The Effects of Intermittent Pneumatic Compression on Electrodiagnostic Parameters of Median Nerve in Patients with Mild Carpal Tunnel Syndrome

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ABSTRACT

Background: According to the pathophysiology of carpal tunnel syndrome, reducing of the pressure and tension in the carpal tunnel and improving in the nerve blood supply could decrease the patient's signs and symptoms. Therefore, the purpose of this study was the effect of Intermittent Pneumatic Compression in the Electrodiagnostic parameters of the median nerve in patients with mild carpal tunnel syndrome.

Methods: In this double blind randomized clinical trial, thirty subjects with Carpal Tunnel Syndrome were included. The subjects were randomly divided into Neurodynamic group and Intermittent Pneumatic Compression group. The Intermittent Pneumatic Compression group was treated with compression instrument (Model 2008 WIC) in addition to conventional therapy. The Neurodynamic group received ULTT2a for median nerve by Butler methods and conventional therapy, including TENS, Hot pack, US and free active exercises. Interventions were conducted three times per week for four weeks. Overall, subjective symptoms, score of disability and electrodiagnostic parameters of median nerve were measured before and after intervention by Boston questionnaire and electrodiagnostic device. Data were analyzed with paired and independent t tests ($p<0.05$).

Results: Score of Boston Questionnaire and sensory peak latency, sensory nerve conduction velocity of the median nerve significantly were changed, in the both groups ($p<0.05$). But there was no significant difference in Score of Boston Questionnaire and sensory peak latency and sensory nerve conduction velocity between two groups ($p>0.05$). The only significant difference between the two groups was in the distal motor latency of the median nerve ($p<0.05$).

Conclusion: According to the results of the study, Intermittent Pneumatic Compression therapy improved pain and distal motor latency of the median nerve in patients with mild carpal tunnel syndrome. Therefore, we suggest that in addition to routine exercises, Intermittent Pneumatic Compression could also be considered in subjects with mild Carpal Tunnel Syndrome.

Key words: Carpal Tunnel Syndrome, Neurodynamic Technique, Air Compression Massage Therapy.

INTRODUCTION

Carpal tunnel syndrome (CTS) is considered the most common nerve entrapment in the upper limb, which is caused by pressure or tension on the median nerve in the carpal tunnel. These two mechanical factors can lead to intraneural blood circulation dysfunction, destruction of myelin sheath and axon, and changes in supporting connective tissues (1,2). The symptoms of the disease include nocturnal paresthesia, numbness and pain in the dermatome of the median nerve, as well as a decrease in grip strength and atrophy of the thenar muscles (1-6).

Normal carpal tunnel pressure has been recorded from 2 to 10 mmHg (1). Bauman et al. (1981) reported the pressure inside the carpal tunnel in patients with carpal tunnel syndrome at 32 mm Hg in the neutral position, 94 mm Hg in the wrist flexion, and 110 mm Hg in the wrist extension (7). An increase in the pressure inside the carpal tunnel may cause damage to the nerve blood supply and the accumulation of proteins and inflammatory cells in the carpal tunnel. It may cause compartment syndrome due to increased permeability, increased intraneural compression, and the development of intra-fascicular edema (1,7). Moreover, the advancement of neurovascular changes will damage and destruct myelin (1,8).

The changes in the connective tissue of the median nerve are also involved in the development of carpal tunnel syndrome. The flexibility of these connective tissue elements is directly associated with the movement of the nerve inside the sheath or nerve gliding during movements. Hypertrophy of the fibrous tissue around the nerve leads to stretching and tension on the nerve during repetitive wrist flexion and extension tasks (1,9). An increase in the density of fibroblasts, an increase in the size of collagen fibers, vascular proliferation, and Type 3 collagen in the synovial connective tissue occurs following this negative cycle (1). So, it will cause more disruption in the nutrition and blood supply of the elements inside the carpal tunnel and compensatory hypertrophy of the connective tissue elements (1,10,11).

Based on the documents presented, External Pneumatic Compression (EPC) may be one of the therapeutic methods recommended in this regard since one of the primary causes of carpal tunnel syndrome is the disruption of blood supply and nutrition of the elements inside the carpal tunnel (12,13,14,15). Pneumatic systems consist of cuffs that filled and emptied with air intermittently. This compressive wave applies compression on the tissue in a certain direction and at a specific speed and causes a change in the blood flow of the tissue (12). These mechanical systems can accelerate the initial stages of recovery from sports injuries by reducing venous congestion and increasing blood supply (16). They also speed up the process of inflammation and recovery. Compression sleeves activate the pain gate mechanism, reduce pain and facilitate movement by stimulating skin mechanoreceptors (16). Labropoulos et al. (1998) indicated the immediate effects of intermittent pneumatic foot and calf compression on popliteal artery blood flow (15). A systematic review (2008) recommended the use of compression therapy to prevent venous thrombosis and organ edema, heal wounds, and treat lymphedema (13). Agu et al. (2004) reported that a significant improvement in the amount of tissue oxygen is created after the gradual application of compression on the tissue (14). Bochmann et al. (2005) reported that applying external compression on the forearm increases its perfusion, reduces transmural compression and stimulates the myogenic respons. These lead to vascular relaxation and increased blood flow (17).

Since the primary source of CTS has been introduced to be disruption in blood supply and nutrition. Besides, we agree that EPC reduce venous congestion, pain, and improve organ blood supply (16). Therefore, this thesis will arise that neurological signs and symptoms and electrodiagnostic parameters of people with CTS will be affected by improving the blood circulation system and nutrition of tissues and nerves. Thus, the present study investigated the effects of Intermittent Pneumatic Compression in Electrodiagnostic parameters of median nerve in patients with Mild CTS.

Methods

This study was double blind randomized controlled trial. Thirty subjects with mild CTS participated in this study and were divided into two groups by simple non-probability sampling method. The medical ethics committee at the Zahedan University of Medical Sciences approved the study ethics and issued the ethics certification number as IR.ZAUMS.REC.1400.123 and registered with the region's Clinical Trials Registry (IRCT20180714040466N4). All participants signed written informed consents.

Inclusion criteria

Inclusion criteria included men and women aged between 18 and 60 years, mild Carpal Tunnel Syndrome according to Distal Peak Latency(ms) ≥ 3.5, lack of thenar muscles atrophy, current pain and paresthesia in median dermatome, no history of fracture, cervical radiculopathy, structural abnormalities, dizziness and trauma. Also, no history of progressive rheumatic and neurological diseases, long-term use of corticosteroids, malignancy and pregnancy (17-19).

Exclusion criteria

Exclusion criteria included pain or inflammation in wrist, receiving other treatment during the research, unwillingness to continue treatment, not completing the course of treatment, taking painkillers, sedatives and alcohol 48 hours before the test.

Sample Size

The sample size was determined based on a pilot study. Ten subjects were divided randomly into two equal groups, and the main part of study was conducted on them. The means and SDs for the parameters from this pilot study, with α= 0.05 and 90% power were used to calculate the sample size. According to the results of the pilot and the formula stated, the sample size in each group was considered 15 patients.

The sampling method was the simple, non-probabilistic and from the available population. Then, the participants were allocated randomly to two intervention groups, the Neurodynamic group and Intermittent Pneumatic Compression (IPC) group. Randomization was performed using random number sequence. The administrator and participants were informed about the grouping data. But the physiotherapist who assessed the subjects, measured the outcome, and analyzed the data was blinded about the grouping.

Procedure

The initial clinical examination study was performed by demographic information, patient's history, NCV and EMG reports and Upper Limb Tension Test (ULTT) test for diagnostic Carpal Tunnel Syndrome (20). Then, the individuals were selected to enter the study by examining the inclusion and exclusion criteria.

Outcome

Pain and Disability Index: Boston Questionnaire was used to obtain pain and disability level of patients. This questionnaire includes two scores: pain score and disability score. The score one in this questionnaire indicates a lack of problem. As this score goes up, it indicates an increase in pain and disability level (21,22).

Electrodiagnostic measurement (19,20,23,13): To measure the nerve conduction of median nerve, electrodignostic device (model NEMUS 2/EMB, made in Italy, EBNeuro Company) was used. Sensory peak latency, sensory nerve conduction velocity, distal motor latency of median nerve was measured in resting position. For this purpose, the patients were asked to sleep in supine position on the bed with bent knees and put both hands to the sides of the abdomen. Upper limb and hand were placed in neutral and relaxed state. Motor and sensory studies were performed for the median nerves. The Sensory component of nerve was stimulated antidromically while the motor part was stimulated orthodromically. The parameters were obtained include: sensory peak latency and sensory nerve conduction velocity and distal motor latency (23,19).

Intervention

Subjects were randomly divided into two groups: Neurodynamic group and Intermittent Pneumatic Compression group. Patients in both groups received routine physiotherapy treatment including TENS (burst, 20min), Hot pack (20min), US (3min) and free active exercises for hand and fingers. Exercises were completed in three sets with 10 repetitions under the supervision.

In the Neurodynamic group, ULTT2a for median nerve by Butler methods were performed. Techniques were performed in five set with 10 repetitions (20,21,24,25).

In Intermittent Pneumatic Compression group, a Compression instrument (Model WIC-2008, made in Korea, Won Industry Co. LTD) was used (14,15,17). When the person was in a sitting position and the person's arm was fully supported on the chair handle in a completely relaxed state (14,17). The limb of the affected side was completely placed inside the device cuff; the device was set with a maximum pressure of 120 mm Hg and a minimum pressure of 0 mm Hg and alternately. The filling time of the device was 3 seconds and the emptying time was 12 seconds, and the treatment continued for ten minutes (15).

Patients were treated in twelve sessions three days a week for four weeks (13,26). All the variables were measured before and after intervention.

Data analysis

Results were presented as mean values and standard deviation (SD). Criterion of significancy was set as $p<0.05$. Data analysis was performed with SPSS version 27. The assumption of a normal distribution was assessed using the Shapiro-Wilk test. The assumption of equality of variances was tested using Levene's test. The paired and student t-tests were used for within- and between-group comparisons, respectively.

Results

Fifty-three people were nominated for this study, and 30 patients in each group were divided into two groups: Neurodynamic group and IPC group (Fig-1).

Fifty-three people were nominated for this study and 40 of these patients were divided into two groups: Neurodynamic group and IPC group (Fig-1). Figure 2 presents the recruitment strategy and experimental plan. The pilot study showed that 15 subjects would be needed for each group (a total of 30 subjects). Ultimately, 30 subjects finished the study procedure. Thirteen of them were not eligible based upon the inclusion and exclusion criteria. Seven subjects from the IPC group and three subjects from Neurodynamic group left the study because of personal problems, unwillingness to continue treatment and incomplete treatment or reasons unrelated to the investigation. The flowchart of choosing participants in the study is shown in Figure 1.

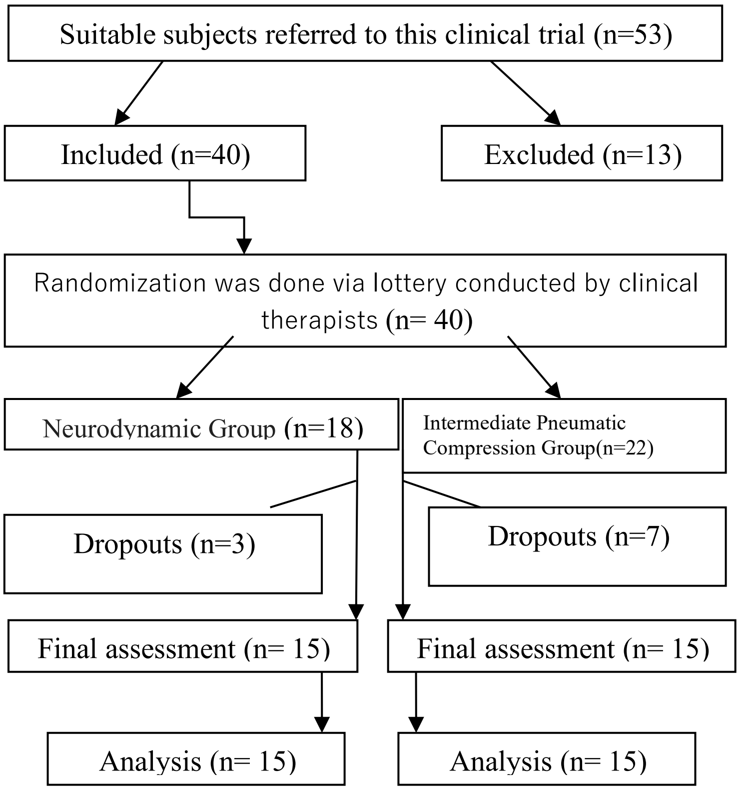

Fig-1: Flow diagram of study selection.

Data were analyzed in SPSS 27 software. To examine the homogeneous of samples in the two groups before intervention, a t-test was used. The results show that the samples in the two groups were equal and homogeneous. The normality of data distribution was examined by the Shapiro-Wilk test. The p-value was not less than 0.05 in the variables of the study. Thus, the tests do not reject the hypothesis of normality and the data are normal (p>0.05).

Table-1- Comparison of demographic characteristics between two groups

Variable	Neurodynamic Group*	Air Compression Massage Group*	sig**
Age (Years)	45.4±12.8	42.00±12.1	0.4
Weight (Kg)	72.3±13.0	71.30±12.9	0.8
Height (Cm)	1.6±0.08	1.6±0.07	0.8
Body Mass Index (BMI) (m^2/Kg)	27.8±3.3	26.4±4.6	0.06

*mean ± standard deviation. ** A significance level of less than 0.05.

Table-1 presents the demographic characteristics of patients including age, height, weight, and body mass index. The demographic characteristics of the patients, which were recorded before intervention, were compared between the two groups. There was no significant difference between the two groups (Table-1).

To examine the homogeneous of samples in the two studied groups before intervention, a t-test was used. The results show that the samples in the two groups were equal and homogeneous (p>0.05).

Within group and between group comparison

Table-2 within and between groups comparison.

	Neurodynamic group (n=15)*		Pvalue-within group**	Intermittent Pneumatic Compression Group (n=15)*		Pvalue-within group**	Pvalue-between group**
	Before	After		Before	After		
Pain	29.2±12.8	22.8±11.2	0.01	31.4±11.5	24.0±10.0	0.000	0.7
Disability	14.4±7.9	11.6±6.6	0.007	15.6±5.1	11.7±4.1	0.000	0.9
Boston Q.	43.2±18.4	34.0±16.4	0.005	47.0±15.8	35.8±13.6	0.000	0.7
Distal Motor Latency (µs)	4.5±0.8	4.1±0.7	0.001	4.0±0.5	3.6±0.5	0.000	0.03
Peak Sensory Latency (µs)	4.3±0.6	4.0±0.6	0.001	4.1±0.4	3.7±0.3	0.000	0.1
Sensory nerve conduction velocity (m/s)	30.4±4.1	32.5±5.1	0.001	31.8±2.9	34.4±3.4	0.001	0.2

*mean ± standard deviation. ** A significance level of less than 0.05.

The results of Table 2 show that the changes in the pain, disability, Score of Questionnaire were significant before and after intervention in both groups (p<0.05). Also, significant changes were observed in the distal motor latency, peak sensory latency and sensory nerve conduction velocity before and after intervention in both groups (p<0.05). The results of the between group comparison show no significant difference in pain, disability, sensory latency and velocity conduction variables after intervention (p>0.05). There were significant difference between the two groups in distal motor latency after intervention (p<0.05).

Discussion

The present study indicated the effect of IPC on sensory and motor parameters of the median nerve and subjective symptoms in patients with mild CTS. However, the between group comparison revealed that there is no difference between the two treatment groups in pain, score of disability, Boston Questionnaire Score, Peak Sensory Latency, Sensory Nerve Conduction Velocity. The Distal Motor Latency of the median nerve showed significantly more reduction in the Intermittent Pneumatic Compression group.

Previous physiological results suggest that increase in carpal tunnel pressure led to nerve compression and tension, dysfunction in intra-neural microcirculation, the accumulation of proteins and inflammatory cells. All this can cause damage to the myelin sheath and axon (1). An increase in carpal tunnel pressure also leads to a reduction in the flexibility of connective tissue elements and nerve stretch during movements (1,7,9,20,27,28). IPC systems are valuable in patients because of their impact on distal arterial flow and peripheral vessels. Thus, external compression is an effective treatment to reduce vascular insufficiency (15). Labropoulos et al. (1998) reported an increase in popliteal artery blood flow following the use of an IPC device. The increase in flow is due to a sharp drop in peripheral vascular resistance and increase in blood circulation (15). Bochmann et al. (2005) showed that forearm arterial blood flow increased and continued for three hours after IPC therapy. Their study confirmed that IPC increases forearm perfusion. The increased compression of the arm and forearm reduces the transmural compression of arterioles and arteries in the forearm, resulting in vascular dilation and increased blood flow in the carpal tunnel area (17). Labropoulos et al. (1998) showed that the Intermittent Pneumatic Compression device is a very effective tool in increasing popliteal artery blood flow in healthy people and people with vascular claudication. IPC increases tissue compression. The increased tissue pressure drains the intravenous veins. When the veins are drained, the venous pressure decreases and arterial-venous pressure gradient increases. Consequently, increased blood flow (15). Following the use of the IPC device, the direct reduction of peripheral vascular resistance and the release of nitric oxide following compression changes on smaller veins and the adjacent arterioles leads to the temporary dilation of arterioles and increase tissue blood flow. Moreover, the auto-regulatory reflexes and myogenic reflexes is another reason for the increase in vascular perfusion after IPC therapy (23,29,30,31,32). A systemic study emphasized the effect of IPC therapy to preventing venous thromboses and limbs edema decrease, wounds healing, and lymphedema treatment (13). Agu et al. (2004) reported that the increase of tissue oxygenation following the application of intermittent compression is one of the significant mechanisms in the use of the Intermittent Pneumatic Compression devices (14).

Based on the pathophysiology of CTS, the increase in edema and swelling and consequently the carpal tunnel pressure increase caused and involved in the occurrence of this injury (1,4,33,34). It is supposed that improvement of tissue blood flow and the reduction of edema and swelling of the carpal tunnel area is one of the mechanisms for improving the symptoms of patients with carpal tunnel syndrome after Intermittent Pneumatic Compression therapy. Therefore, the improvement of the sensory and motor parameters of the median nerve found in this study may be due to the improvement of tissue blood flow and oxygenation in IPC therapy.

The use of neurodynamic techniques is nowadays popular in CTS patients. They are based on restoring the dynamic balance between the nerve and the surrounding tissues, reducing edema and adhesion, improving blood flow and nerve nutrition, improving axon conduction, and reducing pain (2,3,21,25). Wolny et al. (2018) reported a significant difference in the improvement of sensory and motor nerve conduction velocity of median nerve and distal motor latency after neurodynamic techniques. They stated that improving blood supply to the area, reducing mechanical excitability, improving nerve gliding, reducing intra-neural edema, and improving axonal conduction following the implementation of neurodynamic techniques are among the factors that improve subjective symptoms and electrodiagnostic symptoms of patients (2). The results of our study are also consistent with the results of this study. Several studies suggest that gliding exercises lead to a reduction in the subjective symptoms of carpal tunnel syndrome by stretching the tissues adhesions, reducing tenosynovitis, improving venous return, and thus reducing the compression inside the carpal tunnel (3,21). A systematic review study referred to the positive effects of median nerve mobilization in patients with carpal tunnel syndrome (21). Oskouei et al. (2014) also examined the effect of neurodynamic techniques on subjective symptoms and electrophysiological findings of patients with CTS. They concluded that the use of neurodynamic techniques along with routine physical therapy treatments significantly improves the symptoms of CTS. The effect of neurodynamic techniques on CTS symptoms was attributed to the reduction of pressure inside the carpal tunnel, reduction of median nerve edema, improvement of circulation, and release of median nerve adhesions (25). The results of our study confirmed those of the above-mentioned studies as they confirmed the effects of neurodynamic techniques in reducing symptoms such as pain, disability, sensory and motor parameters of patients. Thus, this current study, also recommended this treatment method to improve the symptoms of mild carpal tunnel syndrome.

Generally, the IPC has physiological and neurophysiological effects that reduce edema and swelling, increase blood flow and oxygenation tissue, that may lead to faster healing and accelerating the rehabilitation program. Therefore, the use of such modalities with traditional physiotherapy can increase positive effects of rehabilitation program.

Conclusion

The results of the present study indicate that the combination of routine physiotherapy and IPC therapy could influence in the recovery and reduction of patients' symptoms and electrodiagnostic parameters. However, its effect was not superior compared to neurodynamic techniques plus routine physiotherapy in any parameters but distal latency. Therefore, it seems that it can be recommended to be used in the treatment of patients with mild CTS. Certainly, further study will need.

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Authors' contributions:

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

Conflict of interest

The authors declared no conflict of interest.

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