Photomedicine and Laser Surgery
Volume 24, Number 3, 2006

Pp. 377–382

Effect of Phototherapy on Delayed Onset Muscle Soreness

PETER DOURIS, P.T., Ed.D., VERONICA SOUTHARD, P.T., D.H.Sc., G.C.S., RICHARD FERRIGI, P.T., D.P.T., JOSHUA GRAUER, P.T., D.P.T., DINA KATZ, P.T., D.P.T., CHRISTINE NASCIMENTO, P.T., D.P.T., and PETER PODBIELSKI, P.T., D.P.T.

ABSTRACT

Objective: **The purpose of this study was to investigate the effects of phototherapy on delayed onset muscle soreness (DOMS) as measured using the Visual Analog Scale (VAS), McGill Pain Questionnaire, Resting Angle (RANG), and girth measurements.** ***Background Data:*** **Previous research has failed to prove the beneficial effects of phototherapy on DOMS.** ***Methods:*** **This was a randomized double-blind controlled study with 27 subjects (18–35 years) assigned to one of three groups. The experimental group received 8 J/cm^2 of phototherapy each day for five consecutive days using super luminous diodes with wavelengths of 880 and visible diodes of 660 nm at three standardized sites over the musculotendinous junction of the bicep. The sham group received identical treatment from a dummy cluster. The controls did not receive treatment. The study was completed over five consecutive days: on day one baseline measurements of RANG and upper arm girths were recorded prior to DOMS induction. On days 2–5, RANG, girth, and pain were assessed using VAS and the McGill Pain Questionnaire.** ***Results:*** **The experimental group exhibited a significant decrease in pain associated with DOMS compared to the control ($p = 0.01$) and sham groups ($p = 0.03$) based upon the VAS at the 48-h period. The McGill Pain Questionnaire showed a significant difference in pain scores at the 48-h period between the experimental and the sham groups ($p = 0.01$). There were no significant differences day to day and between the groups with respect to girth and RANG.** ***Conclusion:*** **The results of this study provide scientific evidence that phototherapy as used in this study provides a beneficial effect to patients who may experience DOMS after a novel exercise session.**

INTRODUCTION

DELAYED ONSET MUSCLE SORENESS (DOMS) is defined as a type I muscle strain that occurs following new exercise.[1] Generally, DOMS occurs after exercise has been completed and increases in intensity within the first 24 h after exercise, peaks at 24–48 hours, and then subsides within 5–7 days post-exercise. Individuals experiencing DOMS often report varied symptoms of pain, soreness, muscular stiffness, tenderness, strength loss, restricted movement and swelling.[1–14] All individuals regardless of their fitness levels, who attempt to perform a new or unusual type of exercise are subject to DOMS. In physical therapy, DOMS may occur secondary to the unaccustomed exercises commonly performed during a therapeutic exercise session. This pain and discomfort may discourage a patient from returning to physical therapy or disrupt their rehabilitation progress.[14]

There are a number of possible etiologies of DOMS. Researchers have illustrated a series of events that explain the DOMS phenomenon. Initially, high tensile forces damage muscle fibers and connective tissue that causes disruptions to the z-lines and the myotendinous junction. This in turn activates the inflammation process, and subsequently activates pain receptors.[1,10] Within approximately 8 hours of the injury, there is a significant elevation in circulating neutrophils.[1,11] Mast cells and histamine production are stimulated. Monocytes that convert into macrophages accumulate at the injury site and produce prostaglandins.[1] Elevated levels of prostaglandin activate type III and IV pain receptors within 24–48 h resulting in the sensation of DOMS.[1,11]

Department of Physical Therapy, School of Health Professions, Behavioral and Life Sciences, New York Institute of Technology, Old Westbury, New York.

Although eccentric exercise has been identified as the primary facilitator of DOMS, any unaccustomed physical activity has been cited.[2] The degree of muscle pain and soreness are related to the intensity of the muscular contractions and the duration of the exercise. Further, exercise intensity has been found to be a greater determining factor over the type of muscle contraction.[2]

Phototherapy is currently used to treat a variety of musculoskeletal conditions.[15–17] It has proved to be an effective modality in the treatment of pain,[18–20] arthritis,[18] muscle spasm,[20] trigger points,[19] fibromyalgia,[20] carpal tunnel syndrome,[21] temporomandibular joint dysfunction,[22] neuralgia,[22] orthopedic injuries,[22] and diabetic wound healing.[22] The photochemical effects of phototherapy provide additional cellular ATP which allows the inflammation process to start earlier and be more acute and severe thus fostering tissue healing and pain management.[23] Phototherapy modulates pain through its direct effect on peripheral nerves.[22,24] When examining the depth of penetration of light, characteristics such as wavelength, intensity and tissue type are key factors. Light with wavelengths of between 600 and 1000nm promote tissue repair and are therefore most commonly used in the clinical setting.[22] The recommended dosage per point for soft tissue inflammation[24] is 4–8 J/cm^2.

Numerous studies have investigated treatment and preventative strategies for DOMS.[1,3–7,9,11,12] These studies have examined the efficacy of a variety of anti-inflammatory agents, oral analgesics, and physical modalities, which have all yielded conflicting and equivocal results.[1,3] Physical modalities that have been investigated include massage,[11] electric stimulation,[7] ultrasound,[6,12] and phototherapy.[4,5,9]

Craig et al.[4,5] performed two studies examining the use of phototherapy combined with low-intensity laser therapy in the treatment of DOMS. Experimental DOMS was induced by eccentrically exhausting elbow flexors for three sets of exercise. In the first study, the subjects were randomly assigned to placebo, control, or three treatment groups.[4] The treatment groups were irradiated at pulses of 2.5, 5, or 20 Hz, respectively, for 12 min (660–950 nm; 31.7 J/cm^2) over a 3-day period. Treatment began following DOMS induction. The results indicated no significant effect on range of motion (ROM), pain, or tenderness measures. The tenderness measures in the treatment groups remained higher than both placebo and control group on the 3rd day post-exercise, which led to the evaluation of the effectiveness of phototherapy combined with low-intensity laser therapy over an extended measure of time. Subsequently Craig et al.[5] studied effects of phototherapy combined with low-intensity laser therapy on the pain and dysfunction associated with DOMS over an 11-day period. As in his previous study, subjective pain was measured using the Visual Analog Scale (VAS) and the McGill Pain Questionnaire (MPQ). The treatment group was given four minutes of multidiode irradiation (660–950 nm; maximum output 534 mW; 11 J/cm^2 pulsed at 73 Hz).[5] The results again showed no consistent statistically significant differences between groups. The multisource arrays used in Craig's study had a limited ability to conform to the arm, secondary to a lack of flexibility of the diodes. Poor contact results in a reduction in the delivery of effective radiation, even with the increase in J/cm^2. A 30% loss of energy results when the energy source is 1 mm away from the skin.[15]

Glasgow et al.[9] attempted to improve the previous Craig studies by utilizing monochromatic infrared arrays, with flexible diodes applied directly to the skin resulting in more effective irradiation. Using the weight of subjects' concentric 1-repetition maximum and eccentrically exhausting the elbow flexors for one set of exercise was employed to induce DOMS. Isometric peak torque, ROM, and pain were assessed prior to and immediately following DOMS induction. The treatment group received phototherapy at wavelengths of 840 nm (3.0 J/cm^2, mean power output of 250 mW; pulsed at 1 kHz) for 4 consecutive days, 24 h following DOMS induction. The results suggested that phototherapy seemed to be ineffective in the management of DOMS.[9] This study contrasts with those previous studies reported by Craig et al.,[4,5] possibly due to differences in induction protocols, treatment device, latency of treatment, and the array used. Even though there was a more efficient delivery of radiation as compared to Craig's studies, the energy dosage may not have been strong enough to effectively treat the area. They utilized a dosage of 3 J/cm^2 and current practice dictates a dosage up to 8 J/cm^2 according to Enwemeka.[24] Craig et al[4,5] may have failed to demonstrate the efficacy of phototherapy due to: excessive DOMS induction, the method of application, and low therapeutic dosage. Glasgow[9] attempted to repeat Craig's study by decreasing the amount of eccentric exercise from three sets to one set, delivery of the phototherapy at 3 J/cm^2 with a "flexible monochromatic diode" (840 nm) allowing for direct skin contact and more efficient delivery of phototherapy. Glasgow also concluded that phototherapy was ineffective in the management of DOMS.

In the present study, we modified Glasgow's method by using a phototherapy device that has two therapeutic wavelengths (660 and 880-nm) versus a monochromatic 840-nm wavelength, increasing energy density from 3 to 8 J/cm^2, changing the number of treatment areas from one to three, and beginning treatment immediately after DOMS induction instead of waiting 24 h, over a 5-day period. The aim of this study was to investigate the effects of phototherapy on DOMS paying careful attention to those parameters that appeared to require modification.

METHODS

Subject selection

This randomized double-blind controlled study utilized a sample of convenience. Five men and 22 women between the ages of 21 and 35 (mean, 24.1; SD, 3.0) were recruited from the New York Institute of Technology campus in Old Westbury, New York. Subjects who met the inclusion criteria were randomly assigned to one of three groups: control, sham and experimental. Subjects that met the inclusion criteria were healthy individuals between 18 and 35 years, and were asked to refrain from any form of exercise for the duration of the study. The Institutional Review Board at the New York Institute of Technology approved this study, and all subjects read signed an informed consent form prior to participating in the study. Exclusion criteria included; subjects who participated in an exercise strength training program within 6 months, any

individual with pre-existing orthopedic complications that would have affected the exercise involved, individuals with cardiac or respiratory conditions including asthma that would have put them at risk for exercising, pregnancy, history of active hemorrhaging, history of blood clots or cancer, open wounds, and photosensitivity.

Materials

Materials included VAS, MPQ, goniometer, tape measure, preacher bicep curl bench, dumbbells weighing 5–100 pounds, and a Dynatron Solaris Phototherapy Unit (Dynatronics Co., Salt Lake City, UT).

Procedures

The study was completed over five consecutive days: Day One- Each subject was randomly assigned, under strictly controlled double-blind conditions, to one of three experimental groups: Control, Sham, and Experimental. Measurements of resting extension angle (RANG) and upper arm girth measurements, height, weight, one-repetition maximum (1-RM) were recorded prior to DOMS induction for all subjects. The elbow flexors of the non-dominant hand were used for this study. Subjects were seated at the preacher bench with their shoulders at a 45° angle. Their concentric 1-RM was determined using a dumbbell with 5-pound increments. The weight used for pain induction was their 1-RM. The experimenter then raised the subjects elbow position to 135° of flexion (upright position) and the subject was asked to lower this 1-RM weight eccentrically for 3 sec. This was done to exhaustion, which is the point at which the subject was no longer able to control the descent of the weight. Regardless of group allocation, all subjects received instruction about phototherapy prior to treatment, which was performed on each day as defined below. The principle investigator was the only one who knew which phototherapy machine had the dummy cluster probe. The sham group received "placebo treatment" from the dummy cluster probe. The experimental group received phototherapy. The control group did not receive any treatment. Immediately after DOMS induction, control, phototherapy and sham treatment was administered. The control group received 5 min rest in a supine position with the forearm resting comfortably across their chest. The experimental group received phototherapy from the Dynatron Solaris Phototherapy Unit (Dynatronics Co.). The phototherapy cluster probe has a treatment area of 5 cm^2. The cluster probe was directly applied to a standardized site on the skin over the musculotendinous junction of the biceps. In addition, it was applied 5 cm away and at a 45-degree angle from the original area for an additional two treatment sites. The dosage was 8 J/cm^2 per site (80 sec), which represents the energy density.[23] The power density at the application site was 100 mW/cm^2. The Dynatron Solaris Phototherapy Unit incorporates 32 infrared superluminous diodes emitting a wavelength of 880 nm and four visible diodes at a wavelength of 660 nm. Subjects in the sham group were treated in an identical fashion to those in the experimental group except that they received placebo irradiation from the dummy cluster probe. Treatments and measurements continued as specified for each group on days 2–5. Measurements included girth, RANG, MPQ, and VAS, which were administered at 24-h) intervals (±2 h) for the duration of the study.

Measurements

RANG. An increase in RANG indicated a shortening of the muscle, or worsening of the condition. RANG was assessed using a universal goniometer. For this, the subject stood with the arm hanging freely in a semipronated position. To standardize measurements, the lateral epicondyle, the head of the humerus were marked, and distally the radial styloid was marked with semi-permanent ink.[9]

Girth. Upper arm circumference measurements were taken at a distance of 70 mm from the elbow joint (the line between the medial and lateral epicondyles) using an anthropometric tape measure. The distances were marked with semi-permanent ink to ensure replication throughout the study.[12]

Pain assessment. Subjective pain was assessed by using the VAS and the MPQ. Following DOMS induction on day 1, each subject was asked to rate their highest level of pain over the previous 24-h period by marking a graphic pain scale on a 10-cm line, marked "no pain" on one end and "maximal pain" on the other. Pain was quantified by measuring the distance, to the nearest millimeter. In addition, each subject completed a MPQ describing "the worst pain" experienced during the previous 24 h.[9]

Statistical analysis

Repeated measures analyses of variance were used to determine if there were any differences in girth and RANG between the groups. The pain scores at the 48-h period were utilized for data analysis because it has been shown that DOMS peaks at 24–48 h.[1–15] The MPQ scores were analyzed with the Kruskal-Wallis *H* test and post hoc Mann-Whitney *U* test for pair wise comparisons. The VAS scores were analyzed using the analysis of covariance (ANCOVA) on the 48-h scores with the 24-h scores serving as the covariate. All post hoc analysis for pair wise comparisons utilized the Bonferroni correction. Randomization to the treatment groups occurred prior to beginning of the study. Therefore, ANCOVA was utilized to control for the effects of the VAS scores at the 24-h period, partitioning out their variability, allowing for a more valid explanation of the relationship between phototherapy and pain at the 48-h period.[25] An alpha level of $p < 0.05$ was used for all statistical comparisons. All statistical procedures utilized SPSS version 10.0 (SPSS, Chicago, IL).

RESULTS

Girth

All subjects experienced a similar non-significant increase in girth over time without a significant difference between the groups as shown by Figure 1. Repeated measures analysis of variance (ANOVA) showed no significant differences over time for the 3 groups.

RANG

The hanging angle of the elbow also showed no significant measurable changes group to group in response to the repeated measures ANOVA. The subjects experienced a similar non-

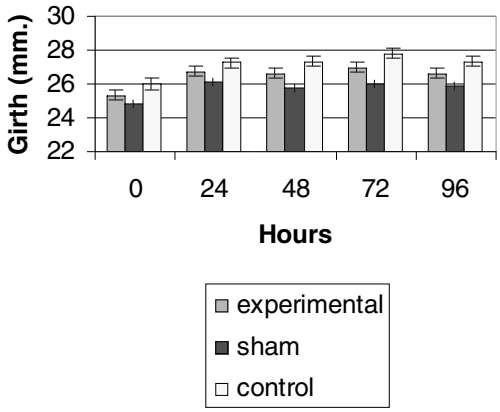

FIG. 1. Girth (means ± SE) changes over time.

significant increase in RANG over the 5-day period without significant differences between the groups as shown by Figure 2.

McGill Pain Questionnaire

The MPQ required the use of non-parametric statistics. It was determined that at 48 h there was a significant difference (p = 0.05) in subjective pain between the groups as demonstrated by the Kruskal-Wallis H test. Post hoc analysis utilizing the Mann-Whitney U showed a significant difference between the sham group and the experimental group (p = 0.01). Results from the MPQ scores are summarized in Figure 3.

Visual Analog Scores

The VAS scores at the 48-h period were analyzed with an ANCOVA with the 24-h scores serving as the covariate. There

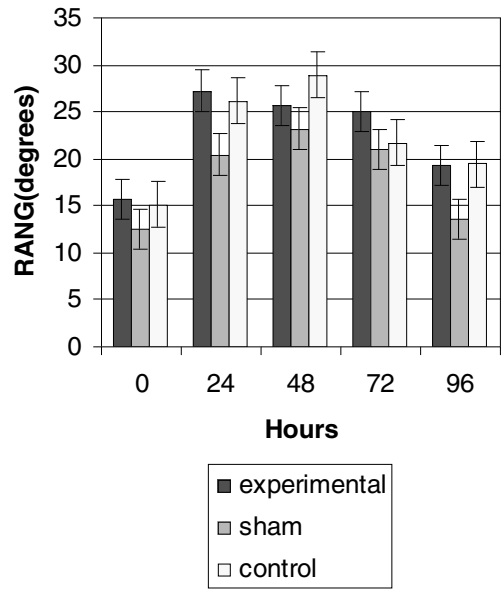

FIG. 2. RANG (means ± SE) changes over time.

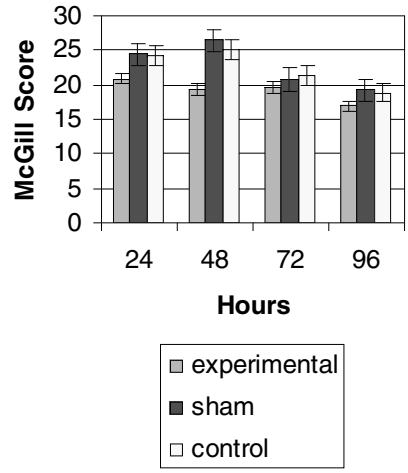

FIG. 3. McGill Pain Questionnaire Scores (means ± SD) over time.

was a significant difference between the groups (p = 0.01). Pair wise comparisons utilizing the Bonferroni, revealed the significant differences between the experimental and the sham groups (p = 0.03) and between the experimental and control groups (p = 0.01). Results from the VAS scores are summarized in Figure 4.

DISCUSSION

Our results indicate that phototherapy as used in this study provided a beneficial effect in the reduction of symptoms on the subjects who experienced DOMS. This contrasts with several previous studies on DOMS.[3–7,9,12] Previous investigators have posited reasons for the insignificance of phototherapy on DOMS which included the use of subtherapeutic dosage, insufficient duration, poor contact, varied frequencies, and overzealous DOMS induction.[4,5,9]

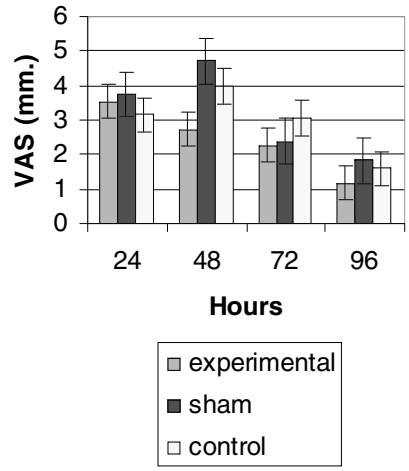

FIG. 4. Visual Analog Scores (mean ± SE) over time.

We believe the beneficial effects of phototherapy on DOMS as reported resulted in part from using a higher dosage and maintaining good contact. These parameter enhancements are the result of a variety of improvements in phototherapy application, technology and methodology based on the work of Craig,[4,5] Glasgow,[9] and Enwemeka.[24] Flexible cluster heads and precise determination of the treatment sites allowed for direct application to the intended treatment areas. We focused treatment on three separate sites of the musculotendinous junction of the biceps as opposed to one area, therefore extending the treatment area. Treatment began immediately following DOMS induction on day 1 as opposed to Glasgow,[9] who waited until day 2 to begin treatment. Based on these results, one could hypothesize that the earlier administration promoted light energy absorption and reduced the pain perception evidenced in this group. Phototherapy has been proven to modulate pain through its direct effect on peripheral nerves, accelerating the inflammatory process and aiding tissue repair.[17,22–24] Phototherapy has been shown to markedly promote muscle regeneration in the traumatized area following injury.[26] Therefore immediate treatment should result in less pain via effects on the peripheral nerves and/or speedy induction of the inflammatory response.

Previous research collected data over an eleven day period.[4,5,9] Due to the curvilinear nature of DOMS, we decided to focus the statistical analysis of the pain scores on the 24–48-h period when DOMS has been shown to peak.[1] Figures 3 and 4 demonstrate the highest pain scores within the 24–48-h period for the control and sham groups. Conversely, in this study the pain scores of the experimental group began to decrease following the 24-h period as result of phototherapy.

Girth measurements demonstrated non-significant changes over the five-day period without any significant differences between the groups as shown by Figure 1. RANG measures followed the same curvilinear response to DOMS as pain did, peaking at the 48-h period before subsiding as shown by Figure 2, with no significant differences between the groups.

Future studies should utilize more valid measures of volumetric changes in the affected limb. Other studies can also assess the benefit of applying the diode directly to where the subject experiences the pain rather than a predetermined location as was used in this study. Additionally, this study should be replicated using other populations such as trained women and men, different age groups, and other muscle groups to fully investigate the efficacy of phototherapy on DOMS.

CONCLUSION

In summary, the results of this study provide scientific evidence that phototherapy, and its current applications, provide a beneficial effect to patients who may experience DOMS after exercise. Patients or persons who experience DOMS can benefit from phototherapy with the treatment parameters used in this study. This may improve compliance with new therapeutic exercise regimes.

REFERENCES

1. Cheung, K., Hume, P.A., and Maxwell, L.L. (2003). Delayed onset muscle soreness treatment strategies and performance factors. Sports Med. 33, 145–164.
2. Carpinelli, R., and Gutin, B. (1991). Effects of miometric and pliometric muscle actions on delayed muscle soreness. J. Appl. Sport Sci. Res. 5, 66–70.
3. Connolly, A.J., Sayers, S.P., and MacHugh, M.P. (2003). Treatment and prevention of delayed onset muscle soreness. J. Strength Cond. Res. 17, 197–208.
4. Craig, J.A., Barlas, P., Baxter, G.D., et al. (1996). Delayed onset muscle soreness: lack of effect of combined phototherapy/low-intensity laser therapy at low pulse repetition rates. J. Clin. Laser Med. Surg. 14, 375–380.
5. Craig, J.A., Barron, J., Walsh, D.M., et al. (1999). Lack of effect of combined low-intensity laser therapy/phototherapy (CLILT) on delayed onset muscle soreness in humans. Lasers Surg. Med. 24, 223–230.
6. Craig, J.A., Bradley, J., Walsh, D.M., et al. (1999). Delayed onset muscle soreness: lack of effect of therapeutic ultrasound in humans. Arch. Phys. Med. Rehabil. 80, 318–323.
7. Denegar, C.R., Yoho, A.P., Borowicz, A.J., et al. (1992). The effects of low-volt micro amperage stimulation on delayed onset muscle soreness. J. Sport Rehabil. 1, 95–102.
8. Francis, K.T. (1983). Delayed muscle soreness: a review. J. Orthop. Sports Phys. Ther. 5, 10–13.
9. Glasgow, P.D., Hill, J.D., McKevitt, A., et al. (2001). Low-intensity monochromatic infrared therapy: a preliminary study of the effects of a novel treatment unit upon experimental muscle soreness. Lasers Surg. Med. 28, 33–39.
10. Gulick, D.T., and Kimura, I.F. (1996). Delayed onset muscle soreness: what is it and how do we treat it? J. Sport Rehabil. 5, 234–243.
11. Hilbert, J.E., Sforzo, G.A., and Swensen, J. (2003). The effects of massage on delayed onset muscle soreness. Br. J. Sports Med. 37, 72–75.
12. Symons, T.B., Clasey, J.L., Gater, D.R., et al. (2004). Effects of deep heat as a preventative mechanism on delayed onset muscle soreness. J. Strength Cond. Res. 18, 151–161.
13. Tokmakidis, S.P., Kokkinidis, E.A., Smilios, I., et al. (2003). The effects of ibuprofen on delayed onset muscle soreness and muscular performance after eccentric exercise. J. Strength Cond. Res. 17, 53–59.
14. Weber, M.D., Servedio, F.J., and Woodall, W.R. (1994). The effects of three modalities on delayed onset muscle soreness. J. Orthop. Sports Phys. Ther. 20, 236–242.
15. Turner, J.T., and Hode, L. (2002). *Laser Therapy. Clinical Practice and Scientific Background.* Sweden: Primer Books.
16. Belanger, A. (2003). *Evidence-Based Guide to Therapeutic Physical Agents.* Baltimore: Lippincott Williams and Wilkins.
17. Enwemeka, C.S. (2003). Evidence-based clinical application of laser phototherapy. Presented at the Continuing Education Workshop, New York Institute of Technology, Old Westbury, NY.
18. Ozdemir, F., Birtane, M., and Kokino, S. (2001). The clinical efficacy of low-power laser therapy on pain and function in cervical osteoarthritis. Clin. Rheum. 20, 181–184.
19. Simunovic, Z. (1996). Low-level laser therapy with trigger points technique: a clinical study on 243 patients. J. Clin. Laser Med. Surg. 14, 163–167.
20. Gur, A., Karakoc, M., Nas, K., et al. (2002). Efficacy of low-power laser therapy in fibromyalgia: a single blind, placebo-controlled study. Lasers Med. Sci. 17, 57–61.
21. Wong, E., Lee, G., Zucherman, J., et al. (1995). Successful management of female office workers with “repetitive stress injury” or

"carpal tunnel syndrome" by a new treatment modality—application of low-level laser. J. Clin. Pharm. Ther. 33, 208–211.
22. Enwemeka, C.S. (2004). Therapeutic light. J. Rehabil. Jan/Feb, 20,22–25,56–57.
23. Mendez, T., Pinheiro, A., Pacheco, M., et al. (2004). Dose and wavelength of laser influence on the repair of cutaneous wounds. J. Clin. Laser Med. Surg. 22, 19–25.
24. Enwemeka, C.S., and Pontinen, P.J., eds. (2003). *Light Therapy Applications*.
25. Portney, L.G., and Watkins, M.P. (2000). *Foundations of Clinical Research* 2nd ed. Upper Saddle River, NJ: Prentice Hall Health.
26. Bibikova, A., and Oron, U. (1993). Promotion of muscle regeneration in the toad (*Bufo viridis*) gastocnemius muscle by low-energy irradiation. Anat. Rec. 235, 374–380.

Address reprint requests to:
Dr. Peter Douris
New York Institute of Technology
500 Bldg., Rm. 501
Old Westbury, NY 11568-8000

E-mail: pdouris@nyit.edu