# A study to analyze the effectiveness of exercise program in improving the proprioceptive acuity among patients with chronic neck pain

**S. Deepika Shristhudhi[1], A. D. Gopalswami[2], P. Antony Leo Aseer[3]**

[1]Post Graduate Student, [2]Associate Professor, [3]Professor & Vice Principal, Faculty of Physiotherapy
Sri Ramachandra Institute of Higher Education and Research (SRIHER), Chennai 600116, Tamil Nadu India

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Corresponding author: **A. D. Gopalswami.** Email:adgopalswami@gmail.com


## ABSTRACT

**Introduction and Aim:** Neck pain is estimated to affect 10% to 20% of the Indian population every year, with1/3rd of people developing chronicity, which is predominantly due to impaired proprioception. Clinical texts specifically recommend the assessment and management of proprioceptive dysfunction, there is lack of clear evidence for proprioceptive dysfunction in different subgroups of chronic neck pain

**Materials and Methods:** Thirty-two subjects were included and sub-grouped based on their dysfunction. Group A- mechanical neck pain (n= 10), Group B- upper cervical involvement (n= 10) and Group C- cervical radiculopathy (n= 12). The baseline evaluation consisted of Cervico Cephalic Relocation (CCR) test, Deep Cervical Flexor (DCF) endurance, and Neck Disability Index (NDI) questionnaire, which was again taken at the end of two weeks following intervention.

**Results:** In all three groups, joint position error was observed and following intervention, a significant improvement in the outcomes had occurred, with greater improvement in Group A, followed by B, then C. On comparison between the groups, the right and left rotations of CCR, DCF endurance and NDI (p value< 0.05) were not similar, whereas, the improvement in flexion and extension of CCR (p value> 0.05) were similar.

**Conclusion:** Proprioception training should form an integral part of rehabilitating patients with chronic neck pain.


**Keywords:** Neck pain; proprioception; cervical joint position error; Cervico cephalic relocation test.

## INTRODUCTION

Neck pain forms a major public health problem, both in terms of personal health and overall well – being, with a prevalence rate of 30 – 50% of adults among general population. Approximately, 50 – 85% of individuals with neck pain do not experience complete resolution of symptoms and may go on to chronic, disabling pain (1). Treatment of chronic neck pain has always been a challenging area for Physiotherapists.

Proprioception involves sensations generated within the body, which contributes to the awareness of relative orientation of body parts, both at rest and in motion. This proprioceptive system depends upon simultaneous activity of different types of mechanoreceptor afferent neurons. They provide information for reflex regulation of muscle tone, awareness of position sense and movement sense, and have been isolated in most spinal tissues (2). Restitution of healthy neuromuscular motor patterns and increased sensory input variation through proprioception training is thought to reduce mechanical stress through improved muscular co-ordination and may prevent recurrence and chronicity of neck pain (3).

Mechanical neck pain is a general term that refers to any type of pain caused by placing abnormal stress and strain on muscles of neck. Typically, mechanical neck pain results from poor postural habits (4). Neck flexion, forward head posture, scapular retraction, forward stoop posture are some of the faulty postural alignments, resulting in neck pain due to increased cervical muscle activity in order to support head in forward position, leading to increased fatigue. Apparently, muscles and other soft tissues tighten up due to excessive overload required to hold the head in position (5). This chronic overload and tightening of soft tissues may result in decreased blood flow and oxygen to the soft tissue, ultimately causing pain. In such cases, a fault in joint position sense becomes apparent due to inappropriate variability in postural control. Due to the disturbance caused to joint position sense, individual is subjected to faulty posture in the continuum. The impaired joint position sense can worsen the alignment of the cervical spine and lead to impaired stability (6).

The presence of high densities of muscle spindles in the slow twitch muscle fibers of small intrinsic deep dorsal and sub occipital muscles play an important role in postural control (7). Therefore, upper cervical involvement causes impaired proprioception along with altered afferent input from the facet, in case of facet joint involvement. The impact at many levels of the nervous system can change muscle spindle sensitivity and alter the cortical representation and modulation of cervical afferent input, leading to one of the major physiological basis for proprioception deficit in cervical radiculopathies (8). Moreover, the occurrence of severe degenerative joint disease among individuals deprived of protective proprioceptive sensibility leads to repetitive, longitudinal, impulsive loading, which increases the risk of tissue injury from uncontrolled motion. This highlights the essential role of proprioceptive training in maintaining dynamic cervical spine stability (9).

The proprioception training involves Cervico cephalic relocation (CCR) training, Deep cervical flexor (DCF) training and dorsal neck muscle training. CCR training improves the proprioceptive acuity by activating the proprioceptors in different planes of movement (10). DCF training also plays a major role in improving the proprioceptive acuity by activating the relatively high density of muscle spindles present in the deep cervical flexor musculature and decreasing the excessive stress paced on the joints and other structures of the cervical region (11). Fatigue of the dorsal neck muscles deteriorates the ability to reproduce a given joint angle causing a significant proprioception deficit. Hence, training of the dorsal neck muscles plays an important role in improving the proprioceptive acuity (7).

The proprioceptive mechanisms controlling the head on the body can be tested clinically by simple target – matching tasks, to evaluate the ability to relocate the Natural Head Posture (NHP) known as the Cervico Cephalic Relocation test (CCR). In addition, Chattanooga's pressure biofeedback and NDI were used to evaluate endurance of deep cervical flexors and functional outcomes respectively.

It becomes utmost necessity on the part of physical therapist to employ and disturb the vicious cycle of pain, altered proprioception, mal-alignment and pain. Thus, the study was aimed at evaluating the proprioceptive deficit in patients with three categories of neck pain – mechanical neck pain, upper cervical involvement, and cervical radiculopathies and to evaluate the improvement in proprioceptive acuity among the three categories of neck pain patients following intervention.

## MATERIALS AND METHODS

The Ethics Committee for students' projects, Sri Ramachandra Institute of Higher Education and Research, approved this experimental study (REF: CSP/18/SEP/73/263). This study was registered in Clinical Trial Registry- India (CTRI/2019/02/017685).

### Method

The Quasi – Experimental study (pre-post design) was conducted in Outpatient Physiotherapy Department, Sri Ramachandra Hospital, Chennai. The recruitment process had started in December 2018 and completed by April 2019 with two weeks follow up for all participants. All the participants received a verbal explanation of the research project and an informed consent was obtained. The sample design was a probability sampling, thirty-five samples were included for the study, out of which there were three drop- outs due to lack of follow-up. Hence, samples included for data analysis were thirty-two.

### Study participants

**Subjects who met the inclusion criteria were recruited for the study.**

Inclusion criteria are both male and female genders, age group:
21-55 years, neck pain with minimum duration of 8- 12 weeks, unilateral or bilateral pain in the posterior neck or shoulder region and pain in the cervical region when moving or palpating the cervical spine, upper cervical involvement with or without headache and C1- C2 rotational deficits, patients with cervical radiculopathy.

Exclusion criteria are past trauma to cervical region, past fracture or surgery in cervical spine, deformity of the spine (kyphosis, Scoliosis), inner ear infections, inflammatory rheumatologic disease, vertebro - basilar artery insufficiency, malignancy, neurological evidence leading to balance disturbances (e.g. sensory ataxia).

The patients who had fulfilled inclusion criteria were included for the study. The participants were categorized into three groups depending upon their clinical presentations. Group A – patients with mechanical neck pain (n=10), Group B – upper cervical involvement (n=10), Group C – cervical radiculopathies (n=12). The patients then underwent a pre- test evaluation of CCR test, pressure biofeedback and NDI in order to obtain a baseline measure, followed by intervention for a period of two weeks (three days/ week).

### Intervention

1. **Cervical joint position sense: relocation with laser feedback:**
   - Head relocating to neutral position with eyes opened (vertical/ horizontal/ diagonal) (Figure: 1).

- Head relocating to predetermined position in range with eyes opened. (vertical/ horizontal/ diagonal)
- Head relocating to neutral position with eyes closed. (vertical/ horizontal/ diagonal)
- Head relocating to predetermined position in range with eyes closed (vertical/ horizontal/ diagonal) (12).

**Fig. 1:** Cervical joint position sense training

2. **Cervical movement sense: - with laser feedback:**
   - Tracing a line (vertical/ horizontal) (figure: 2)
   - Tracing an intricate pattern at slow and fast speed (a figure of eight/ zig – zag/ alphabet) (12).

**Fig. 2:** Cervical movement sense training

3. **Re- education of dcf movement pattern:**
   - Gentle and controlled nodding action (Figure: 3a)
   - Repeated and sustained DCF progression from 22 – 30 mmHg with pressure bio – feedback in supine lying, knees bent (Figure: 3b) (12).

**Fig. 3a:** DCF training

**Fig. 3b:** DCF training

4. **Re- education of dorsal neck muscles:**
   - Cranio- cervical extension, cranio cervical rotation (<40°), cervical extension while keeping the cranio-cervical region in neutral done in prone in elbow/ 4 -points kneeling positions. (Figure: 4a)

- Co – contraction of deep cervical flexors/ extensors (Figure: 4b).
- Isometric hold in the range of cervical extension (12)

**Fig. 4a:** Dorsal neck muscle strengthening

**Fig. 4b:** Dorsal neck muscle strengthening

**Outcome measures**

**Cervico– cephalic relocation test**

Blindfolded subjects were seated on a chair paced 90cms from a white wall with the target maze in front. Each subject had a laser pointer attached on the head. Following the procedure, subjects were instructed to memorize the neutral head position to duplicate it after the active movement of maximal amplitude of the head. Once the reference point was achieved, the subject concentrates on this position for a couple of seconds. The subject then performs a maximal flexion/ extension and rotation (left and right) for approximately two seconds and tries to find the initial reference point with a maximum of precision without speed instruction. When subject reaches the reference point, he should again concentrate on the reference point for several seconds. 8-10 trials were performed with eyes opened before the actual performance. The actual performance is done with eyes closed and without any feedback (9). The distance between the target point and the relocated point was taken as global cervico- cephalic relocation error.

**Cranio cervical flexion test (CCFT)**

The CCFT was performed with the patient in supine crook lying with the neck in a neutral position (no pillow) such that the line of the face was horizontal and a line bisecting the neck longitudinally was horizontal to the testing surface. The un-inflated pressure sensor was placed behind the neck so that it abuts the occiput and is inflated to a stable baseline pressure of 20 mm Hg, a standard pressure sufficient to fill the space between the testing surface and the neck but not push the neck into a lordosis. The device provides the feedback and direction to the patient to perform the required five stages of the test. The patient was instructed that the purpose of test was not strength but rather precision. The movement was performed gently and slowly as a head nodding action. The cranio cervical flexion tests the activation and endurance of the deep cervical flexors in progressive inner range positions as the patient attempts to sequentially target five, 2-mm Hg progressive pressure increases from the baseline of 20 mm Hg to a maximum of 30 mm Hg as well as to maintain a isometric contraction at the progressive pressures as an endurance task (13).

**Neck disability index (NDI)**

It is a self-rated, condition-specific functional status questionnaire with 10 items including pain, personal care, lifting, reading, headaches, concentration, work, driving, sleeping and recreation. The NDI has sufficient support and usefulness to retain its status as the most commonly used self-report measure for neck pain (14).

Following the intervention, the subjects underwent a post- test evaluation. The pre and post -test measures were included for data analysis.

**Data analysis**

The gathered data was analyzed with IBM SPSS statistics software 23.0 version. For descriptive statistics, frequency and percentage analysis were used for categorical variables whereas, mean and S.D were used for continuous variables. To find the significant difference between the bivariate samples in paired groups the paired sample ‘t’- test was used. For the multivariate analysis, the one-way ANOVA with Turkey’s Post- Hoc test was used. In all the above statistical tools, the probability value 0.05 is considered as significant level.

**RESULTS**

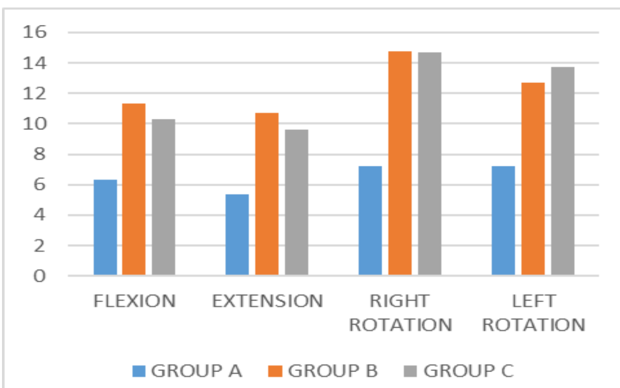
30 subjects were included in the study and all subjects completed the follow up at 2weeks. On comparing between the groups, post– intervention comparison of CCR, DCF, and NDI shows insignificance in CCR-flexion and extension (p – value 0.19 and 0.07 respectively) and significance in other variables (p –

value < 0.05) (Table 1). The analysis was carried out using Turkey's Post – Hoc test.

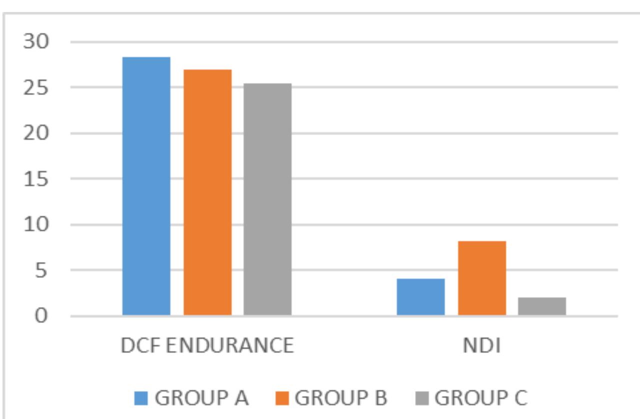
**Table 1:** Post– intervention comparison of CCR, DCF, and NDI between the groups

| Variables | Mean | SD | f- value | p-value |
|---|---|---|---|---|
| CCR – flexion | | | | |
| Group A | 6.34 | 3.15 | | |
| Group B | 11.31 | 6.64 | | |
| Group C | 10.30 | 7.81 | 1.75 | 0.191 |
| CCR – extension | | | | |
| Group A | 5.37 | 2.22 | | |
| Group B | 10.71 | 7.78 | | |
| Group C | 9.6 | 2.46 | 2.27 | 0.079 |
| CCR – Right rotation | | | | |
| Group A | 7.19 | 3.5 | | |
| Group B | 14.74 | 6.46 | | |
| Group C | 14.67 | 5.98 | 6.394 | 0.005 |
| CCR – Left rotation | | | | |
| Group A | 7.22 | 2.76 | | |
| Group B | 12.73 | 7.02 | | |
| Group C | 13.37 | 6.6 | 3.48 | 0.044 |
| DCF - Endurance | | | | |
| Group A | 28.4 | 1.57 | | |
| Group B | 27 | 1.69 | | |
| Group C | 25.5 | 1.50 | 9.104 | 0.000 |
| NDI | | | | |
| Group A | 4 | 2.44 | | |
| Group B | 8.2 | 3.91 | 3.94 | 0.030 |
| Group C | 6.5 | 3.55 | | |

CCR –Cervico cephalic relocation, DCF – Deep cervical flexor, NDI – Neck disability index.




**Graph 1:** CCR – Mean score of flexion, extension, right and left rotation between the groups




**Graph 2:** Mean score of DCF endurance and NDI between the groups

On analyzing within the groups, it shows that, there occurs a significant difference in all the variables (p value <0.05) in all the three groups – A (Table 2), B (Table 3) and C (Table 4). This analysis was carried out using paired t test.

**Table 2:** Analysis of CCR, DCF and NDI in group A within the group

| Variables | mean | SD | t- value | p- value |
|---|---|---|---|---|
| CCR – flexion: | | | | |
| pre | 27.3 | 12.177 | 5.27 | 0.000 |
| Post | 6.34 | 3.15 | | |
| CCR – Extension: | | | | |
| Pre | 23.61 | 13.44 | 4.23 | 0.000 |
| Post | 5.37 | 2.22 | | |
| CCR- Right rotation: | | | | |
| Pre | 22.91 | 8.17 | 5.59 | 0.000 |
| Post | 7.19 | 3.5 | | |
| CCR – Left rotation: | | | | |
| Pre | 21.71 | 8.26 | 5.26 | 0.001 |
| Post | 7.22 | 2.76 | | |
| DCF Endurance: | | | | |
| Pre | 24 | 0 | -8.82 | 0.000 |
| Post | 28.4 | 1.57 | | |
| NDI: | | | | |
| Pre | 14.8 | 7.64 | 5.28 | 0.000 |
| Post | 6.3 | 2.44 | | |

CCR –Cervico cephalic relocation, DCF – Deep cervical flexor, NDI – Neck disability index.

**Table 3:** Analysis of CCR, DCF and NDI in group B within the group

| Variables | Mean | SD | t- value | p- value |
|---|---|---|---|---|
| CCR – flexion: | | | | |
| pre | 27.84 | 9.73 | 4.44 | 0.000 |
| Post | 11.31 | 6.64 | | |
| CCR – Extension: | | | | |
| Pre | 27.67 | 14.62 | | |
| Post | 10.71 | 7.78 | 3.24 | 0.004 |
| CCR- Right rotation: | | | | |
| Pre | 29.07 | 12.23 | 3.28 | 0.004 |
| Post | 14.74 | 6.46 | | |
| CCR – Left rotation: | | | | |
| Pre | 24.14 | 8.52 | 3.27 | 0.004 |
| Post | 12.73 | 7.02 | | |
| DCF Endurance: | | | | |
| Pre | 23 | 1.05 | -6.32 | 0.000 |
| Post | 27 | 1.69 | | |
| NDI: | | | | |
| Pre | 15.1 | 5.57 | 5.57 | 0.000 |
| Post | 5.9 | 3.91 | | |

CCR –Cervico cephalic relocation, DCF – Deep cervical flexor, NDI – Neck disability index.

**Table 4:** Analysis of CCR, DCF and NDI in group C within the group

| Variables | mean | SD | t- value | p- value |
|---|---|---|---|---|
| CCR – flexion: | | | | |
| pre | 27.31 | 11.96 | 4.12 | 0.000 |
| Post | 10.30 | 7.81 | | |

| | | | | |
|---|---|---|---|---|
| CCR – Extension:<br>Pre<br>Post | <br>26.22<br>9.6 | <br>9.05<br>4.77 | 5.63 | 0.000 |
| CCR- Right rotation:<br>Pre<br>Post | <br>28.88<br>14.67 | <br>10.36<br>5.98 | 4.11 | 0.000 |
| CCR – Left rotation:<br>Pre<br>Post | <br>26.07<br>13.37 | <br>8.86<br>6.60 | 3.98 | 0.000 |
| DCF Endurance:<br>Pre<br>Post | <br>22.66<br>25.5 | <br>0.98<br>1.50 | -5.45 | 0.000 |
| NDI:<br>Pre<br>Post | <br>10.5<br>10.5 | <br>6.67<br>3.55 | 6.07 | 0.000 |

CCR –Cervico cephalic relocation, DCF – Deep cervical flexor, NDI – Neck disability index.

## DISCUSSION

This experimental study reveals that, there is presence of proprioception deficit not only among chronic mechanical neck pain patients but also in patients with chronic upper cervical involvement and cervical radiculopathy. In past literatures, there are very few evidences for the prevalence of proprioception impairment among patients with upper cervical involvement and cervical radiculopathy. The salient feature of present study is that, it assesses the involvement of proprioceptive deficit into cervical flexion, extension, right and left side rotational movements, as well as the response of each pathology to proprioceptive training. Another salient feature is that, it proposes a treatment protocol aimed at improving the proprioceptive acuity of neck for patients with chronic neck pain, which are specially designed to target the deep sub-occipital muscles and reflex connections, other than gaze stabilization and coordination exercises.

With regard to the postural control system, patients with neck pain demonstrated altered proprioception (tested by cervical joint position sense), balance disturbances, altered head – neck coordination, and altered postural activity of cervical muscles (15). Abnormal Joint Position Error (JPE) also has been detected in patients with chronic neck pain using either tests of ability to relocate the natural head posture after an active movement or to actively relocate a position within a movement plane. These disturbances of postural control have been caused possibly due to altered input from cervical afferents to higher centers (16).

There are abundant receptors in the deep cervical muscles, and multiple cervical central and reflex connections to the vestibular, visual, and postural control systems. In particular, the deep portions of the sub-occipital muscles have the highest cervical receptor density and are known to have a specific role in these reflex and central connections and in postural control (7).

In patients with chronic neck pain, due to overuse, repetitive or serious trauma and muscle weakness, the elasticity of non-contractile tissues becomes enlarged, thereby stabilize the neutral position, and contractile tissues become weak, leading to functional restriction, which in over a period of time leads to proprioception deficit (17).

Abnormal joint position error was assessed with the help of CCR test, which has been an effective outcome measure in evaluating the proprioception deficit. The CCR test when used to test neutral head positioning, executed in its original form (i.e., 10 trials) had a fair to excellent reliability (Intra-Class Correlation Coefficients ranged from 0.52 to 0.81 and from 0.49 to 0.77, for absolute and variable errors, respectively ie., testing the global components of joint position error (18). The findings of this study is more or less in accordance to the present study, and depicted in the tables 2, 3 and 4 which provided a significant improvement in CCR of $< 0.0001$ within all the three groups.

On the other hand, it has identified that, one of the major causes of postural impairment and proprioception deficit was less endurance of cervical flexor muscle. Following training of deep cervical flexors, the patients had shown substantial improvements. Thus, in addition to the CCR test, DCF endurance test was used as one of the outcome measures in the present study. This has been adopted from a study which stated that, Inter-rater reliability (Intra-Class Correlation Coefficients- ICC) for the CCFT was 0.91 (95% confidence interval, 0.83-0.96), with a reasonable agreement on the Bland-Altman plot confirming high reliability of the test (19). In the present study, this training procedure provided a significant improvement in CCR of 0.001, when compared between the subgroups of neck pain in patients with proprioception deficit as documented in the table 1.

The reliability of Neck Disability Index questionnaire was proved by a systemic Review, stating that, the NDI has acceptable reliability, although Intra-Class Correlation Coefficients (ICCs) range from 0.50 to 0.98. In addition, the reported Clinically Important Difference (CID) is inconsistent across different studies ranging from 5/50 to 19/50 (20). The NDI is strongly correlated (>0.70) to a number of similar indices and moderately related to both physical and mental aspects of general health. Henceforth NDI, which was presently used, yielded a significant outcome with a p- value of 0.003(table 1).

The present study protocol intervened cervical proprioception deficit through three types of training programs – proprioception training through target maze, DCF training and Dorsal neck muscle strengthening. According to a study done on proprioceptive training, the results stated that both proprioceptive training and DCF training have a demonstrable benefit on impaired cervical JPE in people with neck pain, with marginally more benefit gained from proprioceptive training (21). The results suggest that improved proprioceptive acuity following intervention with either of the exercise protocol may occur either by an improved quality of cervical afferent input or by addressing input through direct training of relocation sense. Another study (7) stated that, reduced strength of the dorsal neck muscles altered the repositioning acuity in sagittal plane (p- value < 0.0001). Hence, dorsal neck muscle strengthening was included as a part of the treatment regime and proved to be effective in achieving desired outcome.

## Clinical implications

The prevalence and management of proprioception deficit among patients with chronic mechanical neck pain and whiplash associated disorders have been proved adequately by the previous studies. It was adopted presently. The subgrouping of neck pain was done in a study and investigated the proprioception deficit among patients with chronic mechanical neck pain (22), whereas, proprioception deficit among subgrouping of neck pain was not attempted in the past studies. In addition, we had intervened the proprioception impairment with training protocols and the outcomes have proven to be clinically significant. Although, statistical analysis in table 1 revealed that CCR test into flexion and extension was not significant with p – values of 0.19 and 0.07 respectively, few outcomes proved statistically significant were CCR test into right and left rotations with p- values of 0.005 and 0.04 respectively. Similarly, the DCF endurance and NDI score proved to be statistically significant with p-values 0.000 and 0.03 respectively.

## CONCLUSION

The outcomes of present study revealed the presence of proprioception deficit among chronic mechanical neck pain, chronic upper cervical involvement and cervical radiculopathy patients. Following the intervention, all the three groups responded well, in terms of proprioceptive acuity, DCF endurance and NDI scores. Thus, it may be inferred that, inclusion of such training for chronic neck pain patients may potentially benefit them. In addition, this may be recommended as a part of treatment regimen in out- patient treatment protocol.

## FUTURE SCOPE

- ✓ Long term effects of the treatment may be evaluated on larger sample size.
- ✓ Cervico – cephalic relocation error may be measured in a multi – dimensional plane.

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