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ORIGINAL ARTICLE

Association among clinical severity indicators, psychological health status and elastic properties of neck muscles in patients with chronic mechanical neck pain

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Abstract

Background Since objective stiffness measures are not consistent with the patients' perception and its correlation with the clinical severity of neck pain is not clear, novel studies assessing the clinical relevance of muscle stiffness are needed.

Objectives To analyze the correlation among psychological factors, clinical severity indicators, and muscle stiffness in neck muscles in patients with chronic mechanical neck pain, and compare these factors with asymptomatic controls.

Methods A cross-sectional observational study was conducted. Participants included cases with chronic neck pain and asymptomatic controls, assessed for muscle stiffness using shear wave elastography, psychological health (anxiety and kinesiophobia), and clinical severity. Data analysis involved correlation matrices and comparison between groups.

Results Although no significant differences in levator scapulae stiffness were observed between groups ($p > 0.05$), patients exhibited significantly increased stiffness in the anterior scalene and cervical multifidus muscles ($p = 0.009$ and $p = 0.040$, respectively). STAI scores were significantly higher in patients for both subscales (STAI-S $p = 0.002$ and STAI-T $p < 0.001$), but no kinesiophobic behaviors differences were found ($p > 0.05$). Significant correlations between pain chronicity, intensity, disability, and psychological factors were confirmed. Notably, the levator scapulae stiffness was positively associated with disability, anxiety, and kinesiophobia (all $p < 0.01$). However, the anterior scalene and cervical multifidus stiffness, even if significantly associated with demographic factors ($p < 0.05$), were not associated with clinical or psychological outcomes.

Conclusion The findings underscore the intertwined nature of psychological factors and muscle stiffness in chronic neck pain, suggesting the need for integrated approaches in treatment that consider both physical and psychological dimensions.

Key points

- Objective stiffness measures are controversial with patients' subjective perceptions.
- This study contributes to understanding the multifaceted nature of chronic neck pain.
- Physical and psychological factors are encouraged to be considered.
- This integrated approach could potentially improve clinical outcomes.

Keywords Anxiety · Kinesiophobia · Muscle stiffness · Neck Pain · Shear wave elastography

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Introduction

Neck pain is defined as any discomfort, tenderness, or pain in the neck area, often associated with muscle strain, ligament sprains, and other soft tissue injuries [1]. Although the estimated prevalence rate of neck pain is considerably high (in 2017 was 3551.1 per 100,000 individuals [2]), there are additional concerns that justify the need of investigate this condition. For instance, epidemiological studies indicate that the prevalence seems to increase over time [3] and, despite the favorable natural history of neck pain, its high rates of recurrence and chronicity present a significant challenge [4]. These facts involve a significant economic and social burden, with healthcare spending in the United States for low back and neck pain combined reaching an estimated $134.5 billion in 2016 [3]. Additionally, neck pain has been linked to substantial work absences, with millions of individuals missing workdays, further emphasizing its impact on productivity and economic stability [5].

Neck pain multifaceted nature is highlighted by its potential causes, which can range from acute traumatic injuries, such as whiplash, to more chronic issues like degenerative disc disease or arthritis [6–8]. Psychological factors, including stress and depression, along with physical factors, such as poor posture and prolonged sedentary activity, contribute to the complexity of diagnosing and treating this musculoskeletal condition [9]. Although guidelines evaluating the appropriateness of imaging studies are available for patients suffering neck pain (differentiating acute and chronic stages, in traumatic and non-traumatic patients) [10, 11], imaging studies often fail to identify structural findings associated with the symptoms reported by the patients [12].

Since patients with neck pain commonly report subjective neck stiffness [13], and considering that previous studies using objective methods for assessing muscle stiffness such as shear wave elastography (SWE) showed a controversy between the objective measures and the patients' perception [13] and its correlation with neck pain clinical severity is not clear [13–17], there is a need of novel studies exploring cofounding factors explaining these findings. Therefore, given the clear association of chronic neck pain with psychological factors [18, 19] and the contradictory findings in terms of muscle stiffness in patients with neck pain, it is crucial to understand neck pain underlying mechanisms, including the role of psychological factors and its interaction with muscle stiffness.

Hence, the main objective of this study was to analyze the correlation among anxiety and kinesiophobia as psychological health status outcomes; pain duration, intensity and related-disability as clinical severity indicators; and the levator scapulae, anterior scalene and cervical multifidus muscles stiffness in patients with chronic mechanical neck pain. As a secondary objective, this study aimed to analyze shear wave speed and psychological health status differences between cases with neck pain and asymptomatic controls.

Methods

Study design

Between November 2022 and April 2023, a cross-sectional observational study including two profiles of volunteers (cases with chronic neck pain and asymptomatic controls) was conducted in Madrid, Spain. For ensuring an appropriate quality of the report, the study adhered to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) for case-control and cross-sectional studies [20] and the Enhancing the QUAlity and Transparency Of health Research (EQUATOR) guidelines [21]. In addition, the study protocol and the ethical considerations including the participants' rights were supervised and approved by the Ethics Committee of a third-party University prior to starting the data collection.

Participants

Participants were recruited by posting announcements throughout the Campus, indicating the instructions to contact the research team, the requirements to participate and a QR code linked to the informed consent document containing all the study information. Two groups were defined: one of asymptomatic individuals (controls) and another of individuals suffering from bilateral chronic idiopathic neck pain (cases).

Common eligibility criteria for both cohorts included being aged between 18 and 65 years old, absence of previous history of traumatic events (e.g., whiplash, fractures or fissures), surgeries or neuropathic disorders of the head or spine and not being under any treatment potentially affecting the muscle tone or psychological disorders (e.g., physiotherapy, or drugs such as muscle relaxants, anxiolytics, or antidepressants). To be allocated to the control group, participants had to confirm no episodes of neck pain for at least the previous year. On the other hand, participants allocated to the cases group had to report bilateral pain (as previous studies reported that bilateral pain is associated with higher levels of central sensitization and poorer functionality compared with patients with unilateral pain [22, 23], a minimum average pain of 3.5 points on the Visual Analogue Scale (as this is the cut-off for determining at least moderate pain intensity [24]), and 15 points on the Neck Disability Scale

(which is cutoff point that optimized disability sensitivity and specificity [25]).

Sample size calculation

Since two statistical methods were used for meeting the objectives purposed, two sample size calculations were made. For assessing mean differences between cases and controls, the G*Power software v.3.1 was utilized. The two-tailed t-test a priori analysis for calculating mean differences between two independent samples resulted in a total sample of $n=128$ participants ($n=64$ per group) setting a standard effect size of $d=0.5$, $\alpha=0.05$, $\beta=0.8$ and allocation ratio of $N2/N1=1$.

Regarding the correlation analysis, the minimum sample size required was calculated following the Harry's formula for studies analyzing multivariate correlations [26] ($n=50+$number of variables) since this method demonstrated enough power for detecting associations and factor analyses [27]. Since a total of 11 variables were included in the correlation matrix, at least 61 cases with neck pain were required ($n=50+11=61$).

Outcomes

Demographic and clinical data

All participants filled out a standardized document for collecting the demographic and clinical. Participants were asked about their age (years), height (m), weight (kg) and body mass index (BMI = $\frac{weight}{height^2}$ kg/m^2) [28].

Those participants assigned to the cases group reported the symptoms duration (months) and recurrence rate (number of episodes per year). In addition, pain-related disability and pain intensity were assessed using the Neck Disability Index (NDI) and the Numeric Pain Rating Scale (NPRS), respectively.

The NDI is a self-reported questionnaire adapted to multiple languages which consists of 10 items evaluating how neck pain interferes on daily live physical tasks and related complaints (i.e., headaches or concentration impairments). Final scores range from 0 to 100 and can be used to classify the disability as "mild" (10–28 points), "moderate" (30–48 points), "severe" (50–68 points) or complete (>70 points) [29].

The NPRS is a pain intensity scale where all the cases were asked to rate from 0 (no pain) to 10 (the worst pain imaginable) their pain intensity. In order to improve the accuracy of the measurements, a mean average at 3 different moments (the current pain intensity during the data collection, the worst and lowest pain intensity perceived during the previous week) was calculated [30]. This scale can be used to classify pain intensity as "mild" (≤5 points), "moderate" (6–7 points) or "severe" (≥8 points) [31].

Psychological health status

The State-Trait Anxiety Inventory (STAI) was the self-reported questionnaire used for measuring the presence and severity of current symptoms of anxiety and a generalized propensity to be anxious. It consists of two subscales for evaluating (1) their current state of anxiety using items that measure subjective feelings of apprehension, tension, nervousness, worry, and activation/arousal of the autonomic nervous system (STAI-S) and (2) stable aspects of anxiety proneness including general states of calmness, confidence, and security (STAI-T). Scores for each subscale range from 20 to 80, where higher scores are indicative of greater anxiety and scores >40 points are indicative of clinically significant symptoms [32].

Participants' kinesiophobic behaviors were evaluated using the short form of the Tampa Scale for Kinesiophobia (TSK-11). Based on 11 items, this questionnaire is used to quantify the fear of movement in chronic pain conditions in a 0–44 points scale [33].

Stiffness assessments of neck muscles

All the shear wave elastography (SWE) images were collected using a US device Logiq E9 with a linear transducer (6–15 MHz ML-6-15-D) by the same examiner (+10 years of experience using US for musculoskeletal assessments). Standard console settings, including a frequency of 12 MHz, gain of 65 dB, and depth of 4.5 cm, were used for all acquisitions.

For assessing the levator scapulae and the cervical multifidus muscles, participants were relaxed in the prone position (for avoiding muscle contraction and reduce stiffness variability) with a neutral cranio-cervical angle, a pillow under their ankles and the upper limb resting at 90º of shoulder abduction and elbow flexion. The procedures to locate the structures have been described recently in the literature [34, 35] and demonstrated to be acceptable reliable at C4-C5 level. On the other hand, participants were turned to the supine position for assessing the anterior scalene muscle. The procedure followed for identifying the anterior scalene muscle stiffness was previously tested by Varol et al. [36] and showed to be highly reliable at C7 level. Therefore, all measurements were conducted following the instructions of these reliability and validity studies as detailed in Appendix I.

After acquiring all the SWE images, the 3 muscles were carefully contoured avoiding the inclusion of bones or

connective tissues to obtain the stiffness metrics. An illustrative example of each muscle is shown in Fig. 1. Since generally shear wave speed (SWS) showed to be more accurate in comparison with Young's modulus and both are strongly correlated, only SWS was used in the analyses [34].

Statistical analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 27.1 for Mac OS (Armonk, NY, USA), setting the two-tailed significance level at $p < 0.05$ for all the analyses.

First, the distribution of continuous variables was verified using histograms and Shapiro-Wilk tests to summarize the participants' characteristics using descriptive statistics in accordance with the data distribution. Next, mean demographic differences between genders and groups (cases and controls) were checked using Student's T-tests for independent samples with a 95% confidence interval. This test was also used for assessing pain intensity and related-disability differences between males and females in the cases group, psychological differences between cases and controls and SWS differences between sides and groups. The between-gender comparison for categorical data (recurrence rate) was performed using the Chi-Square test.

Finally, a Pearson's correlation matrix was calculated for analyzing the strength (absolute r values ranging between 0 and 0.3 are interpreted as poor, 0.3 to 0.6 as fair, 0.6 to 0.8 as

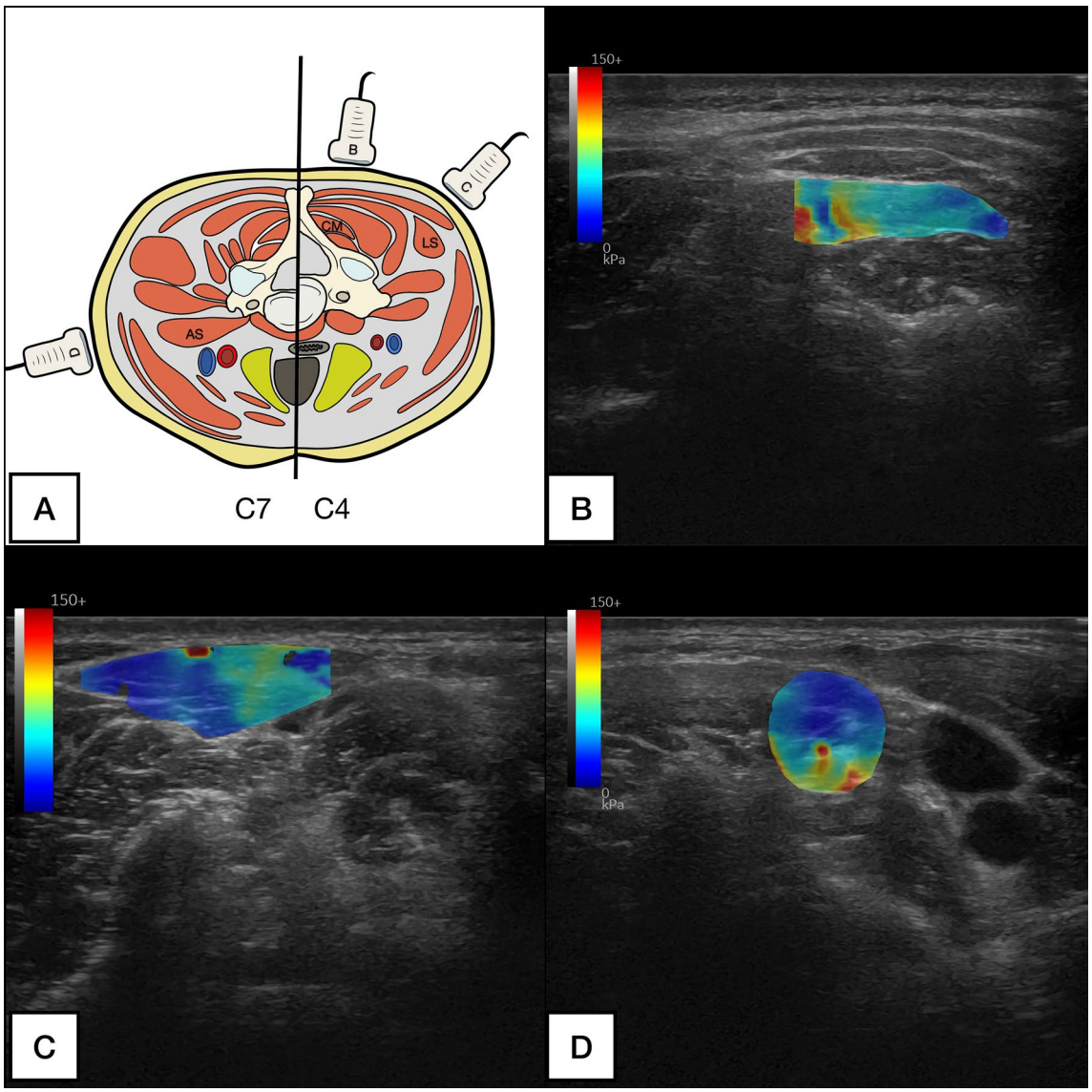

Fig. 1 Illustrative anatomical ross-section of the neck at C4 and C7 levels (**A**) indicating the probe placement for obtaining the shear wave elastography (SWE) images of the cervical multifidus muscle (**B**) and levator scapulae -LS- (**C**) and anterior scalene -AS- (**C**) muscles and the region of interest selected for each muscle

Table 1 Participants' sociodemographic characteristics

Variables	Cases ($n=64$)			Controls ($n=64$)			Between-group Differences
	Male ($n=30$)	Female ($n=34$)	Difference	Male ($n=34$)	Female ($n=30$)	Difference	
Demographic Data							
Age (y)	21.8 ± 3.1	20.7 ± 2.5	1.1 (-0.1;2.3) $p=0.072$	21.9 ± 5.3	19.7 ± 1.8	2.2 (-0.4;4.8) $p=0.092$	0.2 (-0.9;1.4) $p=0.702$
Height (m)	1.78 ± 0.07	1.64 ± 0.06	0.14 (0.12;0.17) $p<0.001$	1.77 ± 0.07	1.63 ± 0.05	0.13 (0.10;0.17) $p<0.001$	0.04 (0.01;0.08) $p=0.002$
Weight (kg)	83.5 ± 26.0	61.8 ± 11.2	21.7 (13.9;29.4) $p<0.001$	75.0 ± 14.0	65.1 ± 12.9	9.9 (2.3;17,4) $p=0.011$	2.9 (-2.8;8.7) $p=0.319$
Body Mass Index (kg/m^2)	26.3 ± 9.0	23.0 ± 4.4	3.2 (0.4;6.0) $p=0.024$	23.7 ± 4.1	24.1 ± 3.9	0.4 (-1.8;2.6) $p=0.714$	0.3 (-1.4;2.1) $p=0.703$
Clinical Data							
Symptoms duration (months)	15.5 ± 8.5	12.2 ± 8.2	3.2 (-1.8;8.3) $p=0.210$				
Recurrence (%)			$p=0.130$				
1 Episode during this year	18.8	23.3					
2 Episode during this year	18.8	6.7					
3 Episode during this year	25.0	16.7					
4 Episode during this year	0.0	10.0					
≥5 Episode during this year	37.5	43.3					
Neck Disability Index (0-100)	26.9 ± 9.6	27.8 ± 9.8	1.0 (-3.2;5.2) $p=0.643$				
Pain Intensity (0–10)	5.6 ± 1.6	6.0 ± 1.7	0.4 (-0.3;1.1) $p=0.271$				

moderate, and 0.8 to 1.0 as strong) and direction (a positive sign indicates a proportionally directed association while a negative sign indicates a proportionally undirected association) of paired associations. After calculating the correlation matrix and identifying SWE factors associated with neck pain indicators, a hierarchical regression model was calculated to analyze the individual contribution of SWE scores for each muscle on neck pain variance. To minimize the risk of bias, multicollinearity and shared variance analyses were performed, considering correlations among SWE scores exceeding $r>0.80$. Variables were included in the regression equation based on a significance threshold of $p<0.05$ for the critical F value.

Results

From 128 participants potentially eligible for participation, none was excluded (all met the eligibility criteria) nor dropped (all the measurements were valid) and therefore, 128 participants were finally included in the data collection. As described in Table 1, $n=64$ participants were asymptomatic controls (53% males) and $n=64$ cases (47% males). The demographic analysis revealed significant height and weight differences between males and females in both groups as expected (cases: both $p<0.001$; controls: $p<0.001$ and $p=0.011$ respectively). The between-group differences showed that cases and controls had com-parable age, weight and BMI ($p>0.05$), but cases were significantly taller ($p=0.002$). Re-garding the cases clinical data, the obtained results suggested comparable pain intensity, related-disability, recurrence and duration between males and females (all, $p>0.005$).

Table 2 Psychological health status and neck muscles stiffness scores

Variables	Cases ($n=64$)	Controls ($n=64$)	Between-group Differences
Shear Wave Elastography			
Anterior Scalene (m/s)	2.42 ± 0.53	2.15 ± 0.53	0.27 (0.07;0.48) $p=0.009$
Levator Scapulae (m/s)	2.96 ± 1.04	2.70 ± 1.03	0.25 (-0.10;0.61) $p=0.159$
Cervical Multifidus (m/s)	3.46 ± 1.15	3.09 ± 1.01	0.36 (0.01;0.70) $p=0.040$
Psychological characteristics			
STAI – S (20–80)	44.3 ± 7.8	39.8 ± 9.8	4.5 (1.7;7.3) $p=0.002$
STAI – T	44.7 ± 6.6	40.1 ± 7.6	4.5 (2.2;6.7) $p<0.001$
TSK-11	22.0 ± 6.1	20.8 ± 6.2	1.2 (-0.8;3.1) $p=0.248$

The shear wave elastography results are summarized in Table 2. Since the analyses revealed no side-to-side asymmetries in cases nor controls (both, $p>0.05$), the table shows the mean average of both sides for cases and controls. Although both groups showed comparable levator scapulae

Table 3 Pearson's correlation matrix evaluating the association among demographic, clinical, psychological and muscular characteristics

	1	2	3	4	5	6	7	8	9	10
1. Age										
2. BMI	0.271**									
3. Pain duration	n.s.	n.s.								
4. Pain intensity	n.s.	n.s.	0.417**							
5. NDI	n.s.	n.s.	0.338**	0.674**						
6. STAI-S	0.247**	n.s.	0.222**	0.288**	0.421**					
7. STAI-T	n.s.	n.s.	0.192*	0.367**	0.476**	0.743**				
8. TSK-11	n.s.	n.s.	n.s.	n.s.	0.184*	n.s.	0.217**			
9. LS stiffness	0.319**	n.s.	n.s.	n.s.	0.351**	0.236**	0.359**	0.404**		
10. AS stiffness	n.s.	−0.175**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.197*	
11. CM stiffness	0.206**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.216**

stiffness ($p=0.159$), cases were characterized by faster SWS in both the anterior scalene and the cervical multifidus muscles ($p=0.009$ and $p=0.040$, re-spectively).

The psychological health of the sample is also reported in Table 2. Although the results revealed no significant fear of movement differences between cases and controls ($p=0.248$), cases reported significantly greater STAI scores in both subscales (STAI-S $p=0.002$ and STAI-T $p<0.001$).

Finally, the Pearson's correlation matrix analyzing the association among demo-graphic, clinical, psychological and neck muscles stiffness is summarized in Table 3. Multiple correlations among pain characteristics and psychological health outcomes were found. For instance, pain chronicity was positively correlated with pain intensity ($p<0.01$), pain-related disability ($p<0.01$), and anxiety (STAI-S $p<0.01$ and STAI-T $p<0.05$); pain intensity was positively associated with neck disability and anxiety (all, $p<0.01$) and neck disability was positively associated with anxiety and kinesiophobia (all, $p<0.01$). Re-garding the associations found for muscle elasticity, the results revealed that the levator scapulae muscle stiffness was positively associated with age, disability, anxiety and ki-nesiophobia (all, $p<0.01$) and the anterior scalene and cervical multifidus stiffness were significantly associated with BMI ($p<0.01$) and age ($p<0.05$) respectively but not associated with any clinical or psychological outcome (all, $p>0.05$). Since a significant correlation was identified exclusively between the SWS of the levator scapulae muscle and the NDI, a single regression model was calculated. The analysis yielded an adjusted R^2 of 0.009, an unstandardized B coefficient of 1.26 (standard error 0.8585), a standardized beta coefficient of 0.127, a t-value of 1.469 (95% CI: -0.436 to 2.957) and a p-value of 0.144.

Discussion

To the authors' knowledge, this is the first study analyzing how demographic, clinical, psychological, and muscular stiffness variables interrelate in individuals with chronic idiopathic neck pain and deferred with asymptomatic controls. The results of this study revealed two key findings. First, the results of the study revealed that the levator scapulae stiffness was comparable between groups and cases demonstrated faster SWS (and consequently, greater stiffness [37] for the anterior scalene and cervical multifidus muscles. This finding is crucial as it highlights the role of muscle stiffness in chronic neck pain, a relatively underexplored area. Secondly, this research found multiple correlations among pain characteristics, psychological health outcomes, and muscle elasticity, highlighting the complex interplay between physical symptoms and psychological states in chronic neck pain described in previous research [3]. While the association between neck pain with muscle stiffness [13, 38–40] and psychological factors has been widely discussed [18, 41, 42], there is a paucity of literature that examines the influence of psychological health with muscle stiffness. However, despite the correlation between the levator scapulae stiffness and neck disability, the regression analysis revealed that the predictive capacity of muscle stiffness for neck disability is limited. This suggests that while muscle stiffness may contribute to neck pain's clinical presentation, it is unlikely to independently explain the variability in neck disability, reinforcing the need for a multifactorial approach when understanding and addressing chronic idiopathic neck pain.

These results are particularly relevant as they provide valuable insights into a challenging classification of neck pain which is the most prevalent [43]. While in other classifications of neck pain (e.g., those with a traumatic origin or cases presenting with neurological signs or symptoms [44]) imaging findings often correlate more closely with the clinical status of the patients and play a critical role in diagnostic and therapeutic decision-making, in patients with idiopathic

neck pain the identification of abnormal imaging findings often has limited prognostic value due to their high prevalence in both symptomatic and asymptomatic individuals [12].

Evidence is consistent regarding the association of neck pain with anxiety, kinesiophobia, stress, and depression. These psychological factors contribute to the severity and persistence of neck pain, suggesting that psychological interventions might be beneficial alongside traditional physical therapies. For instance, anxiety amplifies the perception and duration of neck pain, leading to a more chronic and intense pain experience; kinesiophobia contributes to the avoidance of physical activity, which can exacerbate neck pain through muscle weakness and stiffness; stress perpetuates the cycle of pain and depression is linked to an increased pain perception [18, 41, 42]. Considering the different biomechanical roles and varying susceptibility of specific muscles to stress-induced tension or guarding mechanisms [45, 46], these factors may explain why the levator scapulae (which is a dynamic muscle heavily involved in neck and shoulder movements [47]), exhibited significant correlations with anxiety, kinesiophobia, and disability while other muscles with less dynamic roles, such as the anterior scalene (with an accessory inspiratory function [48]) or the cervical multifidus (spinal stabilizer [49]), did not show such associations.

On the other hand, the association between muscle stiffness and neck pain remains uncertain. Dieterich et al. [17] compared muscle stiffness using SWE at 5 different sites (trapezius, splenius capitis, semispinalis capitis, semispinalis capitis and multifidus) between women with chronic non-specific neck pain and asymptomatic women. Their results revealed that patients did not demonstrate higher objective muscle stiffness than asymptomatic women (consistently across various muscle-specific regions and tasks), even if the subjective perception indicated greater stiffness in this group. In fact, Wolff et al. [38] found that patients with idiopathic chronic neck pain were characterized by a softer sternocleidomastoid muscle compared with asymptomatic controls during forward reaches. The authors justify these findings to pain-avoidance movement strategies adaptations since opposite findings were reported for the upper trapezius muscle and the stiffness changes were independent of muscle activity [38].

Our findings further highlight the need to interpret muscle stiffness with caution, as greater stiffness does not necessarily correlate with the clinical presentation of neck pain. While the anterior scalene and cervical multifidus muscles demonstrated significantly increased stiffness in patients with chronic neck pain compared to controls, these differences were not associated with clinical outcomes. This suggests that the increased stiffness in these muscles might represent compensatory responses or specific biomechanical adaptations rather than markers of clinical severity. Interestingly, the levator scapulae muscle, despite showing no significant stiffness differences between patients and controls, was the only structure to demonstrate a significant correlation with a clinical severity indicator. Therefore, the relationship between the elastic properties of the muscles and the clinical severity indicators appears to be determined by biomechanical and anatomical factors. This underscores the need to clarify whether the stiffness of certain muscles should be considered in diagnostic decision-making or as a therapeutic target, taking into account the individual characteristics of each muscle. Further research is warranted to explore these associations and evaluate their potential relevance in clinical practice.

For instance, Valera-Calero et al. [14] compared the stiffness properties of the upper trapezius muscle at specific locations (active and latent myofascial trigger points and control locations) between asymptomatic subjects and patients with chronic neck pain and analyzed the association between muscle stiffness and clinical severity outcomes. The authors found a slight general muscle stiffness between cases and controls, with no differences between active, latent or control regions, and no correlations between SWE metrics with pain intensity, pain extent, pain-related disability (in accordance with Xie et al. [39]) or pressure pain thresholds. Although Kocur et al. [40] found that female office workers with neck pain exhibited greater upper trapezius stiffness than asymptomatic controls, these results should be considered carefully since no perceived pain thresholds were found between both groups and these differences could not be totally attributed to neck pain.

Our results revealed that the stiffness of specific muscles might discriminate patients suffering from neck pain and asymptomatic individuals, but greater stiffness may not involve poorer clinical or psychological health related status. Since the anterior scalene and cervical multifidus muscles were significantly stiffer in the cases group, further studies are needed to provide diagnostic accuracy estimates (i.e., sensitivity and specificity) comparing different subgroups of patients as SWE may show significant associations just with specific severities as occurs with intramuscular fatty infiltration [50].

One of the most interesting findings of this study was the absence of levator scapulae stiffness differences between cases and controls despite the significant associations found with pain-related disability, anxiety and kinesiophobia. Our hypothesis for explaining this controversy is that, even if statistically significant, the magnitude of the STAI score difference between cases and controls was small. Further studies including asymptomatic samples with lower estimates of anxiety are needed to confirm this hypothesis. In addition, given the structures specificities, further research is needed

analyzing different muscles to propose those structures that better reflect the patients' status.

Limitations

Although this research has several strengths (adequate sample size, use of reliable US procedures for multiple muscles and supported patient-reported outcome measures), several limitations should be acknowledged in this study for avoiding the overestimation of these findings. First, even if SWE is recognized currently as the most appropriate tool to objectively assess the muscle stiffness, is based in US physics and potential anisotropic errors (SWS scores may differ depending on slight probe inclinations) may lead on wrong conclusions. Secondly, the psychological health status of our sample of asymptomatic subjects did not differ as much as expected from the cases. As discussed previously, this fact may play a critical role in the results obtained and need to be contrasted in future studies. Third, all SWE images were acquired at rest. Comparing the elastic properties of these muscles during functional or specific tasks, may involve greater capacity to discriminate cases with chronic neck pain or stronger associations with the clinical severity or psychological status. Finally, this study excluded patients with neck pain resulting from traumatic events or those with neurological signs or symptoms and focused on idiopathic neck pain. This limits the generalizability of our findings to these populations. Therefore, further research is needed assessing patients with different classifications of neck pain such as trauma-induced neck pain, degenerative conditions with radiological confirmation, or cervical radiculopathy.

Conclusion

The main rationale for conducting this study was the limited evidence analyzing the association among psychological health, clinical severity outcomes and muscle stiffness in individuals with chronic idiopathic neck pain offers significant insights into the complex nature of neck pain. Our results not only reaffirm the association of neck pain with psychological factors like anxiety and kinesiophobia but also opens new avenues for understanding the role of muscle stiffness in chronic neck pain. Despite the absence of significant differences in specific muscles stiffness between affected individuals and controls, the study highlights the potential of assessing selective structures as a discriminative factor for identifying patients with neck pain. Further research is needed to evaluate the diagnostic accuracy of SWE and its association with different outcomes including patients with different neck pain severity in order to enhance clinical assessments and treatments. This study represents a step forward in the multidisciplinary approach to managing chronic neck pain, advocating for the integration of psychological assessments and interventions alongside traditional physical therapies to address the multifaceted nature of this condition.

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Data availability All data derived from this study are presented in the text.

Declarations

Ethical approval Institutional Review Board approval was obtained by the Clinical Ethics Committee of Hospital Universitario 12 De Octubre (ID: CEIm 24/121).l

Statistics and biometry One of the authors has significant statistical expertise.

Informed consent Written informed consent was obtained from all subjects (patients).

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

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