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Effects of home exercise program on endurance, disability and daily participation in non-specific neck pain

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TITLE PAGE

EFFECTS OF HOME EXERCISE PROGRAM ON ENDURANCE, DISABILITY AND DAILY PARTICIPATION IN NON-SPECIFIC NECK PAIN

Running Title: ENDURANCE ON DISABILITY AND PARTICIPATION

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EFFECTS OF HOME EXERCISE PROGRAM ON ENDURANCE, DISABILITY AND DAILY PARTICIPATION IN NON-SPECIFIC NECK PAIN

ABSTRACT

Propose: Neck pain affects the proprioception of the cervical region due to the involvement of the neuromuscular system. Muscle activation decreases with the affected deep sensation. Neural inhibition in muscles affects sensoriomotor inputs and motor control decreases. All of these can cause muscle spasm, decreased cervical mobility and functional limitation. The aim of the study was to examine the relationship between muscular endurance, disability level and life participation in patients with nonspecific neck pain (NSNP).

Method: This study involved 65 individuals with NSNP, randomized via closed envelope method into exercise and control groups. The exercise group underwent a four-week intervention, while the control group was provided an informative booklet explaining conditions that can affect neck health and how to respond to these conditions was provided. Demographic data questionnaire, cervical flexion/extension/deep flexion endurance tests, Visuel Analog Scale (VAS), Northwick Park Neck Pain Questionnaire (NPNPQ) and Keele Participation Assessment (KPA) were applied to the participants. Our clinical trial, with the identifier number NCT05259358, was registered in the ClinicalTrials.gov database on January 15, 2022.

Results: After treatment, there was a statistical difference between the groups only in the NPNPQ scale ($p<0.005$). In neck endurance tests, there was no statistical difference between the two groups before treatment ($p>0.005$), but the increase in

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the exercise group after treatment was statistically more significant compared to the control group.

Conclusion: As a result of home exercise program treatment in patients with NSNP, it was found that there was a positive change in muscular endurance, a decrease in the level of disability and a positive change in the level of participation in life.

Keywords: nonspecific neck pain**,** exercise, endurance, disability, participation

Highlights:

- Baseline functional status can be taken as a criterion for patient selection instead of demographic factors,
- Could recommending functional activity-orientated modifications in exercise prescriptions instead of endurance.
- Traditional home exercises must be supported by technology-based systems.

INTRODUCTION

Non-specific neck pain (NSPN) is the fourth most common major cause of musculoskeletal disorders worldwide. More than 70 percent of the world's population is known to experience neck pain at some point in their lives [1].

Neck pain affects the proprioception of the cervical region due to the involvement of the neuromuscular system. Muscle activation decreases with the affected deep sensation. Neural inhibition in muscles affects sensoriomotor inputs and motor control decreases. All of these can cause muscle spasm, decreased cervical mobility and functional limitation [2]. Assessment of the disability resulting from the loss of these functions associated with neck pain is necessary to manage neck pain. In the activity and participation section of the International Classification of Functioning, Disability and Health (ICF), it is stated that the activities of daily

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living are limited due to neck pain in the daily life of the person both at work and at home, and this increases the level of disability of the person [3].

Persistent neck pain and the associated increase in disability may prevent individuals from fully performing their life roles and negatively affect participation in daily life activities, work-related tasks, and social interactions [4].

In the literature, studies using craniocervical flexor exercise as a treatment have reported a decrease in patient complaints in the neck, improvement in functional impairment and increased activation of the cervical flexor muscles. In addition, cervical extensor muscles are considered to be equally important in the rehabilitation of patients with neck pain [5,6].

While there is evidence in the current literature regarding the effectiveness of home-based exercises in NSNP management, most of these studies have focused on basic clinical parameters (pain, disability), and there has been a lack of research that simultaneously evaluates patient-centered outcomes such as objective measurements of muscle performance and life participation. In this context, the aim of this study is to investigate the comprehensive effect of a standardized home exercise program on pain, functional disability, muscle endurance, and life participation using a randomized controlled design.

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METHODS

The study was designed as a prospective, randomized controlled trial. The sample consisted of 65 Turkish patients aged 18–65 years with non-specific neck pain who applied to the Physical Therapy and Rehabilitation Outpatient Clinic, volunteered to participate, and met the study’s inclusion criteria.

Patients diagnosed with non-specific neck pain were screened for red and yellow flags and evaluated by a medical doctor prior to inclusion. Additionally,

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individuals who had been diagnosed with non-specific neck pain for at least three months, had not undergone spinal or lower extremity surgery within the past six months, and had no orthopedic injuries or neurological deficits were included in the study.

Participants who did not meet the inclusion criteria, withdrew voluntarily, or failed to adhere to the exercise protocol were excluded from the study (Figure 1, CONSORT diagram).

Ethics committee approval was obtained for the study with the decision of Süleyman Demirel University faculty of medicine clinical research ethics committee dated 03.08.2021 and numbered 16/261. The study was conducted in accordance with the ethical standards of the Committee on Human Experiments of the Declaration of Helsinki. After the individuals participating in the study were informed about the study verbally and in writing, those who volunteered were included in the study. Written informed consent was obtained from all patients enrolled in the study.

The study was registered at ClinicalTrials.gov (Identifier: NCT05259358) on January 15, 2022.

Demographic information including age, gender, body mass index (BMI), educational status, occupation, marital status, and smoking status was recorded. Cervical flexion, cervical extension, and deep cervical flexion endurance tests were performed. Pain intensity was assessed using the Visual Analog Scale (VAS), neck disability using the Northwick Park Neck Pain Questionnaire (NPNPQ), and participation level using the Keele Participation Assessment (KPA), a brief ICF-based measure.

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After baseline assessments, participants were randomized into either the exercise group or the control group using a block randomization method. The randomization sequence, with variable block sizes of 4 and 6, was generated by an independent researcher not involved in the study using a computer-based random number generator. Group allocations were concealed in sequentially numbered, opaque, sealed envelopes. Following completion of the baseline assessment, the enrolling physician opened the next envelope in sequence and informed the participant of the assigned group.

All outcome measures were assessed at baseline (Week 0) and after completion of the four-week intervention period (Week 4) by the same physiotherapist, who remained blinded to group allocation throughout the study (Figure 2).

Participants allocated to the exercise group received a four-week home-based exercise program. The program included postural correction exercises, chin tuck exercises, cervical range of motion exercises in all directions, neck isometric exercises, cervical stabilization exercises, and stretching exercises targeting the pectoralis, latissimus dorsi, upper trapezius, levator scapulae, rhomboid, and scalene muscles.

Participants were instructed to perform each exercise at home with 3 sets of 10 repetitions daily for four weeks. To facilitate adherence and ensure correct performance, participants were provided with visual educational materials, including videos and pictures demonstrating the exercises. In addition, participants completed a daily exercise tracking form, and weekly reminder phone calls were made throughout the intervention period.

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Participants in the control group did not receive any exercise intervention during the study period. Instead, they were provided with an informative booklet containing information about cervical anatomy, proper posture during daily activities, appropriate sleeping positions, and recommendations for protecting neck health.

At the end of the four-week intervention period, all participants returned to the clinic for reassessment. Exercise adherence was evaluated based on participants' exercise tracking forms and self-reports. Participants who discontinued the exercise program for at least three consecutive days or followed the program for less than one week were excluded from the study. No serious exercise-related adverse events were observed during the study period.

Measurements:

Primary Outcome Measures:

1-Endurance of cervical flexor muscles: For the assessment of deep neck flexor muscle endurance, the patient was asked to lift his/her head approximately 2-2.5 cm from the stretcher while in the supine hook position. Verbal warnings such as "keep your chin steady" and "keep your head upright" were given to prevent loss of position during the test. The test was terminated when the patient's pain was unbearable and when he/she broke the desired position and the maximum time was recorded in seconds [7].

2-Endurance of the cervical extensor muscles: The patient was positioned prone with their head off the stretcher, arms at the sides, and supported by a belt at the 6th thoracic vertebra. They were instructed to retract their chin and hold the position. A stopwatch recorded the time (in seconds) until the patient could no longer

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maintain the horizontal position due to pain, discomfort, or request, marking the maximal cervical extension endurance time [8].

3-Northwick Park Neck Pain Questionnaire (NPNPQ): The NPNPQ assesses patients' neck disability levels through a 9-item questionnaire. It evaluates neck pain severity, sleep disturbances, arm numbness/tingling, symptom duration, pain during weight-bearing, reading, watching TV, work, housework, social activities, and driving. Each item is scored 0-4. For non-drivers, the total score is out of 32; for drivers, it is out of 40. The Turkish version has established reliability and validity [9,10].

Secondary Outcome Measure:

1- Visual Analogue Scale (VAS): With the VAS, individuals were asked to rate their pain between 0-10. 0 indicated no pain and 10 indicated severe pain. 1-3 is defined as mild pain, 4-6 as moderate pain, and 7-10 as severe pain [11].

2-Endurance of the cervical deep flexor muscles: To measure deep cervical muscle endurance, the individual was positioned supine with hands by the trunk and legs in a hooked position. The head was slightly retracted (chin tuck). The physiotherapist placed their thumb and index finger on the occiput's most prominent area. The patient was instructed to lift the upper head just enough to break contact with the fingers. The test ended, and time was recorded (in seconds), when the patient experienced excessive pain, lost the chin tuck position, fully flexed the head, or activated superficial flexor muscles (e.g., sternocleidomastoid or anterior scalene) [12].

3- Keele Participation Assessment (KPA): The KPA evaluates participation areas, interpersonal relationships, home environment, education, work, functionality, and social life based on the ICF classification. It consists of 11

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questions, with responses ranging from "Always" to "Never." Scores range from 0 to 11, where 0 indicates no participation restrictions, and 1-11 indicates restrictions in at least one activity. Responses of "Sometimes," "Rarely," or "Never" score 1 point, while "Always" or "Most of the time" score 0. The questionnaire takes approximately 3-5 minutes to complete [13, 14].

Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics version 27. The sample size was determined by an a priori power analysis performed for the primary analysis method, repeated measures ANOVA. The normality of the data was assessed using the Shapiro–Wilk test and Q–Q plots. Variables that met the assumption of normal distribution were analyzed using parametric tests, whereas non-normally distributed variables were analyzed using non-parametric tests.

Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as frequency and percentage (%). Between-group comparisons of demographic and baseline characteristics were performed using independent samples t-tests or Mann–Whitney U tests, as appropriate. Within-group changes in outcome measures were assessed using paired-samples t-tests or Wilcoxon signed-rank tests, depending on data distribution.

Between-group differences over time were primarily analyzed using mixed-design repeated measures ANOVA for normally distributed variables, examining group, time, and group × time interaction effects.

To further control for potential baseline differences and adjust for confounding variables, analysis of covariance (ANCOVA) was additionally performed for post-intervention cervical flexion endurance, cervical extension endurance, Kinesiophobia (KPA), and Northwick Park Neck Pain Questionnaire (NPNPQ) scores.

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In these models, post-treatment scores were entered as dependent variables, group as the fixed factor, and baseline values of the respective outcome measure were included as covariates. Age, BMI, education level, and baseline VAS scores were also entered as additional covariates. In our preliminary analyses, we also observed that there were no differences between groups for other demographic data. Adjusted mean values were calculated, and statistical significance was set at $p < 0.05$.

RESULTS

Participant Characteristics

A total of 65 participants were included (35 in the exercise group (EG) and 30 in the control group (CG)). Analysis of demographic data revealed significant differences between the groups in age, BMI, education level, chronic disease, and previous attempts to receive treatment for pain ($p < 0.05$; Table 1).

Changes in Clinical and Endurance Outcomes

Cervical flexion endurance and extension endurance improved significantly in the exercise group following the intervention, whereas no significant changes were observed in the control group. Similarly, significant improvements were observed in KPA and NPNPQ scores in the exercise group, while scores remained stable in the control group. Effect sizes (Cohen's d) confirmed the clinical relevance of these changes, with VAS showing a large effect ($d = 1.747$), NPNPQ a large effect ($d = 1.14$), KPA a moderate effect ($d = 0.77$), cervical flexion endurance a moderate effect ($d = -0.87$), and cervical extension endurance a moderate effect ($d = -0.59$). Deep cervical flexion endurance did not show statistically significant changes and is not included here.

Time × Group Interactions

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Repeated measures ANOVA with Greenhouse–Geisser correction revealed statistically significant time × group interactions for cervical flexion endurance ($F(1,63) = 16.009$, $p < 0.001$, partial $\eta^2 = 0.203$) and cervical extension endurance ($F(1,63) = 11.895$, $p = 0.001$, partial $\eta^2 = 0.16$), indicating greater improvements over time in the exercise group compared with the control group. No significant changes were observed for deep cervical flexion endurance ($p = 0.657$).

Comparison of Baseline and Postintervention Outcomes by Demographic and Clinical Characteristics

Table 3 compares baseline and postintervention scores among participants in the exercise group based on their demographic and clinical characteristics. In analyses by gender, a significant difference was found only in baseline flexion endurance scores, with male participants scoring higher than females ($p=0.039$). In comparisons based on marital status, baseline KPA ($p=0.036$) and postintervention KPA ($p<0.001$) scores were found to be higher in married participants compared to single participants; no significant differences were observed in other variables. Significant differences were found in baseline KPA ($p<0.001$), postintervention KPA ($p=0.010$), and baseline NPNPQ ($p=0.038$) scores among occupational groups; post-hoc comparisons revealed that students, in particular, had higher KPA scores compared to housewives. In comparisons based on chronic disease status and pain history, no significant differences were found between groups for any measurement variables before or after treatment ($p>0.05$). In correlation analyses, age, BMI, and the number of years since the onset of pain were found to have no significant association with the baseline and postintervention measurement variables ($p > 0.05$). In contrast, a positive and statistically significant correlation was found between pain duration and the baseline VAS score ($r = 0.397$, $p = 0.018$). Overall,

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in the exercise group, the majority of the measurement variables showed significant differences based on demographic characteristics, particularly in relation to flexion endurance, the KPA, the NPNPQ, and pain duration.

Study Protocol Availability

The full protocol of the study is available via the ClinicalTrials.gov (NCT05259358) registration or upon request from the corresponding author.

DISCUSSION

In this study, a structured home-based exercise program led to meaningful improvements in cervical flexion and extension endurance, pain intensity, participation in daily life activities, and neck pain–related disability in individuals with chronic neck pain. These improvements were observed in the exercise group compared with the control group and remained significant after accounting for demographic characteristics and baseline pain levels. The magnitude of change suggests clinically relevant benefits in both physical endurance and patient-reported outcomes. In contrast, deep cervical flexion endurance did not demonstrate a significant between-group improvement, indicating that the exercise program may have selectively influenced certain cervical endurance components rather than deep stabilizing muscle performance.

The results obtained strongly support the view that structured exercise is an effective basic approach in the management of chronic neck pain. Significant improvements in patient-reported outcomes such as cervical endurance, pain intensity, and disability status related to neck pain, particularly participation in daily life activities, emphasize the importance of a comprehensive rehabilitation approach. Decreases in participation in daily life activities and neck disability levels demonstrate that exercise not only increases physiological capacity but also

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improves patients' pain perception, fear of movement, and confidence in daily living activities [15]. More importantly, the fact that these improvements remain significant even after controlling for factors such as age, BMI, education level, and initial pain intensity suggests that structured exercise may be a valid treatment option for a broad patient population, relatively independent of demographic barriers. This finding supports the view that exercise is not a “one-size-fits-all” approach, but can be effective even in heterogeneous groups when well-structured.

However, the lack of a significant change in the endurance of the deep neck flexor muscles provides an important indication that the effects of exercise interventions on the cervical musculature may be selective and specific. This finding is consistent with previous literature. For example, Falla et al. [16] reported specific activation and endurance deficits in the deep cervical flexor muscles in individuals with neck pain, which are not fully addressed by general exercise programs. The specialized role of these muscles in cervical stabilization and fine motor control suggests that general endurance and strength exercises may not be sufficient to improve this parameter. Accordingly, more specific exercise approaches targeting deep cervical muscles, such as craniocervical flexion training, may be required [17].

From a broader rehabilitation perspective, resistance and strength training have been shown to be important components in the management of chronic neck pain. Andersen et al. demonstrated that high-intensity resistance training targeting the neck and shoulder musculature leads to greater improvements in pain reduction, muscle strength, and functional capacity compared with low-intensity or general exercise interventions [18]. This supports the importance of exercise intensity and progressive resistance as key determinants of neuromuscular adaptation. In the present study, the absence of a clearly defined resistance progression in the home-

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based exercise program may explain the limited improvement in deep cervical flexor endurance despite significant gains in pain and disability outcomes. Therefore, incorporating progressive resistance principles into home-based exercise programs may further enhance muscular adaptations and functional recovery.

The functional improvement findings of our study were consistent with Kim and Shin [19], which showed that home exercise programmes provided significant improvement in neck disability level scores in individuals with chronic neck pain. Similarly, He et al. [20], meta-analysis reported that self-management strategies were effective in reducing functional limitations due to neck pain. The predictive role of pre-treatment disability level was analysed by Zabala-Mata et al. [21], emphasised that baseline functional status may be critical in determining treatment response.

However, the lack of change observed in endurance parameters was not consistent with Andersen et al. [22], which showed that 12 weeks of resistance exercises provided a significant increase in neck muscle endurance. This difference may be explained by the fact that the intensity and duration of the exercise protocol in our study were insufficient for endurance development. Kaynak et al. [23], suggests that exercise effectiveness may vary depending on individual factors, which partially contradicts our finding of no effect of demographic factors. It is known that endurance adaptations require specificity and adequate dosage [24,25]. Mechanistic studies show that neck muscle performance depends on the task, direction, and speed [26,27]. Therefore, the lack of a significant effect on endurance following a four-week general exercise program can be explained by the program's lack of specificity and intensity [28,29].

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Exercise physiology research indicates that eccentric and low-metabolic-cost isometric exercises can increase sustainable torque [30]. In future programs, integrating these principles into neck endurance exercises may yield more effective results [31].

The stability observed in the control group of our study is consistent with the findings of Chys M et al. [32] with the findings of the expected natural healing curve. However, the fact that pre-treatment pain levels did not predict outcomes partially contradicts the literature [33] which generally argues that pain intensity is important in determining prognosis. This may be due to the heterogeneous nature of our study population.

People with chronic pain have been reported to experience more problems in social life than healthy individuals. During periods of intense pain, a decrease in social life satisfaction and social participation can be observed [34]. With a decrease in social participation, individuals' daily lives become more difficult and social isolation, depression and physical disability may increase [35]. In our literature review, we did not find any study evaluating the effect of exercise on pain and participation in life in patients with nonspecific neck pain. In our study, it was observed that individuals with nonspecific neck pain had problems in participation in life due to pain and neck exercises contributed to improvement in this sense. The rare study we encountered in the literature on this subject showed the effect of Pilates exercises applied with conventional treatment in terms of reducing pain and improving participation in life in nonspecific neck patients, while the effect of exercise alone was not found [36]. In future studies, we believe that investigating the effect of different types of exercises on the person's participation in life and biopsychosocial sense will contribute to the literature.

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In our study, although improvement in pain, muscular endurance and participation in life was noted in the home exercise group, only the level of disability decreased significantly after treatment. Igbal et al. [6] reported that stretching and strengthening exercises may affect muscular endurance, improved torque production of the healed muscle and disability. In addition, many studies have shown a positive correlation between neck exercises and neck pain level and disability level [19, 20]. We think that this significant result in our study may be due to the decreased pain level and increased muscular endurance of the patients, as in similar studies in the literature, as well as the increased patient participation and previous treatment services in our study.

Our results support the potential of home exercise programmes, in particular, to provide functional improvement in neck pain management. However, the lack of change in endurance parameters suggests that the duration and intensity of intervention should be re-evaluated. The conflicting findings in the literature emphasise the importance of individualised treatment approaches in neck pain management. In recent years, technology-assisted rehabilitation approaches (e.g., virtual reality-based “Necknasium,” tension estimation using head-tracking devices) have become increasingly prevalent [37, 38]. These systems can increase compliance and dosage accuracy by adding biofeedback to home exercises [39]. However, these studies have focused more on engineering and feasibility, and their clinical efficacy has not yet been widely proven [40]. In the future, randomized controlled trials comparing traditional home exercises with technology-assisted systems are needed [41].

As an innovative aspect of our study, we can say that the paradigm of the functional improvement-endurance distinction was questioned by demonstrating

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that home exercises provided significant improvement in functional disability level but were ineffective in endurance parameters. It is widely accepted that age, BMI and sociodemographic factors modulate treatment response in chronic pain studies [42]. However, this study provides a new perspective that standardised protocols may also be effective rather than individualised adaptations, as the effect of self-exercise emerged independently of these factors. By emphasising the critical role of pre-treatment functional status (neck disability level) in predicting outcomes, the study proposes a new predictive model based on ‘functional baseline status’ as an alternative to the ‘pain severity-focused’ prognosis models in the literature [43].

The limited sample size and short follow-up period of our study limit the generalisability of the findings. In addition, the level of resistance used in the exercise protocol was not objectively quantified or standardized, which may limit the reproducibility of the intervention across different clinical settings. In future studies, it is recommended to compare the effects of different exercise protocols on both functional outcomes and endurance parameters. Furthermore, longitudinal studies examining the predictive role of pre-treatment disability level in more detail are needed.

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CONCLUSION

In conclusion, this study demonstrated that a home-based structured exercise intervention (self-exercise) produced significant improvements in pain, functional disability, and kinesiophobia in individuals with chronic neck pain. Although no significant improvement was observed in deep cervical flexor endurance, the findings highlight the importance of individualized exercise approaches targeting the deep cervical stabilizing system to optimize rehabilitation outcomes.

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Additionally, baseline neck disability levels were identified as a significant predictor of post-treatment outcomes.

REFERENCES

1- Kazeminasab S. et al. Neck pain: global epidemiology, trends and risk factors. *BMC Musculoskelet Disord*. **3**;23(1):26. doi: 10.1186/s12891-021-04957-4. (2022).

2- Qu N, Tian H, De Martino E & Zhang B Neck Pain: do we know enough about the sensorimotor control system?. *Front. Comput. Neurosci.* **16**, 946514. doi: 10.3389/fncom.2022.946514. (2022).

3- Andelic, N. et al. Linking self-determined functional problems of patients with neck pain to the International Classification of Functioning, Disability, and Health (ICF). *Patient Preference and Adherence,* ***6,*** 749–755. https://doi.org/10.2147/PPA.S36165. (2012).

4- Ortego G, Lluch E, Herrero P, Boudreau SA & Doménech-García V. Profiling and association over time between disability and pain features in patients with chronic nonspecific neck pain: a longitudinal study. *J Clin Med.* **28,** 11(5):1346. doi: 10.3390/jcm11051346. PMID: 35268437; PMCID: PMC8911229. (2022).

5- Colman D. et al. Exercise therapy including the cervical extensor muscles in individuals with neck pain: A systematic review. *Clinical Rehabilitation*. **37**(12):1579-1610. doi:10.1177/02692155231184973. (2023).

6- Iqbal ZA, Alghadir AH & Anwer S. Efficacy of deep cervical flexor muscle training on neck pain, functional disability, and muscle endurance in school teachers: a clinical trial. *Biomed Res Int.* **13**, 2021:7190808. doi: 10.1155/2021/7190808. /2021/7190808. (2021).

7- Pardos-Aguilella, P. et al. Correlation between neck muscle endurance tests, ultrasonography, and self-reported outcomes in women with low cervical disability and neck pain. *Applied Sciences*, ***13***(18), 10106. https://doi.org/10.3390/app131810106. (2023).

ARTICLE IN PRESS

8- Colman D. et al. Cervical muscle activation in response to an extensor endurance test in individuals with and without neck pain: a muscle functional magnetic resonance imaging study. *Musculoskelet Sci Pract.* **82**, 103522. doi: 10.1016/j.msksp.2026.103522.(2026).

9- Bicer, A., Yazici, A., Camdeviren, H., & Erdogan, C. Assessment of pain and disability in patients with chronic neck pain: Reliability and construct validity of the Turkish version of the neck pain and disability scale. *Disability and Rehabilitation,* **26,** (16), 959–962. https://doi.org/10.1080/09638280410001696755. (2004).

10- Leak, AM. et al. The northwick park neck pain questionnaire, devised to measure neck pain and disability. *British Journal of Rheumatology,* **33** (5), 469–474. https://doi.org/10.1093/rheumatology/33.5.469. (1994).

11- Manako T, Imade S, Yamagami N, Yamamoto S & Uchio Y. The clinical outcomes of scaphoid nonunion treated with a precisely processed autologous bone screw: a case series. *Arch Orthop Trauma Surg*. **143,** (2):627-635. doi: 10.1007/s00402-021-04092-8. (2023).

12- Broisler CN, Gaban GLNA, Vivaldini MRS, Nunes GS & Selistre LFA. Intra- and inter-rater reliability, standard error of measurement, and minimal detectable change of the cranio-cervical flexion test in individuals with non-specific chronic neck pain. *Musculoskelet Sci Pract*. **76,** 103258. doi: 10.1016/j.msksp.2025.103258. (2025).

13- Gürsan, K., & Bayar, K. Adaptation of the keele assessment of participation into turkish: validity and reliability studies. *Sakarya University Journal of Holistic Health, 5*(3), 218–233. https://doi.org/10.54803/sauhsd.995688. (2022).

14- Wilkie, R., Peat, G., Thomas, E., Hooper, H., & Croft, P. R. The keele assessment of participation: a new instrument to measure participation restriction in population studies. Combined qualitative and quantitative examination of its

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psychometric properties. *Quality of Life Research,* ***14***(8), 1889–1899. https://doi.org/10.1007/s11136-005-4325-2. (2005).

15- Kurt M. et al. Effects of combined supervised and telerehabilitation exercise programs on pain and disability in dentists with chronic neck pain: a randomized controlled trial. *BMC Musculoskeletal Disorders,* **26** (1): 240. https://doi.org/10.1186/s12891-025-09010-2. (2025).

16- Falla D., Jull G. & Hodges P. Training the cervical muscles with prescribed motor tasks does not change muscle activation during a functional activity. *Manual Therapy,* **13,** (6), 507–512. https://doi.org/10.1016/j.math.2007.07.001. (2008).

17- Chaiyawijit S & Kanlayanaphotporn R. McKenzie neck exercise versus cranio-cervical flexion exercise on strength and endurance of deep neck flexor muscles, pain, disability, and craniovertebral angle in individuals with chronic neck pain: a randomized clinical trial. *J Man Manip Ther.* **32**,(6):573-583. doi: 10.1080/10669817.2024.2337979. (2024).

18- Andersen LL, et al. Effect of two contrasting types of physical exercise on chronic neck muscle pain. *Arthritis Rheum.* **15**, 59(1):84-91. doi: 10.1002/art.23256. (2008).

19- Kim WD & Shin D. Comparison of outcomes of physical therapy exercises combined with either a video-based smartphone application system or a written exercise program handout in 34 patients with non-specific neck pain. *Med Sci Monit*. **31**, 30:e945349. doi: 10.12659/MSM.945349. (2024).

20- He X, et al. Comparison of mobile health-based exercise vs traditional exercise for chronic neck pain: a systematic review and meta-analysis. *J Pain Res.* **7**, 18:4639-4649. doi: 10.2147/JPR.S526845. (2025).

21- Zabala-Mata J et al. Limited association between central pain processing and clinical outcomes in non-specific chronic neck pain after a manual therapy intervention: A secondary analysis. *Musculoskelet Sci Pract. 77*, 103323. doi: 10.1016/j.msksp.2025.103323. (2025).

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22- Andersen, C. H., Andersen, L. L., Zebis, M. K., & Nielsen, P. K. Effect of scapular function training on chronic pain in the neck/shoulder region: A randomised controlled trial. *Journal of Occupational Rehabilitation.* **30**, (1), 125–134. https://doi.org/10.1007/s10926-019-09854-1. (2020).

23- Kaynak, H., Kaynak, D., & Öztürk, A. The effectiveness of exercise interventions on pain and disability in chronic neck pain: A systematic review with meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy,* **51**, (3), 101–112. https://doi.org/10.2519/jospt.2021.9876. (2021).

24- Miranda, IF, Dhein W, Neto EW & Loss JF. Comparison of maximum voluntary isometric contraction to normalize superficial neck muscle EMG. *Journal of Bodywork and Movement Therapies*. **45,** 238–243. https://doi.org/10.1016/j.jbmt.2025.08.005. (2025).

25- Peterson G, Nilsson D, Jönsson M. Bennett K & Peolsson A. Neck muscle function improves after neck exercises in individuals with whiplash-associated disorders: a case–control ultrasound study with speckle-tracking analyses. *Sci Rep* **14**, 18793 https://doi.org/10.1038/s41598-024-69136-6. (2024).

26- Schomacher J, Dideriksen JL, Farina D & Falla D. Recruitment of motor units in two fascicles of the semispinalis cervicis muscle. *J Neurophysiol*. **107**, (11):3078-85. doi: 10.1152/jn.00953.2011. (2012).

27- Yang R et al. Biomechanical mechanisms of multidirectional dynamic compensatory muscle fatigue induced by abnormal cervical curvature: a cross-sectional case-control study based on surface electromyography and Cobb angle. *Front Sports Act Living.* **4**, 7:1704956. doi: 10.3389/fspor.2025.1704956. (2025).

28- Sjøgaard, G., Rosendal, L., Blangsted, A. K., Sogaard, K., & Krustrup, P. The role of exercise intensity and duration in the rehabilitation of work-related muscle pain. *Scandinavian Journal of Work, Environment & Health,* **46**, (4), 341–352. https://doi.org/10.5271/sjweh.3886. (2020).

ARTICLE IN PRESS

29- Peterson G, Nilsing Strid E, Jönsson M, Hävermark J & Peolsson A. Effect of neck-specific exercises with and without internet support on cervical range of motion and neck muscle endurance in chronic whiplash-associated disorders: analysis of functional outcomes of a randomized controlled trial. *J Rehabil Med*. **29**, 56:jrm34785. doi: 10.2340/jrm.v56.34785. (2024).

30- Massimiliano A et al. Regional Differences In Mitochondrial Adaptations After Eccentric Resistance Training In Old Men: 2529. *Medicine & Science in Sports & Exercise* **56**, (10S):p 946.| DOI: 10.1249/01.mss.0001060768.67796.ee. (2024).

31- Amjad M, Ur Rehman SS, Fatima G, Ikram M & Ghafoor S. Comparative effects of isometric and isotonic global neck muscles strengthening exercise programme on pain, range of motion, strength, function and quality of life in patients with chronic mechanical neck pain. *Journal of the Pakistan Medical Association*. **74,** (10), 1843–1846. https://doi.org/10.47391/JPMA.11378. (2024).

32- Chys M et al. Evaluating the effectiveness of patient-tailored treatment for patients with non-specific (sub)acute neck pain. *Musculoskelet Sci Pract.* **75**, 103235. doi: 10.1016/j.msksp.2024.103235. (2025).

33- Peterson G, Ljunggren S & Peolsson A. Factors related to pain and disability outcomes after an ınternet-delivered or physiotherapist-led exercise program for ındividuals with chronic whiplash symptoms: secondary analysis of a randomized controlled study. *JMIR Hum Factors*. **30,** 12:e67991. doi: 10.2196/67991. (2025).

34- Chen Z, Tse MMY & Wong BYM. exercise habits and preferences of community-dwelling older adults with chronic pain: an exploratory study. *Healthcare (Basel).* **11,** 13(4):384. doi: 10.3390/healthcare13040384. (2025).

35- Shimoda T, Tomida K, Nakajima C, Kawakami A & Shimada H. Combined self-reported and device-measured physical activity assessment and disability ıncidence in older adults. *J Am Med Dir Assoc*. **26,** (6):105375. doi: 10.1016/j.jamda.2024.105375. (2025).

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36- Sathiyaseelan N. et al. Effectiveness of biopsychosocial approach for subacute neck pain among geriatrics. *Fizjoterapia Polska*. **24,** (4), 147–152. (2024).

37- Chen, Y., Wang, L., & Zhang, H. Virtual reality-based rehabilitation for neck pain: A feasibility study. *Journal of Rehabilitation Technology, **15,*** (2), 45–58. (2021).

38- Lee, K., & Park, J. Head-tracking devices for neck muscle tension estimation: A validation study. *Sensors, **22***, (8), Article 3015. https://doi.org/10.3390/s22083015. (2022).

39- Kim, J., Park, S., & Choi, M. Biofeedback-enhanced home exercise adherence in chronic neck pain: A pilot randomized trial. *Clinical Rehabilitation,* **37**, (5), 623–634. https://doi.org/10.1177/02692155221141089. (2023).

40- Garcia, M., Lee, S., & Thompson, R. Engineering-focused vs. clinically validated digital health tools in musculoskeletal rehabilitation: A scoping review. *Health Technology Assessment,* **29, (**4), 112–125. (2023).

41- Wang, X., Liu, Y., & Zhou, F. Comparative effectiveness of traditional vs. technology-assisted neck rehabilitation: A systematic review and meta-analysis protocol. *BMJ Open,* **14**, (1), Article e078432. https://doi.org/10.1136/bmjopen-2023-078432. (2024).

42- Guerra-Arencibia L et al. Effectiveness of a telerehabilitation-based exercise program in patients with chronic neck pain-a randomized clinical trial. *Sensors (Basel).* **18**, 24(24):8069. doi: 10.3390/s24248069. (2024).

43- Letzel J, Angst F & Weigl MB. Multidisciplinary biopsychosocial rehabilitation in chronic neck pain: a naturalistic prospective cohort study with intraindividual control of effects and 12-month follow-up. *Eur J Phys Rehabil Med.* **55,**(5):665-675. doi: 10.23736/S1973-9087.18.05348-0. (2019).

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Data Curation, Investigation, Methodology, Software, Validation. FS: Formal Analysis.

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Table 1. Comparisons of demographic and health related status

Parameters	**Exercise group (n=35) M±SD**	**Control group (n=30) M±SD**	P value
Gender			
Female	29	22	0.352
Male	6	8	
Marital status			
Married	28	17	0.06
Single	7	13	
Education			
Graduate	2	6	**<0.001**
Undergraduate	8	11	
High School	6	13	
Middle school	19	0	
Work			
Employee	11	17	0.111
Student	4	3	
Housewife	20	10	
Age (years)	42.37±10.33	34.43±11.95	**0.006**
BMI (kg/cm^2)	26.83±5.23	23.97±4.44	**0.031**
Chronic disease			
Yes	19	11	0.05
No	16	19	
Previously treated for pain			
Treated	24	8	0.001
Not treated	11	22	

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When did your pain first occur (years ago)	6.38±6.10	4.14±4.09	**0.103**
Pain duration (hours)	16.60±10.57	10.07±10.87	**0.085**

BMI: body mass index

Table 2. Changes in outcome measures before and after intervention in the exercise and control groups

Parameter	**Group**	**Mean±SD**		**p[1] value**	Cohen D	p[2] value	Partial η^2
		Baseline	**Postintervention**				
Flexion endurance	EG	60.49±60.45	74.80±67.16	<0.001	**0.87**	**<0.001**	0.20
	CG	54.14±84.75	54.91±84.39	0.647	0.10		
Extension endurance	EG	124.40±116.76	124.40±116.76	0.001	0.59	0.008	0.11
	CG	125.33±193.73	125.33±193.73	0.221	0.08		
Deep flexion endurance	EG	29.46±37.59	29.46±37.59	0.175	0.23	0.657	0.003
	CG	23.79±21.57	23.79±21.57	0.240	0.23		
KPA	EG	4.23±3.18	4.23±3.18	<0.001	0.77	0.001	0.234
	CG	2.20±2.23	2.20±2.23	0.264	0.22		
NPNPQ	EG	16.49±6.01	16.49±6.01	<0.001	1.14	<0.001	0.387
	CG	6.27±4.98	6.27±4.98	0.326	0.21		
VAS	EG	7.17±2.09	7.17±2.09	<0.001	**1.747**	<0.001	0.560
	CG	3.46±2.63	3.40±2.66	0.601	0.18		

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p^1 indicates within-group pre–post comparison (paired samples test). p^2 indicates the time × group interaction effect from mixed-design ANOVA. Partial η^2 represents the effect size for the interaction. KPA: Keele Participation Assessment, NPNPQ: Northwick Park Neck Pain Questionnaire, VAS: Visuel Analog Scale

Tablo 3. Baseline and Postintervention Measurement Findings in the Exercise Group Acc
Characteristics

	Parameters	**n**	**Baseline VAS**	**Postinter. VAS**	**Baseline Cervical Flexion Endurance**	**Postinter. Cervical Flexion Endurance**	**Baseline Cervical Extension Endurance**	**Postinter. Cervical Extension Endurance**	**Baseline Cervical Deep Flexion Endurance**	**Postinr. Cervic Deep Flexio Endur nce**
Gender	Women	29	7,48±2,10	3,55±2,01	43,52±36,58	57,17±41,82	118,59±120,24	168,10±155,67	25,45±38,48	35,07±3,95
	Men	6	5,67±1,37	3,67±2,73	142,50±87,46	160,00±101,82	152,50±102,93	164,83±110,86	48,83±27,80	56,50±2,02
	t		2,02	-0,12	-2,72	-2,43	-0,64	0,05	-1,41	-1,54
	p		0,052	0,905	0,039	0,056	0,525	0,961	0,169	0,133
Marital status	Married	28	7,36±2,20	3,82±2,07	56,46±56,41	72,25±64,36	114,04±103,61	163,14±145,95	31,57±41,78	38,93±3,92
	single	7	6,43±1,51	2,57±2,07	76,57±77,72	85,00±82,28	165,86±162,59	185,14±164,41	21,00±6,83	38,00±1,33
	t		1,05	1,43	-0,78	-0,44	-1,05	-0,35	0,66	0,07
	p		0,301	0,163	0,44	0,66	0,3	0,73	0,514	0,946
Work	employee a	11	7,09±1,51	4,18±2,36	81,00±70,19	95,36±79,62	104,82±51,09	151,18±109,57	34,45±26,27	45,27±2,93
	Hausewife b	4	6,25±1,71	2,50±2,08	111,25±90,97	119,75±98,71	228,00±200,33	239,50±208,47	22,75±7,89	42,50±1,08
	Student c	20	7,40±2,44	3,45±1,96	39,05±37,14	54,50±45,75	114,45±118,74	162,15±156,50	28,05±46,15	34,40±3,34
	F / Welch		0,5 f	1,02 f	2,5 w	2,54 f	0,7 w	0,54 f	0,17 f	0,44 f
	p		0,611	0,374	0,153	0,095	0,526	0,587	0,847	0,65
	Differences									
Chronic disease	Yes	19	6,95±2,25	3,84±2,22	56,89±62,68	68,89±69,37	125,74±130,68	169,47±150,41	25,00±21,99	42,89±3,99
	No	16	7,44±1,93	3,25±1,98	64,75±59,53	81,81±65,99	122,81±101,98	165,25±148,91	34,75±50,67	33,81±1,31
	t		-0,69	0,83	-0,38	-0,56	0,07	0,08	-0,76	0,84
	p		0,498	0,415	0,708	0,579	0,942	0,934	0,453	0,405
Previously treated for pain	Treated	24	7,33±2,14	3,46±2,15	47,13±37,56	59,71±39,89	126,25±132,13	176,17±168,76	28,63±42,95	36,92±3,59
	Not treadet	11	6,82±2,04	3,82±2,09	89,64±88,51	107,73±99,69	120,36±78,56	148,73±89,05	31,27±23,59	42,73±2,92
	t		0,67	-0,46	-1,53	-1,54	0,14	0,63	-0,19	-0,5
	p		0,507	0,646	0,152	0,15	0,892	0,534	0,85	0,621
Age		**r**	-0,098	0,163	0,095	0,112	-0,05	0,07	0,287	0,222
		p	0,574	0,349	0,585	0,522	0,776	0,689	0,094	0,2
BMI		**r**	-0,218	-0,115	0,063	0,062	-0,11	-0,067	0,132	0,027
		p	0,209	0,512	0,72	0,723	0,53	0,704	0,449	0,879

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When did your pain first occur	**r**	-0,042	0,191	0,241	0,301	-0,073	0,112	0,157	0,09
	p	0,809	0,271	0,162	0,079	0,677	0,521	0,367	0,606
Pain duration	**r**	0,397*	0,149	-0,138	-0,106	-0,053	0,056	0,081	-0,13
	p	0,018	0,394	0,429	0,543	0,764	0,75	0,646	0,458

KPA: Keele Participation Assessment, NPNPQ: Northwick Park Neck Pain Questionnaire, BMI: Body Mass Index

Figure 1. Consort diagram

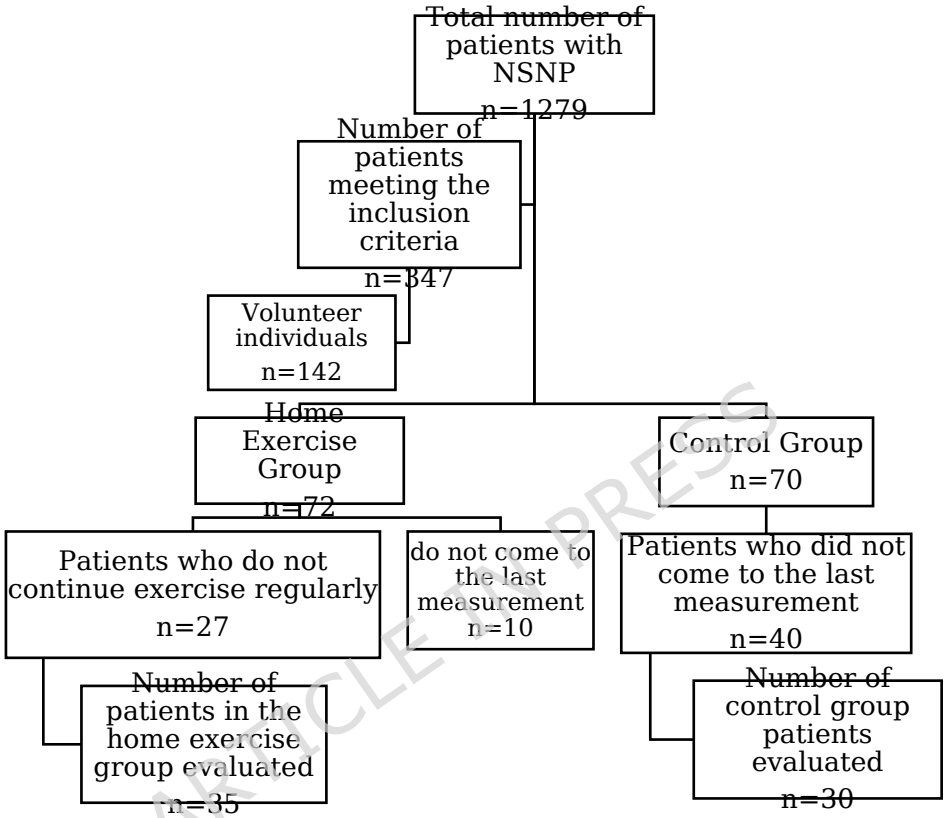


Figure 2. Study timeline and participant involvement

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Study Timeline and Participant Involvement

STUDY PHASE	EXERCISE GROUP	CONTROL GROUP	OUTCOME ASSESSMENTS
Week 0 (Baseline)	Exercise instruction and training	Informative booklet provided	Baseline assessments performed
Week 1-4	Home exercise program (3 sets × 10 repetitions/day) + weekly phone reminders + exercise tracking form	No exercise intervention	-
Week 4 (Postintervention)	Return to clinic	Return to clinic	Post-intervention assessments performed

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