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A comparative study between the effect of low level laser therapy and hand splint on the spasticity of wrist flexors in stroke patients

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Comparison between the effect of low level laser therapy and hand splint in connection with spasticity of wrist flexors in stroke patients. Forty five patients of both sexes aged between 40 to 60 years were divided into three equal groups. Group I was treated with laser radiation for ten minutes three days a week for one month, Group II was treated with hand splint for one month, and group III was treated with laser radiation along with splints for one month. The patients in the three groups received the treatment six to eighteen months following the lesion; the three groups had been assessed using electro-diagnostic studies Modified Ashworth Scale, O.B goniometer, and (H/M ratio). Out of 45 participants, 21 were male (46.67%) and 24 were females (53.33%). significant differences between pre-treatment and post-treatment values of Ashworth scale, OB goniometer and H/M ratio within the three groups ($P<0.05$). The improvement percentage was the same results while Ashworth scale or O.B goniometer which was 33.33%, 33.3%, and 50%, H/M ratio had a percentage of 15.03%, 10.45%, and 20.11% in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy), respectively. Combination of laser therapy and splinting accomplished the best improvement, while the laser therapy or hand splint had the least improvement.

Keywords stroke, spasticity, laser, splint.

INTRODUCTION

Cerebrovascular accident (CVA) is defined as interruption of brain blood supply in a non-traumatic way, that lead to a rapid loss of brain function due to impairing demand for oxygen and nutrients, which culminates in defected tissue with impaired neuronal system, generating a neurological deficit, caused by blocked or burst blood vessels (Sims et al., 2010; das Neves et al., 2016). A CVA is also referred to as a stroke may occur due to thrombosis, embolism, or hemorrhage. As a result, the damaged area of the brain is incapable of functioning, which leads to the incapability of moving one or more limbs on one side of the body, or altered sensation or cognitive and language impairment (Wintermark

et al., 2008).

American Heart Association classified stroke as the second largest cause of death in adults and the third leading cause of disability worldwide (American Heart Association, 2002; Lopez et al., 2006; Murray et al., 2012). Current expectations estimate the number of deaths from a stroke will rise to 7.8 million in 2030. After stroke, individuals are often left with sensorimotor impairments, such as paresis and abnormal muscle tone, which significantly limit their ability to mobilize and participate in activities of daily living (Auchstaetter et al., 2016). Seventy percent of people with stroke will experience arm weakness, and 62% of these will not recovery dexterity in the arm at 6 months post stroke (Kwakkel et al., 2003).

Spasticity, or Spastic hypertonia, originally defined in 1980 as a velocity-dependent hypertonia that is one of the positive components of an upper motor neuron syndrome (Lance, 1980; Sheean, 2002). Recently, researches put another expression to spasticity called Post-stroke spasticity (PSS) which has been described as a velocity-dependent increase in muscle tone with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflex and presenting as intermittent/sustained involuntary muscle activation (Pandyan et al., 2005). This definition has again been incorporated sensori-motor control, resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles which illustrate the decreased range of motion, voluntary strength, and the increased joint stiffness (Pandyan et al., 2005). In addition to the impairment of neurons, spasticity leads to metabolic changes in muscle fibers. Accumulation of lactic acid happens due to decrease blood flow and oxidation ability of free fatty acids, muscles use glycogen instead which cause pain and function limitations characterized among stroke patients (Barber et al., 2011; dos Reis et al., 2015; das Neves et al., 2016). Approximately 20–40% of patients that have suffered a stroke develop spasticity (Sommerfeld et al., 2004; Barlow, 2016). Therapeutic intervention is essential with stroke patients to decrease mortality rate and help patients to perform their daily life activities (Welmer et al., 2006). Therapeutic interventions involving stretching, neurectomy, intrathecal baclofen, pump placement, botulinum toxin injection, and electrical stimulation of the muscles are merely slightly efficient (Lieber et al., 2004). Poor quality medication of spasticity may cause agony, contractures, and pressure sores and all that can affect the activity. Multidisciplinary management strategy is important to help this precise case through up-to-date approaches of interventions involving physical management program and medication (Stevenson, 2010).

Pharmacological management can be classified to oral medications and focal treatment, despite stroke survivors suffer from cognitive deficiencies that can deteriorate the central effects of oral medications, or they can be taking medicine that comparatively contradicts with the usage of some specific anti-spasticity drugs (Francisco et al., 2012). Baclofen is the most common medicine used for curing spasticity (Krach, 2001). Intrathecal baclofen works directly on the GABA receptors in the lumbar spinal cord where a high concentration of receptors allows small doses to be effective without the negative side effects. It is originally used to treat patients with spinal injuries, and it is also very effective in treating multiple sclerosis (MS) and hemiplegia, including post-stroke spasticity (Graham, 2013). Focal therapies like Botulinum toxins reduce muscle tone after suffering a stroke and also have the benefit of aiming at certain muscle groups or patterns of spasticity without the dangers of the standardized side effects such as drowsiness, cognitive impairment, and generalized weakness that are specifically associated with the elderly (Graham, 2013).

Physical therapies play a critical role in rehabilitation of stroke patients. Most interventions are based on exercise and specific training which aims to improve active function require the presence of some movement within the arm initially (Allison et al., 2016). The implementation of low-level laser therapy (LLLT) has focused on rehabilitation of fatigued muscles, muscular disorders, improved muscle through raising the metabolism at cellular level, leading to accelerated ATP production and protein synthesis. New blood vessels are formed and collagen synthesis is increased. Vascular relaxation and increased skin microcirculation are noted following administration of LLLT (Karu, 2003; Kai et al., 2013; das Neves et al., 2016). Upper limb orthoses or splints are widely advocated and used in such cases (Tyson et al., 2011). Orthosis is defined as an externally applied device used to modify the structural or functional characteristics of the neuromusculoskeletal system. Its prime role is to regulate abnormal motion of one or more body segment(s) around a joint(s) by applying forces to either side of a joint to redistribute the forces acting on that joint; it

controls the positions and movements and limits or prevents undesirable ones (Tyson et al., 2011). Hand splinting is one of the methods presented to decrease muscle tone of the upper extremity is the use of hand splints. In addition to the fact that it is a non-invasive and economical method, it has the extra advantage of focusing on the functional aspects of the hand (Langlois et al., 1991).

We aimed in our study to compare the effect of low level laser therapy and hand splint on the spasticity of wrist flexors in stroke patients in order to reduce associated mortality and disability among those patients. We hypothesize that patients' motivation and cooperation was similar, patients have exerted maximum effort during treatment sessions, and equipment was valid, reliable and accurate.

MATERIALS AND METHODS

Study design

A cohort study was conducted at outpatient clinic, Faculty of Physical Therapy, Cairo University in order to compare between the effect of LLLT and hand splint in connection with spasticity of wrist flexors in stroke patients.

Study population and Sample size

Forty five patients of both sexes were randomly selected from the outpatient clinic, Faculty of Physical Therapy. Patients were divided into three subgroups: 1st group was treated by laser+ physical therapy program, 2nd group was treated by splint+ physical therapy program, and 3rd group was treated by laser+ splint + physical therapy program. Subjects included in the study were aged between 40 to 60 years, duration of illness from 6 to 18 months, males and females, and suffer from middle cerebral artery infarction. Subjects are excluded if they had one or more of the following criteria: Severe spasticity, Contractures in muscles of wrist, Bony block in the wrist, Recent operation in the wrist, Malignant diseases, Infectious diseases, Heavy blood losses, and other neurological or medical diseases (tumor, vascular disease,…etc.) affecting the tested joint region.

Assessment

Assessment was made before and after all treatment sessions. We used 3 instruments for assessment. H/M ratio: Electrophysiologic studies were carried out using a Nihon Kohden MEB_9200K Neuropack machine (Tokyo, Japan), software V.08.11 (Tokyo, Japan), in the Clinical Neurophysiology unit of Kasr Alainy Hospital, Cairo University. Myrin O.B goniometer: was used to assess range of motion (ROM) of the wrist joint. It consists of a fluid-filled rotatable container mounted on a plate. Modified Ashworth scale: was used to assess the degree of spasticity. It measures the resistance during passive soft tissue stretching. It is a rapid and effortless measuring device that helps with assessing the effectiveness of treatment. if it is performed more than three times, the short term effect of stretch can influence the score (Bohannon et al., 1987).

Treatment

Laser Therapy: Goiotto Gallium-Arsenide cluster diode laser wavelength of 905 nm. Gallium-Arsenide (GA-AS) laser parameters are 905 nm wavelengths, 5 mW/cm2 voltage, 8 J/cm2 energy density for 10 minutes 12 sessions 3 times per week for one month. The patient was asked to sit on the plinth with his upper limb totally extended; the therapist was sitting beside the patient fixing the laser probe on the common flexor origin. Splint: Static wrist cocks up splint: worn by the patient for four hours per day at night daily for one month.

Data collection

Prior to the final analysis, the data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk test was applied, that indicates the data were not normally distributed. All these findings allowed the researchers to conduct parametric and non-parametric analysis.

Statistical analysis

The statistical analysis was performed through utilizing statistical SPSS Package program version 20 for Windows (SPSS, Inc., Chicago, IL). The following statistical procedures were conducted: Quantitative parametric descriptive statistics including the mean and standard deviation for demographic data (age and duration of illness), Quantitative non-parametric descriptive statistics including the median and interquartile range (IQR) for Ashworth's scale, O.B goniometer, and Hmax: Mmax ratio variables, Qualitative descriptive statistics including the number and percentage of the affected side and sex distributions, One way analysis of variance (ANOVA-test) to compare among laser therapy and splinting, laser, as well as splint groups for demographic data (age and duration of illness), Chi-square test ($\chi 2$- test) to compare among laser

therapy and splinting, laser, and splint groups of the affected side and sex distributions, Wilcoxon test to compare the data between pre-treatment and post-treatment within each study group (laser therapy and splinting, laser, and splint) for the tested variables (Ashworth scale, O.B goniometer, and Hmax: Mmax ratio), and Friedman test to compare among laser therapy and splinting, laser, and splint groups for Ashworth scale, O.B goniometer, and Hmax: Mmax ratio variables. P-value equal to or less than 0.05 was considered statistically significant.

Sampling Technique

Stratified sample technique was used in which participants were divided into 3 strata (groups).

Administrative consideration:

The Researchers fulfilled all the required official approvals.

Ethical Considerations:

Ethical approval was taken from the ethical committee, before interviewing, the researchers explained the purpose to all respondents and oral consent was asked from all the participants or their family. The participants had the right not to participate in the study or to withdraw from the study prior to completion. Confidentiality and privacy were guaranteed for all participants.

RESULTS

Demographics

The mean values of age were close in the three groups: group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy) were 56.20 ±3.83, 56.17 ±3.27, and 57.67 ±3.30 years, respectively. Duration of illness was 15 months as recommended in inclusion criteria and the mean values between 3 groups were 15.20 ±2.83, 15.33 ±3.49, and 15.53 ±2.94 months, respectively. The statistical analysis by one way analysis of variance revealed the absence of significant differences (P>0.05) in demographic data (age and duration of illness) among 3 subgroups (Table 1).

Table 1: comparison of age and duration of illness among 3 groups treated from Spasticity of Wrist Flexors in Stroke Patients from an outpatient clinic, Faculty of Physical Therapy, Cairo University.

Items	Age (year)	Duration of illness (month)
Group 1 (laser + physical therapy)	56.20 ±3.83	15.20 ±2.83
Group 2 (splint + physical therapy)	56.17 ±3.27	15.33 ±3.49
Group 3 (laser + splint +physical therapy)	57.67 ±3.30	15.53 ±2.94
F-value	0.907	0.044
P-value	0.411	0.957

Table 2: comparison of sex distribution among 3 groups treated from Spasticity of Wrist Flexors in Stroke Patients from an outpatient clinic, Faculty of Physical Therapy, Cairo University.

Items	Males	Females
Group 1 (laser + physical therapy)	8/15 (53.33%)	7/15 (46.67%)
Group 2 (splint + physical therapy)	8/15 (53.33%)	7/15 (46.67%)
Group 3 (laser + splint +physical therapy)	5/15 (33.33%)	10/15 (66.67%)
Total	21/45 (46.67%)	24/45 (53.33%)
Chi-square value	1.607	
P-value	0.442	

Males were more than a half in group 1 and group 2 with a percentage of 53.33% in both groups and females were 46.67%. Although, females represent a higher percentage in group 3 (66.67%) rather than males (33.33%).The statistical analysis by Chi-square test (χ2-test) revealed that there were no significant differences (P=0.442; P>0.05) in sex distributions among 3 subgroups therapy (Table 2).

Comparisons between pre-treatment and post-treatment values of Ashworth scale within each group

In pre-treatment, Ashworth scale median scores tended to increase skeletal muscle tone which in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy) were 3, 3, and 4, respectively (Figure 1). In the other hand, after treatment Ashworth scale median score was slightly decreased in the three groups to 2 to achieve 33.33%, 33.3%, and 50% improvement percentage in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy), respectively (Figure 2). The statistical analysis by Wilcoxon test showed that there were significant differences between pre-treatment and post-treatment values of Ashworth scale within the three groups (P=0.0001; P<0.05). In contrast, the statistical analysis by Friedman test showed that there were not any crucial distinctions in the pre-treatment (P= 0.85; P>0.05) and the post-treatment (P= 0.54; P>0.05) of Ashworth scale (Table 3).

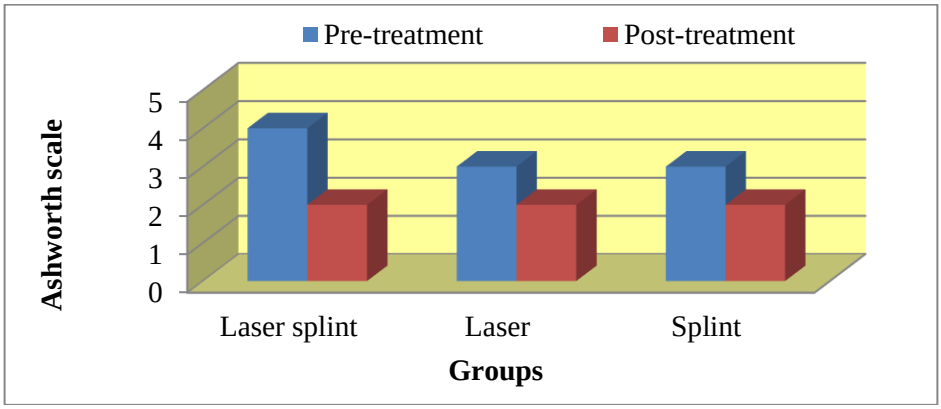

Figure 1: shows median values of pre-treatment and post-treatment of Ashworth scale among 3 groups.

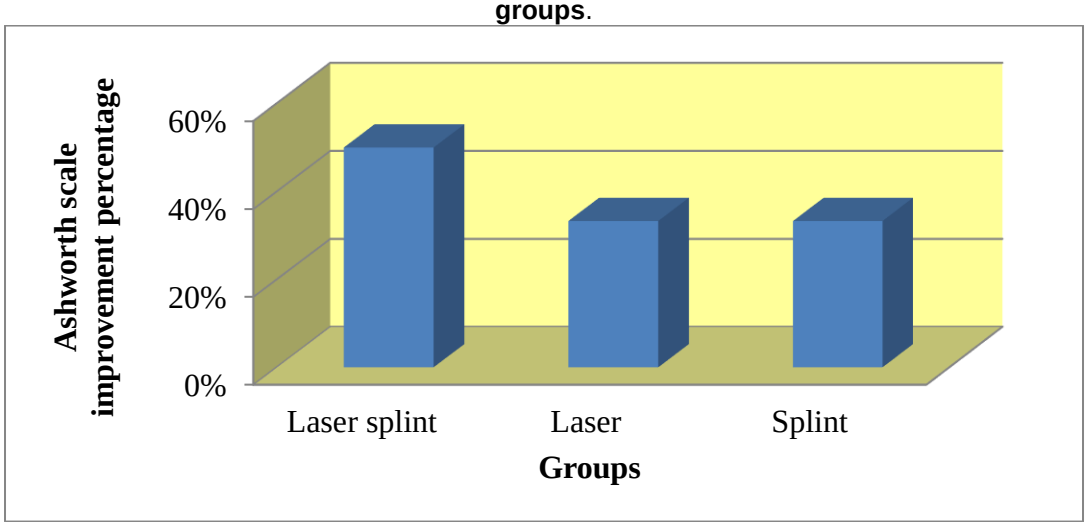

Figure 2: shows Ashworth scale improvement parentage among 3 groups

Table 3: comparison between pre-treatment and post-treatment values of Ashworth scale within each group from the outpatient clinic, Faculty of Physical Therapy, Cairo University.

Items	Ashworth scale			Friedman test	
	group 1 (laser + physical therapy)	group 2 (splint + physical therapy)	group 3 (laser + splint + physical therapy)	F-value	p-value
Pre-treatment (Median, IQR)	3 (2,3)	3 (2,3)	4 (3,4)	0.95	0.85
Post-treatment (Median, IQR)	2 (1,2)	2 (1,2)	2 (2,3)	0.66	0.54
Difference	1.00	1.00	2.00		
Improvement percentage	33.33%	33.33%	50.00%		
Z-value	3.873	3.873	3.626		
P-value	0.0001	0.0001	0.0001		

*p<0.05 is considered significant

Table 4: comparison between pre-treatment and post-treatment values of O.B goniometer within each group from the outpatient clinic, Faculty of Physical Therapy, Cairo University.

Items	O.B goniometer			Friedman test	
	group 1 (laser + physical therapy)	group 2 (splint + physical therapy)	group 3 (laser + splint + physical therapy)	F-value	p-value
Pre-treatment (Median, IQR)	3 (2,3)	3 (1,3)	2 (1,3)	2.47	0.29
Post-treatment (Median, IQR)	4 (3,4)	4 (3,4)	3 (2,4)	8.9	0.012
Difference	1.00	1.00	1.00		
Improvement percentage	33.33%	33.33%	50.00%		
Z-value	2.395	2.438	3.324		
P-value	0.041	0.038	0.002		

*p<0.05 is considered significant

Comparisons between pre-treatment and post-treatment of O.B goniometer within each group:

In pre-treatment O.B goniometer median values in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy) were 3, 3, and 2, respectively. In the other hand, after treatment OB goniometer median values were slightly increased in group 1 and group 2 to 4, while group 3 O.B goniometer median was 3 (Figure 3). The improvement percentage was similar to Ashworth scale 33.33%, 33.3%, and 50% improvement percentage in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy), respectively (Figure 4). The statistical analysis by Wilcoxon test showed that there were significant differences between pre-treatment and post-treatment values of OB goniometer within the three groups ($P<0.05$) (Table 4).

Comparisons between pre-treatment and post-treatment of Hmax: Mmax ratio within each group

In pre-treatment median Hmax: Mmax ratio in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy) were 1.53, 1.34, and 1.79, respectively. In the other hand, after treatment Hmax: Mmax ratio median values was slightly decreased to 1.30, 1.34, and 1.79 in group 1, group 2, and group 3, respectively (Figure 5). The improvement percentage was much less than similar achieved in the Ashworth scale and OB goniometer, 15.03%, 10.45%, and 20.11% improvement percentage in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy), respectively (Figure 6). The statistical analysis by Wilcoxon test showed that there were significant differences between pre-treatment and post-treatment values of Hmax: Mmax within the three groups ($P<0.05$). The statistical analysis by Friedman test showed that there were not any crucial differences in pre-treatment ($P= 0.05$; $P>0.05$), while there was a significant difference in post-treatment ($P= 0.03$; $P<0.05$) of Hmax: Mmax ratio among laser therapy and splinting, laser, and splint groups (Table 5).

Comparison of the affected side among laser therapy and splinting, laser, and splint groups

Figure 7 represents the affected side distribution percentage in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy). The affected side distribution revealed the reported percentages of right-sided were 46.70%, 53.30%, and 66.70%, respectively, while the numbers of the left-sided reported percentages were 53.30%, 46.70%, and 33.30%, respectively. The statistical analysis by Chi-square test (χ^2-test) showed that there were not any crucial distinctions ($P=0.533$; $P>0.05$) in the affected side distributions and the way of treatment among laser therapy and splinting, laser, and splint groups.

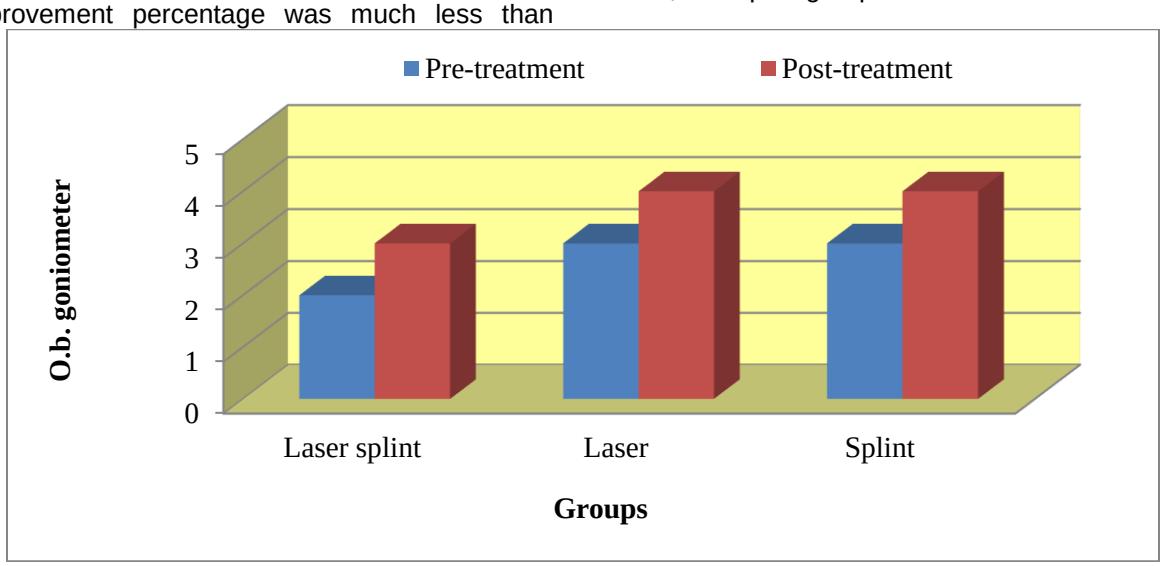

Figure 3: shows median values of the pre-treatment and post-treatment of O.B goniometer among 3 groups

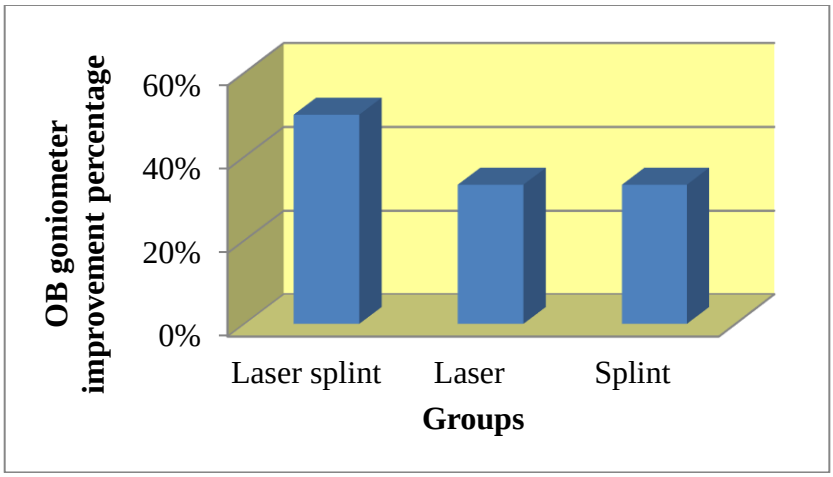

Figure 4: shows OB goniometer improvement parentage among 3 groups

Table 5: comparison between pre-treatment and post-treatment values of Hmax: Mmax ratio within each group from the outpatient clinic, Faculty of Physical Therapy, Cairo University.

Items	Hmax: Mmax ratio			Friedman test	
	group 1 (laser + physical therapy)	group 2 (splint + physical therapy)	group 3 (laser + splint + physical therapy)	F-value	p-value
Pre-treatment (Median, IQR)	1.53 (1.41,1.65)	1.34 (1.24,1.45)	1.79 (1.63,1.96)	9.40	**0.05**
Post-treatment (Median, IQR)	1.30 (1.09,1.51)	1.20 (1.05,1.35)	1.43 (1.32,1.54)	12.13	**0.03**
Difference	0.23	0.14	0.36		
Improvement percentage	15.03%	10.45%	20.11%		
Z-value	4.357	2.430	3.408		
P-value	0.001	0.028	0.001		

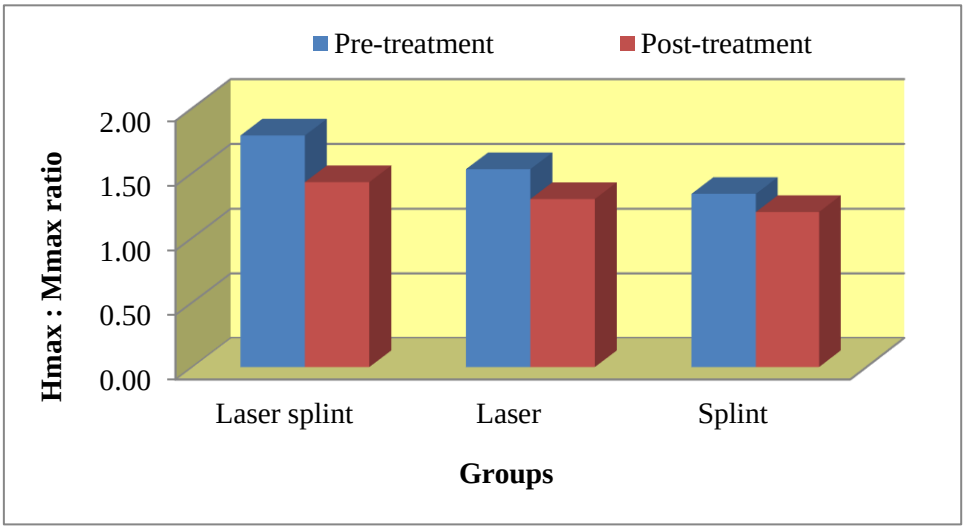

Figure 5: shows median values of pre-treatment and post-treatment of Hmax: Mmax ratio among 3 groups

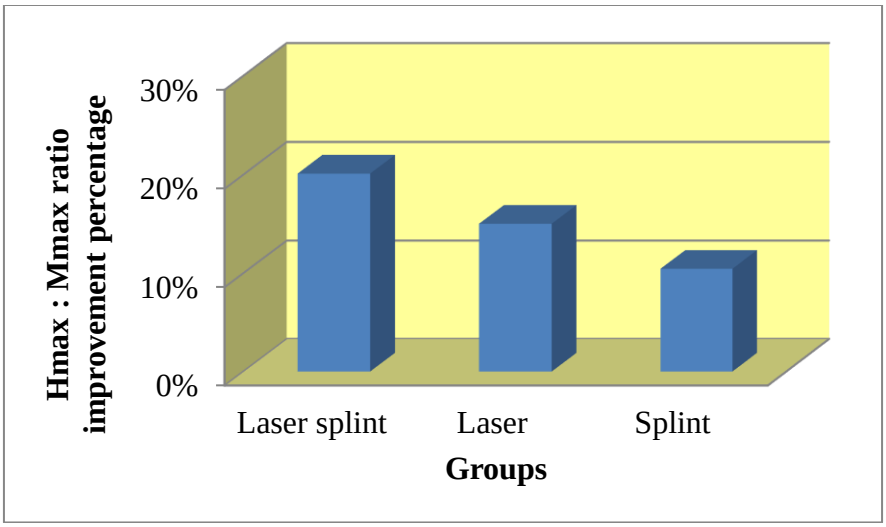

Figure 6: shows Hmax: Mmax ratio improvement parentages among laser therapy among 3 groups

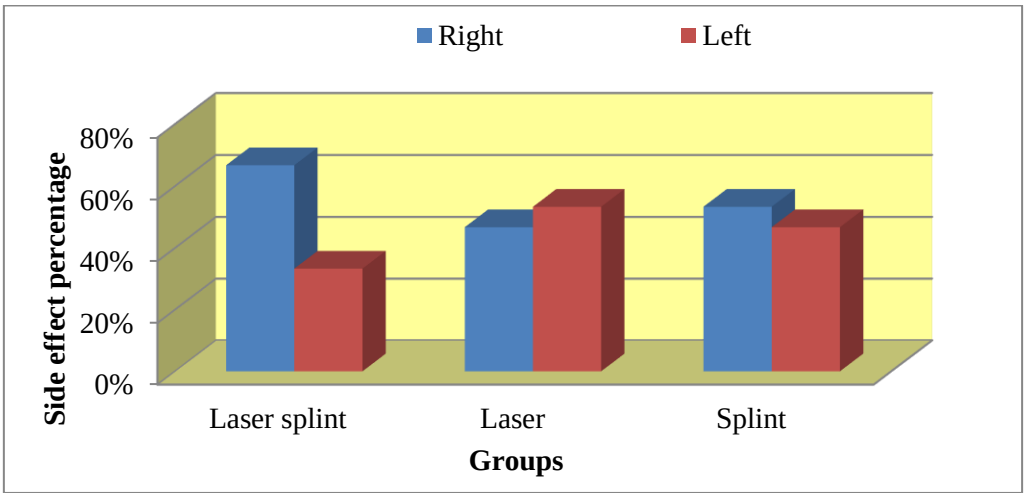

Figure 7: shows the affected side distributions among 3 groups

DISCUSSION

The current research was conducted to compare the effect of laser, splint, and laser therapy and splinting on spasticity of wrist flexors in stroke patients. Forty five stroke patients of both sexes were examined during this study, fifteen patients in each group. Laser group was treated by gallium arsenide laser device. Splint group wore cock up wrist splint for four hours everyday night and laser splint group was treated by both modalities along with a physical therapy program. All patients were assessed by electrodiagnostic studies (H/M ratio), O.B goniometer and modified Ashworth scale. One quick and easy way to measure spasticity is the Modified Ashworth Scale (MAS). The MAS calculates resistance during passive soft-tissue stretching (Levine, 2009). The validity of MAS has been estimated neurophysiologically with the measurement of wrist flexor spasticity in stroke patients. A significant positive correlation between the MAS scores and H/M ratio was found indicating the validity of the MAS (Abolhasani et al. 2012). O.B goniometer is applied to assess ROM at some joints. It has the advantage of assessing the passive range of motion (PROM) more easily since the therapist doesn't have to hold onto the goniometer and can stabilize the proximal joint segment by one hand while

peacefully moving the distal segment by the other.

The mean age of our participants was near to the mean age of participants in another study which was 56.7+/-12.8 years. They comprised 37(46.2%) right hemiparetic and 43 (53.8%) left hemiparetic patients (Bello et al., 2012).The affected side distribution in our result also close to the previous study, our results revealed the reported percentages of right-sided were 46.70%, 53.30%, and 66.70%, respectively), while the numbers of the left-sided reported percentages were 53.30%, 46.70%, and 33.30%, respectively).

Modified Ashworth Scale, O.B goniometer, and H/M ratio were our tools to measure spasticity of the muscle in stroke patients. They are reliable measures of spasticity and utilized by many previous studies (Cooper et al., 2005; Naghdi et al., 2007; Bovend'Eerdt et al., 2009; Mezaal et al., 2011).

Post-treatment results of the current study revealed improvement in moderate spasticity in wrist flexors for all the patients of the three groups according to Ashworth scale, O.B goniometer and H/M ratio.

Improvement percentages in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy) measured by Ashworth scale were 33.33%, 33.3%, and 50%, respectively. This means that the improvement percentage of the laser therapy and splinting group (group 3) was higher than the other two groups; laser group (group 1) and splint group (group 2), had equal improvement percentages and results. O.B goniometer assures the same results of the Ashworth scale to conclude equal improvement percentage. In contrast, the improvement percentage was decreased while using H/M ratio to 15.03%, 10.45%, and 20.11% improvement percentage in group 1 (laser + physical therapy), group 2 (splint + physical therapy), and group 3 (laser + splint + physical therapy), respectively. This means that the laser therapy and splinting group (group 3) accomplished the best improvement, while the laser group (group 1) followed and the splint group (group 2) had the least improvement.

According to Ashworth scale and O.B goniometer, the percentage of improvement was higher than the one recorded using H/M ratio in the three groups; this proves that it is better to use the two modalities side by side in treating wrist flexors' spasticity in hemiplegic patients. Our finding was in accordance with a previous study suggesting that LLLT using λ = 830 nm may be beneficial in accelerating recovery of muscle spasticity (Lee et al., 2011). Another study revealed that low-level energy exposures from an 808-nm diode laser is an effective short-term therapeutic tool. This modality raised the mouth opening amplitude and reduced the muscle tone of kids with spastic CP over three weeks of intermittent laser applications (Santos et al., 2016). In the other hand, some studies claimed that LLLT can lead to increasing the recruitment of muscle fibers and, consequently, increasing the spastic muscle fatigue (das Neves et al., 2016).

Laser and splint had equal improvement rates according to Ashworth scale and O.B goniometer, this suggests that they have similar effects on wrist flexors' spasticity and can be used interchangeably; while according to H/M ratio laser has better effects in comparison to splints. Splint effectiveness was assessed in a systemic review study that concluded that splinting makes no difference to hand function, added there is insufficient evidence to either support or refute the effectiveness of hand splinting for adults following stroke (Lannin et al., 2003; Suat et al., 2011).

Limitations to this study include the facts that a sample size used was small. We recommend more research should be done to apply using different types and parameters of laser therapy and study the effectiveness of Splinting. Physical therapy program has to be more advanced to increase the quality of life of stroke survivor.

CONCLUSION

Gallium Arsenide laser and cock up splint are better than using a laser or splinting methods separately in the treatment of spasticity of wrist flexors in stroke patients.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

AUTHOR CONTRIBUTIONS

ZNS designed and performed the experiments and also wrote the manuscript. GSE designed the experiments. AMN performed the H/M ratio electro-diagnostic assessment for all the patients. RMK designed experiments and reviewed the manuscript. YMM designed experiments and reviewed the manuscript. All authors read and approved the final version.

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