

doi: 10.63360/ipmm.v1.e6

Longitudinal observational Study

Longitudinal relationship between disability and psychosocial factors in patients with chronic nonspecific neck pain

Gorka Ortego¹  0009-0000-5344-3831

Enrique Lluch²  0000-0003-4119-7551

Victor Doménech-García^{3,4}  0000-0002-7007-0368

¹Servicio Aragonés de Salud: Zaragoza, Spain.

²Universidad de Valencia, Valencia, Spain.

³Aalborg University, Aalborg, Denmark.

⁴Universidad San Jorge, Zaragoza, Spain.

ABSTRACT

Background and objectives: To longitudinally investigate the relationships between neck/arm disability and psychosocial factors in individuals with chronic nonspecific neck pain (NSNP) at baseline, one month, and six months after a standardized physiotherapy intervention. A secondary aim was to compare psychosocial factors of individuals with chronic NSNP to healthy controls at baseline.

Methods: A total of sixty-eight individuals with chronic NSNP and healthy controls were recruited. Neck/arm disability, stress, anxiety, depression, pain catastrophizing, kinesiophobia, health-related quality of life and sleep quality were assessed in individuals with chronic NSNP. For the cross-sectional assessment, psychosocial factors were compared to healthy controls.

Results: Neck/arm disability and psychosocial factors remained unchanged during the study in chronic NSNP individuals. Furthermore, several correlations were found between neck/arm disability and psychosocial factors along the time. Significant intergroup differences were found in stress, anxiety, depression, pain catastrophizing, kinesiophobia, health-related quality of life and sleep quality. However, there were no differences in catastrophizing and kinesiophobia between chronic NSNP and healthy groups.

Conclusions: Psychosocial factors tend to maintain over time in individuals with chronic NSNP despite receiving standardized physiotherapy intervention. Future studies should investigate whether individualized physiotherapy interventions addressing psychosocial factors modify the course of disability over time in individuals with chronic NSNP.

Keywords: Disability; nonspecific neck pain; psychosocial factors.

1. Introduction

The prevalence and disability associated to neck pain has increased markedly in the last 25 years⁽¹⁾. Although it generally has a favorable prognosis, one third of people with acute neck pain develop chronic neck pain⁽²⁾, resulting in high levels of physical disability and healthcare costs⁽³⁾ and having a significant impact on health-related quality of life⁽⁴⁾. The essential feature of nonspecific neck pain (NSNP) is the lack of a specific systemic disease or pathology as the underlying cause⁽⁵⁻⁷⁾. Rather, it is widely recognized that chronic NSNP is multifactorial in nature, with both physical and psychosocial factors contributing to patients' pain experience⁽⁸⁾.

Anxiety and stress are two of the most important psychological factors that have been shown to be associated with higher levels of disability in individuals suffering from different musculoskeletal pain conditions⁽⁹⁾. Specifically in individuals with chronic NSNP, some studies have demonstrated an association with stress as well as between anxiety and disability levels⁽¹⁰⁻¹²⁾. Depression also seems to be correlated with neck pain and disability levels although results from different studies are somewhat contradictory^(11, 13, 14). Fear and avoidance of movement is also considered an important factor associated to disability in individuals with chronic NSNP⁽¹⁵⁾. Moreover, the presence of pain catastrophizing beliefs, broadly defined as an exaggerated negative orientation toward pain stimuli and pain experience⁽¹⁶⁾, has shown to increase 3.8 times the risk for pain chronicity⁽¹⁷⁾ and to be associated with high levels of disability in individuals with chronic NSNP⁽¹⁰⁾. Additionally, in individuals with chronic neck pain, poor sleep quality has been related with disability⁽¹⁸⁾. However, the trajectory of sleep quality has not been investigated in individuals with chronic NSNP yet.

To the authors' knowledge, the relationship between psychosocial factors and neck/arm disability levels in individuals with chronic NSNP has not been evaluated over time and it has been barely investigated in some observational studies^(19, 20). Moreover, it has been suggested that due to the cross-sectional nature of the studies, conclusions on causal impact are limited and longitudinal study designs would be necessary to better understand the relationship between psychosocial factors and neck disability⁽²¹⁾. Furthermore, exploring associations between these psychosocial factors over time in individuals with chronic NSNP could be relevant to design more specific treatment strategies for the clinical practice.

The purpose of this study was to investigate the associations between neck/arm disability and psychosocial factors (i.e., stress, anxiety, depression, pain catastrophizing, kinesiophobia, health-related quality of life and sleep quality) in individuals with chronic NSNP, both cross-sectionally and longitudinally. As a secondary aim, the psychosocial profile of individuals with chronic NSNP was contrasted with a healthy control group. It was hypothesized that neck/arm disability would be associated with psychosocial factors over time in individuals with chronic NSNP.

2. Materials and Methods

2.1. Study Design

This study is part of a multidimensional longitudinal study in individuals with chronic NSNP, who were followed for a 6-month period. Age and gender-matched healthy controls were evaluated at baseline. The research was guided from May 2020 to January 2021 in accordance with the STROBE statement⁽²²⁾. Prior beginning the study, all individuals read and signed an informed consent. The local Research Ethics Committee authorized the study (record no. 19/17), and all procedures were conducted according to the Helsinki Declaration. The study was recorded on ClinicalTrials.gov (NCT04330573).

Individuals with chronic NSNP were recruited by referrals from a public hospital's rehabilitation service, while healthy controls were recruited through announcements. One blinded assessor performed all the outcome measurements in both groups. Healthy controls were evaluated at baseline for the cross-sectional study, whereas individuals with chronic NSNP were evaluated at baseline, at 1-month and at 6-months follow-up for the longitudinal study. All individuals with chronic NSNP were treated by three independent physiotherapists for four-weeks with a standardized conservative physiotherapy treatment program consisting of daily 45min-sessions (5 sessions/week) of general neck exercises⁽²³⁾ and transcutaneous electrical nerve stimulation, implemented at the public hospital. After the first month, the participants did not receive any physiotherapy treatment. Since the aim of the study was to evaluate psychosocial factors from a pragmatic perspective, the treatment that the participants received was independent from the study and the authors did not influence its characteristics.

2.2. Participants

Inclusion criteria for individuals with chronic NSNP were: 1) aged between 18 and 65 years; 2) being able to understand, write, and speak in Spanish; 3) having suffered neck pain during the last 12 weeks; 4) pain localized in the neck region with or without pain radiation to the upper limb^(6, 7); 5) negative Spurling test; 6) a score <12 on the Self-Administered Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS)⁽²⁴⁾; 7) negative Upper Limb Neurodynamic Test 1 (ULNT1)⁽²⁵⁾; and 8) a score <12 on the PainDetect⁽²⁶⁾.

Individuals with chronic NSNP were excluded from the study if any of the following criteria were present: 1) presence of red flags or serious pathology as reported in the medical history (i.e. tumor, fracture, metabolic diseases, rheumatoid arthritis, osteoporosis); 2) cervical radiculopathy⁽²⁷⁾; 3) fibromyalgia; 4) previous neck surgery; and 5) currently undergoing any treatment for neck pain or having received treatment for neck pain during the previous three months.

Sample size was calculated using sample calculation software (Mallinckrodt General Clinical Research Center, Boston, USA) based on the NDI and QuickDASH as the primary outcome measures. This calculation revealed a minimum sample size of 13 individuals per group for a power of 0.9 using NDI (minimum detectable change 8.4; standard deviation 8.1)⁽³⁸⁾ and 25 individuals per group for a power of >0.8 calculated with QuickDASH (minimum detectable change 11; standard deviation 18.6). Considering the biggest sample size (i.e., with QuickDASH) and 30% dropout rate, the sample size calculation was increased to 34 individuals per group.

2.3. Variables and Follow-up

Primary outcome measurements

Neck/arm disability measured with the Neck Disability Index (NDI) and the 11-item disabilities of the arm, shoulder and hand questionnaire (QuickDASH) were selected as the primary measurements to assess neck/arm disability^(28, 29).

The NDI is a self-applied questionnaire consisting of 10 sections with 6 possible answers representing six progressive levels of functional disability, rated from 0 to 5, with 0 being the first level and 5 the last level of each section. The total score ranges from 0 to 50 points, with higher scores indicating greater disability. The test-retest reliability has proven to be adequate (ICC=0.97) and it has been validated for the Spanish language⁽³⁰⁾.

The Spanish QuickDASH is a shortened version of the DASH questionnaire which is used for assessing upper extremity disability in patients with neck pain^(28, 29). QuickDASH is scored from 0 (no disability) to 100 (worst possible disability). Cross-cultural adaptation process and reliability of the DASH questionnaire (Spanish version) were well defined with excellent test-retest reliability (ICC = 0.90 – 0.94)⁽²⁹⁾.

Secondary outcome measurements

DASS-21 is a 21-item self-reported instrument designed to measure three related negative emotional states including depression, anxiety, and stress. It is comprised of 21-items, with seven items for each subscale. Each item in the three scales is rated from 0 to 3 (0= it never happened to me; 3= it happened to me almost always) (total score ranging from 0 to 63). The Spanish version of the DASS-21 has shown good reliability (ICC= 0.96)⁽³¹⁾.

The Spanish version of the Tampa Scale of Kinesiophobia (TSK-11) was used to measure fear of movement⁽³²⁾. Each item of the TSK-11 is scored on a four-point Likert-type scale that ranges from 0= “*strongly agree*” to 4= “*strongly disagree*”. Total scores then range from 11 to 44 with higher scores indicating more fear of movement. The Spanish version of the TSK-11 has shown good psychometric reliability for chronic pain (ICC= 0.81)⁽³³⁾.

Pittsburg Sleep Quality Index (PSQI) was used to assess participants' sleep quality and disturbances during the last six months⁽³⁴⁾. It consists of 19 items which are rated on a four-point scale (0–3) and grouped into seven components (sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medications, and daytime dysfunction). Total PSQI scores were calculated as the summation of seven component scores ranging from 0 to 21, with higher score indicating poorer sleep quality. The Spanish version of PSQI has shown good psychometric reliability for chronic pain (ICC=0.77)⁽³⁵⁾.

Health-related quality of life was measured with the Spanish version of the EuroQoL Five Dimensions and Five Levels (EQ-5D-5L). EQ-5D-5L consists of two elements: The first one is a 5-item questionnaire, with one item corresponding to each assessed domain (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), and five levels on each domain (1-no problems, 2-slight problems, 3-moderate problems, 4-severe problems, and 5-extreme problems). The interpretation of the results on the EQ-5D-5L was by means of the Index (EQ-Index).

The second part of the questionnaire is a vertical 20 cm Visual Analogue Scale (EQ-VAS) in which participants are asked to self-rate their health, from 0 “The worst health you can imagine” to 100 “The best health you can imagine.” The Spanish EQ-5D-5L has shown a minimal floor and ceiling effects (<3%) and a good reliability (ICC= 0.86)⁽³⁶⁾.

Pain catastrophizing scale (PCS) consists of 13 questions addressing feelings and thoughts related to the experience of pain. Each question is answered on a 5-point Likert scale with 0 being “not at all” and 4 being “all the time”, giving a total score ranging from 0 to 52. The higher the score, the more catastrophizing thoughts are present. The Spanish version of PCS has demonstrated acceptable psychometric properties with a good reliability (ICC= 0.84)⁽³⁷⁾.

After collecting sociodemographic information, individuals with chronic NSNP who received the standardized treatment in the public hospital were assessed within a single session at baseline (both the chronic NSNP and healthy control groups), at 1-month and at 6-month follow-up (only the chronic NSNP group), whereas healthy controls were only assessed at baseline.

2.4. Risk of Bias

To decrease the risk of bias in this study, all participants were assessed by an independent physiotherapist. Three independent physiotherapists, each blinded to the results of the assessments, performed the treatments.

To address other potential biases, we adopted additional strategies, such as randomly assigning participants to treatment, conducting regular training for physiotherapists to standardize procedures, and employing robust statistical methods to analyze the data, including intention-to-treat analyses to account for dropouts.

2.5. Statistical Analysis

Data were analyzed using SPSS version 21.0 (SPSS, Inc, Chicago, IL). Results are expressed as mean and standard deviation (SD), considering the 95% CI. The Kolmogorov-Smirnov test was used to analyze the normal distribution of the data. Quantitative data with a normal distribution (e.g., PCS, NDI) were analyzed with parametric tests. In the cross-sectional part of this study, an independent t-test was used to compare the psychosocial outcomes between the chronic NSNP and healthy control groups. Effect sizes were calculated through Cohen's d according to the formula $d = \text{mean difference} / \text{SD}$. Effect sizes were considered small if $d \leq 0.2$, medium if $d \geq 0.2$ or $d \leq 0.8$ and large if $d > 0.8$ ⁽⁶¹⁾. A per protocol analysis was carried out, not considering missing data. A complementary intention to treat analysis was also done to compare the results and analyze if there are any differences due to a different methodology of analysis.

A repeated-measures analysis of variance (ANOVA) with Bonferroni post-hoc test was performed in the chronic NSNP group to compare all the outcome measures between baseline, 1-month and 6-month intervals. The influence of pain duration (months with pain before entering the study) at baseline on the rest of outcome measures was analysed as a co-variable with an Analysis of Covariance (ANCOVA).

Correlations between neck/arm disability measured with the QuickDASH and NDI and psychosocial outcomes in the chronic NSNP group at baseline, 1-month and 6-month were estimated

using Pearson's correlation coefficient. Correlations between neck/arm disability changes and the rest of outcome measures over time were also estimated using the Pearson's correlation coefficient. For all statistical analyses, differences were considered significant if $p < 0.05$.

3. Results

3.1 Sample Description

A total of 68 individuals participated in the study (Figure 1). Nine individuals from the chronic NSNP group dropped out (three at 1-month and six at 6-month follow-up). No significant between-groups differences were observed for sociodemographic data at baseline (all $p > 0.05$) (Table 1).

Table 1. Demographics of participants in chronic Nonspecific Neck Pain (NSNP) and healthy control groups. Continuous variables are expressed as a mean and standard deviation ($\pm$ SD) and categorical variables^a are expressed as mean and percentage. Pain duration is expressed as a median and interquartile range (IQR) and refers to the total time with symptoms at baseline. * $p < 0.05$ ** $p < 0.01$

	Chronic NSNP group (n=34)	Healthy control group (n=34)	p-value
	Mean $\pm$ SD	Mean $\pm$ SD	
Age (years)	47.9 $\pm$ 10.8	44.4 $\pm$ 10.7	0.18
Gender, n female (%) ^a	82.4 %	76.5 %	0.55
Height (cm)	165 $\pm$ 8.02	168.2 $\pm$ 8.7	0.30
Weight (kg)	67.9 $\pm$ 13.7	71.1 $\pm$ 12.0	0.19
Pain duration (months)	48 (24-129)		

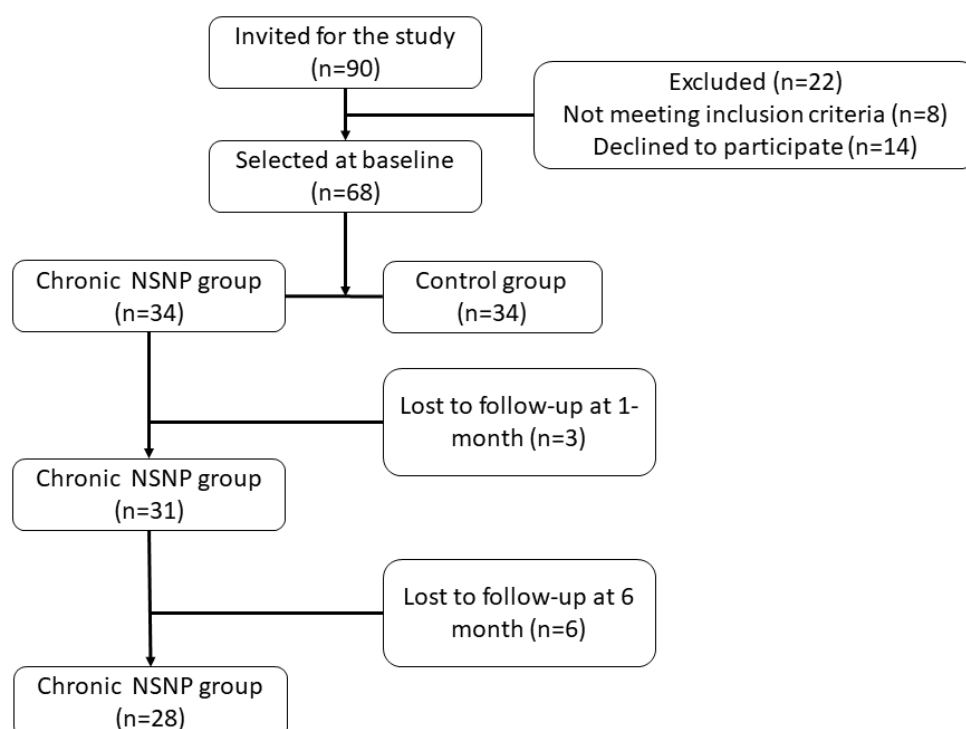


Figure 1. Flowchart of participants. Abbreviations: NSNP, nonspecific neck pain.

3.2. Main Variables

Longitudinal assessments of neck/arm disability and psychosocial factors within individuals with chronic NSNP (longitudinal study).

Neck/arm disability, pain catastrophizing, sleep quality, kinesiophobia, stress, anxiety, depression and health-related quality of life in the chronic NSNP group remained unchanged during the whole study (Table 2)

Table 2. Neck Disability Index (NDI), pain catastrophizing (PCS), Kinesiophobia (TSK-11), health-related quality of life (EQ-5D-5L and EQ-VAS), stress, anxiety, depression (DASS-21) and Sleep quality (PSQI) in the chronic Nonspecific Neck Pain (NSNP) group at baseline (n=34), 1-month (n=31) and 6-months (n=28) are expressed as a Mean and Standard deviation (SD). Repeated measures ANOVA. *P<0.05 **P<0.01

	Baseline (n=34) Mean ± SD	1-month (n=31) Mean ± SD	6-months (n=28) Mean ± SD	Differences baseline/1-month Mean + SD (P-value)	Differences 1-month/6-months Mean + SD (P-value)	Differences baseline/6-months Mean + SD (P-value)
NDI (0-50)	15 ± 6.2	13.7 ± 6.1	13.1 ± 7.5	1.3 ± 0.7 (0.34)	0.6 ± 0.9 (1)	1.9 ± 0.8 (0.06)
QuickDASH (0-100)	29.9 ± 15.4	29.4 ± 15.9	31.4 ± 19.7	0.5 ± 1.9 (1)	-2 ± 3 (1)	-1.5 ± 2.8 (1)
PCS (0-52)	14.7 ± 10.4	11.3 ± 9.2	11.4 ± 10	3.4 ± 1.4 (0.18)	-0.1 ± 1.3 (1)	3.3 ± 1.4 (0.11)
PSQI (0-21)	8.7 ± 4.4	8.3 ± 4.7	7.8 ± 5	0.4 ± 0.5 (1)	0.5 ± 0.6 (1)	0.9 ± 0.6 (0.67)
TSK-11 (11-44)	23.4 ± 6	23.2 ± 5.6	21.8 ± 6.4	0.2 ± 0.7 (1)	1.4 ± 0.8 (0.3)	1.6 ± 1 (0.43)
EQ-5D-5L (0-1)	0.74 ± 0.18	0.73 ± 0.19	0.70 ± 0.17	0.0 ± 0.0 (1)	0.0 ± 0.0 (1)	0.0 ± 0.0 (0.86)
EQ-VAS (0-100)	67.6 ± 16.2	69.58 ± 15.6	70.82 ± 16.4	-1.98 ± 2.3 (0.67)	-1.24 ± 2.1 (1)	-3.22 ± 2.7 (0.7)
DASS-21						
Stress (0-21)	7.9 ± 4	7.7 ± 5.2	6.5 ± 4.7	0.2 ± 0.6 (1)	1.2 ± 0.6 (0.33)	1.4 ± 0.6 (0.07)
Anxiety (0-21)	3.6 ± 3.3	3.9 ± 3.6	3.2 ± 3.7	-0.3 ± 0.4 (1)	0.7 ± 0.3 (0.43)	0.4 ± 0.5 (0.81)
Depression (0-21)	2.21 ± 2.5	2.6 ± 3.5	3 ± 3.7	-0.39 ± 0.5 (1)	-0.4 ± 0.5 (1)	-0.79 ± 0.6 (0.61)

Correlation analysis between neck/arm disability and psychosocial factors along baseline, at 1-month and 6-months in the chronic NSNP group (longitudinal study).

Regarding neck disability, a moderate positive correlation was observed between NDI and PCS (0.62 p<0.01), PSQI (0.52 p<0.01), EQ-5D-5L (-0.42 p<0.01), DASS-21 stress (0.43 p=0.01), DASS-21 anxiety (0.49 p<0.01) and DASS-21 depression (0.35 p=0.04) in the chronic NSNP group at baseline (Table 3). This correlation continued at 1-month and 6-month follow-up between NDI and PSQI (1-month: 0.69 p<0.01, 6-months: 0.62 p<0.01), EQ-5D-5L (1-month: -0.6 p<0.01, 6-months: -0.73 p<0.01), PCS (1-month: 0.65 p<0.01, 6-months: 0.54 p<0.01), DASS-21 stress (1-month: 0.54 p<0.01, 6-months: 0.76 p<0.01) and DASS-21 anxiety (1-month: 0.43 p=0.016, 6-months: 0.66 p<0.01). A first exploratory analysis of results showed the existence of a participant with an outlier value in the DASS-21 depression and other in the TSK-11. The results were calculated again removing these outliers and moderate correlations were found between NDI and DASS-21 depression (baseline 0.35 p=0.04; 1-month follow-up 0.51 p<0.01; 6-month follow-up 0.42 p=0.02)

and between NDI and TSK-11 (baseline 0.38 $p=0.03$; 1-month follow-up 0.49 $p<0.01$; 6-month follow-up 0.45 $p=0.01$).

In the case of arm disability, a moderate correlation between QuickDASH and PSQI (0.43 $p=0.01$), EQ-VAS (-0.41 $p=0.015$), DASS-21 stress (0.42 $p=0.013$) DASS-21 anxiety (0.36 $p=0.03$) and TSK-11 (0.38 $p=0.03$) were found at baseline. The correlation between QuickDASH and PSQI (1-month: 0.36 $p=0.03$, 6-months: 0.41 $p=0.02$), TSK-11 (1-month: 0.38 $p=0.03$, 6-months: 0.42 $p=0.02$), DASS-21 stress (1-month: 0.57 $p<0.01$, 6-months: 0.55 $p<0.01$) and DASS-anxiety (1-month: 0.35 $p=0.04$, 6-months: 0.48 $p<0.01$) continued along the time. However, EQ-5D-5L was correlated at 1-month (-0.69 $p<0.01$) and at 6-months (-0.64 $p<0.01$) whereas PCS was only correlated with QuickDASH at 6-months (0.43 $p=0.02$). When the analysis was repeated removing the previously mentioned outlier values the correlation remained significant between TSK-11 and QuickDASH (0.37 $p=0.039$) at baseline being still evident at 1-month (0.38 $p=0.03$) and 6-month follow-up (0.42 $p=0.02$). Furthermore, QuickDASH showed a moderate positive correlation with DASS-21 depression at 1-month (0.56 $p<0.01$). A summary of all correlations between neck/arm disability and the rest of outcome measures in the chronic NSNP group at baseline, 1-month and 6-month follow-up are shown in Table 3.

Table 3. Correlation coefficients between Neck Disability Index (NDI), QuickDASH and the rest of outcomes (Pain catastrophizing (PCS), Kinesiophobia (TSK-11), stress, anxiety, depression (DASS-21), health-related quality of life (EQ-5D-5L) and sleep quality (PSQI)) in the chronic Nonspecific Neck Pain (NSNP) group. Effect size is shown by the same correlation coefficients. Pearson correlation.^a Spearman correlation ^b $p<0.05$ ^c $p<0.01$.

	Baseline (n=34)		1-Month (n=31)		6-Months (n=28)	
	NDI	QuickDASH	NDI	QuickDASH	NDI	QuickDASH
PCS	0.62** (0.00)	0.28 (0.1)	0.65** (0.00)	0.28 (0.11)	0.54** (0.003)	0.43** (0.02)
TSK-11	0.38* (0.03)	0.37* (0.039)	0.49** (0.004)	0.38* (0.03)	0.45** (0.01)	0.42* (0.02)
PSQI	0.52** (0.002)	0.43** (0.01)	0.69** (0.00)	0.36* (0.03)	0.62** (0.00)	0.41* (0.02)
EQ-5D-5L	-0.42* (0.013)	-0.17 (0.31)	-0.6** (0.00)	-0.69** (0.00)	-0.73** (0.00)	-0.64** (0.00)
EQ-VAS	-0.32 (0.06)	-0.41** (0.015)	-0.21 (0.25)	-0.22 (0.23)	-0.35 (0.06)	-0.31 (0.1)
DASS-21						
Stress	0.43* (0.01)	0.42* (0.013)	0.54** (0.002)	0.57** (0.001)	0.76** (0.00)	0.55** (0.002)
Anxiety	0.49** (0.003)	0.36* (0.03)	0.43* (0.016)	0.35* (0.04)	0.66** (0.00)	0.48** (0.009)
Depression	0.35* (0.04) ^a	0.27 (0.12) ^a	0.51** (0.003) ^a	0.56** (0.001)	0.42* (0.02)	0.18 (0.34)

Comparison of psychosocial factors between the chronic NSNP and healthy control groups at baseline (cross-sectional study).

Significant differences between groups were found at baseline in health-related quality of life, sleep quality, stress, anxiety and depression with a medium effect size (Table 4).

Table 4. Stress, anxiety, depression (DASS-21), health-related quality of life (EQ-5D-5L and EQ-VAS) and sleep quality (PSQI) for the nonspecific neck pain (NSNP) and control groups showed differences and no difference in Kinesiophobia (TSK-11) and pain catastrophizing scale (PCS). The Student t test. ^a Depression is expressed as a range and typical error. ^bMann-Whitney test. ^cThe d Cohen (2t/√g). Abbreviations standard deviation (SD).

	Mean ± SD chronic NSNP group (N= 34)	Mean ± SD Control group (N=34)	Differences (P-value)	Effect size ^c
PCS (0-52)	14.7 ± 10.4	10.6 ± 10.1	0.1	-
TSK-11 (11-44)	23.4 ± 6	20.9 ± 8.7	0.19	-
EQ-5D-5L (0-1)	0.74 ± 0.18	0.97 ± 0.04	0.00**	-0.66
EQ-VAS (0-100)	67.6 ± 16.2	88.4 ± 8.2	0.00**	-0.62
PSQI (0-21)	8.7 ± 4.4	4.6 ± 3	0.00**	0.47
DASS-21				
Stress (0-21)	7.9 ± 4	3.3 ± 2.8	0.00**	0.55
Anxiety (0-21)	3.6 ± 3.3	1 ± 2	0.00**	0.43
Depression (0-21)	40.41 (0.43)	28.59 (0.35)	0.009** ^b	-0.31

4. Discussion

4.1. The course of neck/arm disability and psychosocial factors in the chronic NSNP group.

Disability and psychosocial factors remained unchanged at 6-months follow-up, which indicates that disability and psychosocial factors are reluctant to improve in a condition where pain tends to persist, such as NSNP, even following a standardized physiotherapy treatment. This is in line with another cross-sectional study finding correlations between psychosocial factors such as pain catastrophizing or health-related quality of life and disability in chronic NSNP individuals⁽²⁰⁾. A reason explaining the lack of improvement on these variables may be the physiotherapy intervention being focused only on biomedical aspects such as strength and classic analgesia (i.e., TENS), ignoring the psychosocial factors, where physiotherapists tend to feel less prepared to address⁽³⁹⁾. However, some studies suggested that physiotherapy treatments with a psychosocial approach improve disability individuals with chronic NSNP^(40, 41). Furthermore, it has been suggested that individualized treatment is key^(42, 43) when managing complex pain conditions such as chronic NSNP, which may explain the differences found as in the present study the treatment was the same for all.

4.2. Correlations between neck/arm disability and psychosocial factors along baseline, at 1-month and 6-months in the chronic NSNP group.

According to the results of our study, neck disability was associated with anxiety, depression, stress, pain catastrophizing, kinesiophobia, sleep quality, and health-related quality of life. An interesting finding of the study was that these correlations remained constant over time.

The literature recognizes anxiety as an important psychological factor associated with disability in individuals with neck pain which is in accordance with the results of the present study^(14, 44). Nevertheless, in the present study, the effect sizes of these associations were found to be higher than previous studies^(14, 44), something that could be attributed in part to the better homogeneity of the sample used in the current study, since all patients suffered from chronic NSNP. Moreover, anxiety could be a key psychological factor leading individuals with chronic NSNP to greater disability sustained over time.

The association between depression and neck disability in chronic neck pain is unclear. On the one hand, Duyur Cakit et al.⁽⁴⁵⁾ found similar results to ours while other studies found a lack of association between depression and neck disability^(11, 44). On the other hand, Elbinoune et al.⁽⁴⁴⁾ suggested, using a multivariate analysis, that educational level was related to depression. The differences found between our study and the aforementioned one could be due to not having taken into account the educational level, which might be a factor to be included in future studies.

The association between kinesiophobia and neck disability is in line with previous studies which found that kinesiophobia was highly associated with disability, as it led patients to avoid movement, exercise, or activities due to fear of pain or re-injury^(46, 47).

To the best of our knowledge, our study is the first to investigate and find a relationship between neck disability and pain catastrophizing over time in individuals with chronic NSNP. These results reinforce the importance of pain catastrophizing concerning neck disability in individuals with chronic NSNP^(11, 20, 48).

With respect to health-related quality of life, the findings are difficult to explain. While EQ-5D-5L correlated positively with neck disability over time, no correlations were found for EQ-VAS. This could be because the general feeling of health-related quality of life would not affect the level of disability while the factors specifically asked in the inventory such as pain intensity, could do it. Despite there are no studies relating health-related quality of life with neck disability in chronic NSNP individuals longitudinally, one study has addressed the relationship between quality of life and disability showing similar correlation findings in individuals with chronic low back pain⁽⁴⁹⁾.

The bidirectional relationship between sleep problems and chronic pain, especially in spinal pain, is well established^(18, 50). However, the relationship between neck disability and sleep quality has been poorly studied in individuals with chronic neck pain. In our study we found a moderate correlation between neck/arm disability and sleep quality over time, which is aligned with a previous study conducted in individuals with chronic neck pain⁽¹⁸⁾. This is another reason why clinical management of disability in individuals with NSNP should be comprehensive and address non-physical factors such as sleep.

There was a moderate positive relationship between QuickDASH and stress, anxiety, kinesiophobia and sleep quality over time. Despite the lack of studies investigating this relationship in individuals with chronic NSNP, similar studies assessing individuals with arm pain reinforce our hypothesis⁽⁵¹⁻⁵³⁾, although more research is needed. On the other hand, our findings about the discontinuous correlations between arm disability and health-related quality of life and depression over time are difficult to explain. One explanation might be that these factors are more directly associated with the intensity of pain than with disability. In fact, a longitudinal study on individuals with chronic NSNP found that pain intensity was correlated with arm disability⁽⁵⁴⁾, which indicate that the relationship between these psychosocial factors, disability and pain may be complex.

To the best of our knowledge, this is the first study analyzing longitudinally the correlations between neck/arm disability and psychosocial factors in chronic NSNP individuals. Other studies carried out in individuals with chronic low back pain showed similar results^(49, 55), suggesting that kinesiophobia is predictor of low back disability and that health-related quality of life is longitudinally related to low back disability. Due to the non-specific characteristic of pain, these results could be extrapolated to our study.

4.3. Comparison of psychosocial factors between the chronic NSNP and healthy control groups at baseline

Our findings show significant differences in health-related quality of life, sleep quality, stress, anxiety and depression with a moderate effect size between chronic NSNP and control group, which is in line with previous studies^(56, 57). Nevertheless, our study found no difference in pain catastrophizing and kinesiophobia between chronic NSNP and control groups. This could indicate that kinesiophobia and pain catastrophizing do not necessarily contribute to the development of chronic NSNP and might not be as important as other psychosocial factors such as stress, depression or anxiety.

Regarding kinesiophobia, our findings differ from the published by Beltran-Alacreu et al., who found differences in kinesiophobia between the chronic NSNP and healthy groups⁽⁵⁸⁾. A possible explanation could be that the participants in our study had lower NDI values, with mean scores ranging from 13.1 to 15 whereas in the aforementioned study the NDI values ranged from 10.19 to 29.22. However, these authors also found differences in the patients with mild disability, who showed similar NDI values than our sample, so other factors apart from the level of disability may be influencing the results. According to Sanson et al., the duration of pain is related to kinesiophobia in individuals with chronic pain⁽⁵⁹⁾ and it would explain the differences for the group with mild disability, whose pain duration was 72 months whereas in our sample it was 48 months.

Unlike our results, other investigations obtained significant differences in pain catastrophizing between the chronic NSNP and healthy groups^(10, 20). When comparing the average values for the NSNP group, they were similar to the aforementioned studies, whereas in the case of healthy controls the mean values in our study were higher. Therefore, the differences with the previous study should be found in factors which explain that healthy controls had higher scores in the PCS. One possible factor could be the age, which was higher (44.4 ± 10.7) in our popula-

tion when compared with the aforementioned studies, carried out in adolescents (17.02 ± 0.56)⁽¹⁰⁾ and young adults (27.63 ± 4.46)⁽²⁰⁾. As hypothesized by Dixon et al., standard catastrophizing scores would be mainly determined by personality traits in young adults and successively shaped by the individual pain experience gathered during life⁽⁶⁰⁾. Moreover, as suggested by Ruscheweyh et al.⁽⁶¹⁾ catastrophizing may develop over a life time, with a more affective connotation in younger adults to a measure more related to perceived sensory pain characteristics in older adults, which may also explain the differences found with other studies in the literature. Overall, all these findings remark the idea that some psychosocial factors are closely linked to the development of chronic NSNP and the need to clinically address chronic NSNP with a multimodal approach⁽⁴⁰⁾, in which the assessment of psychological stress, anxiety, depression, health-related quality of life and sleep quality receive special attention.

There are certain limitations that must be taken into account. The size of the sample did not allow for a more comprehensive statistical model including a regression analysis, which could have provided more information on predictive values of psychosocial factors. In addition, the observational design of the study did not allow establishing a cause-effect relationship between psychosocial factors and neck/arm disability.

5. Conclusions

This longitudinal study showed moderate positive correlations between psychosocial factors and neck/arm disability in individuals with chronic NSNP during a period of 6 months. Therefore, psychosocial factors tend to maintain over time in individuals with chronic NSNP despite receiving physiotherapy intervention. Future studies should investigate whether individualized physiotherapy interventions addressing psychosocial factors modify the course of disability over time in individuals with chronic NSNP.

References

1. Hurwitz EL, Randhawa K, Yu H, Côté P, Haldeman S. The Global Spine Care Initiative: a summary of the global burden of low back and neck pain studies. *Eur Spine J*. 2018;27(Suppl 6):796-801.
2. Côté P, Cassidy DJ, Carroll LJ, Kristman V. The annual incidence and course of neck pain in the general population: a population-based cohort study. *Pain*. 2004;112(3):267-73.
3. Bertozzi L, Gardenghi I, Turoni F, Villafañe JH, Capra F, Guccione AA, et al. Effect of therapeutic exercise on pain and disability in the management of chronic nonspecific neck pain: systematic review and meta-analysis of randomized trials. *Phys Ther*. 2013;93(8):1026-36.
4. Cerezo-Téllez E, Torres-Lacomba M, Mayoral-Del-Moral O, Pacheco-da-Costa S, Prieto-Merino D, Sánchez-Sánchez B. Health related quality of life improvement in chronic non-specific neck pain: secondary analysis from a single blinded, randomized clinical trial. *Health Qual Life Outcomes*. 2018;16(1):207.
5. Cerezo-Téllez E, Torres-Lacomba M, Mayoral-Del Moral O, Sánchez-Sánchez B, Dommerholt J, Gutiérrez-Ortega C. Prevalence of Myofascial Pain Syndrome in Chronic Non-Specific Neck Pain: A Population-Based Cross-Sectional Descriptive Study. *Pain Med*. 2016;17(12):2369-77.

6. Kaka B, Ogwumike OO, Adeniyi AF, Maharaj SS, Ogunlade SO, Bello B. Effectiveness of neck stabilisation and dynamic exercises on pain intensity, depression and anxiety among patients with non-specific neck pain: a randomised controlled trial. *Scand J Pain*. 2018;18(2):321-31.
7. Borghouts JA, Koes BW, Bouter LM. The clinical course and prognostic factors of non-specific neck pain: a systematic review. *Pain*. 1998;77(1):1-13.
8. Paksaichol A, Lawsirirat C, Janwantanakul P. Contribution of biopsychosocial risk factors to nonspecific neck pain in office workers: A path analysis model. *J Occup Health*. 2015;57(2):100-9.
9. Vranceanu AM, Bachoura A, Weening A, Vrahas M, Smith RM, Ring D. Psychological factors predict disability and pain intensity after skeletal trauma. *J Bone Joint Surg Am*. 2014;96(3):e20.
10. Sá S, Silva AG. Repositioning error, pressure pain threshold, catastrophizing and anxiety in adolescents with chronic idiopathic neck pain. *Musculoskelet Sci Pract*. 2017;30:18-24.
11. Dimitriadis Z, Kapreli E, Strimpakos N, Oldham J. Do psychological states associate with pain and disability in chronic neck pain patients? *J Back Musculoskelet Rehabil*. 2015;28(4):797-802.
12. Svedmark Å, Björklund M, Häger CK, Sommar JN, Wahlström J. Impact of Workplace Exposure and Stress on Neck Pain and Disabilities in Women-A Longitudinal Follow-up After a Rehabilitation Intervention. *Ann Work Expo Health*. 2018;62(5):591-603.
13. Rajala U, Keinänen-Kiukaanniemi S, Uusimäki A, Kivelä SL. Musculoskeletal pains and depression in a middle-aged Finnish population. *Pain*. 1995;61(3):451-7.
14. Luo X, Edwards CL, Richardson W, Hey L. Relationships of clinical, psychologic, and individual factors with the functional status of neck pain patients. *Value Health*. 2004;7(1):61-9.
15. Jull G, Sterling M, Falla D, Treleaven J, O'Leary S. Whiplash, headache and neck pain: research-based directions for physical therapies. China: Churchill Livingstone Elsevier 2008.
16. Sullivan M, Bishop S, Pivik J. The Pain Catastrophizing Scale: Development and Validation. 1995 (17):524-32.
17. Walton DM, Macdermid JC, Giorgianni AA, Mascarenhas JC, West SC, Zammit CA. Risk factors for persistent problems following acute whiplash injury: update of a systematic review and meta-analysis. *J Orthop Sports Phys Ther*. 2013;43(2):31-43.
18. Kang JH, Chen HS, Chen SC, Jaw FS. Disability in patients with chronic neck pain: heart rate variability analysis and cluster analysis. *Clin J Pain*. 2012;28(9):797-803.
19. Macías-Toranzo I, Sánchez-Ramos JL, Rojas-Ocaña MJ, García-Navarro EB. Influence of Psychosocial and Sociodemographic Variables on Sickness Leave and Disability in Patients with Work-Related Neck and Low Back Pain. *Int J Environ Res Public Health*. 2020;17(16).
20. Rampazo É, da Silva VR, de Andrade ALM, Back CGN, Madeleine PM, Arendt-Nielsen L, et al. Sensory, Motor, and Psychosocial Characteristics of Individuals With Chronic Neck Pain: A Case-Control Study. *Phys Ther*. 2021.
21. Pedrero-Martin Y, Falla D, Martinez-Calderon J, Liew BXW, Scutari M, Luque-Suarez A. Self-efficacy beliefs mediate the association between pain intensity and pain interference in acute/subacute whiplash-associated disorders. *Eur Spine J*. 2021;30(6):1689-98.
22. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet*. 2007;370(9596):1453-7.

- 23.** Kashfi P, Karimi N, Peolsson A, Rahnama L. The effects of deep neck muscle-specific training versus general exercises on deep neck muscle thickness, pain and disability in patients with chronic non-specific neck pain: protocol for a randomized clinical trial (RCT). *BMC Musculoskelet Disord.* 2019;20(1):540.
- 24.** López-de-Uralde-Villanueva I, Gil-Martínez A, Candelas-Fernández P, de Andrés-Ares J, Beltrán-Alacreu H, La Touche R. Validity and reliability of the Spanish-language version of the self-administered Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS) pain scale. *Neurologia.* 2018;33(8):505-14.
- 25.** Nee RJ, Jull GA, Vicenzino B, Coppieters MW. The validity of upper-limb neurodynamic tests for detecting peripheral neuropathic pain. *J Orthop Sports Phys Ther.* 2012;42(5):413-24.
- 26.** De Andrés J, Pérez-Cajaraville J, Lopez-Alarcón MD, López-Millán JM, Margarit C, Rodrigo-Royo MD, et al. Cultural adaptation and validation of the painDETECT scale into Spanish. *Clin J Pain.* 2012;28(3):243-53.
- 27.** Wainner RS, Fritz JM, Irrgang JJ, Boninger ML, Delitto A, Allison S. Reliability and diagnostic accuracy of the clinical examination and patient self-report measures for cervical radiculopathy. *Spine (Phila Pa 1976).* 2003;28(1):52-62.
- 28.** Alreni ASE, Harrop D, Lowe A, Tanzila Potia, Kilner K, McLean SM. Measures of upper limb function for people with neck pain. A systematic review of measurement and practical properties. *Musculoskelet Sci Pract.* 2017;29:155-63.
- 29.** García González GLA, Aguilar Sierra SF, Rodríguez Ricardo RMC. Validación de la versión en español de la escala de función del miembro superior abreviada: Quick Dash. *Revista Colombiana de Ortopedia y Traumatología.* 2018;32(4):215-9.
- 30.** Andrade Ortega JA, Delgado Martínez AD, Almécija Ruiz R. Validation of the Spanish version of the Neck Disability Index. *Spine (Phila Pa 1976).* 2010;35(4):E114-8.
- 31.** Daza P, Novy DM, Stanley MA, al. e. The Depression Anxiety Stress Scale-21: Spanish Translation and Validation with a Hispanic Sample. 2002(24):195–205.
- 32.** Gómez-Pérez L, López-Martínez AE, Ruiz-Párraga GT. Psychometric Properties of the Spanish Version of the Tampa Scale for Kinesiophobia (TSK). *J Pain.* 2011;12(4):425-35.
- 33.** Hapidou EG, O'Brien MA, Pierrynowski MR, de Las Heras E, Patel M, Patla T. Fear and Avoidance of Movement in People with Chronic Pain: Psychometric Properties of the 11-Item Tampa Scale for Kinesiophobia (TSK-11). *Physiother Can.* 2012;64(3):235-41.
- 34.** Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 1989;28(2):193-213.
- 35.** Hita-Contreras F, Martínez-López E, Latorre-Román PA, Garrido F, Santos MA, Martínez-Amat A. Reliability and validity of the Spanish version of the Pittsburgh Sleep Quality Index (PSQI) in patients with fibromyalgia. *Rheumatol Int.* 2014;34(7):929-36.
- 36.** Bilbao A, García-Pérez L, Arenaza JC, García I, Ariza-Cardiel G, Trujillo-Martín E, et al. Psychometric properties of the EQ-5D-5L in patients with hip or knee osteoarthritis: reliability, validity and responsiveness. *Qual Life Res.* 2018;27(11):2897-908.
- 37.** García Campayo J, Rodero B, Alda M, Sobradiel N, Montero J, Moreno S. [Validation of the Spanish version of the Pain Catastrophizing Scale in fibromyalgia]. *Med Clin (Barc).* 2008;131(13):487-92.

- 38.** Jorritsma W, Dijkstra PU, de Vries GE, Geertzen JH, Reneman MF. Detecting relevant changes and responsiveness of Neck Pain and Disability Scale and Neck Disability Index. *Eur Spine J.* 2012;21(12):2550-7.
- 39.** Brunner E, Dankaerts W, Meichtry A, O'Sullivan K, Probst M. Physical Therapists' Ability to Identify Psychological Factors and Their Self-Reported Competence to Manage Chronic Low Back Pain. *Phys Ther.* 2018;98(6):471-9.
- 40.** Javdaneh N, Saeterbakken AH, Shams A, Barati AH. Pain Neuroscience Education Combined with Therapeutic Exercises Provides Added Benefit in the Treatment of Chronic Neck Pain. *Int J Environ Res Public Health.* 2021;18(16).
- 41.** Bruflat AK, Balter JE, McGuire D, Fethke NB, Maluf KS. Stress management as an adjunct to physical therapy for chronic neck pain. *Phys Ther.* 2012;92(10):1348-59.
- 42.** Daenen L, Varkey E, Kellmann M, Nijs J. Exercise, not to exercise, or how to exercise in patients with chronic pain? Applying science to practice. *Clin J Pain.* 2015;31(2):108-14.
- 43.** Borisovskaya A, Chmelik E, Karnik A. Exercise and Chronic Pain. *Adv Exp Med Biol.* 2020;1228:233-53.
- 44.** Elbinoune I, Amine B, Shyen S, Gueddari S, Abouqal R, Hajjaj-Hassouni N. Chronic neck pain and anxiety-depression: prevalence and associated risk factors. *Pan Afr Med J.* 2016;24:89.
- 45.** Duyur Cakit B, Genç H, Altuntaş V, Erdem HR. Disability and related factors in patients with chronic cervical myofascial pain. *Clin Rheumatol.* 2009;28(6):647-54.
- 46.** George SZ, Fritz JM, Erhard RE. A comparison of fear-avoidance beliefs in patients with lumbar spine pain and cervical spine pain. *Spine (Phila Pa 1976).* 2001;26(19):2139-45.
- 47.** Landers MR, Creger RV, Baker CV, Stutelberg KS. The use of fear-avoidance beliefs and nonorganic signs in predicting prolonged disability in patients with neck pain. *Man Ther.* 2008;13(3):239-48.
- 48.** Thompson DP, Urmston M, Oldham JA, Woby SR. The association between cognitive factors, pain and disability in patients with idiopathic chronic neck pain. *Disabil Rehabil.* 2010;32(21):1758-67.
- 49.** Mutubuki EN, Beljon Y, Maas ET, Huygen FJPM, Ostelo RWJG, van Tulder MW, et al. The longitudinal relationships between pain severity and disability versus health-related quality of life and costs among chronic low back pain patients. *Qual Life Res.* 2020;29(1):275-87.
- 50.** Kelly GA, Blake C, Power CK, O'keeffe D, Fullen BM. The association between chronic low back pain and sleep: a systematic review. *Clin J Pain.* 2011;27(2):169-81.
- 51.** Roh YH, Noh JH, Oh JH, Baek GH, Gong HS. To what degree do shoulder outcome instruments reflect patients' psychologic distress? *Clin Orthop Relat Res.* 2012;470(12):3470-7.
- 52.** Vranceanu AM, Safren S, Zhao M, Cowan J, Ring D. Disability and psychologic distress in patients with nonspecific and specific arm pain. *Clin Orthop Relat Res.* 2008;466(11):2820-6.
- 53.** Luque-Suarez A, Martinez-Calderon J, Navarro-Ledesma S, Morales-Asencio JM, Meeus M, Struyf F. Kinesiophobia Is Associated With Pain Intensity and Disability in Chronic Shoulder Pain: A Cross-Sectional Study. *J Manipulative Physiol Ther.* 2020;43(8):791-8.
- 54.** 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.* 2022;11(5).

55. Alamam DM, Moloney N, Leaver A, Alsobayel HI, Mackey MG. Multidimensional prognostic factors for chronic low back pain-related disability: a longitudinal study in a Saudi population. *Spine J.* 2019;19(9):1548-58.
56. López-de-Uralde-Villanueva I, Notario-Pérez R, Del Corral T, Ramos-Díaz B, Acuyo-Osorio M, La Touche R. Functional limitations and associated psychological factors in military personnel with chronic nonspecific neck pain with higher levels of kinesiophobia. *Work.* 2017;58(3):287-97.
57. Ortego G, Villafane JH, Domenech-Garcia V, Berjano P, Bertozzi L, Herrero P. Is there a relationship between psychological stress or anxiety and chronic nonspecific neck-arm pain in adults? A systematic review and meta-analysis. *J Psychosom Res.* 2016;90:70-81.
58. Beltran-Alacreu H, López-de-Uralde-Villanueva I, Calvo-Lobo C, Fernández-Carnero J, Touche R. Clinical features of patients with chronic non-specific neck pain per disability level: A novel observational study. *Rev Assoc Med Bras (1992).* 2018;64(8):700-9.
59. Sanson N, Hach S, Moran R, Mason J. Behavioural activation and inhibition systems in relation to pain intensity and duration in a sample of people experiencing chronic musculoskeletal pain. *Musculoskelet Sci Pract.* 2020;47:102129.
60. Dixon KE, Thorn BE, Ward LC. An evaluation of sex differences in psychological and physiological responses to experimentally-induced pain: a path analytic description. *Pain.* 2004;112(1-2):188-96.
61. Ruscheweyh R, Nees F, Marziniak M, Evers S, Flor H, Knecht S. Pain catastrophizing and pain-related emotions: influence of age and type of pain. *Clin J Pain.* 2011;27(7):578-86.

Editorial information

Correspondence

gortsan-ext@salud.aragon.es · Tel.: +34656550334

Dates

Received: 08.01.2025

Accepted: 24.01.2025

Published: 24.02.2025

Author Contributions

Conceptualization, G.O. and V.D.; methodology, G.O.; software, G.O.; validation, G.O., E.L. and V.D.; formal analysis, E.L.; investigation, V.D.; resources, G.O.; data curation, G.O.; writing—original draft preparation, V.D.; writing—review and editing, G.O., E.L. And V.D.; visualization, V.D.; supervision, E.L.; project administration, V.D. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Local Ethics Committee (record no. 19/17).

Clinical trial Registration

NCT04330573.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement

Data is unavailable due to privacy restrictions.

Acknowledgments

None.

Conflicts of Interest

The authors declare no conflicts of interest.

Suggested citation

Ortego G, Lluch E, Doménech-García V. Longitudinal relationship between disability and psychosocial factors in patients with chronic nonspecific neck pain. Invasive Physiother Musculoskelet Med. 2025;1:e6. doi: 10.63360/ipmm.v1.e6

Disclaimer/Publisher's Note

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of IPMM and/or the editor(s). IPMM and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Copyright

© 2025 by the authors.

Publication under the terms and conditions of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA) license

(<https://creativecommons.org/licenses/by-nc-sa/4.0/>)