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Effects of laser therapy and Grimaldi's muscle shortening maneuver on spasticity in central nervous system injuries

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Background an Aims: For 2003 year until today we treated hundreds of patients with Central Nervous System Injuries (CNSI), using Non-Surgical Laser Therapy (NSLT) obtaining good results in terms of sensibility and movement. In order to increase muscle strength and to further explore new emerging synergies, we have also started using a physical therapy practice based on the most current knowledge about the motor control, called Grimaldi's Muscle Shortening Maneuver (GMSM). Spasticity is often the most disabling symptom and the current therapies are still not able to heal it at all. The goal of our study is to suggest a new way of treatment of spasticity, supporting it with objective measurements of muscle thresholds.

Materials and Methods: In 2016-2017, 36 patients with traumatic or degenerative CNSI were enrolled. Lasers used were 808 nm, 10600 nm, and 1064 nm, applied with a first cycle of 20 sessions, four a day. Patients were subjected to Grimaldi's Muscle Shortening Maneuver (MSM) twice a day, ten sessions at all, working selectively on hypertonic muscles and their antagonists. Before treatment, tonic stretch reflex thresholds (TSRTs) in Gastrocnemius Lateralis (GL) were assessed through a surface electromyography (sEMG) device paired with an electrogoniometer. Antagonist muscle force (Tibialis Anterioris) was assessed by some electronic hand-held dynamometers. For the clinical measure, we used the Modified Ashworth Scale (MAS). All tests have been performed at the baseline (before starting treatments), after one week (at the end of the last treatment) and after a month.

Results: Results were considered positive if the instrumental assessment procedure showed modifications in TSRT values and subjects improved their antagonist muscle strength. Results showed modifications in TSRT values at every follow up. The average comparison between the follow-ups was always statistically significant (p .000). The increase in Tibialis Anterioris muscle strength was statistically significant as well (p .000). MAS showed some differences between follow-ups but not all of them are statistically significant (T0-T1 p .063, T1-T2 p .001, T0-T2 p .000). Encouraging results suggest a possible correlation between laser and MSM therapies and modifications of TSRT in spastic muscles.

Conclusion: Associating laser treatment and Grimaldi's Muscle Shortening Maneuver (MSM) seems to be effective on spasticity in patients affected by traumatic or degenerative CNSI. Obviously, this kind of study design showed a lot of limits however this clinical series could be an

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****Running title:***
NSLT and GMSM on spasticity in CNSI

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important hint for every researcher working in the complex field of spasticity, a symptom that is poorly defined and hardly treated.

Key words: Laser Therapy, Grimaldi Muscle Shortening Maneuver, spasticity, tonic stretch reflex threshold, laser biomodulation, motor control.

Introduction

From December 2003 until December 2018, we treated hundreds of patients with Central Nervous System Injuries (CNSI), using Non-Surgical Laser Therapy (NSLT) (1) obtaining good results in terms of sensitivity and movement (2). To increase muscle strength and to further explore new emerging synergies, we have also started using a physical therapy practice based on the most current knowledge about motor control (3, 4), called Grimaldi's Muscle Shortening Maneuver (GMSM) (5-8). Spasticity is one of the most common and disabling symptoms that results from a first motor neuron injury and afflicts over 12 million people worldwide (9). As reported by Bhimani (10), it has been estimated the prevalence of lower limb spasticity for stroke from 40 to 60 per 100,000, for multiple sclerosis from 2 to 350 per 100,000, for cerebral palsy from 260 to 340 per 100,000 and for spinal cord injuries from 22 to 90 for 100,000. The annual incidence of the spastic of the lower limb, however, is estimated for stroke from 30 to 485 per 100,000, for traumatic brain injury from 100 to 235 per 100,000 and for spinal cord injuries from 0.2 to 8 for 100,000. For Blanchette *et al.*, (11) the prevalence of spasticity in post-stroke subjects is highly variable, ranging between 17.0% and 42.6% in patients in the chronic phase of recovery.

The importance of spasticity by the fact that it interferes with functional recovery and leads to secondary complications such as muscle retractions, weakness and pain [12)]. It is responsible for insomnia and muscle fatigue and can interfere with mobility, transfers, self-care, activities of daily life and society. Clinical factors such as urinary tract infections and bedsores are a cause of increased spasticity (13).

Because of these invalidating causes, spasticity is the burden on caregivers exponentially.

The definition of spasticity is common suggested by Lance: "A motor disorder caused by a speed-reflex increase of the stretch tonic reflex with exaggerated tendon response, resulting from a hyperexcitability of the stretch reflex as a component of the syndrome of the first motoneuron" (14). However, the definition of the term spasticity is still not well established and is not commonly accepted.

For the symptom of spasticity, given the lack of agreement on the definition and the lack of consistency of the most used evaluation methods available, nowadays there are great difficulties in validating measurement systems and in suggesting any kind of treatment. The literature review allows us to point out that the most commonly used methodologies often do not collate with the latest neuro-physiological and motion control discoveries or the most common spasticity definitions. The framing of tone disorders within the threshold control theory allows a parameterization of the spasticity symptom which, in turn, can represent a valid unit of measurement. Several authors have experienced this type of measurement through portable devices, achieving good results in terms of intra and inter-rater reliability.

The stretch reflex threshold (SRT) is an integral part of the lambda model of motor control. It represents the joint angle at which motoneurons and respective muscles of the joint begin to be recruited. Research in animals and in chronic stroke subjects suggests that SRT may be altered by descending pathways, including cortico-spinal systems with or without a concomitant alteration in the reflex gain. (3)

SRT depends on velocity of stretch. Taking this into account, it is called the dynamic SR threshold (DSRT). The tonic SRT (TSRT) represents a specific value of the DSRT for zero velocity. DSRTs and TSRT are expressed in relation to the actual configuration of the joint within a body frame of reference. In particular, when the threshold lies within the biomechanical range of the joint and the patient has no ability to shift this threshold angle, it separates the joint configurations in which muscles

are spastic from those in which they are not, thus quantifying an important, spatial aspect of the motor control impairment (3, 4).
The goal of our study is to suggest a new way of treatment of spasticity, supporting it with objective measurements of muscle thresholds.

Materials and Methods

2.1 Subjects

In 2017 – 2018, 36 patients (23 men) with traumatic or degenerative CNSI – with injuries sustained at least one year before laser treatment and documented by NMR or CT, ESSP, and ESMP – were enrolled (mean age 30,97 ± 8,91; range 18-52) **(table 1)**. Selection criteria are shown in **table 2**.
Informed consent was obtained from all individual participants included in the study.

SUBJECT	SEX	AGE	PATHOLOGY
1	M	32	SCI
2	M	28	SCI
3	W	29	SCI
4	M	42	SCI
5	M	52	CP
6	M	22	SCI
7	M	43	Stroke
8	M	18	CP
9	M	30	SCI
10	M	39	Stroke
11	W	41	SCI
12	W	36	SCI
13	W	32	SCI
14	W	39	CP
15	W	27	CP
16	W	26	Stroke
17	M	18	Stroke
18	M	45	SCI
19	M	18	SCI
20	M	22	Stroke
21	M	28	SCI
22	W	29	SCI
23	M	22	SCI
24	M	36	SCI
25	M	21	SCI
26	M	39	SCI
27	W	41	SCI
28	M	20	SCI
29	M	25	SCI
30	M	41	SCI
31	W	37	SCI
32	W	23	Stroke
33	M	20	SCI
34	M	31	SCI
35	W	36	Stroke
36	W	27	SCI

Table 1. Characteristics of participants

36 Participants

Inclusion Criteria:	Exclusion Criteria:
Both sex, 18 – 40 years old	- Surgical intervention contra-nature
- CNSI occurred at least one year before	- Orthopedic complications (deformity, pain)
- Spasticity in ankle joint (MAS 1-3)	- Inability to join the program in its entirety (economic, logistic, voluntary, etc)
	- Cognitive impairments

Table 2. Inclusion and exclusion criteria

2.2 Evaluators

Three physiotherapists (two males and one female) evaluated each subject. The evaluators had similar amounts of clinical experience (4.5 and 5 years). All had been specializing in neurorehabilitation for at least three years prior to the study. Evaluators were not blinded to the objectives of the study.

2.3 Experimental protocol

Before treatment, TSRTs were assessed through a surface electromyography (sEMG) device (Enraf Nonius Myomed 632X) paired with an electro-goniometer (Jtech Medical Commander Echo). All tests have been performed at the baseline (before starting treatments), after one week (at the end of the last treatment) and after a month.

2.3.1 Clinical testing

For the clinical measure, we used the Modified Ashworth Scale (MAS). The MAS is a 6-point ordinal scale, ranging from 0 (no increase in tonus) to 4 (rigid limb), based on the subjective impression of the examiner of the resistance felt to stretching the knee extensors at a low velocity (15).
Bohannon and Smith (1987) reported an inter-evaluator agreement of 86.7% with no more than one grade difference between evaluators (s=0.85, $p<0.001$). Since the MAS is more reliable than the original Ashworth Scale for the evaluation of spasticity in the elbow flexors (15), this test was only performed by one evaluator. Three stretches were performed at a velocity of approximately 80-100°/s, and the highest MAS score was recorded.

2.3.2 Instrumented testing

After cleaning the skin, two disposable square silver-silver chloride self-adhesive electrodes (center-to-center distance of 3.5 cm) were placed over the motor points of the agonist muscle. The reference electrode was placed over a bony prominence near the observation point. The axis of rotation of a calibrated electro-goniometer was positioned above the rotation axis of the joint in question. The electro-goniometer arms were aligned with the subject's bone segments and fixed in place with self-adhesive straps.

The determination of DSRT proceeded as follows: Step 1: subject, evaluator and session codes were entered in the database. Step 2: the baseline EMG was established with the subject completely relaxed and the EMG gain was adjusted to ensure that the signal was not saturated. This was done by stretching the muscle three to five times at high velocity and monitoring the EMG response. Once the gain was set, it was not readjusted during the remainder of the evaluation. Step 3: the starting angle of the joint was chosen. Step 4: A trial consisting in a very slow passive stretch (0.5 °/s) of the agonist muscle was performed. When muscles started to show EMG activity, the experimenter noticed the angle value showed by the electro-goniometer previously fixed to the examined joint.

That value is rated as the DSRT of the spastic muscle and it could be compared with its TSRT because of the very slow velocity of stretching. Antagonist muscle strength was assessed too through handheld electronic dynamometers (Jtech Medical Commander Echo). This kind of evaluation was also administered one week and two months later the first one.

2.4 Intervention

Lasers used were 808 nm (Eufoton, Trieste, Italy), 10600 nm (General Project, Firenze, Italy) and 1064 nm (Eufoton, Trieste, Italy), applied with a first cycle of four sessions per day for a total of 20 sessions **(Table 3)**.

	Treatment of Inflammation and Edema	Support of Nerve Regeneration	Muscle Tone	Anti-inflammatory Muscle Tone
Laser	diode 808 nm wavelength	diode 808 nm wavelength	CO_2 10,600 nm wavelength	Nd-YAG 1064 nm wavelength
Output power	10 W	10 W	15 W	5 W
Spot size	5 cm	5 cm	10 cm	6 mm
Fluence	12 J/cm^2	4 J/cm2	36 J/cm^2	35 J/cm^2/passage
Total Energy	720 J	240 J	variable	variable
PW Repetition Frequency	1000 HZ	10 HZ	100 HZ	1 HZ
Tissue Target	Spinal Lesion	Nerve Trigger Points Coherence Domains	Around the lesion	Area of Lesion and muscle-tendon unit
Sessions per day	4	4	4	4
Sessions per Cycle	Cycles of 20 sessions, with interval of 1 month			

Table 3. Parameters of laser treatment

Different laser wavelengths were used because each wavelength has a different penetration 16,17). Details about the dosage are specified in **table 3**. One dosage of 720 Joules/cm2 in total used with laser 808 nm, aimed at achieving an anti-inflammatory effect, according to current knowledge 1, 16, 18, 19, 20). Another dosage of 240 Joules/cm2 in total was used for regenerative purposes 1, 16, 21, 22), always with the same laser 808. Lasers of 10600 nm and 1064 nm were used at dosages of 36 Joules/cm2 that could influence muscle tone 23, 24, 25).

The patients participated in specific physical therapy training (Grimaldi's Muscle Shortening Maneuver – GMSM) twice a day, for a total of ten sessions, working selectively on ankle' s plantar and dorsiflexor muscles (Tibialis Anterioris and Gastrocnemius Lateralis). GMSM is a technique which works on neuromuscular spindles with the aim of producing stimulation. It intentionally balances the shortening and lengthening of the muscle simultaneously 5-8). This process produces an informational catastrophe in the neuromuscular spindles forcing them to set new muscle thresholds. This kind of maneuver is an active but involuntary training for the patient.

The participants were lying on their backs on a physiotherapy table with the knee stabilized at about 90° flexion by means of a roller cushion and quick release restraining straps, with the foot resting outside the lower edge of the bed and the ankle resting on a 5 cm thick U-shaped bearing fixed to the same edge using adhesive materials.

A first skin protection bandage was applied to the patient (using skin-saving plaster covered with simple absorbent paper held together and fixed to the limb by strips of adhesive bandage plaster) starting from the distal third of the leg to cover the entire foot. Secondly, the flexible rod was fixed (a harmonic steel rod 60 cm long, 6 cm wide and 0.5 cm thick, covered with 1 cm high foam rubber for the whole extension on one of the two sides and covered in soft neoprene type material) to the plantar surface of the subject's foot using simple adhesive tape so that the rod protrudes for about 5 cm from the rear edge of the heel. From this position the experimenter manually imprinted dorsiflexion stresses in the center of the plantar arch in a rhythmic manner and with a frequency of about 2 Hz for a duration of 15 min. At the upper end of the shaft (the one facing the patient's fingers) small parallelepiped iron weights (1.2 or 3 kg) of the same width as the rod and with max height of 1 cm could be fixed by total coverage with bandage plaster, to increase the elastic return of the harmonic steel in the case in which the ankle excursion was so reduced by spasticity that it could not provide the necessary space for the oscillation.

2.5 Statistical analysis

In statistical analysis we used the Kolmogorov-Smirnov Test to analyse the distribution of values for TSRT, MAS and Force variables. For evaluating the muscle strength, TSRTs and MAS scores we compared the results obtained for each parameter in three observation times (T0, T1, T2). For this reason, we used a non-parametric Wilcoxon Test for paired samples, which let us know if there are significant differences between the follow-ups for continuous variables (strength, TSRTs). For ordinal ones (MAS) we used the sign test with the same aim.

2.6 Ethical Considerations

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The authors declare that they have no conflict of interest.

Results

Regarding TSRTs, results showed modifications in TSRT values at every follow up.
TSRTs decreased by an average of 5,66° in the treatment group at the first follow up and 4,81° at the second. In this way, after one month we found an increase of 10,47° with respect to the baseline **(Fig. 1)**

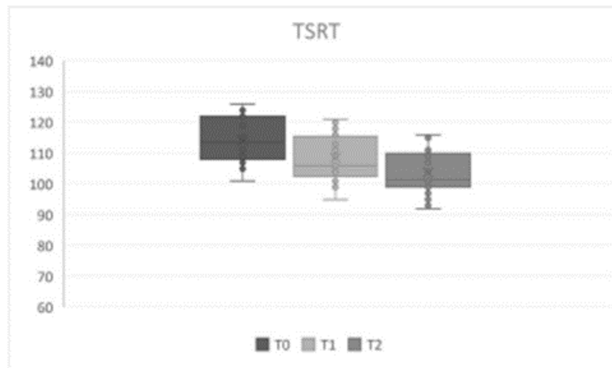

Fig. 1. Decrease of Tonic Stretch Reflex Threshold values through follow-ups

This decrease was statistically significant, in addition, the TSRT change obtained between follow-up, (T0-T1) (T1-T2) (T0-T2) are statistically significant (p.000) **(table 4)**.

TSRT

		T0	T1	T2
36 SUBJECTS	AVERAGE	114,19	108,53	103,72
	STANDARD DEVIATION	7,210	7,213	6,696
	STANDARD ERROR	1,202	1,202	1,116
	WILCOXON TEST	T0-T1 **0,000**	T1-T2 **0,000**	T0-T2 **0 ,000**

Table 4. Results regarding TSRT average values through the follow-ups $p<0.05$

Muscle strength was assessed in one movement: ankle dorsiflexion. Force increased by an average of 7,8 N at the first follow up and 8,12 N at the second. In this way, after one month we found an increase of 15,92 N with respect to the baseline **(Fig. 2)**

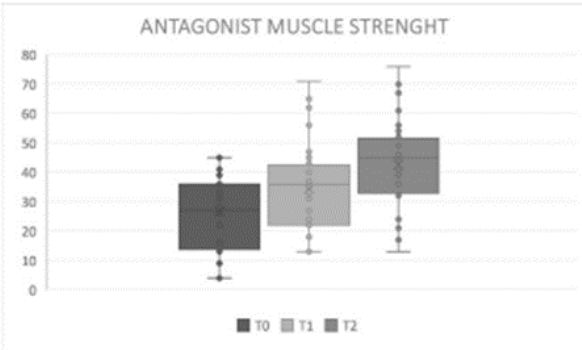

Fig. 2. Increase of antagonist muscle strength through follows-ups

This modification in strength obtained between follow-up, (T0-T1) (T1-T2) (T0-T2) is statistically significant (p.000) **(table 5)**.

ANTAGONIST MUSCLE STRENGHT

		T0	T1	T2
36 SUBJECTS	AVERAGE	26,64	34,44	42,56
	STANDARD DEVIATION	12,036	14,941	15,044
	STANDARD ERROR	2,006	2,490	2,507
	WILCOXON TEST	T0-T1 **0,000**	T1-T2 **0,000**	T0-T2 **0 ,000**

Table 5. Results regarding antagonist muscle strength average values through the follow-ups p<0.05

Modified Ashworth Scale was administered to all subjects at every follow-up, assessing the passive resistance to stretch of plantar flexors muscles. This parameter showed some differences between follow-ups but not all of them are statistically significant (T0-T1 p.063, T1-T2 p.001, T0-T2 p.000) **(table 6)**.

Discussion and Conclusion

Decreasing values of TSRT through the follow-ups suggest that both treatments had some direct effect on spasticity in Gastrocnemius Lateralis thus freeing some degrees of freedom in the movement of the affected ankle. This improvement in motor control is also supported by an increase in data's regarding muscle strength of the antagonist muscle.

Clinical data emerged from MAS scores have also some statistical significances but no correlation was observed relating them to TSRT scores suggesting that this kind of scale is not a real measure of spasticity but rather an assessment of muscle resistance to passive stretch, as found in literature.

SUBJECT	T0	T1	T2
1	3	3	2
2	3	3	3
3	3	2	2
4	3	3	2
5	2	1	1
6	2	2	1
7	3	3	2
8	2	2	1
9	2	2	2
10	2	2	2
11	3	3	2
12	3	3	3
13	3	3	3
14	3	3	2
15	3	3	2
16	2	2	2
17	2	2	2
18	2	2	2
19	3	3	3
20	3	2	2
21	3	3	3
22	2	2	2
23	3	2	2
24	3	3	3
25	2	2	2
26	2	2	1
27	1	1	1
28	2	2	1
29	3	3	3
30	1	1	1
31	1	1	1
32	2	2	1
33	1	1	1
34	2	1	1
35	2	2	2
36	2	2	2
MEDIAN	**2**	**2**	**2**
SIGN TEST	**MAS T0-T1 0.063**	**MAS T1-T2 0.001**	**MAS T0-T2 0.000**

Table 6. Results regarding MAS median values through the follow-ups p<0.0

Obviously, this study could not state any kind of cause/effect ratio because of its many limits in all the study design. The lack of a control group, wide inclusion criteria and the combination of two different kinds of treatment are issues needing to be solved through a higher-level study design.
However, we think that this clinical series could be an important hint for every researcher working in the complex field of spasticity, a symptom that is poorly defined and hardly treated.

Declarations

Funding: all this study was self-funded by the authors themselves.

Conflicts of interest/Competing interests: the authors declare that they have no conflict of interest.

Ethics approval: all procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Consent to participate All the subjects signed an informed consent to participate according to the Italian laws and the ethical standards of the institutional and/or national research committee.
Consent for publication All the subjects signed an informed consent to the publication of results accordingly to the Italian laws and the ethical standards of the institutional and/or national research committee.

Availability of data and material: all data and material are available at the corresponding author institution address.

References

[1] Longo L: Nonsurgical Laser Treatment (NSLT) of Central and Peripheral Nervous System Injuries. Photomed Laser Surg, 2017; 35(4): pp. 181-183.

[2] Longo L, Giubilo F, Romanelli C, Longo D: Laser and Physical Therapy Applied to Traumatic Central Nervous System Injuries: Update. Advances in Laserology, 2013, Selected Papers of Laser Florence 2013 Congress, Medimond Publisher, Bologna, 2013.

[3] Latash ML, Levin MF, Scholz JP, Schoner G: Motor control theories and their applications: Medicina (Kaunas), 2010; 46(6): pp. 382-392.

[4] Feldman AG: The nature of voluntary control of motor actions in Motor control and learning. 2006, Francis Lestienne & Mark L. Latash. New York, NY: Springer Science. pp. 3-9.

[5] Grimaldi L, Fantozzi M, Marri P, Lippi P, Catelani G: Evocazioni di componenti motorie assenti nelle lesioni del sistema nervoso centrale II. In: Criteri di organizzazione degli atti motori. Pisa. 1986, Giardini Editori e Stampatori in Pisa.

[6] Longo D, Longo L, Lippi P, Cherubini G, Mangé V: Effects of laser therapy and Grimaldi's muscle shortening manoeuvre on motor control of subjects with incomplete spinal cord injuries. Laser Ther, 2017; 26(3): pp. 203-209.

[7] Melchiorre D, Maresca M, Bracci R, Ravaschio A, Valiensi B *et al*: Muscle shortening manoeuvre reduces pain and functional impairment in shoulder impingement syndrome: clinical and ultrasonographic evidence. Clin Exp Rheumatol, 2014; 32(1): pp. 5-10.

[8] Melchiorre D, Lippi P, Marchi A, Maresca M, Bravi R *et al*: Muscle shortening maneuver and not topical anti-inflammatory therapy is effective in reducing the width of subacromial-subdeltoid bursa in shoulder impingement syndrome. Proc SPIE, 2018; 10582: pp. 1-6.

[9] Calota A., Feldman AG., Levin MF: Spasticity measurement based on tonic stretch reflex threshold in stroke using a portable device. Clin Neurophys, 2008; 119(10): pp. 2329-2337.

[10] Bhimani R, Anderson L: Clinical Understanding of Spasticity: Implications for Practice. Rehabil Res Pract, 2014; 2014: pp. 1-10.

[11] Blanchette AK, Mullick AA, Moïn-Darbari K, Levin MF: Tonic Stretch Reflex Threshold as a Measure of Ankle Plantar-Flexor Spasticity After Stroke. Phys Ther, 2016; 96(5): pp. 687-695.

[12] Malhotra S, Pandyan AD, Day CR, Jones PW, Hermens H: Spasticity, an impairment that is poorly defined and poorly measured. Clin Rehabil, 2009; 23: pp. 651-658.

[13] Bhimani R, Anderson LC, Henly SJ, Stoddard SA: Clinical Measurement of Limb Spasticity in Adults: State of the Science. J Neurosc Nurs, 2011; 43: pp. 104-115.

[14] Lance JW: The control of muscle tone, reflexes, and movement: Robert Wartenberg Lecture. Neurology, 1980; 30(12): pp. 1303-1313.

[15] Pandyan AD, Johnson GR, Price CI, Curless RH, Barnes MP, Rodgers H: A review of the properties and limitations of the Ashworth and modified Ashworth Scales as measures of spasticity. Clin Rehabil, 1999; 13(5): pp. 373-83.

[16] Longo L: Laser Manual of Medical Technology. 2014, OEO Publisher, Firenze.

[17] Rochkind S, Rousso M, Nissan M, Villarreal M, Barr-Nea L, Rees DG: Systemic effects of low-power laser irradiation on the peripheral and central nervous system, cutaneous wounds, and burns. Lasers Surg. Med, 1989; 9: pp. 174-82.

[18] Waynant R, Tata D Editors: Proceedings of Light-Activated Tissue Regeneration and Therapy Conference. 2008, Springer NY.

[19] Anders J: The Potential of Light Therapy for Central Nervous System Injury and Disease. Photomedicine and Laser Surgery, 2009; 27(3): pp. 379-380.

[20] Oda-Mochizuki N: Neuronal and cellular effects of low-level laser: Basic and clinical research. Nippon Laser Igakkaishi, 2007; 28: pp. 57-67.

[21] Fork RL: Laser stimulation of nerve cells in aplysia. Science, 1971; 171: pp. 907-908.

[22] Yoshimi Asagai: Application of LLLT in patients with cerebral palsy of the adult tension athetosis type. Nippon Laser Igakkaishi, 2007; 28: pp. 74-76.

[23] Morselli M, Soragni O, Anselmi BP: Very Low Energy Density Treatment by CO_2 laser in sport injuries. Lasers in Surgery and Medicine, 1985; 5: p. 150.

[24] Longo L, Tamburini A, Monti A, Cattaneo L, Sesti AG: Treatment with 904 and 10600 nm laser of acute

lumbago: double blind control. Laser, 1988; I (3): pp. 16-20.

[25] Longo L, Clementi F: CO_2 laser treatment of calcific Metaplasias. In P. Spinelli, M Dal Fante, R Marchesini ed. Photodynamic therapy and Bio-medical lasers, 1993. Excerpta Medica, Internat. Congress Series 1011, Elsevier Publisher, Amsterdam, pp. 186-190.

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