BMC Musculoskeletal Disorders

https://doi.org/10.1186/s12891-026-10183-7

Article in Press

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Received: 19 March 2026

Accepted: 2 July 2026

Published online: 07 July 2026

Cite this article as: Gascón-Jaén J., Poveda-Pagán E., Lozano-Quijada C. *et al.* Surface EMG activity during cervical and upper limb tasks in individuals with neck pain: a systematic review. *BMC Musculoskelet Disord* (2026). https://doi.org/10.1186/s12891-026-10183-7

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TITLE PAGE

Title: Surface EMG Activity During Cervical and Upper Limb Tasks in Individuals with Neck Pain: A Systematic Review

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Surface EMG Activity During Cervical and Upper Limb Tasks in Individuals with Neck Pain: A Systematic Review

Abstract

Background: Neck pain has been associated with altered neuromuscular function, including changes in muscle activation and coordination. However, inconsistencies across studies have limited clinical interpretation and hindered the identification of consistent differences in muscle activation patterns between individuals with neck pain and asymptomatic controls. This systematic review aimed to synthesise evidence on surface electromyography (sEMG) activity during cervical and upper limb tasks in individuals with neck pain compared with asymptomatic controls.

Methods: A systematic search of PubMed, Embase, Web of Science, and the Cochrane Library was conducted from inception to 5 October 2025. Observational studies were eligible if they compared sEMG activity between individuals with and without neck pain during cervical or upper limb tasks and reported sEMG outcomes normalised to a reference contraction. Two reviewers independently screened articles, extracted data, and assessed methodological quality using the Joanna Briggs Institute checklist.

Results: Eighteen studies involving 756 participants met the inclusion criteria. Sixteen reported significant between-group differences in sEMG outcomes, most frequently showing increased amplitude in superficial muscles such as the sternocleidomastoid, upper trapezius, and splenius capitis. Alterations were more consistently observed during cervical tasks, particularly those assessing motor control, whereas findings during upper limb tasks were more variable. Considerable heterogeneity was identified across studies in task design, muscles assessed, and sEMG normalisation procedures.

Conclusions: Sixteen of eighteen studies reported altered muscle activation in individuals with neck pain, particularly during cervical tasks. These findings suggest that altered activation patterns may reflect task-specific adaptations rather than uniform dysfunction, highlighting the importance of considering task-specific neuromuscular responses when assessing and managing individuals with neck pain.

Keywords

neck pain; surface electromyography; EMG; muscle activation; motor control; cervical spine

Introduction

Neck pain is one of the most common musculoskeletal conditions across different age groups and populations [1, 2], with global prevalence estimates ranging from 16.7% to 75.1% [3]. A substantial proportion of individuals with acute neck pain continue to report symptoms one year after onset, with longitudinal studies indicating that approximately one-third to one-half remain symptomatic at that time [4, 5]. Neck pain may also be associated with significant interference in daily function and quality of life [4]. Furthermore, neck pain has been correlated with increased levels of disability [6], resulting in restrictions in activities of daily living and work-related activities [7].

In addition to its functional consequences, neck pain has been associated with neuromuscular alterations, including changes in muscle activation and coordination [8]. Individuals with neck pain often show increased activity in superficial muscles such as the sternocleidomastoid, upper trapezius, and splenius capitis [9, 10]. In contrast, deep cervical flexors such as the longus capitis and longus colli tend to show lower activation [11, 12].

Even during low-load tasks, these alterations have been shown to persist, which suggests that they may be adaptations developed in response to pain [13]. Pain-related motor adaptations may initially serve a protective function but can become maladaptive over time, reinforcing inefficient patterns and symptom persistence [14]. This pattern underscores the relevance of altered muscle activation in individuals with neck pain and highlights the potential of surface electromyography (sEMG) to improve our understanding of neuromuscular dysfunction, which may ultimately inform future intervention strategies [15, 16].

There is a growing interest in the use of sEMG to investigate neuromuscular patterns in individuals with neck pain. However, findings across studies remain somewhat controversial. While some authors report greater neck muscle activation in symptomatic individuals [10], others have observed higher activity in asymptomatic controls [17]. Such inconsistencies may, at least in part, reflect methodological differences between studies [15, 16], as variations in task selection, muscles assessed, and sEMG normalisation procedures may influence the direction and interpretation of muscle activation findings.

Consequently, it remains difficult to determine whether specific patterns of muscle activation are consistently associated with neck pain across studies. This uncertainty complicates the interpretation of sEMG findings and limits our understanding of the neuromuscular alterations observed in individuals with neck pain. Previous reviews have reported differences in muscle activation patterns between individuals with neck pain and asymptomatic individuals [15, 16], yet they have primarily focused on specific muscle groups or tasks and have often included studies without standardised normalisation procedures, which may limit the interpretability and comparability of findings across studies. Synthesising studies that compare symptomatic and asymptomatic individuals using sEMG with normalised data may provide clearer insights into neuromuscular adaptations associated with neck pain. Examining findings according to task type may help clarify whether distinct patterns of muscle activation emerge under different motor demands, thereby improving the interpretability of sEMG findings in individuals with neck pain. Clarifying these activation patterns is especially relevant, as it may inform more targeted interventions, aligning with the growing clinical focus on motor control impairments in individuals with neck pain. Therefore, this systematic review aims to synthesise evidence on cervical muscle activity during cervical and upper limb tasks in individuals with and without neck pain, based on sEMG studies that applied signal normalisation to a reference contraction.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [18]. The protocol was registered a priori in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42024575117.

Eligibility criteria

Studies were eligible for inclusion if they investigated sEMG activity of cervical muscles during cervical or upper limb movements in adult participants (18 years or older) with neck pain and included a comparison group of asymptomatic controls. Studies including adults with neck pain were eligible regardless of symptom duration (acute or chronic), as many sEMG studies do not clearly report pain chronicity. Only observational studies were included, such as cross-sectional, cohort, case–control, or prospective designs. Eligible studies were required to report electromyography (EMG) outcomes obtained using sEMG, normalised to a reference contraction (e.g., maximal or submaximal). Studies that used invasive EMG methods were excluded. Studies involving specific pathologies such as cervical radiculopathy, myelopathy, inflammatory diseases or neoplastic conditions, as well as cervical trauma, cervical surgery, whiplash-associated disorders or pain extending beyond the cervical region were excluded. Only articles published in English or Spanish were considered.

Search strategy

A systematic search was conducted in four electronic databases: PubMed (MEDLINE), Web of Science, Embase, and the Cochrane Library. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to neck pain, electromyography, and asymptomatic populations, using Boolean operators (AND/OR). The search syntax was adapted to the specific requirements of each database and is fully detailed in Supplementary Material S1 (Search strategy). No restrictions were applied regarding publication date or geographic location during the search process. The initial search was conducted on 24 September 2024. An updated search was performed on 5 October 2025. Two reviewers (JGJ and CLQ) independently conducted the search and screening processes using the same predefined criteria. Any discrepancies were resolved through discussion. Manual screening of reference lists from included articles was also performed. A complementary search was also performed in Google Scholar to capture relevant grey literature.

Study selection

After removing duplicates, two reviewers (JGJ and CLQ) independently screened all titles and abstracts identified by the search strategy. Articles considered potentially eligible were retrieved in full text and assessed for inclusion based on the predefined criteria. Disagreements at any stage of the selection process were resolved by discussion and consultation with a third reviewer (SPA). A web-based platform (Rayyan, http://rayyan.qcri.org) [19] was used independently by two reviewers to facilitate the screening process.

Data extraction

Data were independently extracted by two reviewers (JGJ and CLQ). Recorded information included participant characteristics, including symptom duration when reported, task type, EMG normalisation method, and technical acquisition parameters. EMG outcomes were noted in both the time (e.g., amplitude, onset) and frequency (e.g., spectral features) domains, with signal processing procedures documented.

In this review, the term task refers to the experimental motor condition performed during sEMG recording (e.g., the craniocervical flexion test (CCFT), shoulder elevation, or repetitive upper limb movements). The term is used descriptively to refer to the movement paradigm under which muscle activity was assessed and does not intend to represent the broader constructs of body functions or functioning described in the International Classification of Functioning (ICF). Cervical tasks were defined as tasks in which the primary motor demand involved movement of the cervical spine or an isometric contraction of the neck musculature in a specific direction. Upper limb tasks were defined as tasks in which the primary motor demand involved the upper limb.

Discrepancies were resolved through discussion or consultation with a third reviewer (SPA). Extracted data were summarised in tables to support the qualitative synthesis.

Methodological quality assessment

The methodological quality of the included studies was independently assessed by two reviewers (JGJ and CLQ) using the Joanna Briggs Institute critical appraisal checklist for analytical cross-sectional studies [20]. This tool comprises eight items, including sample selection, measurement reliability, confounding factors, and statistical analysis. Items were rated as “yes”, “no”, “unclear”, or “not applicable”. Discrepancies were resolved through discussion or consultation with a third reviewer (SPA). The quality score was calculated as the proportion of “yes” responses relative to applicable items, and studies were categorised as high (≥70%), moderate (40–69%), or low quality (<40%).

Narrative synthesis

A meta-analysis was not performed due to substantial methodological heterogeneity across studies, particularly in the muscles assessed, task types, contraction intensities, and EMG normalisation methods. Studies were grouped and compared according to the general type of movement examined, either cervical or upper limb tasks. Within each category, findings were organised by muscle and by the type of EMG outcome reported, whether amplitude, timing or frequency-related measures. The synthesis considered between-group comparisons (individuals with neck pain vs asymptomatic controls) as reported in the original studies. As EMG amplitude was the most consistently reported variable across studies, the synthesis primarily focused on amplitude-related findings, while timing and frequency-domain outcomes are described when available. Key findings are presented in tables and summarised qualitatively.

Results

A total of 820 records were identified across four databases. After removing duplicates, 437 records were screened, and 65 full-text articles were assessed for eligibility. Eighteen studies [9, 10, 13, 17, 21–34] met the inclusion criteria and were included in the review (Figure 1). The list of excluded full-text articles with the corresponding reasons for exclusion is provided in Supplementary Material S2.

A total of 756 participants were included: 353 individuals with neck pain and 403 asymptomatic controls. All studies that met the inclusion criteria were cross-sectional in design. Most studies described participants as having chronic neck pain [9, 10, 17, 21–24, 28, 30–34], while two required a minimum symptom duration of more than three months [27, 29]. Two studies reported a long-standing or recurrent history of neck pain without specifying a minimum duration (Jull et al., 2004; Lecompte et al., 2008), and one study did not report symptom duration [13]. Sample sizes varied notably across studies, ranging from 24 to 97 participants. The characteristics of the included studies are presented in Table 1. All studies employed sEMG to assess neuromuscular activity during cervical or upper limb tasks. To facilitate interpretation of the heterogeneous findings, the results were synthesised according to task type and subsequently organised by the specific muscles and motor demands assessed within each task category.

EMG findings during cervical tasks

Among the eleven studies evaluating cervical tasks [9, 10, 13, 21, 25–29, 33, 34], ten reported significant differences in muscle activation between individuals with and without neck pain [9, 10, 13, 21, 25, 27–29, 33, 34]. The cervical tasks assessed across studies included the CCFT, isometric cervical contractions, and dynamic cervical movement tasks. Most studies primarily examined EMG amplitude, while fewer assessed timing- or frequency-related outcomes. Overall, the direction and consistency of EMG findings varied according to the specific cervical task and outcome domain assessed. A summary of the proportion of studies reporting significant differences in EMG amplitude during cervical tasks is presented in Figure 2A.

Four studies assessed EMG activity during the CCFT [9, 25, 27, 34]. EMG normalisation procedures differed across studies, with Bonilla-Barba et al. (2020) and

Chahal and Kumar (2015) using MVC-based normalisation, whereas Iliopoulos et al. (2022) and Jull et al. (2004) used a standardised head-lift manoeuvre as the reference contraction. Across these studies, individuals with neck pain consistently showed greater activation of superficial cervical muscles compared with asymptomatic controls. Increased activation was most frequently observed in the sternocleidomastoid [9, 25, 27, 34]. Greater activation of the anterior scalene during the CCFT was reported in individuals with neck pain [9], with similar findings described by Chahal and Kumar (2015), despite limited methodological reporting in that study. In addition, increased activation of posterior cervical muscles, including the upper trapezius and splenius capitis, was identified in individuals with neck pain [9]. Bonilla-Barba et al. (2020) also assessed flexor-extensor activation ratios during the CCFT, although no significant between-group differences were identified.

Four studies assessed EMG activity during isometric cervical contraction tasks, including sustained cervical flexor and extensor endurance tasks, multidirectional isometric contractions, and maximal voluntary side-bending contractions [10, 13, 26, 29]. Three studies used MVC-based reference contractions for EMG normalisation [10, 13, 26], whereas Edmondston et al. (2011) employed a submaximal endurance contraction. Findings across studies were heterogeneous across contraction types and EMG outcomes. During multidirectional isometric contractions, increased sternocleidomastoid activation across all contraction directions was reported in individuals with neck pain, whereas greater upper trapezius and splenius capitis activation was observed only during specific contraction directions [10]. In contrast, Lecompte et al. (2008) found no significant between-group differences in sternocleidomastoid or erector spinae activation during maximal voluntary side-bending contractions, although individuals with neck pain demonstrated a more balanced activation pattern between these muscles, whereas controls showed dominant erector spinae activity. Frequency-related and motor unit findings varied across studies. Higher sternocleidomastoid motor unit firing rates in individuals with neck pain were observed during isometric contractions [13]. During sustained cervical flexion endurance tasks, Edmondston et al. (2011) reported a greater reduction in sternocleidomastoid median frequency in the control group, whereas no significant between-group differences in median frequency for the sternocleidomastoid or upper trapezius were identified during multidirectional isometric contractions [10].

Three studies assessed EMG activity during dynamic cervical movement tasks, including cervical flexion-extension, lateral flexion, and rotation movements [21, 28, 33]. Cheng et al. (2010) and Maroufi et al. (2013) used MVC-based normalisation, whereas Lascurain-Aguirrebeña et al. (2018) normalised EMG amplitude using submaximal isometric contractions. Findings across studies were heterogeneous. Greater activation of posterior cervical muscles in individuals with neck pain was reported for the erector spinae during cervical flexion movements [28]. Similarly, Cheng et al. (2010) reported increased splenius capitis activation during cervical flexion-extension movements, whereas no significant between-group differences were identified for the semispinalis capitis. In contrast, Lascurain-Aguirrebeña et al. (2018) found reduced activation of the right anterior scalene during cervical flexion-extension movements in individuals with neck pain, while no significant between-group differences were identified for the sternocleidomastoid, upper trapezius, or erector spinae.

EMG findings during upper limb tasks

Among the eight studies that assessed EMG activity of cervical muscles during upper limb tasks [17, 22–24, 30–32, 34], seven reported significant differences in muscle activation between individuals with and without neck pain [17, 22–24, 30, 31, 34]. The tasks involved shoulder elevation, flexion, reaching, and repetitive functional movements. All studies assessed time-domain outcomes, primarily amplitude-related measures, and some also examined onset timing. No study reported frequency-domain analyses. The proportion of studies showing significant between-group differences in EMG amplitude during upper limb tasks is presented in Figure 2B.

Two studies assessed EMG activity during functional reaching tasks [17, 31], both of which used MVC-based normalisation. Overall, findings were relatively consistent across studies. No significant between-group differences in sternocleidomastoid activation were identified during any of the reaching conditions assessed [17, 31]. Consistent with these findings, Lin et al. (2021) found no significant differences in splenius capitis activation during forward reaching. In contrast, reduced upper trapezius activation in individuals with neck pain was observed during forward reaching [17] and bilateral reaching tasks [31].

Four studies assessed EMG activity during shoulder elevation and resisted upper limb tasks [23, 24, 30, 34]. Three studies used MVC-based normalisation [23, 24, 34], whereas Wannaprom et al. (2023) normalised EMG data using muscle-specific reference contractions. Findings across studies were relatively consistent, with most studies reporting increased cervical muscle activation in individuals with neck pain during arm elevation tasks. Greater activation of posterior cervical and scapular muscles, including the semispinalis capitis, erector spinae, and upper trapezius, was observed during shoulder flexion, abduction, and external rotation tasks in individuals with neck pain [24, 30]. Similar upper trapezius findings during shoulder flexion, abduction, and shrugging tasks were also described by Chahal and Kumar (2015), although methodological details were limited in that study, whereas no significant between-group differences were identified for the levator scapulae. Increased sternocleidomastoid activation during unilateral shoulder flexion was also reported in individuals with neck pain, together with delayed onset of both the sternocleidomastoid and semispinalis capitis compared with asymptomatic controls [24]. In contrast, Ghaderi et al. (2019) found no significant between-group differences in upper trapezius amplitude during shoulder elevation, although individuals with neck pain demonstrated shorter upper trapezius peak latency. Altered muscle coordination patterns were additionally observed during arm elevation tasks, with higher upper trapezius to lower trapezius and upper trapezius to serratus anterior activation ratios reported in individuals with neck pain during shoulder flexion and abduction tasks [30].

Two studies assessed EMG activity during sustained or repetitive seated upper limb tasks, including a seated computer task and a repetitive dotting task [22, 32]. Falla et al. (2004a) normalised EMG data using sustained isometric contractions, whereas Wolff et al. (2024) used MVC-based normalisation. Wolff et al. (2024) found no significant between-group differences in sternocleidomastoid or upper trapezius activation during a seated computer task. In contrast, Falla et al. (2004a) reported greater sternocleidomastoid activation and lower upper trapezius activation throughout a repetitive seated upper limb task in individuals with neck pain, together with increased anterior scalene activation during the task. A summary of amplitude-related findings, grouped by muscle and task type, is presented in Table 2.

Methodological quality assessment

The methodological quality of the included studies was evaluated using the Joanna Briggs Institute checklist for analytical cross-sectional designs. Of the 18 studies, 13 scored six or more out of eight, indicating high quality (≥70%), while four were rated as moderate quality (50–69%). One study [34] received a score below 50%, reflecting low methodological quality.

Most studies clearly defined their inclusion criteria and employed appropriate statistical methods. In several cases, however, the setting was not described. Some studies offered limited information regarding the identification or control of confounding variables. In addition, aspects of measurement were occasionally unclear. This included insufficient detail on electrode placement, unspecified sampling frequencies, or a lack of task standardisation. A detailed breakdown of individual item responses and total scores is presented in Table 3.

Discussion

This systematic review synthesised EMG findings in individuals with neck pain compared with asymptomatic controls during cervical and upper limb tasks. Altered muscle activation patterns were identified across both task categories, although findings appeared to vary according to the specific task and protocol assessed. Most studies reported differences involving the superficial cervical muscles assessed, particularly the sternocleidomastoid, upper trapezius, and splenius capitis. However, the direction of these differences varied across tasks and protocols, underscoring the need for clinically grounded interpretation of muscle activity patterns.

An important characteristic of the included evidence is that the majority of studies involved individuals with long-standing neck pain conditions. Thirteen studies explicitly described participants as having chronic neck pain, and two additional studies required symptom durations longer than three months. This suggests that the neuromuscular alterations identified in the present review primarily reflect adaptations associated with persistent or recurrent neck pain rather than acute episodes.

Differences between individuals with and without neck pain were mainly observed during cervical tasks, particularly during the CCFT. All studies assessing this task reported increased muscle activation in the neck pain group, most consistently involving the sternocleidomastoid [9, 25, 27, 34]. In asymptomatic individuals, this task is typically characterised by relatively low activity of superficial muscles such as the sternocleidomastoid and anterior scalene, consistent with more effective recruitment of the deep cervical flexors [11]. As the CCFT demands precise activation of the deep cervical flexors while minimising superficial muscle involvement, it appears particularly sensitive to motor control dysfunction and may therefore represent a clinically useful assessment for identifying motor control impairments in individuals with persistent neck pain. Within this context, the increased activation of superficial cervical muscles observed across studies may reflect compensatory recruitment associated with impaired deep flexor function, consistent with previous reports linking superficial flexor overactivity with deep flexor inhibition [11, 12]. These findings further support the relevance of the CCFT for identifying motor control impairments in individuals with persistent neck pain.

In contrast to the consistent results observed during the CCFT, other cervical tasks yielded more variable patterns. Dynamic low-load movements that do not specifically target deep muscular control generally showed fewer between-group differences, although altered activation of muscles such as the splenius capitis and anterior scalene was still reported in some studies [21, 33]. Likewise, findings during isometric cervical tasks were heterogeneous, with between-group differences varying according to the contraction direction and task demands [10, 26]. These findings suggest that neuromuscular responses in individuals with neck pain may vary according to the specific control and stabilisation demands imposed by each cervical task. Interestingly, increased activation was not limited to muscles acting as primary movers. Higher EMG amplitude in posterior cervical muscles such as the splenius capitis and erector spinae was reported during both cervical flexion movements and isometric cervical contraction tasks [10, 28].

The greater activity of the splenius capitis may reflect a compensatory mechanism aimed at increasing spinal stiffness to maintain postural stability in patients with impaired neck motion [21, 35]. Within this context, altered activation of muscles not acting as primary movers may represent protective motor adaptations intended to modify force distribution and reduce mechanical stress on sensitive tissues [36]. Similar coactivation patterns have also been described in a previous systematic review of neck pain populations and interpreted as strategies aimed at preserving cervical stability in the presence of altered neuromuscular control [15].

In contrast to the findings observed during cervical tasks, upper limb tasks appeared to show more task-dependent patterns of cervical muscle activation. During functional reaching tasks, between-group differences in cervical muscle activity were mainly related to reduced upper trapezius activation. Studies assessing forward and bilateral reaching tasks generally reported no significant differences in sternocleidomastoid or splenius capitis activation between individuals with and without neck pain, whereas reduced upper trapezius activation was consistently observed during reaching movements [17, 31]. These findings suggest that neuromuscular alterations during these tasks may be more specifically related to scapulothoracic muscle behaviour than to widespread increases in cervical muscle activity. This pattern is consistent with previous experimental models of pain adaptation, in which reduced activity of agonist muscles has been interpreted as a protective motor response aimed at limiting mechanical stress on painful structures [37, 38].

Whereas relatively limited alterations were observed during functional reaching tasks, shoulder elevation and resisted upper limb tasks more frequently showed increased activation of cervical muscles in individuals with neck pain. Studies assessing these tasks generally reported broader cervical muscle involvement together with alterations in muscle coordination and activation timing during arm elevation movements [24, 30, 34]. Higher activation ratios involving the upper trapezius, together with delayed onset of the sternocleidomastoid and semispinalis capitis, further suggest alterations in muscle coordination beyond changes in activation amplitude during shoulder flexion and abduction tasks [24, 30]. Upper limb tasks involving greater stabilisation demands appear to require increased recruitment of cervical muscles in individuals with neck pain, which may give rise to different muscle coordination patterns during arm movements. Given the stabilising role of cervical muscles during arm movement, these adaptations may reflect compensatory neuromuscular strategies aimed at preserving segmental control during upper limb tasks involving greater stabilisation demands [39, 40].

Sustained or repetitive seated upper limb tasks involve prolonged low-level activation of cervical and scapulothoracic muscles and may therefore represent a distinct functional context compared with reaching or arm elevation tasks. Findings from these tasks were not uniform, with relatively limited or inconsistent upper trapezius alterations, whereas increased activation of superficial cervical muscles such as the sternocleidomastoid and anterior scalene was reported during repetitive upper limb activity in individuals with neck pain [22, 32]. Although these tasks generally involve relatively low levels of muscle activation, sustained low-intensity contractions have previously been associated with neck-shoulder discomfort in occupational settings, as proposed by the Cinderella hypothesis [41]. Within this context, the absence of consistent between-group differences in short laboratory tasks does not necessarily exclude clinically relevant effects of prolonged low-level muscle activation. Future studies using techniques such as high-density EMG may help clarify spatial and temporal redistribution patterns of muscle activity during prolonged low-load tasks that may not be detected using conventional bipolar sEMG recordings [42].

The variability observed in most muscle activation patterns between individuals with and without neck pain is consistent with contemporary models of motor adaptation to pain. Rather than reflecting uniform inhibition or facilitation, pain induces task- and individual-specific changes in motor output, resulting in a redistribution of activity both within and between muscles [14, 43]. This perspective may help explain why the present review identified heterogeneous activation patterns across tasks and muscles rather than a single consistent neuromuscular response in individuals with neck pain.

This review included only studies that applied signal normalisation, given the limitations associated with interpreting raw EMG data in between-subject comparisons [44]. The normalisation method has been suggested to influence the interpretation of EMG findings [45, 46], and submaximal reference contractions have been proposed to reduce potential confounding effects related to pain or fear of pain during maximal efforts [33, 47]. Although different normalisation procedures were used across the included studies, no clear pattern emerged according to the reference contraction employed. Studies using both maximal and submaximal reference contractions reported variable results, and the available evidence does not allow firm conclusions regarding whether one approach provides more consistent findings in individuals with neck pain.

sEMG findings involving cervical muscles included in this review should be interpreted cautiously due to the potential influence of crosstalk from adjacent muscles, particularly when assessing anatomically overlapping or deeper muscles with limited surface accessibility. This issue may be especially relevant during cervical and upper limb tasks involving substantial coactivation or stabilisation demands, in which some assessed muscles may not act as primary movers and selective signal acquisition becomes more challenging. Although several studies reported electrode placement procedures using anatomical landmarks, previously published protocols, or SENIAM recommendations, methodological detail and standardisation varied across studies, and only a limited number explicitly acknowledged the potential influence of crosstalk during signal acquisition or interpretation [10, 32]. Consequently, differences in electrode placement procedures and task-specific neuromuscular demands may have contributed to variability in sEMG findings and may partly explain some of the heterogeneous activation patterns observed across studies in the present review.

Limitations

This review has some limitations that should be considered when interpreting the findings. The exclusion of studies using invasive EMG methods may have limited the understanding of deep cervical muscle behaviour. In addition, differences in task selection, contraction intensity, and EMG normalisation methods across studies complicate direct comparisons and may have influenced the observed variability. The lack of standardisation in signal acquisition, electrode placement procedures, and signal processing further contributes to this complexity, particularly when assessing anatomically overlapping or deeper cervical muscles susceptible to crosstalk. This methodological variability makes it difficult to draw consistent conclusions about muscle activation patterns across studies. Another limitation of this review is the absence of a quantitative synthesis of EMG amplitude outcomes, due to the substantial methodological heterogeneity across the included studies. A formal assessment of certainty of evidence was not performed, as variability across studies limited its applicability in this context. In addition, the terminology used to describe symptom duration varied across studies, and not all studies reported explicit duration criteria, which limited the possibility of exploring potential differences between acute and chronic neck pain. Moreover, the decision to include only studies published in English or Spanish may have resulted in the exclusion of relevant studies published in other languages. Finally, as all included studies were cross-sectional, the direction of the relationship between altered muscle activity and neck pain remains uncertain, and the observed alterations in muscle activation should therefore not be interpreted as causal mechanisms of neck pain.

Conclusion

This systematic review synthesised evidence on cervical muscle activation during cervical and upper limb tasks in individuals with and without neck pain. Altered muscle activation patterns were frequently reported, most commonly increased amplitude in superficial cervical muscles. These alterations were more consistently observed during cervical tasks, particularly the CCFT, which appears sensitive to motor control deficits.

Regarding upper limb tasks, reduced upper trapezius activation was more frequently observed during functional reaching tasks, whereas shoulder elevation and resisted upper limb tasks more commonly showed increased cervical muscle activation and altered coordination patterns. Taken together, the evidence suggests that neck pain is associated with task-specific and potentially compensatory changes in muscle activation patterns. As most included studies involved individuals with long-standing neck pain, the observed patterns may primarily reflect neuromuscular adaptations associated with persistent neck pain conditions. These findings highlight the relevance of considering task-specific neuromuscular responses when assessing and managing individuals with persistent neck pain and may help guide future research and rehabilitation strategies targeting motor control impairments.

List of abbreviations

sEMG: surface electromyography

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROSPERO: International Prospective Register of Systematic Reviews

MeSH: Medical Subject Headings

CCFT: craniocervical flexion test

EMG: electromyography

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are derived from previously published studies, which are cited in the manuscript. No new datasets were generated or analysed in this study.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors received no specific funding for this work.

Authors' contributions

Conceptualization: JGJ, EPP, and RNC; Methodology: JGJ and RNC; Investigation: JGJ, CLQ, SPA; Data curation: JGJ, CLQ, and EPP; Writing – original draft: JGJ and EPP; Writing – review and editing: RNC, EPP, CCM, and SPA; Supervision: SPA.

Acknowledgements

Not applicable.

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Tables

Table 1. Description of included studies.

Author (Date)	Neck pain subjects	Asymptomatic control subjects	Task or movement assessed	Muscles assessed	EMG outcomes (time & frequency domains)	EMG acquisition and electrode placement parameters	Signal Processing Techniques	EMG Normalisation method
Bonilla-Barba et al. (2020)	30 women with mechanical chronic neck pain (mean age 30 ± 11 years)	30 asymptomatic women (mean age 33 ± 11 years)	CCFT, 5 incremental stages (22–30 mmHg), 10 s hold per stage.	-SCM -AS -SPL -UT	Time domain: -SCM and AS: RMS ↑ in NP vs CG at all CCFT stages ($p < 0.001$) -UT: RMS ↑ in NP vs CG at all CCFT stages ($p < 0.001$) -SPL: RMS ↑ in NP vs CG ($p < 0.001$), but not consistently across CCFT stages	-sampling rate 4000 Hz - amplifier gain ×300 -band-pass filter 20–500 Hz (4th-order Butterworth) -electrode placement described using anatomical landmarks	-RMS average over 5 s window per CCFT stage	-MVC (one 2 s trial)
Chahal et al. (2015)	15 patients with chronic neck pain (3 males, 12 females); mean age 22.9 ± 2.0 years	15 asymptomatic subjects (5 males, 10 fem	-Static shoulder abduction to 90° and hold -Shoulder shrug and hold -Craniocervical flexion and hold	-SCM -AS -LS -UT	Time domain: -SCM and AS: ↑ EMG activity in NP vs CG during Craniocervical flexion ($p < 0.05$) -UT: ↑ activation in NP vs CG on the right side during abduction and shrug ($p < 0.05$); no	- EMG acquisition parameters not reported -electrode placement described using anatomical landmarks	- Signal Processing Techniques not reported	-MVC (three 10 s trials)

		ales); mean age 22.5 ± 2.3 years			significant differences on the left side -LS: no significant differences between NP and CG during shrug			
Cheng et al. (2010)	12 subjects with chronic neck pain (6 males, 6 females); mean age 25.4 ± 2.1 years (Graduated students, teachers, or clinicians with work-related pain)	12 healthy young adults (7 males, 5 females); mean age 24.9 ± 1.8 years (Graduated students, teachers, or	-Voluntary neck flexion and extension (neutral-flexed-neutral, neutral-extended-neutral) -3 s hold at end range	-SCM -SPL -SSC	Time domain: -SCM: no significant differences between NP and CG -SPL: ↑ activity in NP vs CG on left ($p = 0.001$) and right ($p = 0.046$). -SSC: no significant differences between NP and CG.	-sampling rate 1000 Hz -amplifier preamplifier gain ×350 (CMRR 95 dB) -band-pass filter 20–350 Hz -A/D 12 bits -electrode placement described using anatomical landmarks	-full-wave rectification -NAIEMG calculated (integrated EMG/duration of contraction, %MVC) -low-pass smoothing (Butterworth, 8th order, 100 ms)	-MVC (three 3 s trials)

		clinicians with work-related pain)						
Edmondston et al. (2011)	13 female patients with postural neck pain; mean age 28.9 ± 12.6 years (University students and staff)	12 asymptomatic female subjects; mean age 26.1 ± 5.3 years (University students and staff)	Sub-maximal isometric endurance tests for neck flexors and extensors (head lift and hold position)	-SCM (bilateral) -ES (C5) (Bilateral)*	Frequency domain: -MF decline in both groups -no significant differences between NP and CG in ES -greater MF decline in CG vs NP in left SCM (p = 0.03)	-band-pass filter 20–1000 Hz (Butterworth, 4th order) -electrode placement described using anatomical landmarks	Time domain -full-wave rectification -low-pass filtering 8 Hz for linear envelope Frequency domain -FFT with overlapping 6 s Hamming windows -median frequency slope determined by linear regression (Hz/min)	-Sub-maximal isometric endurance tests (one 5 s trial)
Falla et al. (2004)	10 subjects with chronic neck pain (3 males, 7 females); mean age 33.6 ± 9.8 years †	10 asymptoma	-Seated repetitive upper limb task (dotting in circles with right hand for 2.5 min, 88 bpm)	-SCM (Bilateral) -AS (Bilateral) -UT (Bilateral)	Time domain: -SCM (left): ↑ EMG amplitude in NP vs CG in	-sampling rate 1000 Hz -amplifier (not specified)	-RMS (1 s) calculated from 5 s epochs -log transformation	-Sustained isometric contraction (three 10 s

		tic control subjects (5 males, 5 females); mean age 31.4 ± 11.5 years			all conditions ($p < 0.05$) -SCM (right): ↑ EMG amplitude in NP vs CG at 10 s, 60 s, and 120 s ($p < 0.05$) -AS (left): ↑ EMG amplitude in NP vs CG at 10 s ($p < 0.05$) -UT (right): ↑ EMG amplitude in CG vs NP at 10 s, 60 s, and 120 s ($p < 0.05$)	-band-pass filter 10–500 Hz -electrode placement based on previously published protocols	-repeated measures general linear model	trials)
Ghaderi et al. (2019)	20 participants with chronic neck pain; mean age 30.93 ± 8.92 years (sex distribution not specified)	20 healthy participants; mean age 31.21 ± 8.75 years (sex distribution not spe	-Shoulder elevation with a pre-determined load (25–30% of an individual's maximum voluntary exertion)	-UT*	Time domain: -UT: UT peak latency: ↓ in NP vs CG ($p < 0.05$) -UT onset: no significant differences between NP and CG -UT peak amplitude: no significant differences between NP and CG	-sampling rate 1500 Hz -amplifier differential (CMRR 95 dB; gain 1000) -noise <1 μV – filter 1–500 Hz (Butterworth) - A/D 14 bits -electrode placement described using anatomical landmarks	-RMS of raw signal -window 50 ms -EMG onset latency mean + 3 SD from baseline -visual verification of onset	-MVC (three 10 s trials)

		cified)						
Hsu et al. (2020)	25 young adults with chronic nonspecific neck pain (12 males, 13 females); mean age 23.1 ± 3.0 years	25 asymptomatic participants (12 males, 13 females); mean age 23.8 ± 2.1 years	-Self-initiated unilateral right-side shoulder flexion to 90° in standing position -Performed under eyes-open and eyes-closed conditions	-SCM -SSC*	Time domain: -SCM and SSC: EMG activation ↑ in NP vs CG ($p \leq 0.05$) -SCM: onset time delayed in NP vs CG ($p \leq 0.05$) -SSC: onset time delayed in NP vs CG ($p \leq 0.05$)	-sampling rate 2000 Hz -band-pass filter: 20–450 Hz -low-pass smoothed (Butterworth, 8th order, 100 ms) -A/D 16-bit -ectrode placement based on previously published protocols	-full-wave rectification -low-pass smoothing (Butterworth, 8th order, 100 ms time constant)	-MVC (three trials)
Iliopoulos et al. (2022)	22 participants with neck pain (11 males, 11 females); mean age 24.9 ± 5.2 years (Undergraduate students and university employees)	22 asymptomatic participants (11 males, 11 females);	-CCFT in supine position using pressure biofeedback - Isometric contractions at pressure levels: 22, 24, 26, 28, and 30 mmHg	-SCM (bilateral)	Time domain: -SCM: ↑ EMG amplitude in NP vs CG with head lift normalisation ($p = 0.024$) -no significant differences between NP and CG with resisted head lift normalisation	-sampling rate: 2000 Hz -amplifier gain ×1000 -band-pass filter: 20–1000 Hz (Butterworth) -electrode placement according to SENIAM recommendations	-RMS analysis with 500 ms windows per pressure level	-Normalised to head lift (10 s standardised maneuver) -Alternative normalisation to resisted head lift (10-s standardised maneuver)

		mean age 25.6 ± 5.8 years (Undergraduate students and university employees)						
Jull et al. (2004)	25 patients with neck pain (5 males, 20 females); mean age 40.3 ± 9.2 years †	25 asymptomatic control subjects (10 males, 15 females); mean	-CCFT -Performed in five incremental stages (22–30 mmHg), each level held for 5 s with 10 s rest	-SCM	Time domain: -SCM: ↑ RMS in NP vs CG ($p < 0.05$)	-sampling rate 1000 Hz -band-pass filter 20–500 Hz -ectrode placement based on previously published protocols	-maximum RMS per stage extracted (1 s window) -left/right SCM averaged -log-transformed data analysis	-Normalised to head lift standardised maneuver (one 10 s trial).

		age 39.3 ± 14.0 years						
Kumar et al. (2010)	34 patients with chronic non-specific neck pain (17 males, 17 females); aged 18–60 years	63 asymptomatic participants (30 males, 33 females)	Isometric exertions in: -Flexion -Antero-lateral flexion (bilateral) -Lateral flexion (bilateral) -Postero-lateral extension (bilateral) -Extension	-SCM (bilateral) -SPL (bilateral) -UT (bilateral)	Time domain: -SCM: EMG activation ↑ in NP vs CG during all contractions ($p < 0.05$) -SPL: EMG activation ↑ in NP vs CG during flexion, antero-lateral and left lateral flexion ($p < 0.05$) -UT: EMG activation ↑ in NP vs CG in all contractions except extension ($p < 0.05$) -onset variables (time to onset, time to peak): calculated but no significant between-group differences reported Frequency domain: -no significant differences in MF between NP and CG;	-sampling rate 2000 Hz -amplifier differential (preamplification ×10; gain 100; CMRR 92 dB) -band-pass filter 20–450 Hz -time constant 25 ms -electrode placement described using anatomical landmarks	Time domain: -full-wave rectification -linear envelope detection -AR4 modelling -extraction of autocorrelations and AR coefficients -wavelet-based extraction of RMS, mean, dispersion, skewness, and kurtosis (8 levels) Frequency domain: -Daubechies wavelet decomposition (8 levels) -spectral features: RMS and 10% band power per level	-MVC (three 3 s trials)

					significant spectral power differences in specific tasks (right SCM during flexion and antero-lateral flexion; left UT during extension tasks) ($p < 0.05$)			
Lascurain-Aguirrebeña et al. (2018)	20 participants with chronic neck pain (3 males, 17 females); mean age 45 ± 13 years	20 asymptomatic participants (5 males, 15 females); mean age 43 ± 13 years	-Forward flexion, side flexion, extension, and rotation of the neck -Movements assessed in 10° increments of the range of motion (ROM)	-AS -SCM -UT -ES	Time domain: -AS (right): ↓ activity in NP vs CG during flexion and extension ($p < 0.05$) -no significant differences between NP and CG in other muscles assessed	-band-pass filter 30–450 Hz (Butterworth, 4th order) -electrode placement described using anatomical landmarks	-full-wave rectification -smoothing with 20-ms moving average window	-Submaximal isometric contractions (30N) (three 10 s trials).
Lecompte et al. (2008)	-9 Neck pain male fighter pilots; mean age 39 ± 3 years	-10 asymptomatic male	-Maximal voluntary isometric contractions in flexion, extension, and left/right side-bending (neutral sitting posture)	-SCM -ES	Time domain: -SCM and ES: no significant differences between NP and control pilots -within NP pilots:	-amplifier gain 1000× -bandwidth 6–400 Hz (−6 dB) -notch filter 50 Hz -electrode placement	-highest torque trial selected -RMS calculated -RMS normalised to flexion and extension -window 500 ms for	-MVC (three 5 s trials)

		fighter pilots; mean age 38 ± 5 years - 8 healthy male non-pilot subjects, mean age 29 ± 7 years			no significant differences between ES and SCM -in healthy non-pilots: ES > SCM during side bending (p < 0.05)	described using anatomical landmarks	peak torque	
Lin et al. (2021)	20 subjects with chronic neck pain (14 males, 6 females); mean age 24.1 ± 3.4 years	20 asymptomatic subjects (14 males, 6	-Functional forward reach task with arm raised to 90° -Reach held for 3 s at farthest point	-UT (Right) -SCM (Right) -SPL (Right)	Time domain: -UT: ↓ EMG activity in NP vs CG at farthest reach point (p = 0.04) -SCM and SPL: no significant differences between NP and CG	-sampling rate 1000 Hz -band-pass filter 40–400 Hz -ectrode placement based on previously published protocols	-RMS analysis	-MVC

		females); mean age 23.7 ± 3.3 years						
Maroufi et al. (2013)	22 women with chronic non-specific neck pain; mean age 23.45 ± 2.6	21 healthy women; mean age 23.4 ± 1.8 years	-Seated cervical flexion-extension task -4 phases (neutral, flexion, sustained flexion, extension) - Each phase 4 s, paced by metronome; 3 trials	-ES -UT	Time domain: -ES: ↑ activity in NP vs CG during background, flexion, and full flexion phases ($p < 0.05$)	-sampling rate 1000 Hz -amplifier differential (CMRR 110 dB; gain 1000; noise <1 μV RMS) -band-pass filter 10–500 Hz -electrode placement described using anatomical landmarks	-RMS analysis with 250-ms window and 50% overlap	-MVC (three 5 s trials)
Wannaprom et al. (2023)	30 participants with chronic nonspecific neck pain and scapular downward rotation (10 males, 20 females); mean age 38.1 ± 10.1 years 30 participants with chronic nonspecific neck pain without scapular dysfunction (11 males, 19 females); mean age 34.8 ± 9.4 years	30 healthy participants without scapular dysfunction (10	-Isometric shoulder exertions in: • 30° flexion • 30° abduction • 30° external rotation -At 20%, 50%, and 100% MVC -Unilateral testing on painful side (NP) or random (controls)	-UT -ES*	Time domain: -UT (NP with SDR): EMG activity ↑ in NP with SDR vs NP without SDR and CG during 30° flexion (20% MVC) and abduction (20% and 50% MVC) ($p < 0.05$) -UT: no significant differences	-sampling rate 1000 Hz -amplifier differential (CMRR 85 dB at 60 Hz; input impedance 200 MΩ) -band-pass filter 10–500 Hz -A/D 16 bits -electrode placement described using anatomical landmarks	-RMS analysis (100-ms moving window) -averaging over 2 s (100% MVC) and 5 s (20% and 50% MVC)	-Reference contractions per muscle (three 10 s trials).

		males, 20 females); mean age 34.2 ± 7.1 years			between groups at 100% MVC or during external rotation -ES (NP groups): EMG activity ↑ in NP vs CG across all tasks and intensities ($p < 0.001$)			
Wolff et al. (2022)	18 participants with chronic neck pain (7 males, 11 females); mean age 34.4 ± 2.5 years	18 asymptomatic participants (7 males, 11 females); mean age 32.2 ± 3.0 years	-Unilateral forward reach to head-high shelf -Bilateral forward reach to head-high shelf -Unilateral upward reach to lightbulb positioned above head height - Each task held for 5 s for data collection	-SCM (bilateral) -UT (bilateral)	Time domain: -SCM: no significant differences between NP and CG in EMG amplitude during any reaching task -UT: EMG amplitude ↓ in NP vs CG during bilateral forward reach ($p = 0.004$); no significant differences between NP and CG in unilateral reaches	-band-pass filter: 30–500 Hz (Butterworth, 3rd order) -electrode placement described using anatomical landmarks	-full-wave rectification -EMG amplitude averaged over 200 ms window	-MVC (two 2 s trials)
Wolff et al. (2024)	15 individuals with chronic neck pain (10 females mean age 36.4	15 matche	-Seated computer task across 9 conditions (3 chair recline angles × 3 head/neck positions)	-UT (UT1, UT2, UT3) -SCM (bilateral)	Time domain: -SCM: no significant	-band-pass filter 30–500 Hz (Butterworth, 3rd	-full-wave rectification -RMS computed	-MVC (two trials)

	± 5.8 years, 5 males; mean age 41.4 ± 9.2 years)	d healthy controls (10 females; mean age 42 ± 5.9 years, 5 males; mean age 37.4 ± 8.6 years)	-2.5 min/condition		differences between NP and CG; in women, ↑ activation in non-dominant SCM vs dominant SCM in neutral head/neck position in NP ($p = 0.03$) -UT: no significant differences between NP and CG	order) -electrode placement described using anatomical landmarks	across trial excluding first and last 10 s	
Yang et al. (2016)	12 patients with mechanical neck disorder (2 males, 10 females); mean age 28.8 ± 8.1 years	12 asymptomatic individuals (5 males, 7 females	-Isometric cervical flexion at 25% MVC using custom device in supine position -20 s contraction	-SCM (bilateral)	Frequency domain: -SCM: initial and mean firing rates ↑ in NP vs CG ($p < 0.05$), except at 15–20% MVC	-sampling rate 20 kHz -band-pass filter 20–1750 Hz -limited electrode placement details reported	-signal decomposition using Precision Decomposition III algorithm -firing rate smoothing with 2 s Hanning filter	-MVC (three 3 s trials)

		); mean age 27.5 ± 6.2 years						

NP, Neck pain group; CG, Control group; n.s., Not significant; CCFT, Cranio-cervical flexion test; MVC, Maximum voluntary contraction; MVIC, Maximum voluntary isometric contraction; EMG, Electromyography; A/D, analog-todigital conversion; CMRR, Common mode rejection ratio; RMS, Root mean square; NAIEMG, Normalised Average Integration of EMG activity; MF, Median frequency; FFT, Fast Fourier Transform; dB, Decibel(s); SCM, sternocleidomastoid; UT, upper trapezius; AS, anterior scalene; SPL, splenius capitis; SSC, semispinalis capitis; LS, levator scapulae; ES, erector spinae.

* Muscle(s) reported in the original study but not included in this review due to anatomical criteria.

† Participant group not included in this review (e.g., whiplash-associated disorder).

Table 2. Summary of EMG Amplitude Changes in Individuals with Neck Pain Relative to Asymptomatic Controls

		SCM	AS	UT	SPL	SSC	ES	LS
Cervical task	Bonilla-Barba et al. (2020)	↑	↑	↑	↑			
	Chahal et al. (2015)	↑	↑					
	Cheng et al. (2010)	n.s			↑	n.s		
	Jull et al. (2004)	↑						
	Kumar et al. (2010)	↑		↑	↑			
	Lascurain-Aguirrebeña et al. (2018)	n.s	↓	n.s			n.s	
	Lecompte et al. (2008)	n.s					n.s	
	Iliopoulos et al. (2022)	↑						
	Maroufi et al. (2013)						↑	
Upper limb task	Chahal et al. (2015)			↑				n.s
	Falla et al. (2004)	↑	↑	↓				
	Ghaderi et al. (2019)			n.s				
	Hsu et al. (2020)	↑				↑		
	Lin et al. (2021)	n.s		↓	n.s			
	Wannaprom et al. (2023)			↑			↑	
	Wolff et al. (2022)	n.s		↓				
	Wolff et al. (2024)	n.s		n.s				

Summary of direction of electromyography (EMG) amplitude changes in individuals with neck pain compared with asymptomatic controls across multiple muscles. ↑ indicates a significant increased amplitude in the neck pain group relative to controls; ↓ indicates a significant decreased amplitude in the neck pain group relative to controls; n.s., no significant differences between groups. Blank cells indicate that the muscle was not assessed in the study. SCM, sternocleidomastoid; UT, upper trapezius; AS, anterior scalene; SPL, splenius capitis; SSC, semispinalis capitis; LS, levator scapulae; ES, erector spinae.

Table 3. Methodological quality assessment of included studies using the Joanna Briggs Institute (JBI) checklist.

Studies	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Score (%)
Bonilla-Barba et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	8 (100%)
Chahal et al. (2015)	Y	U	U	U	N	N	U	Y	2 (25%)
Cheng et al. (2010)	Y	N	Y	Y	Y	Y	U	Y	6 (75%)
Falla et al. (2004)	Y	N	Y	Y	Y	Y	Y	Y	7 (87.5%)
Ghaderi et al. (2019)	Y	Y	Y	Y	Y	Y	Y	Y	8 (100%)
Hsu et al. (2020)	Y	N	Y	Y	Y	Y	U	Y	6 (75%)
Jull et al. (2004)	Y	Y	U	U	Y	Y	Y	Y	6 (75%)
Kumar et al. (2010)	Y	N	Y	Y	Y	N	U	Y	5 (62.5%)
Lascurain-Aguirrebeña et al. (2018)	Y	Y	Y	Y	Y	Y	U	Y	7 (87.5%)
Lecompte et al. (2008)	Y	N	Y	Y	Y	N	U	Y	5 (62.5%)
Lin et al. (2021)	Y	N	Y	Y	Y	Y	U	Y	6 (75%)
Iliopoulos et al. (2022)	Y	Y	Y	Y	Y	N	Y	Y	7 (87.5%)
Maroufi et al. (2013)	Y	N	Y	Y	Y	Y	Y	Y	7 (87.5%)
Edmondston et al. (2011)	Y	Y	Y	Y	Y	U	U	Y	6 (75%)
Wannaprom et al. (2023)	Y	Y	Y	Y	Y	Y	Y	Y	8 (100%)
Wolff et al. (2022)	Y	Y	Y	Y	Y	Y	U	Y	7 (87.5%)
Wolff et al. (2024)	Y	N	U	U	Y	Y	U	Y	4 (50%)
Yang et al. (2016)	Y	N	U	U	Y	Y	Y	Y	5 (62.5%)

Items 1–8 correspond to the JBI checklist for analytical cross-sectional studies: (1) inclusion criteria; (2) subject and setting description; (3) exposure measurement; (4) outcome measurement; (5) confounding factors identification; (6) strategies to deal with confounders; (7) outcome measurement reliability; (8) appropriate statistical

analysis. The score represents the number of 'Yes' responses (maximum = 8). The percentage indicates the proportion of criteria met. Y, Yes; N, No; U, Unnclear

Figure legends

Figure 1. PRISMA 2020 flow diagram for systematic reviews with database, register, and other source searches.

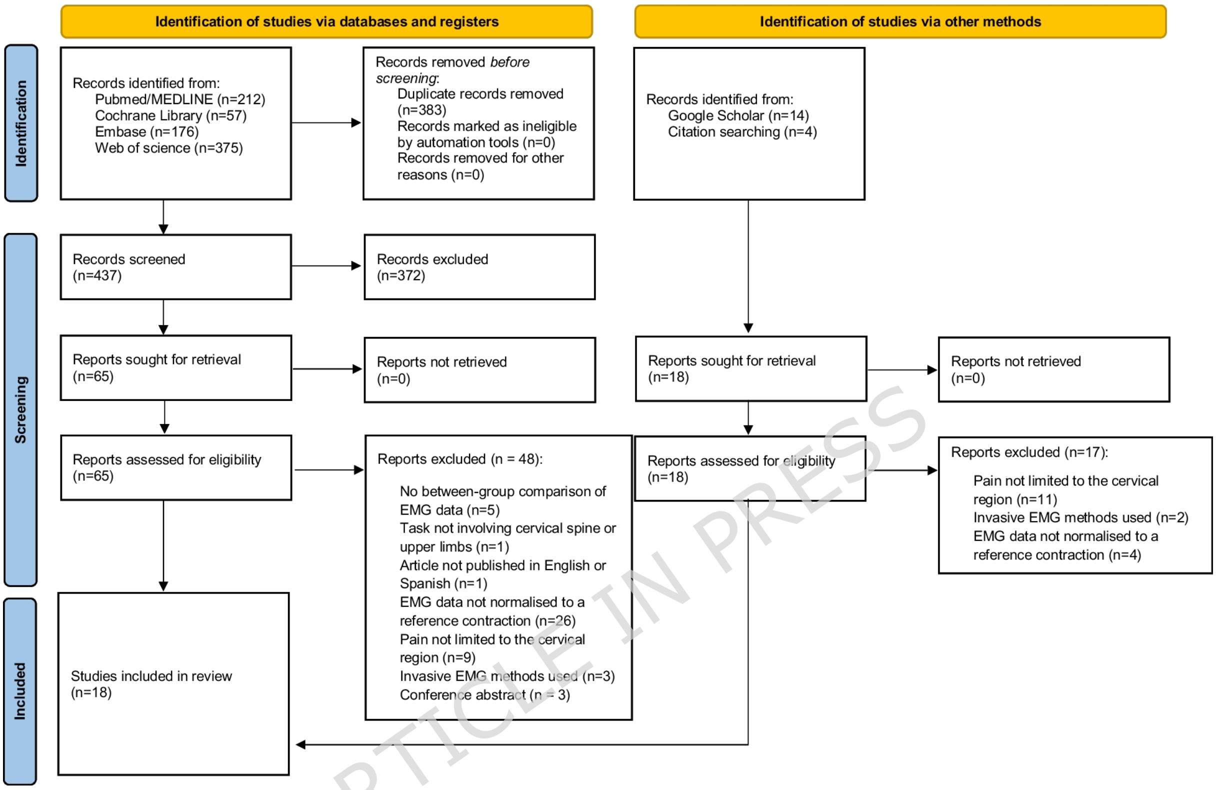
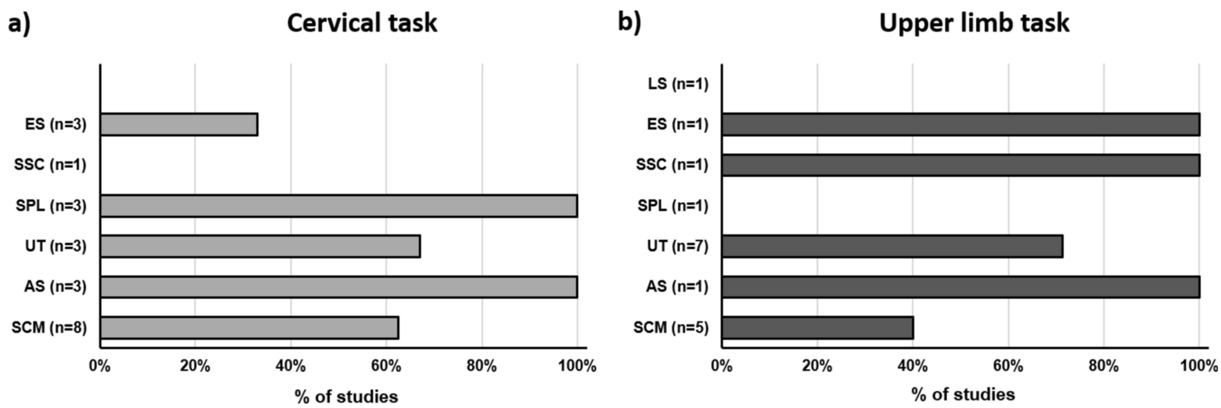


Figure 2. Proportion of studies showing significant EMG amplitude differences between neck pain and asymptomatic individuals.



(a) Cervical tasks and (b) upper limb tasks illustrate the percentage of studies reporting significant between-group differences in electromyography (EMG) amplitude for each muscle. SCM, sternocleidomastoid; UT, upper trapezius; AS, anterior scalene; SPL, splenius capitis; SSC, semispinalis capitis; LS, levator scapulae; ES, erector spinae.