

REVIEW ARTICLE

Biolite: A Patented Ultra-Low-Level Laser-Therapy Device for Treating Musculoskeletal Pain and Associated Impairments



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Available online 14 February 2015

Received: Nov 7, 2014

Revised: Jan 27, 2015

Accepted: Feb 4, 2015

KEYWORDS

balance disorders;
laser acupuncture;
laser therapy;
motor control
dysfunction;
musculoskeletal pain;
risk of fall

Abstract

After an excursus on state-of-the-art knowledge for low-level laser therapy (LLLT), Biolite, a patented ultra-low-level laser therapy device used to treat musculoskeletal pain and associated impairments, is presented. The application protocols include short stimulation of sequences of acupuncture points. The observed effects seem, however, to be far from those that might be expected after acupuncture. The primary effect seems more likely to be an extracellular soft-tissue matrix reaction. The development of the technique, the studies performed, and the evidence collected over > 10 years suggest that specifically modulated laser light can interact with human tissues at light fluences well under those previously considered as being capable of having any effect. Musculoskeletal pain very often becomes an autonomous dysfunction that is independent of the original injury and that can be effectively treated using specific peripheral acupuncture-like stimulation. Because such acupuncture is capable of reducing motor control “interferences” from noxious stimuli, it can improve motor control performance, thereby reducing the risk of falls in the elderly individuals. The proposal of acupuncture-derived protocols to be applied by Western physiotherapists using an ultra-low-level laser therapy device is a further “bridge” between two different, and sometimes very different, clinical worlds to better serve our patients.

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1. Introduction

Laser therapy at low and very-low-light level is widely applied in musculoskeletal pain treatment. On MEDLINE, many papers are currently indexed under low-level laser therapy (LLLT) or very-low-level laser therapy (VLLLT); as of today, on MEDLINE, there are > 3200 papers, 1700 of which were published in the past 5 years, and many of them appear to be very strongly grounded.

The abbreviation LLLT is generally used to indicate a laser therapy using a 100–200-mW power range, whereas VLLLT stands for a laser therapy at lower levels, down to 5 mW. In both cases, both local and distal/reflex stimulation protocols are applied.

LLLT is increasingly being accepted, especially after a systematic meta-analysis by Chow et al [1], which demonstrated the effectiveness of such treatment against neck pain.

The present paper presents a novel therapy that is applied using Biolite, a laser device providing a stimulation at power ranges well under the lower limit of VLLLT, and therefore presented as ultra-low-level laser therapy.

Biolite features a red light ($\lambda = 635$ nm) laser stimulation at 0.03 mW average power for energy doses typically in the range of 0.3 mJ per treated point at an energy density of approximately 0.015 J/cm². These values, according to Tunér and Hode [2], lie below any possible stimulation level according to the Arndt–Schulz rule applied in the field of biology.

According to previous experience and knowledge, as stated by Litscher and Opitz [3], laser acupuncture normally involves much higher power/energy doses.

By contrast, the kind of response obtained with the Biolite treatment is rather different from the one generally observed in acupuncture, at least with regard to musculoskeletal acupuncture.

The main differences are in terms of velocity—a significant modification can often be observed within minutes of the 20-second application—and in terms of the number of required applications—rough but broad-based statistics show that < 3% of patients with musculoskeletal pain actually need a third treatment.

A brief presentation is therefore provided about the Biolite treatment, which is effective over a wide range of musculoskeletal conditions and is accompanied by minimal contraindications and a high compliance by patients. An excursus of the research activities performed is also included to facilitate understanding of the physiological mechanisms likely to be involved.

2. Biolite

Conceived in the Rehabilitation Department of the Colletta Hospital (Arenzano, Genova, Italy) as a result of the expertise and intuition of Dr L. Baratto, who led a joint team composed of the Liguria Region Public Health Service and the Department of Informatics and Biomedical Engineering of the Genova University, Genova, Italy, Biolite has been engineered in close cooperation with RGM SpA (Genova, Italy), which funded a significant part of the R&D activities.

It is an internationally patented device emitting a modulated red laser wave ($\lambda = 635$ nm) with an optical peak power of 2 mW. The modulation consists of the combination of two square waves at 100 Hz and 1 Hz with duty cycles of 1% and 50%, respectively. The average laser power is therefore ~ 0.01 mW. The laser beam converges/diverges and at the focal distance of 35 mm, its spot area is < 0.13 cm².

This stimulation is applied over sequences of acupuncture points to form protocols that are specific for the body section affected rather than for type of affection. It is contraindicated in the following cases: patients affected by neoplastic phenomena; patients bearing any sort of electric stimulator; pregnant women; and human immunodeficiency virus patients.

Its application should be further avoided on epiphyseal cartilages in young patients.

3. Applying Biolite

Applying Biolite is very easy, provided that the therapist can detect the application points from among a selection of 15 acupoints known to promote systemic balancing and located on meridians conveying the energy flow across the affected areas.

It is worth underlining once more that the neurophysiopathological mechanisms activated by Biolite, although involving acupuncture points, seem unlikely to be the ones that are well-known in classical acupuncture. Further studies may perhaps reveal similarities and differences and help explain the complex mechanisms involved [4,5].

Although there are many suggestions of an acupuncture-like mechanism, there are several reasons that may cast some doubts. Laser acupuncture normally requires an energy per point in the area of 1 J [2], whereas with Biolite, we stimulate the point with < 0.3 mJ. When treated with Biolite, patient's perception is often almost zero but, despite this fact, the peripheral modification is generally perceptible within 1 minute from the stimulation. By contrast, traditional acupuncture with mechanical or electrical stimulation of the needle almost always produces a reflex stimulation that is clearly perceivable by the patient.

We are working on the hypothesis that Biolite treatment may stimulate a photon cascade on the extracellular soft-tissue matrix (ECM) that follows the mesh of meridians along the patient's body. The schematic of the process is outlined herein after a few basic statements.

3.1. Basic statements

- (1) The oxygen-emitted photons during the oxidation process (37°C) have a wavelength that can be calculated as ~ 650 nm (very close to Biolite emission).
- (2) The ECM proteins (e.g., proteoglycans, glycosaminoglycans) display a cyclic oxidation/redox period lying between 6 ms and 20 ms (frequencies between 160 Hz and 50 Hz) [6,7]. The Biolite emission is pulsed at 100 Hz.

- (3) On the assumption [2] that approximately 0.1% of the laser power penetrates beneath the dermis, an average energy density under the skin stimulated with a 10-second Biolite emission has an energy density of approximately 10^{13} photons/cm², which is surprisingly similar to the average proteoglycan density of the same order of magnitude (10^{13} photons/cm²).
- (4) The ECM is a mesh of normally folded proteins that, under stress, stretch and tend to couple with water to form a jelly-like compound that shows pH anomalies and an increased resistance to ion circulation [8]. The intersynaptic space is filled by ECM, and erratic nerve signaling across synapsis can be expected whenever local ECM is in gel status.
- (5) Two photons are emitted by each oxidation process but only one is required for the redox process.

3.2. Model

The Biolite stimulation could start a self-amplifying process of photon emission synchronization. This is likely to spread along the meridians and to promote restoration of basic homeostasis wherever an anomalous ECM condition is encountered along the meridian path.

However, should there be any residual resistance in introducing acupuncture concepts into a Western clinical environment, it may help to recall that the United States National Institutes of Health since 1997 has agreed that "There is sufficient evidence of acupuncture's value to expand its use into conventional medicine and to encourage further studies of its physiology and clinical value" (p. 19 in [9]).

In current Western clinical practice, however, it may be difficult for the patient to accept the reflex approach and even more so with Biolite as the energy provided is generally very hard to perceive.

Light paresthesias or "pins and needles" may sometimes be felt over anatomical patterns that can perhaps be promptly understood only by acupuncturists/reflexologists.

It is further hard to believe and accept, by both the patient and—at least at the beginning—the therapist, that the beneficial effect is generally almost immediately perceived (within minutes from the application) and keeps on increasing, settling, sometimes with a temporary relapse, in up to 8 hours.

A wise operational choice is therefore to discontinue the treatment as soon as the therapist observes a significant modification (pain reduction, increase in the range of motion, perceivable decontraction, etc.).

Failing to understand this point may lead the therapist to induce an overstimulation effect in spite of the extremely low energy. This kind of phenomena is, however, well-known [10] and not unique only to laser therapy.

4. Biolite application protocols

It was decided that the choice of a series of standard, repeatable, basic protocols would fit more easily into Western rehabilitation standards. This decision was not an easy one, as the very idea of protocol is notoriously far from acupunctural logic. The majority of physiotherapists trained in accordance with Western medical standards can

thereby achieve a good number of positive results and become interested in the new approach suggested by the Traditional Chinese Medicine.

Specific protocols were set up for musculoskeletal pain treatment, to treat ulcers and wounds, peripheral subacute neuropathies (herpes zoster), scars, and peripheral balance disorders as well as fibromyalgia.

The protocols were developed largely through an empirical set up although obviously one based on certain principles [11,12].

The model we have adopted and that has proven to be effective selects two pairs of points to promote the return to general balance: whenever the patient is in "hyper" condition, to disperse the excess energy, we propose the stimulation of the large intestine (LI4 Hegu) and stomach (ST36 Zusanli). However, whenever the patient is in "hypo" condition, to promote the distribution of fresh energy, we propose the stimulation of triple heater (TH5 Waiguan) and gallbladder (GB34 Yanglingquan).

Some suggestions came from the five-element theory (both ST36 and GB34 are Earth points), whereas LI4 is a Yuan point, and TH5 is connected to Yang Wei Mai and is known to eliminate stasis in Qi flow.

Please remember that we had to select points that could be stimulated without any risk of adverse reactions, and the choice was made with the assistance of some Italian acupuncture schools.

The four points chosen have to be stimulated in a cross-like pattern over the four body regions (left/right hemisoma and upper/lower body; Fig. 1).

The idea of a cross-like sequence came simply from considering the following: the starting point in the quadrant opposite to the dysfunctional one would most likely meet a sol-state ECM endowed with normal metabolism to avoid producing imbalance it seemed logical to propose alternating the stimulation between the two hemisomas.

In treating somatosensory vertigo, the selection of the Taixi (KI3), an Earth and a Yuan point, and of the Kunlun (BL60), a Fire and River point of the five Shu points, was made on the assumption that these balance deficits arise from spasms and musculoskeletal pain that are a specific indication for this combination.

In all other protocols, we assumed that having restored the free Qi flow by stimulation of the balancing couples of either LI4 + ST36 or TH5 + GB34, we could convey the energy along the Jing Jin (sinarteriae nervocardinales): the specific protocols were therefore developed by considering the paths of the meridians across the painful or dysfunctional musculoskeletal zone [13,14]. The selected points are listed in Table 1.

To detect each point, a specific guide is provided to indicate the anatomical references, although the therapist can identify the point by taking advantage of the well-known superior pressure sensitivity of almost all acupuncture points compared with the surrounding skin.

To foster the diffusion of the rebalancing command through the tissues [15,16], it might be helpful to ask for an isometric contraction of the limb where the acupuncture point that has been treated is located.

Thus, it is recommended to perform a quick check of the modification, if any, of the patient's condition after the stimulation of each point, especially if the patient has

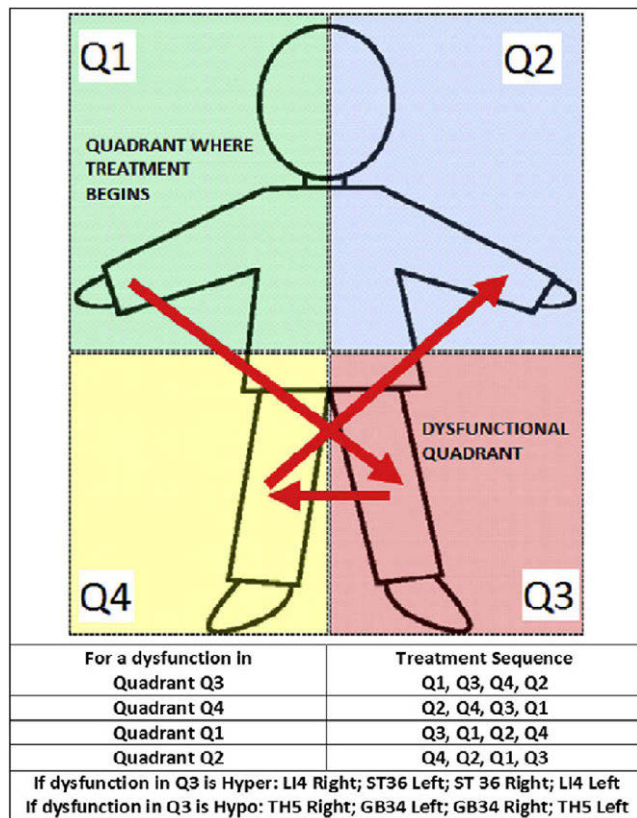


Figure 1 The cross-like treatment sequence.

reported any “strange” sensation: as mentioned earlier, it is recommended that the protocol be discontinued and to wait for an overnight report as soon as a significant benefit is observed.

5. Biolite treatment in the rehabilitation process

The Biolite treatment generally at least modifies the functional symptoms and its application can enhance the overall results of the rehabilitation process due to its analgesic and muscle relaxant effects.

An action mechanism through the ECM and its interactions with the peripheral nervous system seem to offer the most reasonable explanation.

By contrast, this capability of Biolite to interact with the complex dynamic balance between proprioceptive and nociceptive stimulations on the peripheral nervous system can perhaps shed some light on the otherwise unaccountable effects observed when applying Biolite to patients affected by degenerative chronic pathologies or displaying dysfunctions as the result of traumatic events.

Biolite is however not “the solution” whenever musculoskeletal dysfunctions arise from structural and functional modifications that will need a specific rehabilitative approach.

Other clinical syndromes, often referred to as articular dysfunctions or even somatic dysfunctions [17], can often be fully resolved by the rebalancing effect of Biolite. Conditions such as these, in which the pain, often triggered by a mildly traumatic event, persist well beyond the resolution of the trauma, induce contractions that in turn promote a spreading of pain, the onset of “trigger points”, and cause motor control adaptive modifications. The prevalence of these situations in patients requesting physiotherapy treatment is perhaps surprising.

Besides its natural application in musculoskeletal pain treatment, Biolite can be thought of as an effective differential diagnostic tool. By assuming that Biolite can treat a dysfunction or a painful condition, we have to consider

Table 1 Biolite application points.

Ref	Name	Anatomical reference
LI4	Hegu	In the middle of the second metacarpal bone on the radial side.
LI5	Yangxi	On the radial side of the wrist in a depression between extensor pollicis longus and brevis tendons, found when the thumb is tilted upward.
TH5	Waiguan	2 cun over the dorsal wrist flex crease, between the radius and the ulna.
LI11	Quchi	With the elbow flexed, on the radial side of the upper arm at the border of the humerus.
SI2	Qianggu	When a loose fist is made, at the ulnar end of the crease, distal to the fifth metacarpophalangeal joint at the junction of the red and white skin.
SI8	Xiaohai	Between the olecranon process of the ulna and the medial epicondyle of the humerus, found with the elbow flexed.
LV2	Xingjian	On the dorsum of the foot between the first and second toes, proximal to the margin of the web at the junction of the red and white skin.
KI3	Taixi	In the depression midway between the tip of the medial malleolus and the attachment of the Achilles tendon.
BL60	Kunlun	In a depression between the tip of the external malleolus and the Achilles tendon.
ST38	Tiaokou	8 cun below ST35, one finger width lateral from the anterior border of the tibia.
ST36	Zusanli	3 cun below ST35, one finger width lateral from the anterior border of the tibia.
FM23	Xiyan	Lateral and medial knee depressions.
BL40	Weizhong	Midpoint of the transverse crease of the popliteal fossa, between the tendons of biceps femoris and semitendinosus.
GB34	Yanglingquan	In a depression anterior and inferior to the head of the fibula.
BL66	Tonggu	Anterior to the fifth metatarsophalangeal joint.

that if after a temporary benefit, the dysfunction or the pain is appearing once more, there has to be an active irritation process that should be investigated and appropriately reduced.

6. Biolite development

A novel, surprisingly effective laser stimulation was presented in a paper published in 1999 [18]. The stimulation was provided by a square-wave-modulated emission of a very-low-power diode laser, and its effectiveness in the soft-tissue modifications was also the subject of a specific communication [19].

At the same time, in close cooperation with Genova University (Endocrino-Metabolic Sciences Department), a paper was published containing ultrasonographic evidence of this kind of modification in cervical arthritis patients treated using Biolite [20].

A paper published in 2001 suggested a close link between Biolite stimulus and the soft-tissue ECM modifications themselves related to the neurophysiology of "common pain" [21].

A mini review [22] published the available evidence in favor of VLLLT.

The specific device, registered under the name of Biolite, was patented (EP1669102A1), and CE certified (Class IIa) according to standing medical device regulations and made ready for distribution to health professionals.

A paper reporting the clinical evidence in the treatment of conditions that could generally be defined as "common musculoskeletal pain" was also published [23]. The definition of "common musculoskeletal pain" included those painful conditions that are not clearly dependent on modifications of the underlying musculoskeletal tissues/structures, which has a tendency to become chronic regardless of its origin and has a tendency to spread and develop trigger points. In other words, the family of impairments normally referred to as "somatic dysfunction" [24], "articular dysfunction" [25,26], "fibromyalgia" [27,28], and "myofascial pain" [29] was included along with those covered by the well-known theories expressed by Travell and Simmons, Lewitt, Maigne, Chaitow, and others.

The paper [23] on one hand pointed out that the observed effectiveness was well beyond any "placebo" effect and on the other hand focused on the timing of the response to the treatment.

Further activities were performed with regard to the following:

- (1) effects in the treatment of cervical arthritis patients [30,31];
- (2) the correlation between central nervous system lesions, mechanical pain threshold, and proprioceptive control [32,33]; and
- (3) the setting up of models to explain the effectiveness of peripheral stimulation in controlling pain [34].

Besides performing experimental activities on animal models, that confirmed the effectiveness of remote reflex treatment of edema and (acute, chronic, and neuropathic) pain [35], clinical trials were performed

involving antalgic treatments [36–38] and the treatment of cervical arthritis [39].

The results of the trials suggest the interest of performing a course of experimental activities to completely understand the physiological mechanisms involved.

Several papers have been published to communicate the results of these activities. One highly accessed paper was that of Giuliani et al [40], which demonstrated the capability of Biolite emission to increase the resistance of PC12 cells to oxidative stress and to sustain the accelerated growth of PC12 neuritis, thereby suggesting an axonal protection effect.

Further tests have confirmed the effectiveness of Biolite versus validated pain models (acute, chronic, neuropathic, and visceral) through stimulation of the very same points as those included in the clinical protocol (TH5 Waiguan and ST36 ZuSanLi) [41].

Effectiveness versus edema and hyperalgesia in acute pain has been reconfirmed as being that over chronic pain as well as versus thermal hyperalgesia in neuropathic pain. No significant results were obtained versus visceral pain by stimulating the same points.

The favorable reception obtained by two oral presentations at WALT (Eighth International Congress of the World Association for Laser Therapy, Bergen, Norway) with further details of laboratory testing [42,43] has been the trigger for a specific review [44].

Further experimental activities were then started under partial government funding (A Medtech Research Program on Extracellular Soft Tissue Matrix Characteristics and Modifications under Physical Stress under 50% Grant by the Italian government). The results have been published or are in press and include the following. (1) Effectiveness of Biolite emission in the growth of fibroblasts, in the increased synthesis of collagen and integrins. This test was performed by comparing Biolite emission with those of two lasers with the same wavelength and spot size but with different power/modulation (one at the same peak power but with no modulation and the other at 50 mW but with no modulation). Surprisingly enough, the Biolite effectiveness was significantly higher than the others (in press) [45]. (2) Effectiveness of Biolite emission in reinforcing the antibiotic treatment of *Staphylococcus aureus* [46].

Based on the aforementioned clinical evaluation, Biolite's effects in treating scars and in face-lifting applications are currently being planned.

From a different angle, taking into account the evidence relating to noxious stimulation—even under the sensitivity threshold—to proprioceptive motor control deficit, some experimental activities have been performed in the Biolite treatment of patients suffering from balance dysfunctions of nonspecific etiology, such as vertebral arthritis or compensative postural attitudes [47, 48].

7. Conclusion: Areas of further investigation

The experimental evidence points to a few major investigation areas.

- (1) While treating common musculoskeletal pain, Biolite's effectiveness has been consistently found to be in excess of 80% and such a high value can hardly be

accounted for based on the traditional assumption that the pain is the effect of an irritation of underlying structures. The finding strongly supports the validity of the theories in which the tendency of the pain induced by traumatic events is deemed to become a new independent pathology that can be effectively reset, by either various other techniques or Biolite distal stimulation.

- (2) The time course of the beneficial effect starts almost immediately after the treatment and then settles within 24 hours, corroborating the hypothesis that the stimulation starts a self-healing process.
- (3) This seems to confirm the hypothesis that balance disorders are very often dependent on musculoskeletal pain syndromes [49–51]. The Biolite treatment may therefore be effective in reducing risk of fall [52–54] in multifactorial balance disorders in the elderly population. Given the very limited contraindications of Biolite, this may well point to a specific preventive treatment application to reduce the risk of fall in elderly patients.
- (4) The very same approach could perhaps suggest Biolite treatment for chronic degenerative diseases patients with motor control deficit [55]. Balance control is performed through a mix of direct commands, feed-forward anticipatory commands [56], and feedback-based commands [57]. The complex control system relies on redundancies to compensate for unavoidable interferences on the afferent signals coming from proprioceptive and exteroceptive sensors. This kind of interference can be defined as “noise” masking the true signal. “Noise” such as this has been studied as a cause of instability in closed-loop motor control functions, especially in the upright standing balance control [58,59]. The less efficient the system (affected by any kind of impairment or pathology), the less effective the control through efferent lines that can be affected by the “noise” as well [60]. Under these conditions, the loss of control redundancies may become the main reason for the loss of balance or of specific motor control functions [61]. With specific regard to balance, no evidence of effectiveness of Biolite treatment over vestibular or central deficits has been gained so far: only proprioceptive musculoskeletal deficits have been successfully treated and only these are targeted by the present application protocol.

Disclosure statement

M.G. was involved in the design of Biolite and is among the patent inventors. No commercial interest of any sort is, however, involved. All patent rights are owned by RGMD SpA. G.dA. and G.B. privately practice physiotherapy and make use of Biolite. They all declare the absence of any conflicts of interest.

Acknowledgments

Biolite was developed on the basis of an original idea by Dr. Luigi Baratto, Head of the Rehabilitation Department of La

Colletta Hospital within the framework of a cooperation agreement between the Colletta Bioengineering Center [set up between the Liguria Region Public Health Service (ASL 3, Genovese, Osp.le La Colletta, Arenzano, Genova, Italy) and the Department of Informatics and Bioengineering of the University of Genova] and the company RGMD SpA (Genova, Italy). The application protocols were developed by Dr. L. Baratto, Dr. M. Farinelli, and Dr. G. Di Stefano. Biolite is produced by RGMD SpA. This review was performed without any financial support.

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