Cervicocephalic Kinesthetic Sensibility Training Combined with Neurodynamic Mobilization in Double Crush Syndrome Patients

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ABSTRACT

Background: Because of their disparate results, cervical proprioception training and neurodynamic mobilization have each been separately recommended for the treatment of cervical radiculopathy as well as carpal tunnel syndrome. However, investigations for the treatment of Double Crush Syndrome have not looked into the combined effect of these treatments. Therefore, the goal of this study was to ascertain how patients with double crush syndrome's concerning postural control, cervical proprioceptive sense, and electrophysiological findings of the median nerve were affected by cervicocephalic kinesthetic sensibility training coupled with neurodynamic mobilization of the median nerve. **Methods:** In an experimental investigation with 60 patients of both gender who had double crush syndrome, 30 patients from each group. Group A and B were randomly assigned. Cervical proprioceptive training and neurodynamic mobilization for the median nerve was given to Group A, Group B had a conventional physical therapy program. For six weeks, there would be three treatment sessions each week. Outcome indicators including median nerve's electrodiagnostic examination and cervicocephalic kinesthetic sensibility measurements was taken before, three weeks later, and at the conclusion of the sixth week following therapy. **Results:** After six weeks of therapy, when comparing the means of the two groups after the intervention, there is a statistically substantial ($p<0.05$) difference in the enhancement of the end measures. Subjects in Group A improved more significantly than those in Group B. **Conclusion:** The current study finds that the application of a cervical proprioceptive training programme along with neurodynamic mobilization for the median nerve significantly improved patients with double crush syndrome's sensorimotor control of the neck, postural stability, and electro-physiological study results of the median nerve.

Keywords: Median Nerve Sensory Conduction Velocity, Head Reposition Accuracy Tests, Double Crush Syndrome, Cervicocephalic Kinesthetic Sensibility, Neurodynamic Mobilization, Postural Stability, Limit of Stability.

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INTRODUCTION

Patients with carpal tunnel syndrome who also showed clinical and electrophysiological signs of neck nerve abnormalities were said to have the double crush syndrome (DCS). A distal entrapment neuropathy may be brought on by minor sequential impingements along a peripheral nerve. It was thought that altered axoplasmic flow served as the cause of the distal neuropathy. The idea is well supported by clinical research. Patients having carpal tunnel syndrome (CTS) as well as cervical radiculopathy (CR) had a strong correlation. The CTS, cervical spine injury is the furthermost often researched type of double crush syndrome. It has seen that unexplained symptoms of the hands and fingers, such as discomfort in the trapezius first metacarpal joint, more frequently occur with symptoms of the cervical spine than with a clearly documented relationship between carpal tunnel syndrome and the cervical spine[1].

The study of neck-related syndromes has become more dependent on cervical kinesthetic sensibility. Cervical kinesthesia appears to be compromised, particularly in patients who experience more pain and impairment, highlighting the pathophysiology of this condition. Additionally, rehabilitation treatments incorporating kinesthetic exercises have improved kinesthetic sensitivity while simultaneously reducing neck symptoms. Patients with neck pain appear to be less conscious of their head-neck alignment, and some do express complaints of "a wobbly head," which may be caused by a reduced sensation of cervical position[2].

It has been discovered that cervical muscular proprioception affects Postural Stability (PS), as stabilizing the neck would prevent the vestibular system from being positioned optimally, inhibit cervical muscle motion, and probably reduce the effectiveness of the relevant proprioceptors[3]. Pain's nociceptive input can impair proprioceptive information coming from the deep neck muscles' spindles, which leads to a more inaccurate central sluggish adjustment of balance and impaired postural adjustments[2].

It is generally recognized that altering the cervical spine's somatosensory system affects balance performance. For instance, it has been shown that fatigue or neck muscle vibration might impair balance performance[4]. On the other hand, it was noted that neck coordination exercises increased balance performance. Thus, there is strong evidence that postural control and the cervical spine's somatosensory system are closely related[5].

The goal of neural tissue mobilization techniques (NMTs), which emphasis on restoration of the nervous system's capacity to endure the usual compressive, frictional, as well as tensile forces accompanying with daily activities, is to analyze the neural tension in nerves as well as mobilize the nerves that have neural tension either passively or actively by means of Tensioning, Sliding, as well as Single Joint Movement techniques. With this technique, a low-amplitude repeating movement was applied in the direction of the reported neural tension while a gentle amount of strain was applied to the affected nerve root, producing a mild pulling sensation but no pain. NMTs are frequently utilized to normalize the neural receptor in patients with DCS by lowering neural mechanosensitivity, promoting nerve gliding, and reducing nerve adhesion[6].

In patients with DCS, the cervical proprioceptive training program in conjunction with neurodynamic mobilization significantly improved postural stability[7], median nerve electro-physiological research findings[8], and sensorimotor control of the neck[9].

Methodology

Sixty patients of both gender were suffering from double crush syndrome *(unilateral cervical radiculopathy in association with ipsilateral carpal tunnel syndrome)* selected at chronic stage (post three months from onset) due to discogenic lesion as confirmed and referred by a neurologist, with appropriate clinical findings, magnetic resonance imaging (MRI), electrodiagnostic studies, and randomly from physical therapy outpatient clinic of Cairo and MTI universities, the duration of study between October 2020 to July 2022. The patients' ages ranged from 20 to 40, with their BMI were all below 30. Furthermore, this study has been granted permission from the physical therapy department's research ethics committee at Cairo University (P.T.REC/012/004560).

In Group A (study group): In this group, thirty patients received cervical proprioceptive training combined with neurodynamic mobilization for median nerve, with duration of each session about (60 minutes).

In Group B (control group): In this group of the study, thirty patients received conventional selected physical therapy program with duration of each session about (60 minutes).

For six weeks, both groups of patients attended three sessions per week (total 18 sessions). Measurements conducted before, after three weeks, and at the end of treatment program.

The following criteria were used to choose the patients:

- All patients were suffering from double crush syndrome *(unilateral radiculopathy in association with ipsilateral carpal tunnel syndrome)* selected at chronic stage (post three months from onset) and referred by a neurologist, clinical findings, magnetic resonance imaging (MRI), and electrodiagnostic studies recruited to the study.
- All of the patients who were chosen were between the ages of 20 and 40.
- All of the selected patients examined carefully and referred by physician before the study procedures.
- All patients were medically stable, well oriented, well-nourished and co-operative.
- All of the selected patients were free from any previous surgeries for cervical spine or related upper limb.
- All of the selected patients were receiving the same procedures of the study according to each group.
- All of the selected patients were receiving the same medical care.
- The BMI was fewer than 30 Kg/m^2.

The present study excluded the following patients:

- Patients were not be examined or referred by physician before starting of the study.
- Patients with Cervical myelopathy, spondylosis and bilateral diagnostic carpal tunnel syndrome.
- Patients with Vertebrobasilar artery insufficiency and thoracic outlet syndrome.
- Patients with Cerebellar, vestibular lesion or whiplash injury.
- Patients with uncontrolled Diabetes or Diabetic peripheral neuropathy with shoulder problems.
- Patients with Visual and or auditory problems.
- Patients with any inflammatory arthritis, tumors, infection involving the cervical spine.
- Patients with other neuromuscular, musculoskeletal, cardiac or hepatic problems.

The procedures of the current study were divided into two main categories:

Measurement procedures:

a. Initial evaluation procedures (initial phase):

- Each patient was given a thorough physical examination to rule out the potentially life-threatening conditions listed above.
- Name, age, BMI, as well as identification of any functional, social, or psychological difficulties were collected from each patient's history using a questionnaire that had been created in advance.
- Each patient from each group was given a detailed explanation of the purpose of the evaluation methods.

b. Technical measurements phases:

Before in addition to after the study, patients were evaluated with:

a. Assessment of cervicocephalic kinesthetic sensibility performed by Global Postural Analysis System (GPS) (CHINESPORT S.P.A., Code: 01599, SN. 14.0000000001991, Italy), includes DIGITAL CERVICAL HELMET (MicMax, Code: 01618, Item: CSRVICAL TEST, SN. 14.0000000002076, Italy) using Neutral Head Position test (NHP).

b. Assessment of Limit of Stability (LOS) by Biodex balance system (Balance System SD, Model 950-441, SN. 13020193, USA).

c. Electro-physiological study for median nerve (Neurosoft MEP 1658TY, 8 channels, Russia. Neuro-MEP-4 amplifier LF 20 HZ, HF 2 KHz, 50 Hz, and range 1mV).

THERAPEUTIC PROCEDURES:

This was accomplished by the following therapeutic application procedures:

Group A:

This group of patients received:

1. Cervical proprioceptive training program.
2. Neurodynamic mobilization for median nerve.

Group B:

Patients in this group received convention al selected physical therapy program.

I- *Cervical proprioceptive training program:*

- ***Strengthening exercises*[10]*:***

These exercises were created to strengthen the neck muscles' capacity for continuous isometric effort. It contained:

a. Isometric Supine Neck Extension and Retraction:

Started in a hook lying position. The neck had to hyper-extend in order to get the head to the floor because of the anterior head carriage and thoracic hyper kyphosis. A book was placed beneath the head to stop this.

The patient's chin was tucked up against their neck, and then placed their head against the book.

The cervical extensors contracted isometrically in response to this posterior pressure. However, the Levator Scapulae and Upper Trapezius were hardly ever employed. Throughout the workout, the therapist felt these muscles to make sure they weren't overworking the deeper cervical extensors. Within the first two weeks of the therapy's implementation, the patients completed two sets, each set consisting of ten repetitions with ten second holds between each repeat and 10 second rest.

b. Quadruped Neck Extension/Retraction:

The position for this exercise changed to a quadruped. In order to maintain the head and neck in the correct alignment against gravity, the neck extensors have to contract in this position.

Make sure the thoracic and lumbar spines are in a neutral position and the shoulder blades are relaxed. From here, gradually raise your head back up to the ceiling while tucking your chin toward your neck. This extension has to originate from the upper thoracic spine and lower neck. Bringing the neck back into neutral was more important.

The objective was to feel the muscles contracting along the spine; nevertheless, the Levator Scapulae or Upper Trapezius should not become more active. In the third and fourth weeks of the treatment program, the patients completed two sets, each set consisting of 10 repetitions with 10 second holds between each repeat and 10 second rest.

c. Adding Shoulder and Scapular Motion:

To advance the Quadruped Neck Retraction / Extension exercise, shoulder motions were added. This decreased the strain on the neck muscles and improved scapular control and strength.

The first setup was the same as what was previously discussed. The patient may reach his or her arm back toward the ceiling while maintaining a stable neck. The scapula should be taught to retract on the ribs in order to pull the arm. Again, the Levator Scapulae or Upper Trapezius should not have been activated as a result of this. The rhomboid and probably the lower and middle trapezius should be the muscles that propel the motion. A resistance band or free weight is utilized to load the movement. During the fifth and sixth weeks of the treatment program, the patients completed two sets, each set consisting of ten repetitions with ten second holds between each repeat and 10 second rest.

d. Neck Extensors Training in the Prone Position:

The prone posture proved an excellent choice for cervical extensor training. From the quadruped position, this exercise offered a straightforward progression.

The trick to this exercise was to begin with the chin tucked. Then concentrated on lifting the head back, driving the sternum into the ground. The cervical extensors engaged to maintain the proper posture against gravity as long as the head and neck were in alignment. The additional step in this instance was to engage the thoracic extensors since, when lying on one side, the arms are no longer supporting the upper back.

As strength and control increase, more arm and scapular motions are introduced to advance the workout. During the fifth and sixth weeks of the treatment program, the patients completed two sets, each set consisting of ten repetitions with ten second holds between each repeat and 10 second rest.

2. A program for sensorimotor training:

The exercise therapy program aimed to improve sensorimotor control of the cervical region. It included[2] **(Table 1):**

Table (1): Tasks and Progressions to Improve Sensorimotor Control[2]:

Aim	Task	Progression	Duration / Frequency
Cervical position sense	- With the laser **(motion guidance clinician kit)** on the headband to give feedback, the head was moved back to a neutral position with eyes open and held for 3 seconds.	• Eyes closed; check eyes open. • Relocated to points in range located on wall, eyes closed, checked eyes open • Increased speed. • Carried out while standing. • Carried out on unstable surface.	**First session of the week 10 minutes**
Cervical movement sense	- With laser mounted on headband practiced tracing over a pattern placed on the wall, eyes open.	• Increased speed • More difficult as well as intricate pattern. • Small finer movement.	**First session of the week 10 minutes**
Eye follow	- Sit in a neutral neck position, kept the head still and the hands were in the laps. - Moved the laser light back and forth across the wall, while following the laser with the eyes.	• Sit with neck in relative neck torsion position. • Eyes up and down, H pattern. • Increased speed • Increased range of movements. • Carried out while standing. • Carried out on unstable surface.	**Second session of the week 10 minutes**
Eye-head coordination	- Moved eyes to a new focused point and then moved head in the same direction then return to neutral.	• Actively moved head and eyes together same direction. • Moved eyes on one direction and head on opposite direction. • Moved eyes and head together. • Holden a target, kept eyes fixed and move target, head and eyes moved together.	**Second session of the week 10 minutes**
Saccades	- Rapidly moved then focused to particular dots on a wall.	• lengthened the distance. • Put on a distracting background, like stripes. • Fixed gaze, closed eyes, moved head then open eyes to check if gaze was kept.	**Third session of the week 5 minutes**

Gaze stability	- The patient kept looking at a dot on the wall while the therapist moved the patient's trunk and/or head/neck passively. - The patient kept looking at a dot on the wall while the head and neck were actively moved in all directions by the patient.	• Altered the background of the target, plain, stripes, checks. • shifted the emphasis to words or a business card. • Increased speed. • Increased ROM • Progressed from lying to sitting to standing. • Carried out on unstable surface.	**Third session of the week 5 minutes**
Balance	- Remain standing for the full 30 seconds.	• Eyes open then closed. • Firm then soft surface. • Different stances: comfortable, narrow, tandem, single-leg. • Walked with head movements—rotation, flexion and extension—maintained direction as well as velocity of gait. • Performed oculomotor or movement or position sense exercises during balance training.	**Third session of the week 10 minutes**
Total training duration of each session was 20 minutes			

II- *Neuro-Dynamic Mobilization*:

Neural gliding procedure performed for median nerve:

When the therapist sat on the affected side beside the patient then depressed the patient's shoulder by one hand, the patient's arm was passively moved into an abducted position of 90–100 degrees, with the elbow flexed, the forearm supinated, the wrist and fingers extended (as tolerable by the patients). This was followed by the sliding but rather gliding procedure. Subsequently sliding the nerve, the elbow extension (which loads the median nerve) with wrist flexion (which unloads the median nerve) as well as the elbow flexion (which unloads the median nerve) while wrist extended (which loads the median nerve) alternate for three sets, and each set consists of six repetitions. Slow oscillatory movements were used for each set, with a 20-second rest period following each set of 10 seconds (total duration was 10 minutes). The patient advanced to gliding/tensioning technique when the symptoms became better[11].

III- Selected Conventional Physical Therapy Program:

1- For cervical radiculopathy:

- Apply aqua sonic gel to the posterior neck and paraspinal region for five minutes while using a handheld transducer at 1.5 W/cm2 intensity and 1 MHz frequency, and continuous mode[12](ENRAF NONIUS, Sonoplus 490, REF 0498.900, SN. 42.944, 1 & 3 MHz, Netherlands).
- By applying an electrode to the back of the neck and the paraspinal region, transcutaneous electrical nerve stimulation (TENS) is used (Intelect *MOBILE STIM*, Chattanooga, SN.T9175, REF. 2777, MEXICO). In order to control pain, use the following settings for 20 minutes per session: (Mode: M - modulation, Pulse Width: 60 usec, Pulse Rate: 150 Hz, Output: Adjust to Most Comfortable Sensory Intensity)[12].
- 41°C low-level heat wraps that have been used for 20 minutes[13].
- Exercises for stretching: The upper trapezius, sternomastoid, and scalene muscles, which make up the majority of the cervical muscles, were subjected to muscle energy technique[14].

2- For carpal tunnel syndrome:

- The affected wrist was subjected to ultrasound (active) treatment with aqua sonic gel lasting 7 minutes at 1 MHz, 1 W/cm2, with a duty cycle of 1:4 in pulsed mode and a handheld transducer of (5 cm^2)[15](ENRAF NONIUS, Sonoplus 490, REF 0498.900, SN. 42.944, 1 & 3 MHz, Netherlands).
- An electrode should be placed on both sides of the wrist when using Transcutaneous Electrical Nerve Stimulation (TENS), a single channel (Intelect *MOBILE STIM*, Chattanooga, SN.T9175, REF. 2777, MEXICO). In order to control pain, use the following settings for 20 minutes per session: (Mode: M - modulation, Pulse Width: 60 usec, Pulse Rate: 150 Hz, Output: Adjust to Most Comfortable Sensory Intensity)[16].

- 41°C low-level heat wraps that have been used for 20 minutes[17].

STATISTICAL ANALYSIS:

This study's statistical analysis was performed in SPSS for Windows, version 25. (SPSS, Inc., Chicago, IL). This study employed the following statistical techniques:

- Quantitative descriptive statistics data Statistics were calculated for a variety of demographic variables, such as mean and standard deviation for age, BMI, the neutral head position test (right& left rotation), median nerve sensory conduction velocity, and also the limit of stability.
- Qualitative descriptive statistics data number as well as percentage for gender were included
- Independent (unpaired) t-test to contrast between group A as well as group B regarding demographic data variables (age & BMI).
- Chi-square test to contrast between group A as well as group B regarding qualitative variables (gender).
- Multivariate analysis of variance (MANOVA) used to contrast the tested main variables that matter most at different tested groups as well as the measuring periods. We conducted a mixed design 2 x 2 MANOVA test, and the 1st independent variable (among subject factors) was the tested group, which had 2 levels (group A & group B). The 2nd independent variable (within subject factor) was calculating periods using two different levels (beforetreatment vs. aftertreatment) with 4 dependent variables were the neutral head position test (right rotation, left rotation), median nerve sensory conduction velocity, and limit of stability.
- Bonferroni correction test (Post hoc-tests) to contrast between pairwise within as well as between groups of the tested variables exact value of the Pwas substantial from MANOVA test.

Significant level: At the level of probability of 0.05, all statistical analysis produced substantial results ($P \leq 0.05$).

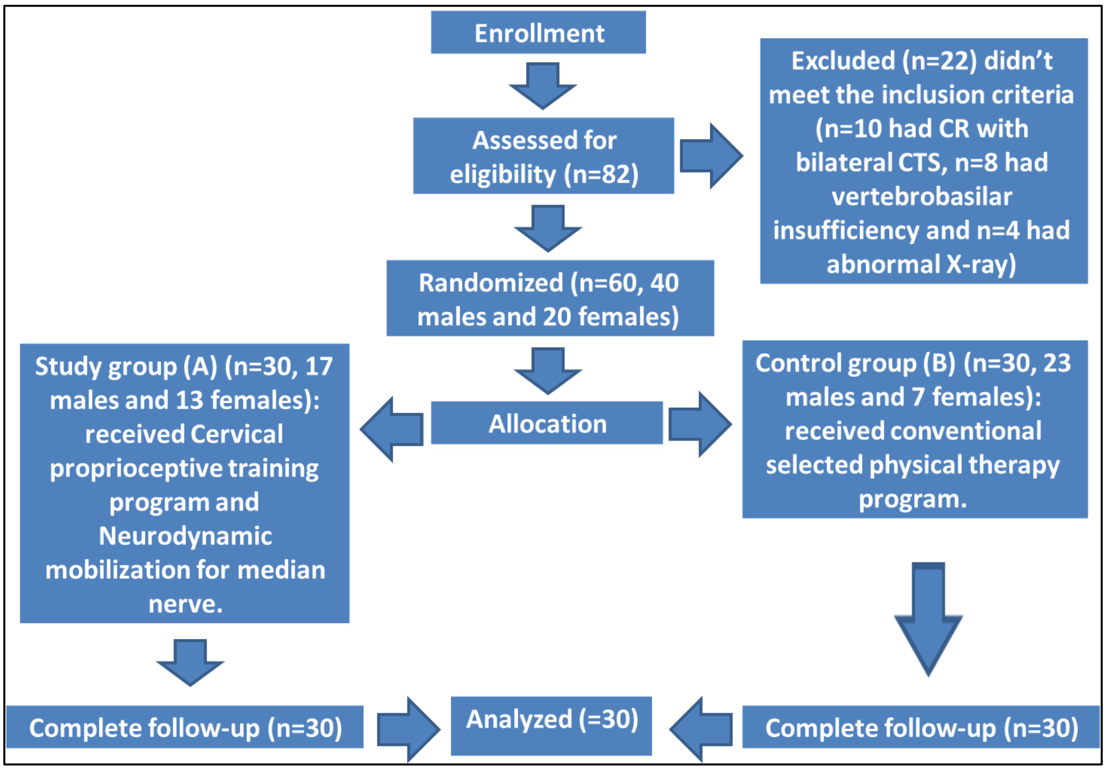

Figure 1. The flow chart for the patient's selection and allocation

RESULTS

1. Physical characteristics of subjects

In this investigation, there were a total of 60 patients, 40 males & 20 females, and they were split randomly into two groups, each including 30 patients. The mean values of age for group A as well as group B were 33.18 ±4.78 and 35.65 ±4.79year, respectively (Table 2). The mean values of BMI in group A as well as group B were 19.48 ±1.30 and 19.80 ±1.55kg/m^2, respectively (Table 2). The statistical analysis showed that there were no substantial differences in age ($P = 0.240$; $P > 0.05$) as well as BMI ($P = 0.314$; $P > 0.05$) between group A & group B.

Table (2): Comparison mean values of physical characteristics between both groups

Items	Physical characteristics (Mean ±SD)	
	Age (Year)	BMI (kg/m^2)
Group A (n=30)	33.18 ±4.78	19.48 ±1.30
Group B (n=30)	35.65 ±4.79	19.80 ±1.55
F-value	1.310	1.014
P-value	0.240	0.314
P<0.05	NS	NS

Data are expressed as mean ±standard deviation P-value: probability value NS: non-significant

This study included the participation of sixty patients, including both males & females (40 males & 20 females). The gender distribution (Table 3) showed that the number (percentage) of males as well as females patients in group A were 17 (56.67 %) and 13 (43.33 %), respectively, while the numbers for group B were 23 (76.67 %) and 7 (23.33 %), respectively (Table 3).

Table (3): Distribution of gender.

Items	Gender	
	Males	Females
Group A (n=30)	17 (56.67%)	13 (43.33%)
Group B (n=30)	23 (76.67%)	7 (23.33%)
Chi-square value	2.700	
P-value	0.100	
P<0.05	NS	

Data are expressed as number (percentage) P-value: probability value NS: non-significant

2×2 Mixed design multivariate analysis of variance (MANOVA)

1. Neutral head position test (NHP)

1.1. Right rotation

Comparison between before and after treatment right rotation within each group

In group A, the mean ±SD values of right rotation before and after treatment were 10.21 ±2.91 as well as 3.05 ±1.75, respectively. Multiple icantly (P=0.0001; P<0.05) declined in right rotation at afterpairwise comparison tests (Post hoc tests) showed that there was substantial improvement contrasted to before treatment by 70.13% percentage of improvement (Table 4).

In group B the mean ±SD values of right rotation before and after treatment were 10.35 ±1.96 as well as 6.00 ±2.21, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) declined in right rotation after treatment contrasted to before treatment by 42.03% percentage of improvement (Table 4).

Table (4): Comparison between before and after treatment right rotation within each group

Items	Right rotation (Mean ±SD)	
	Group A (n=30)	Group B (n=30)
Before treatment	10.21 ±2.91	10.35 ±1.96
Aftertreatment	3.05 ±1.75	6.00 ±2.21
Mean difference	7.16	4.35
Improvement %	70.13%	42.03%
F-value	198.454	74.164
P-value (P<0.05)	0.0001*	0.0001*
Significance	S	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05)

Comparison of right rotation between both groups before and after treatment

Taking into account the effect of the tested group on right rotation (Table 5), no substantial difference (P=0.786; P>0.05) in the mean ±SD values of right rotation before treatment between group A as well as group B (10.21±2.91&10.35±1.96, respectively). Although, there was substantial difference (P=0.0001; P<0.05) in the mean ±SD values of right rotation after treatment between group A as well as group B (3.05±1.75 and 6.00±2.21, respectively). So, these substantial declines in right rotation after treatment are better for group A than group B.

Table (5): Comparison of right rotation between both groups at before and aftertreatment

Items	Right rotation (Mean ±SD)	
	Before treatment	After treatment
Group A (n=30)	10.21 ±2.91	3.05 ±1.75
Group B (n=30)	10.35 ±1.96	6.00 ±2.21
Mean difference	0.14	2.95
F-value	0.074	33.647
P-value (P<0.05)	0.786	0.0001*
Significance	NS	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

1.2. Left rotation

Comparison between before and after treatment left rotation within each group

In group A, the mean ±SD values of left rotation before and after treatment were 10.50 ±2.77& 3.11 ±2.08, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) declined in left rotation after treatment contrasted to before treatment by 70.38% percentage of improvement (Table 6).

In group B the mean ±SD values of left rotation before and after treatment were 9.65 ±2.76& 5.17 ±2.09, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) declined in left rotation after treatment contrasted to before treatment by 46.42% percentage of improvement (Table 6).

Table (6): Comparison between before and after treatment left rotation within each group

Items	Left rotation (Mean ±SD)	
	Group A (n=30)	Group B (n=30)
Before treatment	10.50 ±2.77	9.65 ±2.76
Aftertreatment	3.11 ±2.08	5.17 ±2.09
Mean difference	7.39	4.48
Improvement %	70.38%	46.42%
F-value	178.781	66.494
P-value (P<0.05)	0.0001*	0.0001*
Significance	S	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05)

Comparison of left rotation between both groups at before and aftertreatment

Taking into account the effect of the tested group on left rotation (Table 7), no substantial difference (P=0.123; P>0.05) in the mean ±SD values of left rotation before treatment between group A as well as group B (10.50 ±2.77 & 9.65 ±2.76, respectively). Although, there was substantial difference (P=0.0001; P<0.05) in the mean ±SD values of left rotation after treatment between group A as well as group B (3.11±2.08& 5.17±2.09, respectively). So, these substantial reductions in left rotation after treatment are better for group A than group B.

Table (7): Comparison of left rotation between both groups at before and after treatment

Items	Left rotation (Mean ±SD)	
	Before treatment	After treatment
Group A (n=30)	10.50 ±2.77	3.11 ±2.08
Group B (n=30)	9.65 ±2.76	5.17 ±2.09
Mean difference	0.85	2.06
F-value	2.399	13.907
P-value (P<0.05)	0.123	0.0001*
Significance	NS	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

2. Median nerve sensory conduction velocity (m/s)

Comparison between before and aftertreatment median nerve sensory conduction velocity within each group

In group A, the mean ±SD values of median nerve sensory conduction velocity before as well as after treatment were 48.10 ±0.84 & 54.03 ±0.77, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) improvement in median nerve sensory conduction velocity after treatment contrasted to before treatment by 12.33% percentage of improvement (Table 8).

In group B the mean ±SD values of median nerve sensory conduction velocity before as well as after treatment were 48.00 ±0.78 & 51.05 ±0.73, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) improvement in median nerve sensory conduction velocity after treatment contrasted to before treatment by 6.35% percentage of improvement (Table 8).

Table (8): Comparison between before and after treatment median nerve sensory conduction velocity within each group

Items	Median nerve sensory conduction velocity (Mean ±SD)	
	Group A (n=30)	Group B (n=30)
Before treatment	48.10 ±0.84	48.00 ±0.78
After treatment	54.03 ±0.77	51.05 ±0.73
Mean difference	5.93	3.05
Improvement %	12.33%	6.35%
F-value	1091.382	292.845
P-value (P<0.05)	0.0001*	0.0001*
Significance	S	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05)

Comparison of median nerve sensory conduction velocity between both groups before and aftertreatment

Taking into account the effect of the tested group regarding median nerve sensory conduction velocity (Table 9), no substantial difference (P=0.576; P>0.05) in the mean ±SD values of median nerve sensory conduction velocity before treatment between group A as well as group B (48.10±0.84 & 48.00±0.78, respectively). Although, there was substantial difference (P=0.0001; P<0.05) in the mean ±SD values of median nerve sensory conduction velocity after treatment between group A as well as group B (54.03±0.77& 51.05±0.73, respectively). So, these substantial improvement in median nerve sensory conduction velocity after treatment are better for group A than group B.

Table (9): Comparison of median nerve sensory conduction velocity between both groups before and after treatment

Items	Median nerve sensory conduction velocity (Mean ±SD)	
	Before treatment	After treatment
Group A (n=30)	48.10 ±0.84	54.03 ±0.77
Group B (n=30)	48.00 ±0.78	51.05 ±0.73
Mean difference	0.10	2.98
F-value	0.315	75.212
P-value (P<0.05)	0.576	0.0001*
Significance	NS	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

3. Biodex static limit of stability test

3.1. Overall

Comparison between before and after treatment overall within each group

In group A, the mean ±SD values of overall before and after treatment were 16.45 ±4.34 & 31.03 ±10.60, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that there was substantially (P=0.0001; P<0.05) improvement in overall after treatment contrasted to before treatment by 88.63% percentage of improvement (Table 10).

In group B, the mean ±SD values of overall before and after treatment were 14.95 ±5.41& 16.45 ±6.17, respectively. Multiple pairwise comparison tests (Post hoc tests) showed that no substantial difference (P=341; P>0.05) in overall between before and after treatment by 10.03% percentage of improvement (Table 10).

Table (10): Comparison between before and aftertreatment overall within each group

Items	**Overall (Mean ±SD)**	
	Group A (n=30)	**Group B (n=30)**
Before treatment	16.45 ±4.34	14.95 ±5.41
Aftertreatment	31.03 ±10.60	16.45 ±6.17
Mean difference	14.58	1.50
Improvement %	88.63%	10.03%
F-value	92.429	0.913
P-value (P<0.05)	0.0001*	0.341
Significance	S	NS

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05)

Comparison of overall between both groups before and after treatment

Taking into account the effect of the tested group in general (Table 11) no substantial difference (P=0.341; P>0.05) in the mean ±SD values in general before treatment between group A as well as group B (16.45 ±4.34& 14.95 ±5.41, respectively). Although, there was substantial difference (P=0.0001; P<0.05) in the mean ±SD values as a whole after treatment between group A as well as group B (31.03 ±10.60 &16.45 ±6.17, respectively). So, these substantial improvements in as a whole after treatment are better for group A than group B.

Table (11): Comparison of overall between both groups before and aftertreatment

Items	**Overall (Mean ±SD)**	
	Before treatment	**After treatment**
Group A (n=30)	16.45 ±4.34	31.03 ±10.60
Group B (n=30)	14.95 ±5.41	16.45 ±6.17
Mean difference	1.50	14.58
F-value	0.913	92.429
P-value (P<0.05)	0.341	0.0001*
Significance	NS	S

Data are expressed as mean ±standard deviation
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

DISCUSSION

The present research was set out to investigate the impact of cervicocephalic kinesthetic sensibility training along with neurodynamic mobilization on postural control, cervical proprioception and electrophysiological finding in patients with double crush syndrome.

Sixty patients of both genders were suffering from double crush syndrome *(unilateral cervical radiculopathy in association with ipsilateral carpal tunnel syndrome)* selected at chronic stage (post three months from onset) were split blindly into two groups of equal number. Subjects in the study were given cervical proprioceptive training along with neurodynamic mobilization for median nerve plus conventional chosen physiotherapy program, while subjects in the control group were given conventional chosen physiotherapy program,

All study participants were evaluated both before and after participation by assessment of cervicocephalic kinesthetic sensibility performed by Global Postural Analysis System (GPS) includes DIGITAL CERVICAL HELMET using Neutral Head Position test (NHP), assessment of Limit of Stability (LOS) by Biodex Balance System and Median nerve sensory conduction velocity.

Overall, this study points to an altered neck motor control and electrophysiological finding in patients with double crush syndrome. Outcomes of this research revealed that there was a substantial enhancement in the postural stability, Neutral Head Position test (NHP) and electro-physiological finding of median nerve which indicates better enhancement of cervicocephalic kinesthetic sensibility of cervical spine in group A. In contrast, postural stability was substantially enhanced to a small extent, Neutral Head Position test (NHP) and electro-physiological finding of median nerve; indicating mild enhancement of cervicocephalic kinesthetic sensibility function of cervical spine in group B.

Regarding to the effect of neurodynamic mobilization for median nerve in patients with double crush syndrome, the findings of the present study had shown that the median nerve's sensory conduction velocity as well as Peak sensory latency both improved. Therefore, combination of cervicocephalic kinesthetic sensibility training and neurodynamic mobilization is the best treatment protocol to improve postural control, sensorimotor control of the neck and electrophysiological finding in double crush syndrome patients.

Because stabilizing the neck would prevent the vestibular apparatus from being in its ideal position, limit cervical muscle motion, and probably reduce the effectiveness of the relevant proprioceptors[18], it has been discovered that cervical muscle proprioception affects standing balance. Pain's nociceptive input can impair proprioceptive information coming from the deep neck muscles' muscle spindles, which leads to a more inaccurate central sluggish adjustment of balance and impaired postural adjustments[2].

There are many reasons which have been proposed to explain why there was an influence on postural stability in patients with double crush syndrome after cervical proprioceptive training combined with neurodynamic mobilization for median nerve as a result of increasing the inputs of cervical proprioceptors. The first theory proposed that because vestibular receptors are situated in the skull base, far from the antigravity muscles in the lower body, complex biomechanical information obtained from dispersed joints and body segments must be integrated with movement identified by the vestibular system in order to activate the suitable muscles requisite for balance control. The proper use of vestibular and visual information in postural control requires afferent information gathered from the biomechanical environment is processed centrally. Thus, the proprioceptive input from the neck and also other body segments is crucial for the perception of motion as well as for the coordination of vestibular but also visual influences on postural control[19].

The other theory supposed that there was a rising body of evidence that showed that after a neck injury, some parameters related to cervical functional capacities, including such altered eye movement control, kinesthetic sensibility, or other problems related to distorted postural control, changed. Clinicians have observed that participants with cervical disc disease often feel dizzy and have trouble keeping their balance. These findings support the effectiveness of exercises that target various facets of sensorimotor function. Thus, specific exercises for eye-head-neck coordination may be helpful to reduce pain as well as to improve kinesthetic sense and cervical range of movement[20].

Also, ***Kramer et al., (2013)*** investigated the training effect of resistance with proprioceptive exercises. Results showed that when resistance training was combined with proprioceptive training, muscle hypertrophy as well as proprioception were much better than when resistance training was done alone.

The results of present study are agreed with ***Sawa and Giakas, (2013)*** presented the effect of neural mobilization of median nerve on pain as well as disability in a patient having cervical radiculopathy. At baseline, the patient's pain as well as disability were assessed. All measures of outcomes showed improvements. The results showed that using neural mobilization to treat cervical radiculopathy can significantly reduce pain and disability.

Mohamad B., (2011) studied the impact of proprioceptive rehabilitation programme on sensorimotor control function of cervical spine in cervical discogenic lesion. The cervical position sense test was used to measure the sensitivity of the position of the cervical joints, in addition to the Biodex Balance System was used to measure the overall stability index. Findings revealed that there was a substantial correlation between neck pain as well as changed cervical sensorimotor function. When it came to enhancing the sensorimotor function of the cervical, the cervical proprioceptive rehabilitation programme was better than the physical therapy that was chosen.

On other hand: Neural mobilization (gliding) techniques (NMTs) or neurodynamic mobilization have been advocated in the management of carpal tunnel syndrome (CTS) because they relieve pain right away. With this technique, a low-amplitude, repetitive movement was made in the direction of where the nerve tension was felt, and gentle tension was put on the nerve root that was affected, causing a slight pulling at the pain limit. NMTs are often used to normalise the structure in addition function of CTS patients by minimizing neural mechanosensitivity, promoting nerve gliding, and reducing nerve adherence[6].

The following explanation may be the cause of the noticeable improvement brought on by nerve mobilization. Although these biologically tenable claims have not been proven, it is thought that these therapeutic movements can achieve better intraneural circulation, axoplasmic flow, the viscoelasticity of neural connective tissue, as well as the sensitivity of AIGS symptoms. When combined with the right kind of neurobiology education, these methods may also be able to lessen the patient's unwanted anxiety of movement, which in turn can lessen the pain neuromatrix's sensitivity.[21].

CONFLICTING INTEREST

The authors declared that no conflict of interest is related to this study.

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CONCLUSIONS

The following conclusions were made in light of the study's constraints and findings:

- Patients with double crush syndrome who underwent a six-week program of cervical proprioceptive training and neurodynamic mobilization for the median nerve reported significantly improved postural stability.
- The electro-physiological study finding of the median nerve in patients having double crush syndrome was significantly improved by the cervical proprioceptive training program combined with neurodynamic mobilization for six weeks.
- Patients with double crush syndrome whom underwent a six-week cervical proprioceptive training program in conjunction with neurodynamic mobilization for the median nerve saw a significant improvement in their neck's sensorimotor control.

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