Journal of Advanced Zoology

ISSN: 0253-7214
*Volume **44** Issue **S-5 Year 2023** Page **1484:1491***

Deep Cervical Muscle Strengthening Exercise on Neck Pain Disability: A Randomized Controlled trail study

Thenmozhi Paluchamy[1*], Indhumathi Kannan[2], Tamilselvi S[3], BhuvaneswariG[1], Mary Minolin T[1], Madhan Krishnan[4]

[1]Professor, Saveetha College of Nursing, Saveetha Institute of Medical and Technical Sciences (SIMATS), Thandalam-602105, Chennai, Tamilnadu, India
[2]Saveetha College of Nursing, Saveetha Institute of Medical and Technical Sciences (SIMATS), Thandalam-602105, Chennai, Tamilnadu, India
[3]Associate Professor, Saveetha College of Nursing, Saveetha Institute of Medical and Technical Sciences (SIMATS), Thandalam-602105, Chennai, Tamilnadu, India
[4]Research, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam- 603103, Tamilnadu, India

**Corresponding author's: Thenmozhi Paluchamy*

Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 27 Oct 2023

Abstract

Objective: *The study aimed to investigate the effect of deep cervical flexor muscle strengthening exercises on neck pain disability among undergraduate students.* ***Materials and Methods:*** *A randomized controlled trial was adopted with 60 participants who met the inclusion and were randomly allocated into the study group (n=30) and the control group (n=30). Neck pain disability was evaluated before, one month after the initiation of deep cervical flexor muscle strengthening exercise.* ***Results:*** *Majority (>70%) of the participants were female, with a mean age group of 18.72, and used mobile phones and computers with improper ergonomics. There were significant ($p<0.001$) changes after one month in the overall neck disability index within the study group and between the study and control groups compared by paired t and independent t-test.* ***Conclusion:*** *This finding concludes that the outcome effectively reduces neck pain and its associated disability and could be incorporated into routine day-to-day practice to reduce neck pain, thereby minimizing the disability.*

Keywords: *Neck pain, neck pain disability, deep flexor muscle strengthening exercise, exercise*

1. Introduction

Neck pain is one of the work-related musculoskeletal problems and is a significant cause of morbidity and disability in everyday life and at work. The prevalence of neck pain ranges from 16.7% to 75.1% globally. It is generally higher in women than in men, peaks at around 45 years of age [1] and also higher in high-income countries [1, 4] and urban areas compared with rural areas.[4] Neck pain prevalence is high among undergraduate students [5], and approximately 30% of people with neck pain experience restrictions in their activities of daily living.[6] The Global Burden of Disease 2017 reported that musculoskeletal conditions are the second highest contributor to Global Disability.[7] The causes of neck pain including ergonomic such as strenuous improper posture, physical activity, use of force and vibration, repetitive movement; individual factors like age, body mass index, genetic and family history of pain due to the musculoskeletal problem; behavioral factors are smoking and level of physical activity; and the psychosocial problem of stress, anxiety, depression, and job satisfaction.[8, 9] Poor posture while using a computer by leaning over a computer or hunching over a computer table strains the neck muscles. Forward bending of neck posture for a prolonged time and repetitive movements are significantly associated with neck pain.[10] An increase in time spent texting messages on mobile phones or computers due to advancements in information and communication technologies. The increasing use of new information and communication technologies has led to an increase in time spent texting messages on mobile phones or computers, which might have a long-term impact on neck pain, potentially due to prolonged neck flexion.[11] Several studies suggested a strong relationship between computer usage and neck pain. [12, 14] It also has been proposed that the duration of use of mobile phones,

laptops, computers, TVs, video games, and even backpacks has forced the body to adapt to the forward head posture and kyphosis.[15] Exercise is an essential component of treatment programs for patients with neck pain.[16,17] Research studies proved that the cervical flexor muscles of longus colli and longus capitis strengthened and improved by deep cervical flexor muscle strengthening exercise.[18,19] It plays a vital role in stability throughout the cervical spine and increases amplitude in the more superficial neck muscles, including the sternocleidomastoid and scalene muscles.[20] Maintenance of the upright posture of the neck needs strong muscles; exercises are shown to be beneficial in it. Conventional neck exercises help reduce pain, but the literature suggests that deep cervical flexor muscle strengthening exercise is more effective in reducing disability. Hence, the present study investigated the effect of deep cervical flexor muscle strengthening exercises on neck pain disability among undergraduate students.

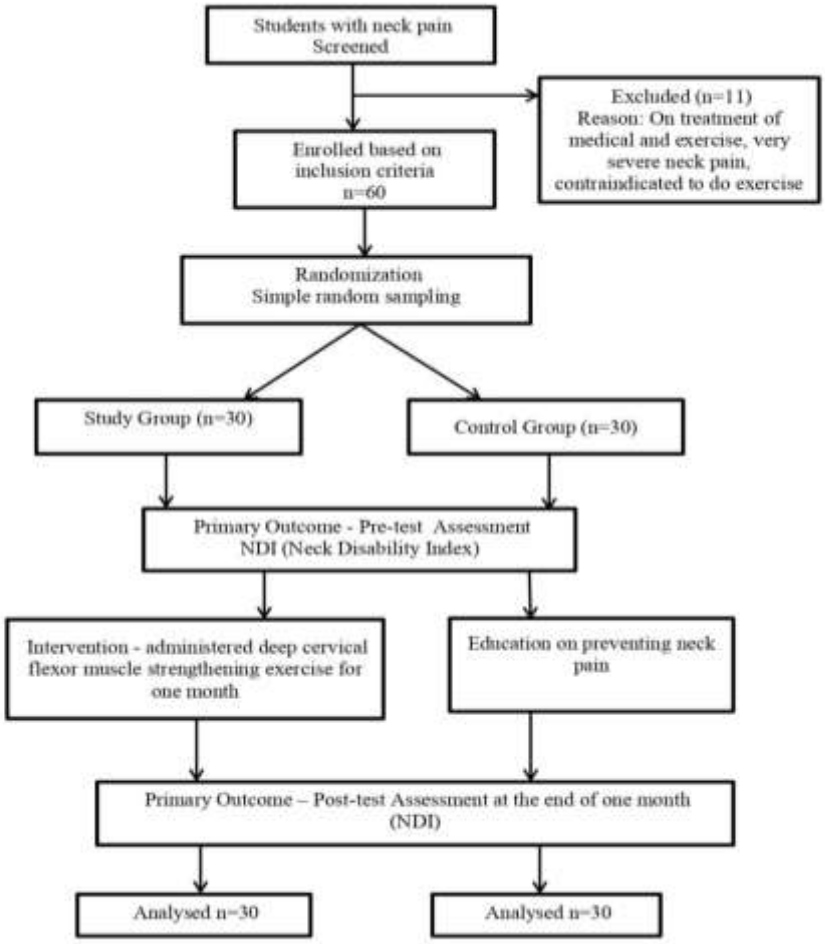
2. Materials And Methods

A randomized controlled trial was adopted to conduct the study by the College of Nursing, Saveetha Institute of Medical and Technical Sciences, between January and February 2022 after obtaining formal permission from the head of the institution. The study group (n=30) and control group (n=30) were selected from the lottery method after the initial neck pain screening. The sample size was calculated by Sigma Plot 13 (Systat Software Inc., USA). The sample size was estimated assuming a 20% improvement in reduction of neck pain disability with a 35% standard deviation, 80% power, 5% significance level, and 10% as drop out; the sample size was rounded off to 30 in each for the control and experimental group. College students, both male and female, who had neck pain disabilities and were willing to participate in the study were included in the study. The students excluded from the study were severe neck pain disability, the treatment for neck pain and contraindicated for doing exercise, and neck pain by any other underlying pathological conditions.

The study participants explained the purpose of the study in their regional language and clarified the doubt. Written informed consent was obtained from the participants after assuring confidentiality. Background information was collected by a self-administered questionnaire using a structured questionnaire. Both groups measured pre-test on neck pain disability using the neck disability index scale. The primary outcome is neck pain disability, measured by the Neck Disability Index (NDI). The intra-class correlation's reliability of the neck disability index scale was 0.98 and had strong correlation coefficients suggesting that it has good construct validity. Hence this tool is more valid and reliable for measuring neck pain disability [21, 22]. The neck disability index is designed to measure the level of neck pain and its impact on the ability to manage it in everyday life. This scale consists of 10: pain intensity, personal care, lifting, reading, headache, concentration, work, driving, sleeping, and recreation. Each section has six statements and is scored on a 0-5 rating scale. The total possible score is 50 and is presented in percentage which is interpreted as 0-4points (0-8%) no disability, 5-14points (10 – 28%) mild disability, 15-24points (30-48%) moderate disability, 25-34points (50- 64%) severe disability, and 35-50points (70-100%) complete disability.

The experimental group received the deep flexor muscle strengthening exercise for one month. The exercise was designed to administer for one month with 20 minutes of exercise per session. It was administered under the direct supervision of the investigators after demonstrating the exercise through PowerPoint and video. It contained two levels, Level I and Level II. In level I, The participants was instructed to sit comfortably, look straight ahead with their feet on the floor, bend their heads forward slightly, and tuck their chin towards the neck. They were also informed to maintain their chin tuck and position the head, so the eyes were leveled with the horizon. This position was maintained for 1-2 minutes and repeated ten times with 5 minutes relaxation intervals after the first five times of exercise posture. In level II, the participants were instructed to perform the same level I exercise and to keep their head and spine straight and lean forward, followed by informing them to keep their elbows on the thighs and hold on to this position for 1-2 minutes. It was repeated ten times with relaxation from the exercise posture after the first five times. During an intervention, the participants were observed for any progress and untoward effects. Post-test assessment of neck pain and disability was done using the same tool at the end of one month for both experimental and control groups. The CONSORT flow chart is given in figure 1.

Figure 1. Consort flowchart of the study



Analysis

The data were analyzed by descriptive and inferential statistical methods using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA) statistical package. The background variables and pre-test and post-test levels of neck pain disability of the participants were described as frequency and percentage. The effectiveness of intervention within the group was calculated by paired t-test, and the effect of intervention between the experimental and control group was compared by unpaired t-test. The probability of $p<0.05$ or less was taken as statistically.

3. Results and Discussion

Regarding background variables, most participants (>70%) were female, age group of 18.72, and were in III to IV Years. All 100% were using electronic gadgets of the mobile phone and laptop or desktop, and more than 50% had a moderate level of neck pain with 4-6 months' duration in both the study and control groups, as depicted in Table 1.

Table 1. Background Variables of Participants

Background Variables	Study Group n=30	Control Group n=30
	Frequency (%)	Frequency (%)
Age in Years		
a.17-18	4 (13%)	3 (10%)
b. 19-20	14 (47%)	18 (60%)
c. 21-22	12 (40%)	9 (30%)
Sex		
a. Male	9 (30%)	6 (20%)
b. Female	21 (70%)	24 (80%)
Year of Study		
a.I Year	7 (23%)	4 (13%)
b. II Year	6 (20%)	7 (23%)

c. III Year	9 (30%)	9 (30%)
d. IV Year	8 (27%)	10 (34%)
Electronic gadgets using		
a. Mobile Phone / Tab	-	-
b. Desktop / Laptop	-	-
c. Combination of both	30 (100%)	30 (100%)
Neck pain Score		
a.Mild	13 (43%)	12 (40%)
b. Moderate	15 (50%)	16 (53%)
c. Severe	2 (7%)	2 (7%)
Duration of Neck pain (months)		
a.Less than 3	3 (10%)	5 (17%)
b. 4-6	15 (50%)	16 (53%)
c. 7-9	7 (23%)	5 (17%)
d. 10-12	5 (17%)	4 (13%)

In the study group pre-test, out of 30 samples, six (20) had no disability, 16(53%) had mild disability, and Eight (27%) had a moderate disability. In contrast, in the post-test, nine (30%), 19 (63%), and Two (7%) had no disability, mild disability, and moderate disability, respectively. In the control group, seven (23%) had no disability, 18 (60%) had a mild disability, and Five (17%) had a moderate disability in the pre-test. In the post-test, 17 (57%) had mild disability, six (20%) had moderate disability, and seven (23%) had no disability, as shown in figure 2.

Figure 2. Comparison of pre-test and post-test score of Neck Disability Index

In the study group, students' mean score of overall neck pain decreased from 7.50±1.81 to 5.03±1.49 and were compared by paired t-test and found a significant difference in the overall neck disability ($p<0.001$). The mean lifting score was decreased from 1.17±0.37 to 0.70±0.46 ($p<0.001$), the mean reading score was decreased from 1.20±0.48 to 0.80±0.45 ($p<0.001$), the mean headache score was reduced from 0.97±0.55 to 0.50±0.40 ($p<0.001$), mean headache score decreased from 1.10±0.40 to 0.63±0.55 ($p<0.001$), mean reading score decreased from 0.37±0.49 to 0.10±0.30 ($p<0.001$) after one month of intervention. Other variables associated with neck pain, like pain intensity, personal hygiene, working, sleep, and recreation, showed a decrease in the level; however not statistically significant. The change in parameters within each variable and group comparisons are given in Table 2.

Table 2. Within Group Analysis of Neck Disability Index

Variables	PretestMean	SD	Post-testMean	SD	Meandifference	Paired't'value & p-value
Painintensity	0.43	0.56	0.33	0.47	0.10	1.14 .264 NS
Personalhygiene	0.37	0.49	0.37	0.49	0.00	0.00 1.000 NS
Lifting	1.17	0.37	0.70	0.46	0.46	5.03 .000 S
Reading	1.20	0.48	0.80	0.45	0.40	3.24 .003 S
Headache	0.97	0.55	0.57	0.50	0.40	3.02 .005 S
Concentration	1.10	0.40	0.63	0.55	0.46	4.47 .000 S
Working	0.83	0.37	0.57	0.50	0.26	2.50 .180 NS
Drive	0.37	0.49	0.10	0.30	0.26	3.24 .003 S
Sleep	0.53	0.57	0.57	0.50	0.16	0.32 .745 NS
Recreation	0.53	0.50	0.40	0.49	0.30	1.43 .161 NS
Overall, Neck Disability Index	7.50	1.81	5.03	1.49	2.46	12.57 .000 S

S- Significant NS – Non-Significant

The post-test mean score of overall neck disability between the study and the control group was compared by independent t-test and found to be statistically significant ($p<0.001$). The post-test mean score of study and control group in other variables of lifting, reading, headache, and concentration were statistically decreased from 0.47±0.50 to 0.03 ±0.32 ($p<0.001$), 0.45±0.67 to 0.07±0.45($p<0.001$), 0.40±0.73 to 0.17±0.79 ($p<0.001$), and 0.47±0.57 to 0.03±0.66 ($p<0.001$) respectively. The change in parameters within each variable and between the group comparisons are given in Table 3.

Table 3. Between Group Analysis of Neck Disability Index

Variables	Study group Mean difference	SD	Control Group Mean difference	SD	Independent 't'Value
Pain intensity	0.10	0.48	0.113	0.57	1.71 .092 NS
Personal hygiene	0.00	0.45	0.10	0.60	0.72 .474 NS
Lifting	0.47	0.50	0.03	0.32	3.95 .000 S

Reading	0.45	0.67	0.07	0.45	3.15 .003 S
Headache	0.40	0.73	0.17	0.79	2.89 .005 S
Concentration	0.47	0.57	0.03	0.66	3.11 .003 S
Working	0.27	0.58	1.03	0.55	1.56 .118 NS
Drive	0.27	0.45	0.00	0.64	1.86 .068 NS
Sleep	0.03	0.55	0.16	0.59	0.89 .372 NS
Recreation	0.130	0.50	0.10	0.40	1.97 .054
Overall neck disability index	2.47	1.07	0.70	1.36	9.97 .000 S

S- Significant NS – Non-Significant

Neck pain is a significant problem affecting young and older adults nowadays due to an increasingly sedentary population with an increasing dependency on computers, mobile phones, and other forms of technology.[13, 14] It is more common for college students as they spend more time using mobile phones, computers, or desktops for their educational preparation and personal use, even using them as recreational tools in the current context. The reported reasons that make undergraduate students prone to neck pain were the usual lack of physical activity, the stress related to studies, and the universal adoption of different digital gadgets that make undergraduate students prone to musculoskeletal pain-related.[25] Physical exercise, duration of reading, and awkward posture were significantly associated with neck pain.[26] The present study findings reveal that all participants were using mobile phones and computers with improper ergonomics, and the majority were female, with a mean age group of 18.72. It also found that more than 50% had mild to moderate disabilities. Proper ergonomics and exercise is the best way to prevent and treat neck pain and its associated disability. Hence the current study investigated the impact of deep cervical flexor muscle strengthening exercise on neck and pain disability among undergraduate students. The study findings proved the significant improvement in overall neck disability index in the study group compared with the control group after thity sessions of deep cervical flexor muscle strengthening exercise within the study group and a significant difference between the study group and the control group. Six weeks of deep flexor and deep extensor muscle strengthening exercises can improve neck disability, pain intensity, CV angle, and neck-muscle strength in chronic mechanical neck pain is consistent with current study findings.[27] Participants who received deep flexor muscle strengthening exercise with pressure biofeedback had shown statistically significant improvement in muscle pain, disability, and endurance. It was also found to be substantial improvements in the disability associated with improvements in pain due to an increase in endorphins, better neuromuscular control, and activation of muscle ergoreceptors.[28] A significant relationship between deep cervical flexors and pain intensity and change in pain level.[29] The present study also showed significant improvement in lifting, reading, concentration, driving, and headache reduction after four weeks of intervention. Four weeks of deep cervical flexor training is more effective than conventional isometrics training in improving forward head posture and decreasing pain and disability in dentists suffering from chronic neck pain.[30]

Deep neck flexor exercise shows statistically significant improvement in functional disability on NDI, cervical lateral flexion, rotation, and reduction in pain.[31] Four weeks of deep cervical flexor training effectively alleviated neck pain and improved functional status in adolescents using computers regularly in the study group compared to the control group. Still, there was no improvement in forwarding head posture, contrasting with the present study finding.[32] The earlier related study results are consistent with the current study finding; however, the current study is limited in measuring cervical muscle strength, muscle endurance, forward head posture, and the long-term effects of exercises. And also, other associated factors for neck pain, like climate conditions, nutrition, and psychological factors, could not be assessed and controlled during the study period. Further study can be recommended for an increase in sample size with a long duration of intervention and follow. A comparative study of deep flexor muscle strengthening exercise with any other ergonomic exercise for work-related neck pain may be considered.

4. Conclusion

In conclusion, the deep cervical flexor muscle strengthening exercise outcome is effective in the reduction of neck pain and its associated disability. The selected participants became comfortable and compliance to practice. It also found that this exercise is very safe as it did not cause adverse effects during the study period and should still be clinically correlated. Deep flexor muscle strengthening exercises could teach undergraduate students to practice and incorporate them into their daily routine to reduce neck pain, thereby minimizing the disability.

Ethics Committee Approval: The study protocol was approved by The Institutional Scientific Review Board under the Saveetha College of Nursing (687/2021/ISRB/SCON dated 25th August 2021). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Participant Consent for Publication: A written informed consent was obtained from the patients.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Was involved in background and research design, patient recruitment, data analyses, writing and editing of the manuscript: T.P, I.K: Design the intervention protocol, reviewing related literature, I.K; Participant recruitment, intervention, data collection, writing and editing of the manuscript: T.P

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

References:

1. Damian Hoy, Lyn March, Anthony Woolf, Fiona Blyth, Peter Brooks, Emma Smith, Theo Vos, Jan Barendregt, Jed Blore, Chris Murray, Roy Burstein, Rachelle Buchbinder. The global burden of neck pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014;73:1309–1315.
2. Fejer R, Kyvik KO, Hartvigsen J. The prevalence of neck pain in the world population: a systematic critical review of the literature. Eur spine J. 2006;15(6):834-48.
3. Childs, JD, Cleland, JA, Elliott, JM, Teyhen, DS, Wainner, RS, Whitman, JM, et al. Neck pain: clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2008;38(9): A1-A34.
4. Hoy DG, Protani M, De R, Buchbinder R. The epidemiology of neck pain. Best Pract Res Clin Rheumatol. 2010;24(6):783-92.
5. Chan LLY, Wong AYL, Wang MH, Cheung K, Samartzis D. The prevalence of neck pain and associated risk factors among undergraduate students: A large-scale cross-sectional study. Int. J. Ind. Ergon. 2020; 76:102934.
6. Picavet HSJ, Schouten JSAG. Musculoskeletal pain in the Netherlands: prevalences, consequences and risk groups, the DMC3-study. Pain. 2003;102:167-178.
7. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet.2018;392:1789-1858.
8. Malchaire JB, Roquelaure Y, Cock N, Piette A, Vergracht S, Chiron H. Musculoskeletal complaints, functional capacity, personality and psychosocial factors. Int Arch Occup Environ Health. 2001;74(8):549–557.
9. Cimmino MA, Ferrone C, Cutolo M. Epidemiology of chronic musculoskeletal pain. Best Practice Res Clin Rheumatol. 2011;25(2):173–183.

10. Cagnie B, Danneels L, Van Tiggelen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: a cross sectional study. Eur Spine J Berlin/Heidelberg: Springer-Verlag. 2007;16(5):679–686.
11. Gustafsson E, Thomee S, Grimby-Ekman A, Hagberg M. Texting on mobile phones and musculoskeletal disorders in young adults: a five-year cohort study. Appl Ergon. 2017;58:208–214.
12. PT Hakala, AH Rimpelä, LA Saarni, JJ Salminen. Frequent computer-related activities increase the risk of neck–shoulder and low back pain in adolescents.Eur JPublic Health. 2006;16(5):536–541.
13. J Auvinen, T Tammelin, S Taimela, P Zitting, J Karppinen. Neck and shoulder pains in relation to physical activity and sedentary activities in adolescence. Spine. 2007;32(9):1038–1044.
14. AM Briggs, LM Straker, NL Bear, AJ Smith. Neck/shoulder pain in adolescents is not related to the level or nature of self-reported physical activity or type of sedentary activity in an Australian pregnancy cohort. BMC Musculoskelet Disord. 2009;10(1):87.
15. S Kumar. Theories of musculoskeletal injury causation. Ergonomics. 2010;44(1):17–47.
16. Kay TM, Gross A, Goldsmith CH, et al. Exercises for mechanical neck disorders. Cochrane Database Syst Rev. 2012;8:CD004250.
17. Leaver AM, Refshauge KM, Maher CG, McAuley JH. Conservative interventions provide short-term relief for non-specific neck pain: a systematic review. J Physiother. 2010;56(2):73–85.
18. O'Leary S, Jull G, Kim M, Vicenzino B. Specificity in retraining craniocervical flexor muscle performance. J Orthop Sports Phys Ther. 2007;37(1):3–9.
19. O'Leary S, Jull G, Kim M, Uthaikhup S, Vicenzino B. Training mode-dependent changes in motor performance in neck pain. Arch Phys Med Rehabil. 2012;93(7):1225–1233. https://ccsbismarck.com/neckflexorstrengthening/ retrieved on 05.02.2022
20. Macdermid JC, Walton DM, Avery S, Blanchard A, Etruw E, McAlpine C, Goldsmith CH. Measurement properties of the neck disability index a systematic review. J Orthop Sports Phys Ther. 2009;39(5):400-17.
21. Vernon H, Mior S. The neck disability index: A study of reliability and validity. J Manipulative Physiol Ther. 1991;14:409-15.https://pubmed.ncbi.nlm.nih.gov/1834753/.
22. Cleland JA, Childs JD, Whitman JM. Psychometric Properties of the Neck Disability Index and Numeric Pain Rating Scale in patients with Mechanical Neck Pain. Arch Phys Med Rehabil. 2008; 89(1):69-74.
23. Young IA, Cleland JA, Michener LA, Brown C. Reliability, Construct Validity, and Responsiveness of the Neck Disability Index, Patient-Specific Functional Scale, and Numeric Pain Rating Scale in Patients with Cervical Radiculopathy. Am J Phy Med Rehabil. 2010; ;89(10):831-839.
24. Behera P, Majumdar A, Revadi G, Santoshi JA, Nagar V, et al. Neck pain among undergraduate medical students in a premier institute of central India: A cross-sectional study of prevalence and associated factors. J Family Med Prim Care. 2020;9: 3574-3581.
25. Weleslassie GG, Meles HG, Haile TG, Hagos GK. Burden of neck pain among medical students in Ethiopia. BMC Musculoskelet Disord. 2020; 21:14.
26. Thavatchai Suvarnnato, Rungthip Puntumetakul, Sureeporn Uthaikhupm Rose Boucaut. Effect of specific deep cervical muscle exercises on functional disability, pain intensity, craniovertebral angle, and neck-muscle strength in chronic mechanical neck pain: a randomized controlled trial. J Pain Res. 2019;12:915–925.
27. Zaheen A. Iqbal, Ahmad H. Alghadir, Shahnawaz Anwer. Efficacy of Deep Cervical Flexor Muscle Training on Neck Pain, Functional Disability, and Muscle Endurance in School Teachers: A Clinical Trial. Biomed Res Int. 2021, Article ID 7190808.
28. Deborah Falla, Shaun O'Leary, Dario Farina, Gwendolen Jull. The change in deep cervical flexor activity after training is associated with the degree of pain reduction in patients with chronic neck pain. Clin J Pain. 2012;28(7):628-34.
29. Bhuvan Deep Gupta, Shagun Aggarwal, Bharat Gupta, Madhuri Gupta, Neha Gupta. Effect of Deep Cervical Flexor Training vs. Conventional Isometric Training on Forward Head Posture, Pain, Neck Disability Index in Dentists Suffering from Chronic Neck Pain. J Clin Diagn Res. 2013;7(10):2261–2264.
30. Priyanka Chauhan, Pooja Attrey, Anand Kumar Singh. Effect of Post Isometric Relaxation with Deep Neck Flexor Exercise in Subacute Mechanical Neck Pain. Int J Health Sci Res. 11(10); 2021: 47-59.
31. Isha Sikka, Chandan Chawla, Shveta Seth, Ahmad H. Alghadir, Masood Khan. Effects of Deep Cervical Flexor Training on Forward Head Posture, Neck Pain, and Functional Status in Adolescents Using Computer Regularly. BioMed Res Int. 2020, Volume 2020, Article ID 8327565.