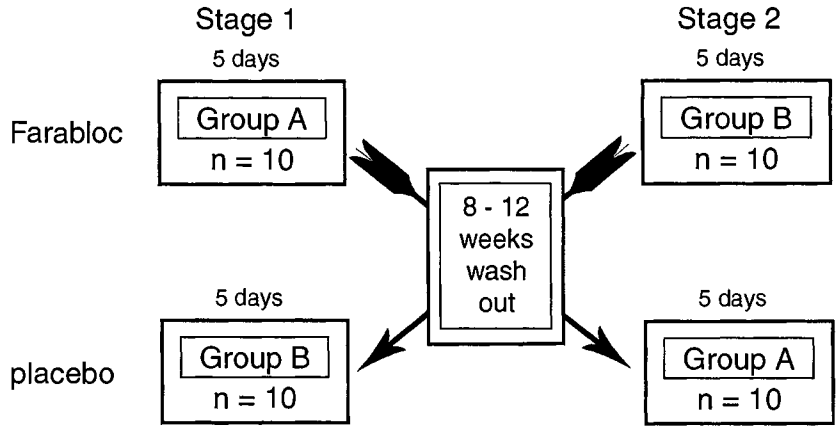

FIG. 1. Schematic showing the randomized, single-blind, placebo-controlled, crossover study design with washout period. Pain and strength were assessed by means of a visual analog scale and knee extensor torque, respectively, at 0, 24, 48, 72, and 96 hours. Levels of malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils were measured at 0, 2, 6, 24, and 48 hours.

100 seconds for 10 repetitions each followed by a 10-second recovery.

Muscle soreness, as evaluated using a visual analog scale (VAS) 10 cm in length, and repeat knee EST were assessed at 0, 24, 48, 72, and 96 hours and repeated after the washout phase. The VAS has been determined to be a valid measure of chronic and experimental pain.[19]

Serum indices of muscle damage were selected for serial assessment over the first 48 hours of each stage. Malondialdehyde was determined as an index of lipid peroxidation that is increased in the process of free radical damage secondary to severe eccentric exercise-induced muscle stress.[20] The standard method of evaluation of serum malondialdehyde values was used.[6] Certain serum enzyme activity maybe increased by muscle damage.[21] Creatine phosphokinase, although highly variable, can be markedly elevated in these circumstances. The method used for measuring creatine phosphokinase was described by Szasz et al.[22] Disruption of the muscle cell membrane will lead to an increased level of myoglobin in serum,[23] so myoglobin concentrations were measured by radioimmunoassay using Nuclear Medical Systems test kit (Organon Teknika Corp., Durham, NC, U.S.A.). White blood cells are known to increase

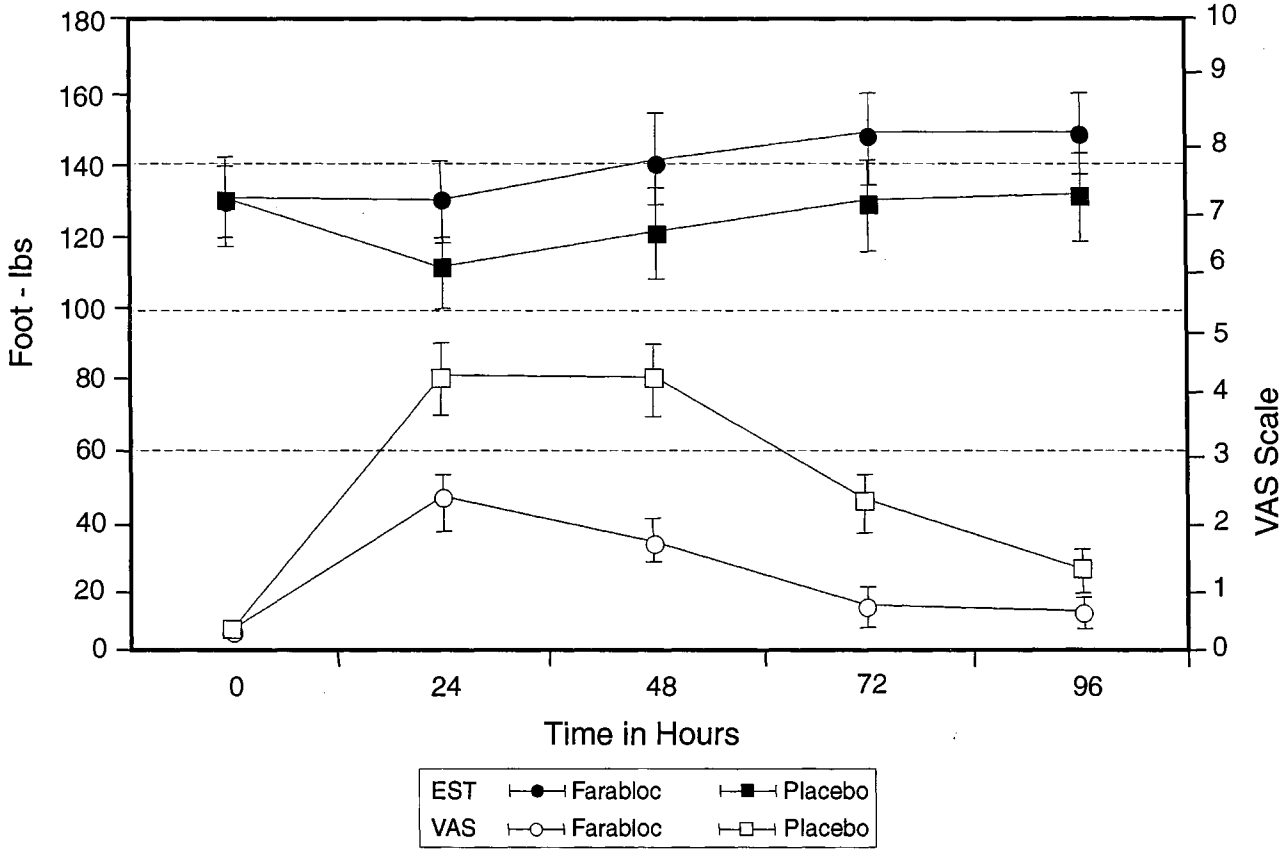

FIG. 2. Comparison of mean ± standard error of strength (EOS) and pain (VAS) between Farabloc and placebo.

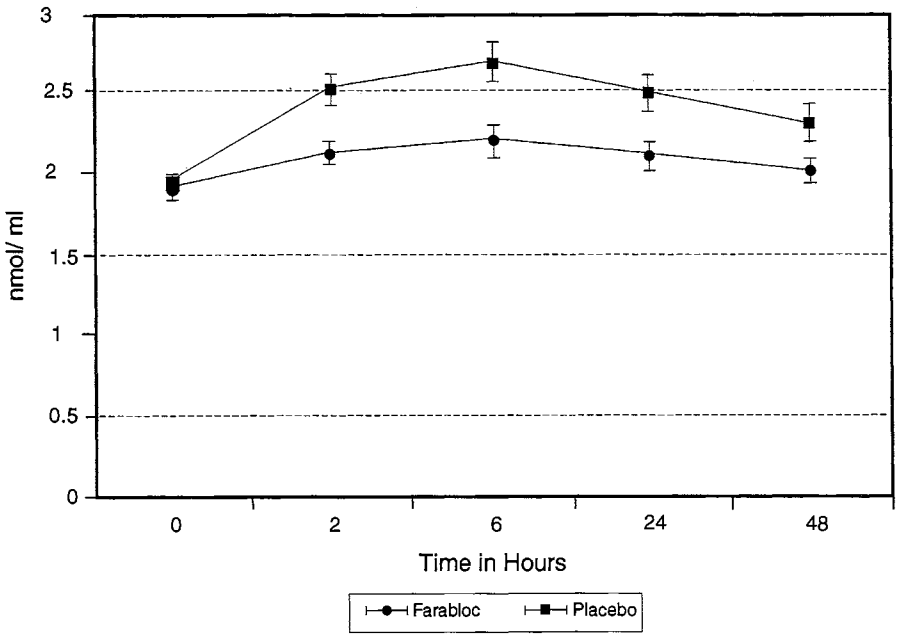

FIG. 3. Comparison of mean ± standard error levels of malondialdehyde in participants treated with Farabloc or placebo.

with severe exercise and muscle damage as a sign of inflammatory response,[2] so standard use of the counting chamber was used to calculate the number of leukocytes and neutrophils. Blood samples were taken from the antecubital fossa of the participants at 0, 2, 6, 24, and 48 hours and used to calculate levels of malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils.

Statistical Analysis

A repeated-measures factorial analysis of variance (ANOVA) was performed on the combined data from the 20 participants for each of the seven variables (VAS, EST, malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, neutrophils) in stages 1 and 2. The data for each variable reflected the reverse order of application of the Farabloc fabric and the placebo fabric for each group of 10 participants. The significance level was set at $p \leq 0.01$ for all statistical procedures.

RESULTS

The results of the VAS data are shown in Figure 2. Comparison of data from the 20 participants yielded significantly different results with Farabloc or placebo fabric ($p = 0.000$). Order effect was significant ($p = 0.010$). The results of the EST data also are shown in Figure 2, and again the difference in results between Farabloc or placebo fabric was significant ($p = 0.003$).

Levels of malondialdehyde also were significantly different ($p = 0.000$) after use of Farabloc or placebo fabric, with an order effect of $p = 0.013$ (Figure 3). Similarly, levels of creatine phosphokinase and myoglobin were significantly different after use of Farabloc and placebo fabric (both $p = 0.000$), with a significant order effect ($p = 0.001$; Figure 4). Finally, levels of leukocytes and neutrophils were significantly different ($p = 0.000$ and $p = 0.008$, respectively) after application of Farabloc and placebo fabric (Figure 5).

DISCUSSION

Double layers of Farabloc fabric wrapped around the thigh of human subjects after eccentric exercise demonstrated attenuation of the symptoms, signs, and muscle inhibition associated with DOMS. Statistical significance was reached for VAS and EST results and for levels of malondialdehyde, creatine phosphokinase, myoglobin, leukocytes, and neutrophils when comparing the Farabloc and placebo treatments.

There was a statistically significant reduction in pain and less loss of strength when Farabloc was used after exercise compared with placebo. The magnitude of this effect suggests a substantial clinical reduction of postexercise disability with this model of muscle injury. Pain results were effected when comparing the Farabloc group with the placebo group after the washout period.

Previous studies have indicated that a single bout of eccentric exercise can effectively reduce muscle damage during a second test.[24] This suggests that a modifying effect on the right quadriceps muscle may have influenced the result of stage 2 even with a washout period of more than 8 weeks. In an other study, the antiinflammatory agent Naproxen was found to decrease perception of muscle soreness and positively influence quadriceps peak torque in subjects with DOMS.[25] These results are consistent with the findings of Conine et al.[7] in their study of phantom limb pain, which demonstrated favorable reductions in pain after application of Farabloc. Lower pain and higher peak torque with Farabloc compared to placebo use suggest that muscle damage is limited, but does not identify a mechanism by which this effect occurs.

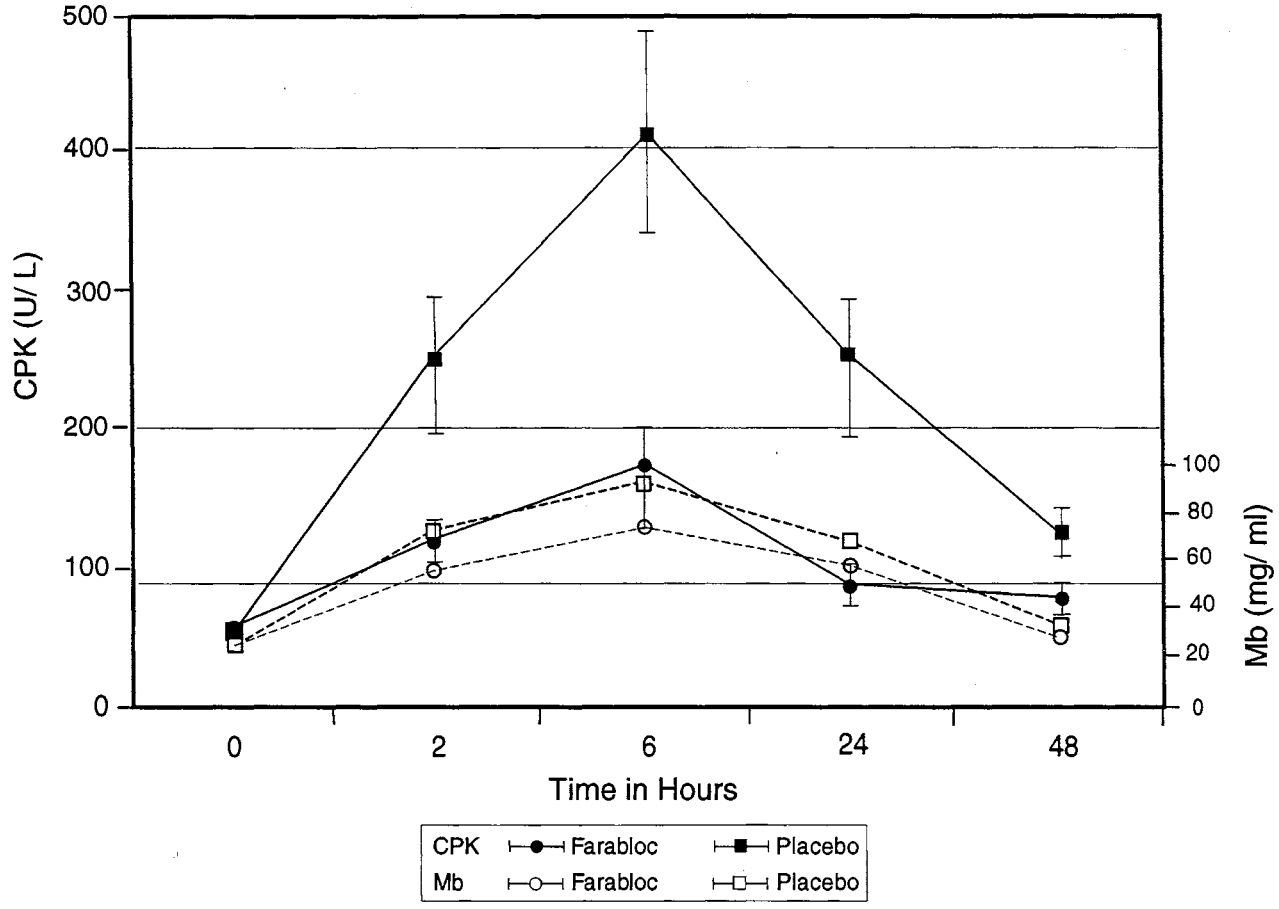

FIG. 4. Comparison of mean ± standard error levels of creatine phosphokinase (CPK) and myoglobin (Mb) in participants treated with Farabloc or placebo.

The findings of this study are consistent with other research that shows that levels of malondialdehyde are elevated for at least 8 hours after exercise.[20] When Farabloc was used by the participants in our study, this serum marker of lipid peroxidation of cell membranes was significantly reduced in every analysis compared with participants who had used a placebo fabric. This result is consistent with reducing free radical damage and limiting lipid peroxidation.

Differences in levels of the inflammatory markers creatine phosphokinase and myoglobin between the Farabloc and placebo groups were significant in all comparisons. Differences in stage 2 may be explained by a learning effect, however. The magnitude of the changes in creatine phosphokinase levels seen in this study was smaller in the placebo group than that observed in studies involving downhill running.[26] This probably is due to differences in timing of blood sampling and in the intensity of exercise. Creatine phosphokinase activity did not return to resting levels at 48 hours. In contrast, myoglobin levels peaked at 6 hours. This may be due to the smaller molecular size of myoglobin.[23] Reductions in levels of creatine phosphokinase and myoglobin are consistent with the possibility that Farabloc stabilizes the muscle cell membrane and reduces release of these substances into serum.

The findings of this study are in conflict with previous research that has shown little change in levels of peripheral leukocytes after DOMS,[24] but are consistent with results of other studies that have demonstrated an increase.[27] The reduction in levels of of leukocytes and neutrophils observed in our study with the use of Farabloc indicates a reduced inflammatory response.

Our findings indicate that the Farabloc fabric, which acts as an electromagnetic shield, can alter the effects of DOMS. Frieder Kempe, the designer of Farabloc, believed that the woven steel alloy threads and nylon fibers acted in a manner similar to a Faraday Cage (personal communication). This interpretation was modified by the study done by the Department of Physics at the University of British Columbia in 1998, in which it was concluded that Farabloc acted as an electromagnetic shield at HF levels but had no magnetostatic shielding properties (McDiarmid S, Trudeau M, unpublished data).

The results of our study in no way explain the mechanism in which the body's response to muscle activity is altered by use of the Farabloc fabric. The significant reduction in levels of malondialdehyde observed in all stages and crossovers with the use of Farabloc is consistent with a decrease in lipid peroxidation and reduced cascade of free radical damage to cell membranes. The

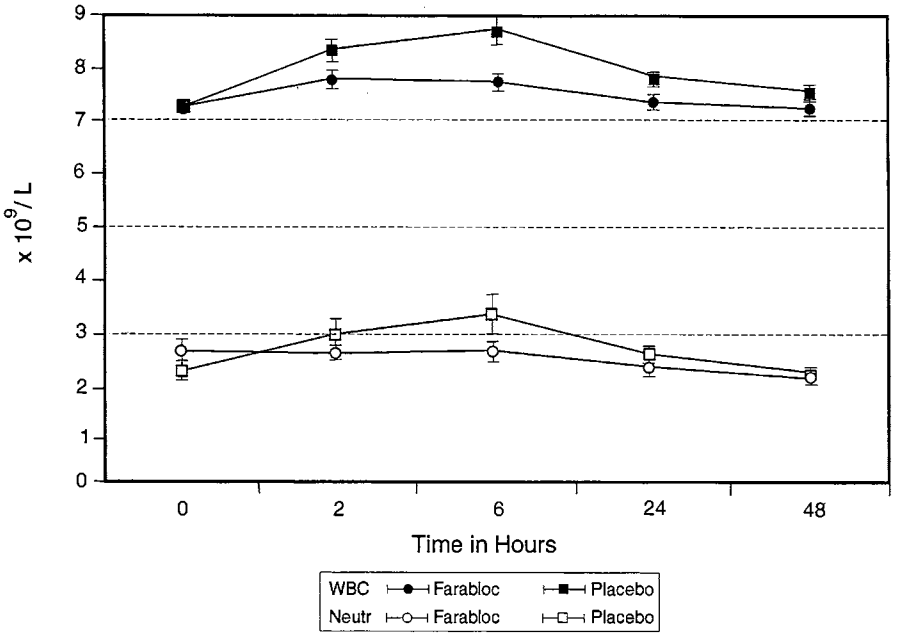

FIG. 5. Comparison of mean ± standard error levels of leukocytes (WBC) and neutrophils (Neutr) in participants treated with Farabloc or placebo.

reduced elevation of creatine phosphokinase and myoglobin suggests that disruption of muscle cell membranes was lessened when Farabloc was used immediately after exercise. The modified response of leukocytes and neutrophils reflects a yet to be determined antiinflammatory effect. The potential application of principles behind these observations to a wide variety of clinical conditions is important. Further study is essential to better understand how an externally applied fabric facilitates an antiinflammatory response.

Our results have shown in a human model of DOMS that the use of Farabloc, an electromagnetic shield, reduced pain, strength loss, and serum markers of inflammation. The limitations of the study do not reveal the mechanism by which Farabloc effects this change. Further research would be necessary to determine the cause of these alterations.

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