

Effects of High-Power Diode Laser Irradiation Combined with Electrical Stimulation on Wrist Pain and Function Following Carpal Tunnel Syndrome

Seyed Mohammad Reza Tabatabai ^a, Siamak Bashardoust Tajali ^a, Behrooz Attarbashi Moghadam ^a, Seyed Mohsen Mir ^a

^a Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

*Corresponding Author: Siamak Bashardoust Tajali, Department of Physiotherapy, Rehabilitation School, Tehran University of Medical Sciences, Enghelab Street, Piche Shemiran, Tehran, Iran; *E-mail*: s_bashardoust@sina.tums.ac.ir; *Tel*: +98-21 77685105 (Ext. 253)

Submitted: 2016-05-02; Accepted: 2016-09-18

Introduction: Carpal Tunnel Syndrome (CTS) is the most common and most well-known compression neuropathy which may manifest as mild, moderate, or severe and lead to various degrees of disability in people. The present study aimed to compare the effect of high-power diode laser beam and Transcutaneous Electrical Nerve Stimulation (TENS) separately and in combination on improvement of wrist pain and function in patients with CTS. **Method and Materials:** The study was designed as a randomized trial. A total of 45 patients (7 men and 38 women) were randomly divided into three groups of high-power laser (n=15), TENS (n=15), and high-power laser with TENS (n=15). The TENS group received conventional TENS on pain site for two weeks as 5 sessions per week and 30 minutes per session. The high-power laser group received 6.5 J/cm² laser for two weeks, five sessions per week. The group of high-power laser with TENS received conventional TENS and then 6.5 J/cm² laser for two weeks as five sessions per week and 30 minutes per session. The Persian McGill Pain Questionnaire, Visual Analogue Scale (VAS), and the 5-point scale of pain severity of McGill Pain Questionnaire (pain severity) were used to assess pain and the Persian version of the Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire was administered to evaluate hand function before and after treatment. All the patients filled a demographic questionnaire including age, height, and weight prior to the intervention. **Results:** The mean scores of McGill, VAS, pain severity, and DASH questionnaires reduced significantly in high-power laser and high-power laser with TENS groups; however, these variables had no significant difference in the TENS group. **Conclusions:** High-power laser diode (808 nm, 6.5 j/cm²) can reduce pain and improve hand function in patients with mild to moderate CTS. Laser-induced anti-inflammatory effects and blood flow improvement are possible causes of decreased pain and sensory signs followed by improvement in hand function.

Key words: Carpal Tunnel Syndrome, High-Power Laser, Hand, Pain, Transcutaneous Electrical Nerve Stimulation

Please cite this paper as: Tabatabai SMR, Bashardoust Tajali S, Attarbashi Moghadam B, Mir SM. Effects of High-Power Diode Laser Irradiation combined with Electrical Stimulation on Wrist Pain and Function following Carpal Tunnel Syndrome. J Clin Physio Res. 2016; 1(2): 61-67. Doi: 10.22037/jcpr.2016.04

Introduction

Carpal Tunnel Syndrome (CTS) is the most common and most well-known compression neuropathy which may manifest as mild, moderate, or severe and lead to various degrees of disability in people. Timely treatment of the disease will result in complete recovery while delayed treatment may bring irreparable effects (1). Clinical symptoms of the disease are seen more in women than in men (2) and include paresthesia, pain, and weakness in muscles innervated by median nerve (3, 4). The symptoms are caused due to compression of the median nerve at the wrist resulting in reduced blood flow (5), which usually intensifies at night (3, 4). CTS is a multifactorial disease, often with an unknown cause (5, 6). Its

incidence is 1% in the general population and occurs commonly in older ages (7). There is no agreement regarding the primary treatment of CTS as surgery or noninvasive (conservative) (8-13). Non-invasive treatments of CTS include Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), local injection of steroids, splinting, modification of activities, nerve and tendon gliding exercises, and the use of physiotherapy modalities such as iontophoresis, ultrasound, TENS, and laser therapy (13-20).

The use of high-power laser has recently been highlighted in physiotherapy. As an advantage, this laser can penetrate deeper than low-power lasers and can stimulate large and deep joints to which low-power laser beams can hardly reach (21). Accordingly, it seems that more energy is transferred into tissues

Table 1. Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> - Patient ≥ 18 years of age - Relevant Symptoms (Pain and/or numbness) for at least two fingers of one hand (thumb, index, middle, or ring finger) for less than one year - Mild to moderate CTS based on NCS results - No thenar atrophy 	<ul style="list-style-type: none"> - Patient with evidence of severe CTS - Thenar atrophy - Any previous hand or wrist surgery - Metabolic diseases (Diabetes mellitus, thyroid or kidney problem) - Diffuse peripheral neuropathy - Cervical radiculopathy - Brachial plexopathy - Proximal median neuropathy - Any known mass, tumor or deformity of the wrist - Any history of severe trauma to the wrist - Pregnancy or location - Connective tissue disorders or arthritis involving hand or wrist - Tenosynovitis - Fibromyalgia or other musculoskeletal disorders - All patients whose type of employment could be a risk factor on CTS, such as secretaries

Table 2. Grading of CTS according to electrodiagnostic findings

Grade Number	Electrodiagnostic Findings
Grade 0	Normal
Grade 1 (very mild)	CTS demonstrable only with most sensitive tests
Grade 2 (mild)	Slow median DSL, slow sensory nerve conduction velocity, normal terminal motor latency
Grade 3 (moderate)	Sensory potential preserved with motor slowing, distal motor latency to Abductor Pollicis Brevis (APB) < 6.5 ms
Grade 4 (severe)	Sensory potential absent but motor response preserved, distal motor latency to APB < 6.5 ms
Grade 5 (very severe)	Terminal latency to APB < 6.5 ms
Grade 6 (extremely severe)	Sensory and motor potentials effectively un-recordable (surface motor potential from APB < 0.2 mV amplitude)

Table 3. Demographic characteristics of the participants in the three groups of TENS, high-power laser, and high-power laser with TENS

Variable	Groups mean (SD)			Minimum			Maximum		
	TENS	Laser	Laser+TENS	TENS	Laser	Laser+TENS	TENS	Laser	Laser+TENS
Age	8.62 (52)	53.6(8.59)	48.60 (9.40)	36	37	35	73	66	62
Weight	52 (8.62)	68.8(9.05)	60.63 (11.69)	59	54	47	88	85	91
Height	166.53 (9.71)	166.44(5.28)	165.26 (9.33)	150	155	152	180	170	182

Table 4. Changes in mean pain score

Group	Variable	Stage		Sig
		Baseline Mean (SD)	After intervention Mean (SD)	
TENS	McGill	33.3 (12.90)	29 (15.91)	0.066
	VAS	6.03 (2.582)	5.61 (2.58)	0.210
	Pain severity	3.00 (1.363)	2.60 (1.18)	0.082
TENS + laser	McGill	31.73 (13.82)	23.20 (13.00)	0.000
	VAS	6.61 (2.98)	3.03 (2.15)	0.000
	Pain severity	3.47 (1.59)	1.27 (0.594)	0.000
High-power laser	McGill	31.47 (12.44)	21.93 (9.40)	0.006
	VAS	6.93 (2.23)	4.57 (2.07)	0.000
	Pain severity	3.20 (1.01)	2.07 (0.961)	0.000

Table 5: Changes in wrist function

Group	Variable	Stage		Sig
		Baseline Mean	After intervention Mean	
TENS	DASH	52 (17.028)	43.18 (17.50)	0.093
TENS+laser	DASH	54.81 (19.32)	30.40 (14.04)	0.002
High-power laser	DASH	56.72 (11.86)	39.81 (19.20)	0.002



Figure 1. Location of the TENS electrodes



Figure 2. Location and the method of laser radiation

during treatment with high-power laser in comparison with low-power laser (22). Few studies have discussed anti-inflammatory, anti-edema, and analgesic effects of high-power laser to justify its use for pain (23-24).

Multiple methods used in the studies such as different types of lasers, different intensities, variables under study (outcome measures), different results, and different times of evaluation after treatment have made difficult the comparison and summarizing the information obtained from these studies to examine the impact of high-power laser beams in the treatment of CTS (25). The present study aimed to compare the effect of high-power diode laser beam and Transcutaneous Electrical Nerve Stimulation (TENS) separately and in combination on the improvement of wrist pain and function in patients with CTS.

Methods and Materials

The study was designed as a randomized experimental research. The medical ethics committee at the Tehran University of Medical Sciences approved the study ethics and issued the ethics certification number as IR.TUMS.REC.1395.2337, plan code: 9211675008. Differential Diagnosis was performed by a neurologist through neurological signs and symptoms. The patients diagnosed with mild to moderate CTS were selected based on clinical symptoms and electrodiagnostic findings. Then, a physical therapist (candidate for doctoral level) evaluated the patients and recruited appropriate candidates for the study based on import/exodus criteria (Table 1). The grades of the CTS were scrutinized using electrodiagnostic findings as the grades 0-3 were mild to moderate and grades 4-6 were identified as severe (26) (Table 2). Two professional individuals carried out the initial assessments and recruitment evaluations.

In the first step, the study was explained to the patients and those who accepted to attend were asked to sign a complete consent form. Inclusion criteria were 18 years of age or older, pain and paresthesia in at least two fingers of one hand (thumb, index, or middle finger), and lack of thenar atrophy. The patients were excluded from the study if they demonstrated any of following

disorders: thenar atrophy, any type of surgery on wrist and/or hand, history of wrist fracture, metabolic diseases (diabetes and thyroid and kidney diseases), peripheral neuropathy, neck radiculopathy, plexopathy and neuropathy of median nerve, pregnancy, lactation, connective tissue diseases, wrist and hand arthritis, tenosynovitis, and fibromyalgia (25).

A total number of 45 patients (38 women and 7 men) were randomly divided, using the table of random numbers, into three groups of trials including: Groups of TENS (n=15; 10 women, 5 men), high-power laser (n=15; 15 women, no man), and high-power laser with TENS (n=15; 13 women, 2 men). All the participants completed the McGill Pain Questionnaire, the Visual Analogue Scale (VAS), the pain severity questionnaire, and Disabilities of Arm, Shoulder, and Hand (DASH) questionnaire prior to the study and immediately after the last session.

The McGill pain questionnaire was applied to identify the level of pain. This pain rating index contains 78 pain descriptor items categorized into 20 subclasses, each containing 2-6 words that fall into 4 major subscales: dimensions of sensory (subclasses 1-10), affective and emotional (subclasses 11-15), evaluation-cognitive (subclass 16), and a miscellaneous group (subclasses 17-23). A 5-point group of pain severity scale was used, as well (27). This questionnaire was previously translated into Persian and validated by Khosravi *et al.* in 2013 (28). To evaluate pain severity, the Persian McGill Pain Questionnaire, VAS, and the 5-point scale of pain severity of McGill Pain Questionnaire (pain severity) were used. The VAS is a 10-cm, non-graded horizontal line with fixed boundaries from no pain to worst possible pain, on which the patient marks his/her pain severity (29). The Persian version of the DASH questionnaire was administered to identify the performance in patients with CTS. DASH questionnaire is a well-known functional reliable validated questionnaire, which can be applied to assess function for upper extremities. The questionnaire was translated and validated into many languages including Farsi (30). It is a 30-item questionnaire designed to measure physical function and symptoms in patients following upper extremity musculoskeletal disorders. (31) The score of the questionnaire can be used to estimate the disability level for

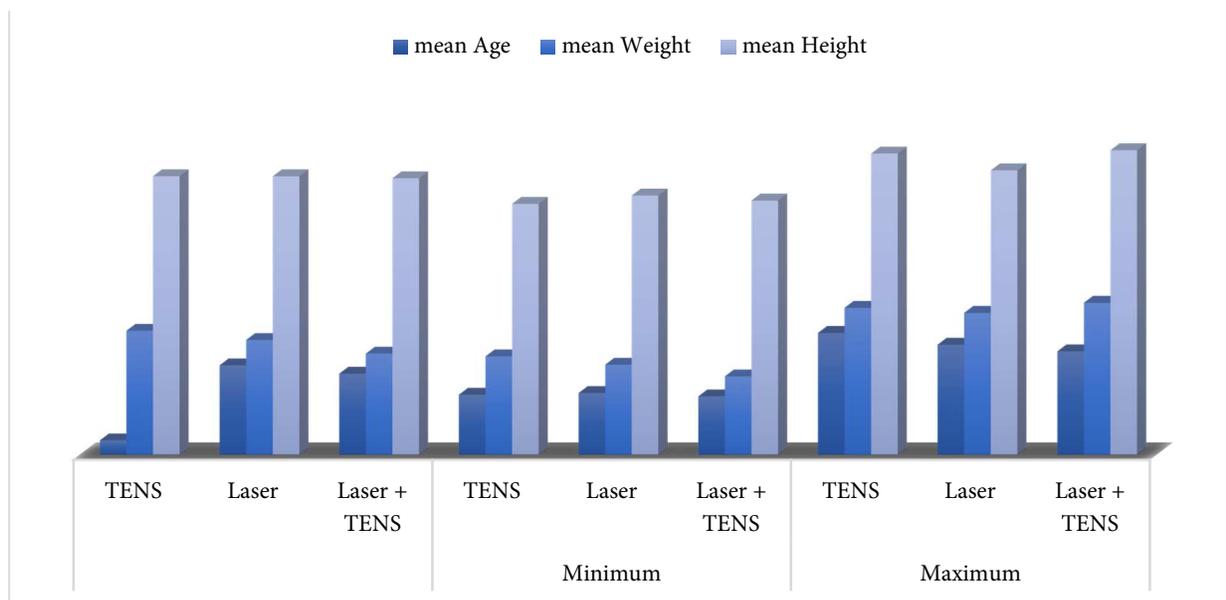


Figure 3. Demographic characteristics of the participants in the three groups of TENS, high-power laser, and high-power laser with TENS

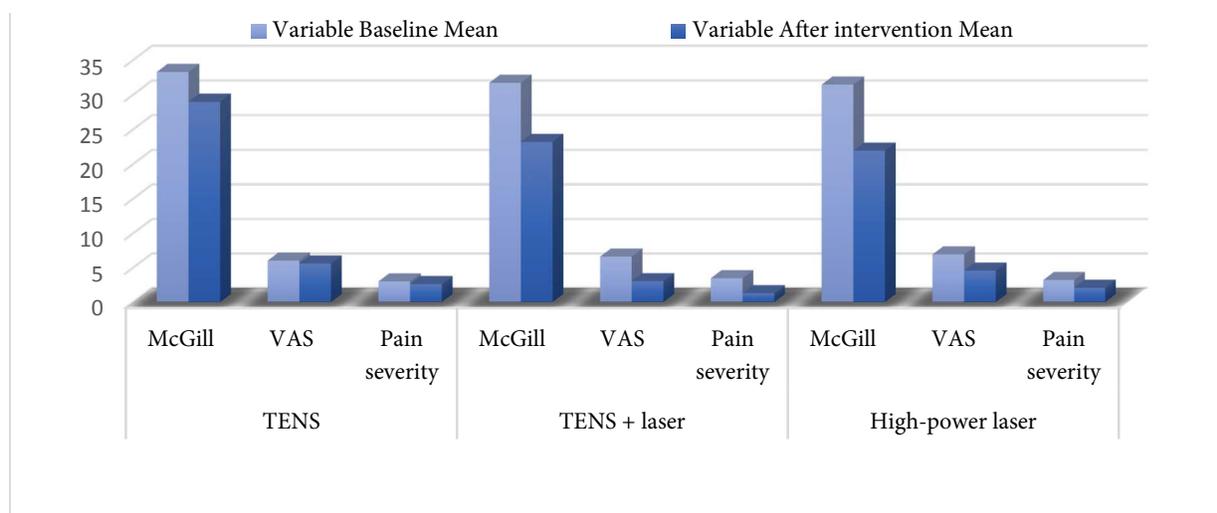


Figure 4. Changes in mean pain score

shoulder, elbow, wrist, and/or fingers. The researchers in the present study monitored changes in patients' symptoms and performances during the trial time and through the research purposes (32-35).

The TENS group received conventional TENS (100 Hz, 80 ms) lower than muscle contraction intensity for two weeks as 5 sessions per week and 30 minutes per session. One electrode was placed over the transverse ligament and the other 10 cm above, over the median nerve pathway (36-37) (Figure 1). Transcutaneous electric current was applied using a TENS device (model ES-420, ITO, Japan) calibrated by the manufacturer prior to running the study.

The high-power laser group received high-power diode laser with continuous wave of 3.2 Watts, maximum peak power of 600 Watts, wavelength of 808 nm, and at a dose of 6.5 J/cm² on two points of 2 cm² over the transverse ligament for two weeks as 5 sessions per week and 7 seconds per sessions (37) (Figure 2). The following formula was used to calculate the amount of the energy received (38-40).

$$\text{Energy (Joule)} = \text{Power (watt)} \times \text{Time (second)} \times \text{Duty cycle}$$

The Lumia 3plus laser device (Fisioline, Italy) was used to apply high-power laser beams. All devices were calibrated prior to

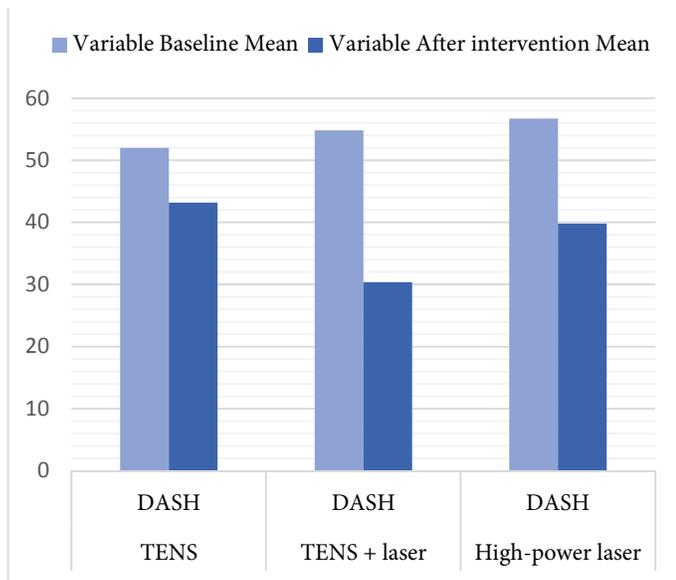


Figure 5. Changes in wrist function

running the study. The group of high-power laser with TENS received conventional TENS (similar to the TENS group) for two weeks as 5 sessions per week and 30 minutes per session followed by laser (similar to the high-power laser group) for 7 seconds.

Results

The demographic characteristics of patients in the three groups are shown in Table 3 and Figure 3. The Kolmogorov-Smirnov showed that patients had a normal distribution in all the three groups of high-power laser, TENS, and high-power laser with TENS.

Results of McGill, VAS, and pain intensity questionnaires

The mean changes in McGill, VAS, and pain intensity scores in the groups are presented in Table 4 and Figure 4. The means of these changes in all three groups were evaluated before and after treatment using paired *t*-test and the results showed that the mean scores of McGill, VAS, and pain intensity in the high-power laser group and the high-power laser with TENS group significantly reduced after treatment. But these changes had no significant decrease in the TENS group.

Results of DASH questionnaire

The mean changes in DASH score in different groups are presented in Table 5 and Figure 5. The scores of all groups were evaluated before and after treatment using paired *t*-test and the results showed that the mean DASH score in the high-power laser group and the high-power laser with TENS group significantly reduced while these changes had no significant decrease in the TENS group ($P=0.093$).

Discussion

CTS is the most common compression neuropathy and the most common cause of hand pain (1). The disease is more prevalent in women than in men (2). CTS is diagnosed according to patients' complaints and clinical symptoms such as weakness and muscle atrophy as well as electrophysiology studies (41). Treatment of the syndrome can vary from non-invasive methods with medication and exercise to surgical treatments (42). There is no agreement regarding the primary treatment of CTS as surgery or noninvasive (8, 11-13). Studies show that symptoms of 43-90% of patients persist after surgery, and symptoms are not reduced in one of every five persons (43-44). Therefore, it can be stated that the minimally invasive treatment is the first treatment of CTS and involves NSAIDs, local injection of steroids, splinting, modification of activities, nerve and tendon gliding exercises, and the use of physiotherapy modalities such as iontophoresis, ultrasound, TENS, and laser therapy (13-20). *In vitro*, laser therapy has a certain positive effect on nerve tissue, improvement of reconstruction and healing (9-10), and Schwann cells proliferation (11). These effects have been reported also in animal models with peripheral nerve damages and in human studies (12).

The results obtained in the current study showed that high-power diode laser beam (808 nm, 6.5 J/cm²) can significantly reduce pain in patients with mild to moderate CTS. In addition, combination of high-power laser and TENS significantly reduced pain in patients, while conventional TENS (100 Hz, 80 ms) for 30 min did not considerably decrease pain.

Casale *et al.* compared effects of TENS with high power laser therapy of a combined wavelengths of 808-1064 nm and 25 Watts output power (18 Watts for 1064 nm and 7 Watts for 808 nm). These researchers applied a total dose of 250 J/cm² of high power laser irradiation over a 10 cm distance of median nerve and studied pain and electro physiological parameters in patients with mild to moderate CTS (36). They found that high-power laser with the mentioned specifications significantly reduced the pain ($P=0.024$) and TENS had a near significant reduction of pain in these patients ($P=0.047$). It seems that the reason for the difference in the results of electrical stimulation in the mentioned study and the present research is the duration of intervention, despite the same treatment parameters. Casale *et al.* applied TENS in 15 sessions (three weeks, 5 sessions per week), while the modality in the present study was used in 10 sessions (two weeks, 5 sessions per week). It seems that the use of transcutaneous electrical stimulation for a longer duration can somewhat relief pain in CTS patients.

In the present study, the function of wrist in the high-power laser group and the high-power laser with TENS group significantly improved but there was no significant improvement in the TENS group. Various factors can affect hand function such as sensory symptoms and complaints,

including pain, tingling, and anesthesia, nerve extension and gliding, nerve conductivity, and muscle strength (45). The effects of laser on nerve conduction velocity, distal latency of median nerve, and pain have been confirmed in several studies (46-50). In general, laser is capable of changing neurophysiologic parameters that can be evaluated and monitored usually in the compression of median nerve at wrist (50). This phenomena can justify the improvement of hand function in the high-power laser group and the high-power laser with TENS group. It seems that deep penetration of high-power laser beam is the reason for the higher effect of this modality in relieving pain in CTS. Although TENS blocks the entrance of pain receptors impulses to the spinal cord through thick nerve fibers (51), it has no identified effect on tissue inflammation and sensory nerve conduction velocity (52).

Conclusion

The current study showed that high-power laser diode (838 nm, 6.5 j/cm²) can significantly reduce pain and improve hand function in patients with mild to moderate CTS at the end of ten treatment sessions. Therefore, it can be concluded that high-power diode laser is an effective and non-invasive method for the treatment of patients with CTS. Further clinical studies are required to prove this hypothesis.

Acknowledgments:

None

Conflict of interest:

None

Funding support:

None

Authors' contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

- Hunter JM, Mackin EJ, Callahan AD. Rehabilitation of the Hand. 5th edition. USA Mosby Company. 2002: PP: 630-639.
- Rempel D, Evanoff B, Amadio PC, De Krom M, Franklin G, Franzblau A. Consensus criteria for the classification of carpal tunnel syndrome in epidemiological studies. *AM J Public Health*. 1998, 88: 1447-1451.
- Katz JN, Simmons BP: Clinical practice, Carpal tunnel syndrome. *N Engl J Med*. 2002, 346: 1807-1812.
- Katz RT. Carpal tunnel syndrome: a practical review. *Am fam physician*. 1994, 94: 1371 -9 and 1385-1356.
- Walker J. Clinical Knowledge Summaries. Carpal Tunnel Syndrome. In: JH Stone, M Blouin. International Encyclopedia of Rehabilitation. 2010, available in <http://cirrie.buffalo.edu/encyclopedia/en/article/286/> Carpal Tunnel Syndrome.
- Marshall S. Carpal tunnel syndrome. *Clin Evid*. 2001, 5, 717-728.
- Brotzman SB, Manske RC. Clinical Orthopedic Rehabilitation: An Evidence-Based Approach, 3rd edition. Elsevier. 2005.
- Arooris S and Spence RA. Carpal tunnel syndrome. *Ulster Med J*. 2008: 77, 6-17
- Prakash KM, Chong S, Leoh TH, et al. Sensitivities of sensory nerve condition study parameters in Carpal tunnel syndrome. *J Clin Neurophysiol*. 2006. 23, 563-567.
- Jerosh-Herold C, Leite JC and Song F. A systematic review of outcomes assessed in randomized controlled trials of surgical intervention for carpal tunnel syndrome using the international classification of functioning Disability and Health (ICF) as a reference tool. *BMC Musculoskelet Disord*. 2006. 7, 96-112.
- Carlson H, Colbert A, Frydl J, Amall E, Elliot M. Carpal tunnel syndrome. *Int J Clin Rheumatol*. 2010. 5, 129-142.
- Gerritsen AA, Dekrom MC, Struijs MA, et al. Conservative treatment option for Carpal tunnel syndrome: a systematic review of randomized controlled Trials. *J Neural*. 2002. 249, 272-280.
- O'Connor D, Marshall SC, Massy-Westrop N and Pitt V. Non-Surgical treatment (other than steroid injection) for Carpal tunnel syndrome. *Cochrane Database Syst Rev*. 2003. 1-15, CD 003219.
- Ayhan-Ardic F. and Erdem H. Long-term clinical and electrophysiological results of local steroid injection in patients with Carpal tunnel syndrome. *Funct Neural*. 2000. 15, 157-165.
- Agarwal V, Singh R, Sachdev A, Wiclaf F, Shekhar S and Goel D. A prospective study of the long- term efficacy of local methyl prednisolone e acetate injection in the management of mild Carpal tunnel syndrome. *Rheumatology (Oxford)*. 2005. 44, 643-650.
- Flondell M, Hofer M, Bjork J and Atrosh I. Local steroid injection for moderately sever idiopathic Carpal tunnel syndrome : protocol of a randomized double blind placebo- controlled trial. *BMC Musculo skeletal Disord*. 2010. 11, 76-79.
- Ly-Pen D, Andreu JL, De blas, G, Sanchez-Dlaso A and Millan I. Surgical decompression versus local steroid injection in Carpal tunnel syndrome: a one-year prospective, randomized, open, controlled clinical trial. *Arthritis Rheum*. 2005. 52, 612-619.
- Hui AC, Wong S, Leung CH, et al . A randomized controlled trial of surgical versus steroid injection for Carpal tunnel syndrome. *Neurology*. 2005. 64, 2074-2078.
- Verdugo R J, Salinas RA, Castillo JL and Cea JG. Surgical versus non surgical treatment for Carpal tunnel syndrome. *Cochrane Database Syst Rev*. 2008. 4, CD 001552.
- Piazzini DB, Aprile I, Ferrara DE, et al . A systematic review of conservative treatment of Carpal tunnel syndrome. *Clin Rehabil*. 2007. 21, 299-314.
- Zati A and Valent A. Physical therapy: new technologies in rehabilitation medicine (translated to English). Edizioni Minerva Medica. 2006. 142-178.

21. Zati A and Valent A. Laser Therapy in Medicine. (translated to English) in: Medical Terapìa elstica: Nuave Technologic in Medicine Riabilitiia. 2006. 162-185.
22. Santamato A, Solfrizzi V, Panza F, Tondi G, Frisardi V, Leggin BG, Ranieri M, Fiore P. Short – term effect of high – intensity laser therapy versus ultrasound therapy in the treatment of people with subacromial impingement syndrome: a randomized clinical trial. *Phys Ther.* 2009. 89 (70): 603-652.
23. Saggini R, Bellomo RG, Cancelli F. Hilterapia and chronic ankle pain syndromes. *Int J of Inf and Sc Culture.* 2009. 3 (3): 22-25: 38-47.
24. Fusakul Y, Aranyavalai T, Saensri P, Thiengwittayaporn S. Low – level laser therapy with wrist splint to treat Carpal tunnel syndrome: a double –blinded randomized controlled trial. *Laser Med Sci,* 2014, 7, 103-114.
25. Bland JDP. A neurophysiological grading scale for carpal tunnel syndrome. *Muscle Nerve.* 2000; 23: 1280-1283
26. Boureau F, Luu M, Doubrere JF. Comparative study of the validity of four French McGill Pain Questionnaire (MPQ) versions. *Pain.* 1992; 50(1): 59-65.
27. Khosravi M, Sadighi S, Moradi Sh, Zendehdel K. Persian McGill Pain questionnaire; Translation, adaptation and reliability in cancer patients: a brief report. *Tehran Univ Med J (TUMJ)* 2013; 71(1): 53-58.
28. Adelmanesh F, Arvantaj A, Rashki H, Ketabchi SM, Montazeri A, Raissi G. Result from the translation and adaptation of the Iranian short-form McGill pain Questionnaire (I-SF-MPQ): preliminary evidence of its reliability, construct validity and sensitivity in an Iranian pain population. *Sport Medicine, Arthroscopy, Rehabilitation, Therapy & Technology.* 2011, 3: 27-37.
29. Mousavi SJ, Abedi M, Askary-Ashtiani A, Karimi A, Khorsandi A. Cultural adaptation and validation of the Persian version of the Disabilities of the Arm, Shoulder and Hand (DASH) outcome measure. *Clin Rehab.* 2008; 22: 749-757.
30. MacDermid JC, Kramer JF, Woodbury MG, McFarlane RM, Roth JH. Interrater reliability of pinch and grip strength measurements in patients with cumulative trauma disorders. *J Hand Ther.* 1994 Jan-Mar;7(1): 10-14.
31. Hoang-Kim A, Pegreff F, Moroni A, Ladd A. Measuring wrist and hand function: common scales and checklists. *Injury* 2011; 42: 253-258.
32. Schoneveld K, Wittink H, Takken T. Clinimetric evaluation of measurement tools used in hand therapy to assess activity and participation. *J Hand Ther* 2009; 22: 221-235.
33. Beaton DE, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts? Validity, reliability, and responsiveness of the Disabilities of the Arm, Shoulder and Hand outcome measure in different regions of the upper extremity. *J Hand Ther* 2001, 14: 128-146.
34. Hudak PL, Amadio PC, Bombardier C. The Upper Extremity Collaborative Group (UECG): Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand). *Am J Ind Med* 1996, 29: 602-608.
35. Casale R, Damiani C, Maestri R, Wells ED. Pain and electrophysiological parameters are improved by combined 830-1064 high-intensity LASER in symptomatic Carpal Tunnel Syndrome versus Transcutaneous Electrical Nerve Stimulation. A randomized controlled study. *Eur Phys Rehabil Med.* 2013; 49: 205-211.
36. Cameron MH. Physical Agent in Rehabilitation: From Research to Practice. 4th edition. P 260 and 290.
37. Fusakul Y, Aranyavalai T, Sean P, Thiengwitt S. Low – level laser Therapy with a wrist splint to treat Carpal Tunnel Syndrome: A double- blinded randomized controlled trial. *Laser Med Sci.* 2014.
38. Ibrahim I, Khan WS, Goddard N, Smitham P. Carpal Tunnel Syndrome: a review of the recent literature. *Open Orthop.* 2012. 6, 69-76.
39. World Association of Laser Therapy (2010). Recommended treatment dose for low laser therapy. Available at : [http:// www.walt . nu](http://www.walt.nu) (Accessed February 10, 2013).
40. Jerosh-Herold C, Leite JC, Song FA. A systematic review of outcome assessed in randomized controlled trials of surgical intervention for carpal tunnel syndrome using the International Classification of Functioning, Disability and Health (ICF) as a reference tool. *BMC Musculoskeletal disord.* 2006; 7: 96-98.
41. Ramibeau G. Recurrent carpal tunnel syndrome. *Chir Main.* 2008; 27: 134-145.
42. Botte MJ, Von Schroeder HP, Abrams RA, Gellman H. Recurrent carpal tunnel syndrome; *Hand Clin.* 1996; 12: 731-743.
43. Gigo-Benato D, Geuna S, Rochkind S. Phototherapy for enhancing peripheral nerve repair; a review of the literature. *Muscle and Nerve.* 2005; 31: 694-701.
44. Oshakouri AE, Talebi GA, Shakouri SK, Ghabili K. Effects of Neuromobilization Maneuver on Clinical and Electrophysiological Measures of patients with Carpal Tunnel Syndrome. *J Phys Ther Sci.* 2014. 26(7): 1017-1022.
45. Naser MA, Hahn KA, Liebrman BE, Branco KF. Carpal tunnel syndrome pain treated with low- level laser and microamperes Transcutaneous electric nerve stimulation: a controlled study. *Aech Phys Med Rehabil.* 2002. 83(7): 978-988.
46. Evcik D, Kavuncu V, Cakir T, Subasi V, Yaman M. Laser therapy in the treatment of Carpal tunnel syndrome: a randomized controlled trial. *Photomed Laser Surg.* 2007. 25(1): 34-39.
47. Shoostari SM, Badice V, Taghizadeh SH, Nematollahi AH, Amanollahi AH, Grami MT: The effects of lower laser in clinical outcome and neurophysiological results of Carpal tunnel syndrome. *Elctromyogr Clin Neurophysiol.* 2008. 48 (5): 229-231.
48. Tascioglu F, Degirmenci NA, Ozkam S, Mehmetoglu O. Low level laser in the treatment of Carpal tunnel syndrome: clinical, electrophysiological, and ultrasonographical evaluation. *Rheumatal Int.* 2012. 32(2): 409-415.
49. Bakhtiary AH, Rashidpour A. Ultrasound and laser therapy in the treatment of Carpal tunnel syndrome. *Aust J Physiother.* 50(3): 147-151.
50. Alfonsi E, Dalla Toffola E, Felicetti G, Zelaschi F, Casale R. Evaluation of the antidromic sensory nerve conduction velocity of the sural nerve before and after antalgic electrostimulation . *G Ital Med Lay.* 1982: 4: 239-240.
51. Brosseau L, Robinson V, Wells G, Debie R, Gam A, Harman K, et al. Low level laser therapy (Classes III) for treating osteoarthritis. *Cochrane Database Syst Rev.* 2007; 18: CD002046.