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The relationship between cervical lordosis and neck pain: A systematic review and meta-analysis

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Abstract: The interpretation of the correlation between cervical lordotic angle (CLA) and neck pain (NP) among clinicians remains contentious, reflecting the nuanced nature of this association within clinical discourse. This relationship assumes paramount importance in clinical practice, as it serves as the cornerstone for devising effective therapeutic strategies aimed at the management and prevention of NP. The objective of this study was to determine the difference in CLA between individuals with and without NP. The inclusion criteria entailed observational studies rigorously evaluating CLA through radiological imaging in both NP patients and healthy controls (HC), while pediatric, geriatric populations, and non-degenerative spinal conditions were excluded. We conducted a thorough electronic search across several databases including Medline, Cochrane Library, Embase, CINAHL, and PEDro. The search strategy employed terms pertinent to cervical alignment and NP, using Boolean logic. Specifically, search terms such as "neck pain*", "cervical pain*", and "lordo*" were used to ensure comprehensive coverage of relevant literature. We estimated the standardized Mean Differences (SMD) and their corresponding 95% Confidence Intervals (CI). Additionally, chi-square and I2 statistics were used to evaluate within-group heterogeneity through a random effects model. A total of 6 studies, involving 436 patients with NP and 491 HC, were identified. Overall, individuals with NP demonstrated a tendency towards smaller CLA compared to the HC group.

Keywords: *Cervical lordosis, Meta-analysis, Neck pain, Systematic review.*

1. Introduction

According to the Global Burden of Disease studies, neck pain (NP), in addition to low back pain, is one of the primary musculoskeletal conditions contributing significantly to years lived with disability [1]. The one-year incidence of NP is around 20%, displaying an high frequency particularly among office and computer-based occupations, and purportedly more prevalent among the female demographic [2-4]. It stands as one of the primary factors for ambulatory healthcare visits, with its prevalence over a 12-month period ranging from 30% to 50% [5].

Biomechanically, a lordotic posture can withstand substantial compressive loads [6] and alleviate stress on the vertebral endplates [7]. Within the cervical spine, the anterior column absorbs 36% of the compressive load, while the facet joints bear 64% [8,9]. In asymptomatic individuals, the cervical spine generally attains lordotic curve, although up to 35% of cases may present with kyphosis [10]. The cervical lordotic angle (CLA) demonstrates notable diversity among asymptomatic individuals and patients with associated conditions [11-13]. In studies that have measured alignment of C2–7 vertebrae using the posterior tangent method, the average CLA in asymptomatic individuals has been variously reported as 40° by Yochum et al. [14], 21.3° by Gore et al. [10], 22.3° by Owens et al. [15], and 34° by Harrison et al [16]. Cervical deformity was initially defined by Smith et al. as a C2–7 angle greater than 0° and a C2–

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7 sagittal vertical axis exceeding 4 cm in their thoracolumbar deformity cohort [17]. In the study conducted by Grob et al. regarding the correlation between NP and cervical lordosis, no significant difference was found between the group with NP and the group without NP concerning the segmental angles, the global curvature, or the presence of straight-spine or kyphotic deformity [18]. However, McAviney et al. identified a significant correlation between cervical pain and lordosis measuring less than 20° [19]. It is surprising to note the inconsistent evidence and perspectives regarding the functions of the cervical lordotic angle (CLA) and its interactions with pathological spinal conditions.

The ongoing advancement and enhancement of our comprehension of the sagittal profile of the cervical spine in individuals with NP carry substantial clinical importance, as they directly influence the formulation and execution of corrective exercise regimens. Despite the rising interest in the association between cervical lordosis and NP, the current body of literature lacks a comprehensive synthesis of available evidence [20]. A meta-analysis is a powerful tool for addressing this gap, offering a systematic and quantitative approach to analyzing relevant studies [21]. By synthesizing data from multiple studies, a meta-analysis can provide a more robust understanding of the association between cervical lordosis and NP, elucidating potential patterns, discrepancies, and areas for further investigation.

This meta-analysis aims to enrich the current knowledge by systematically reviewing and quantitatively synthesizing the existing literature on the association between cervical lordosis and NP. Through a rigorous examination of relevant studies, we seek to elucidate the strength and direction of this association, and offer insights that may inform clinical practice, intervention strategies, and future research endeavors.

2. Materials and Methods

The protocol for this study was registered in PROSPERO (PROSPERO 2023: CRD42023438481) [26]. This research was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA). The studies included in the current meta-analysis are observational design, using data from case-control, cross-sectional, or cohort studies. Given the observational approach, which does not entail the experimental aspect of random allocation to an intervention but rather explores the association between a specific characteristic and the outcome of interest, inherent potential biases may be present in the original studies included in this systematic review. We aimed to thoroughly report on all the recommended items outlined in the reference [27].

2.1. Search Strategies

The electronic database was searched, and the titles and abstracts were independently screened by two physical therapists (KHK and SAP). Through computerized searches of five electronic databases—Medline, EMBASE, Cochrane Library, CINAHL, and PEDro—relevant articles were identified from the date of inception to may 2023. The search strategy employed a combination of free-text terms and Medical Subject Headings. The following keywords were used in the search: "neck pain*", "cervical pain*" and "lordo*". The search criteria were adjusted to limit the findings to human studies published in scholarly journals. Modifications were made to accommodate the varying search methods of each database. Following the removal of duplicates, the screening process was manually repeated to ensure accuracy and completeness. In cases of uncertainty regarding inclusion or exclusion, authors were contacted via email. The electronic search was conducted without any limitations on language.

2.2. Study Selection

Following the thorough electronic search, studies were included based on specific criteria: (1) inclusion of adult subjects, (2) assessment of cervical lordotic angle (CLA) via radiograph, and (3) calculation of CLA in both the patient with NP and healthy control (HC) groups. The following were the exclusion criteria: (1) other causes of NP (eg, degenerated disc, cervical spondylotic myelopathy, etc.), (2) lacking confirmation of the control group, such as healthy volunteers.

2.3. Quality Assessment

Individual studies were assessed for risk of bias using the Newcastle-Ottawa Scale for case-control

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studies [28]. The Newcastle-Ottawa Scale evaluates the selection of subjects, comparability of groups, and ascertainment of exposure in case-control studies. Scores on the Newcastle-Ottawa Scale range from 0 to 9, where less than 6 indicates low quality, less than 8 suggests moderate quality, and 8 or more indicates high quality. Assessments were independently performed by two authors (KHK and SAP). In instances of disagreement, consensus was reached through discussion between the two authors or with the involvement of a third author (CSA).

2.4. Data Extraction

A predefined list of factors that could impact CLA, including age and sex data, was developed. Exclusion criteria were documented, along with the duration and severity of NP in the patient group. In each study, details including the publication year, study design, matching of patient and control groups, country of included studies, and method of CLA measurement were recorded. The CLA was the outcome variable. The mean and standard deviation (SD) of CLA were coded, along with the number of subjects in both the NP and the HC groups. Independently, two reviewers (KHK and SAP) extracted the relevant data and cross-checked their findings to ensure accurate extraction. When necessary, we contacted the primary authors to request additional data or clarification of existing data.

2.5. Statistical Analysis

The standardized mean difference (SMD) was determined by dividing the difference in means between the NP and the HC groups by the pooled SD. Meta-analysis employing a random effects model was utilized to estimate the pooled SMD, while statistical heterogeneity was evaluated using the I2 statistics and the chi-square test. The I2 statistics represent true variation across studies as a percentage, with values around 25% indicating low, 50% medium, and 75% high heterogeneity among studies [29]. We conducted mixed-effects meta-regression to explore heterogeneity, with factors such as gender, age, measurement methods, and results of the quality assessment entered as covariates. None of the studies reported CLA data for both the NP and the HC groups by gender, so we coded the ratio of male and female patients in each group. Data from the included studies were analyzed for comparative meta-analyses using Review Manager (RevMan, version 5.4.1; Nordic Cochrane Center, Cochrane Collaboration, Copenhagen, Denmark) and Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA).

3. Results and Discussion

3.1. Search and Selection of Studies

Following the initial electronic search, a total of 1,020 studies were identified, distributed across Medline (323), the Cochrane Library (78), EMBASE (552), CINAHL (52), and PEDro (15). After removing 228 duplicate studies, the titles of the remaining articles were reviewed. Subsequently, 703 articles, including comments, letters, and conference presentations, were excluded. Among the 89 remaining studies, 45 were deemed irrelevant to the topic. Following abstract screening, 31 studies were excluded due to improper article type, incomplete papers, or lack of CLA data. Upon full-text review of 7 articles, 1 study was excluded due to improper group definition. Ultimately, 6 articles met the inclusion criteria and were included in this review, as depicted in Fig. 1 [19,20,22-25].

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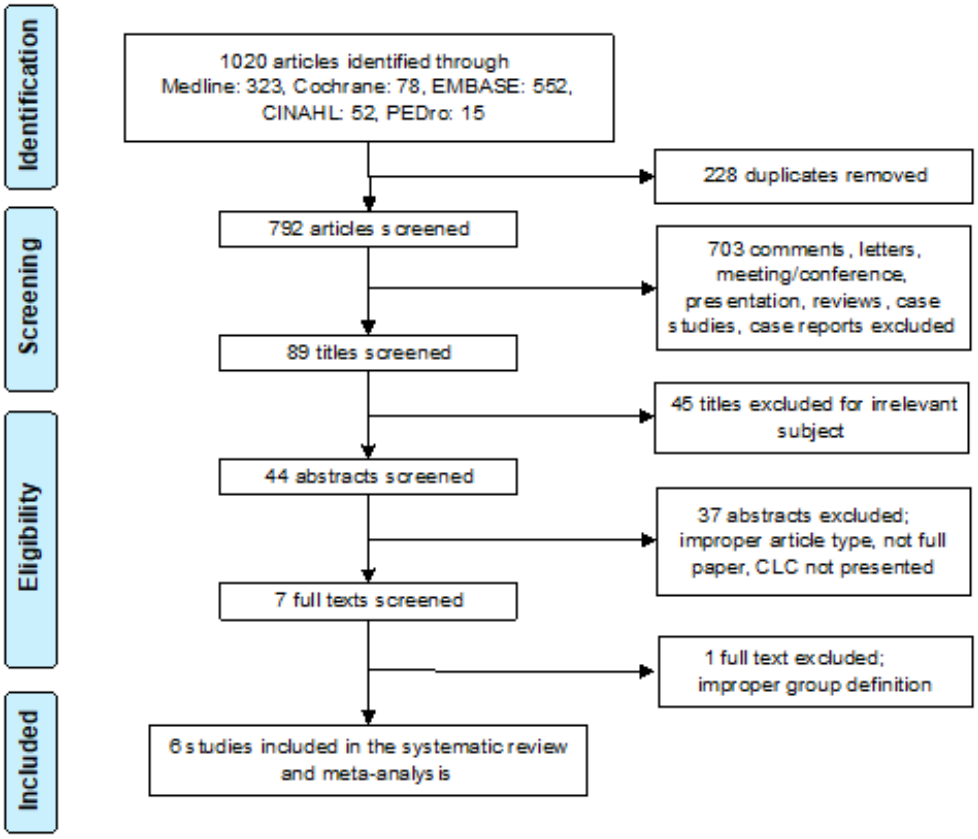

Figure 1.
Flow diagram of searched, screened, and included studies. CLA, cervical lordotic angle.

3.2. Characteristics of Included Studies

All studies included in this review employed a cross-sectional or case-control design, comparing CLA between patients with NP and asymptomatic individuals [19,20,22-25]. The characteristics of the included articles are presented in Table 1.

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Table 1.
Summary of studies in the review.

Study	Study design	Study population	CLA measures	NP measures	Excluded from NP	Risk of bias
Harrison et al. 2004 [22]	Retrospective Case-control	N NP(M:F)=70(38:32), mean age=44.0±15.1 y; HC(M:F)=72(36:36), mean age=40±10.4 y; from USA	Measured by lateral radiograph Position not mentioned ARA(C2–7)	VAS	previous cervical spine surgery, congenital anomaly or cervical spine fracture, severe degenerative change	4/9
McAviney et al. 2005 [19]	Retrospective Case-control	N NP(M:F)=178(83:32); HC(M:F)=99(58:41); mean age=38(9-78) y; from Australia	Measured by lateral radiograph Standing position ARA(C2–7)	VAS, Medical record	Pathology or moderate to severe degenerative changes	6/9
Kim et al. 2015 [23]	Retrospective Case-control	N NP(F)=92, mean age=30.7±8.5 y; HC(F)=231, mean age=27.1±6.5 y; from Korea	Measured by lateral radiograph Position not mentioned Cobb(C2–7)	VAS, SF-36, NDI	Previous cervical spine surgery	5/9
Shilton et al. 2015 [24]	Prospective Cohort	N NP(M:F)=29(8:21), mean age=39.6±12.8 y; HC(M:F)=30(9:21), mean age=40.5±12.7 y; from UK	Measured by lateral radiograph Sitting position ARA(C2–6)	NRS, NDI	Not mentioned	6/9
Gras et al. 2018 [20]	Prospective Case-control	N NP(M:F)=42(5:37), mean age=20.0±1.2 y; HC(M:F)=34(6:28), mean age=20.0±1.3 y; from Egypt	Measured by lateral radiograph Standing position ARA(C2–7)	VAS(>5), NDI(>20% or 10 points) Duration >3month	Postural control training, physical therapy during the preceding 12 months, previous spine surgery, neurological signs, cervical disc herniation, cervical trauma, pregnancy, congenital postural deformities, definitive visual disorder	5/9
Jouibari et al. 2019 [25]	Prospective Case-control	N NP(M:F)=25(4:21), mean age=42.6±11.6 y; HC(M:F)=25(7:18), mean age=44.7±12.1 y; from Iran	Measured by lateral radiograph Standing position ARA(C2–7)	VAS	Previous spine surgery, cervical trauma, medical treatment and/or nonsteroidal anti-inflammatory drugs (NSAIDs) for NP, systematic diseases	6/9

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					involving the cervical spine (e.g., rheumatoid arthritis), depression, pregnancy, any condition that requires prescription of muscle relaxant agents (e.g., seizure), history of cardiovascular and metabolic and pulmonary diseases	

Note: ARA, absolute rotation angle; CLA, cervical lordosis angle; (M:F), (number of male subjects:number of female subjects); HC, healthy control; N, number of subjects; NDI, neck disability index; NRS, numeric rating scale; NP, neck pain; VAS visual analogue scale; SF-36, short form (36) health survey.

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3.3. Measurement Method of the Cervical Lordotic Angle

Three studies measured the CLA in an standing position [19,20,25], one study that measured it in the sitting position [24], and another two studies not mentioned a posture [22,23]. All studies used lateral radiographs. Most studies used an absolute rotation angle (ARA) method to assess the CLA, except for one study used the Cobb method [23]. There was variability in the spinal levels used for measurement across studies. In the study using the Cobb method, the measurement was taken from the inferior end plate of C2 to indicate the upper boundary of the CLA and the lower boundary of the CLA was determined by measuring the superior end plate of C6 [23]. Among the five studies employing the posterior tangent method, four of them measured ARA of cervical lordosis of C2-7 vertebrae [19,20,22,25] and the other one study measured it from the C2 through C6 vertebrea [24].

3.4. Risk of Bias

Results from using the Newcastle-Ottawa Scale are presented in Table 2. Two studies were rated of good quality [24,25] while 2 were rated of moderate quality [19,20] and the rest were of low quality [22,23]. The included studies adjusted for various confounding factors: four studies adjusted for both age and gender [20,23-25], while one studies for gender only [22] and one did not control for both age and gender [19].

Table 2.
Quality assessment of the included studies by Newcastle-Ottawa Scale.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Risk of bias**
Harrison et al. 2004	1	0	0	1	1	0	1	1	0	5/9
McAviney et al. 2005	1	1	1	1	1	0	1	1	0	7/9
Kim et al. 2012	0	0	0	1	1	1	1	1	0	5/9
Shiton et al. 2015	1	1	1	1	1	1	1	1	0	8/9
Gras et al. 2018	1	0	1	1	1	1	1	1	0	7/9
Jouibari et al. 2019	1	1	1	1	1	1	1	1	0	8/9

3.5. Cervical Lordotic Angle in The Neck Pain and Healthy Control Groups

The data from six studies (n = 927 participants) comparing CLA between the NP and the HC groups demonstrated high heterogeneity across studies (I^2=88%, p<.001). Following meta-regression analyses were conducted to explore the origins of heterogeneity. In the meta-regression analysis, the factors such as age, gender, measurement methods, and results of the quality assessment were found to have no significant influence on the degree of heterogeneity. The SMD was -0.46 (95% CI = −0.89, 0.03), indicating a statistically significant difference in the CLA between NP and HC participants (Fig. 2). An SMD with a negative value implies that the NP group exhibits a smaller CLA compared to the HC group. In four studies, the NP group exhibited a reduced CLA compared to the HC group, and the difference was statistically significant [19,20,22,23].

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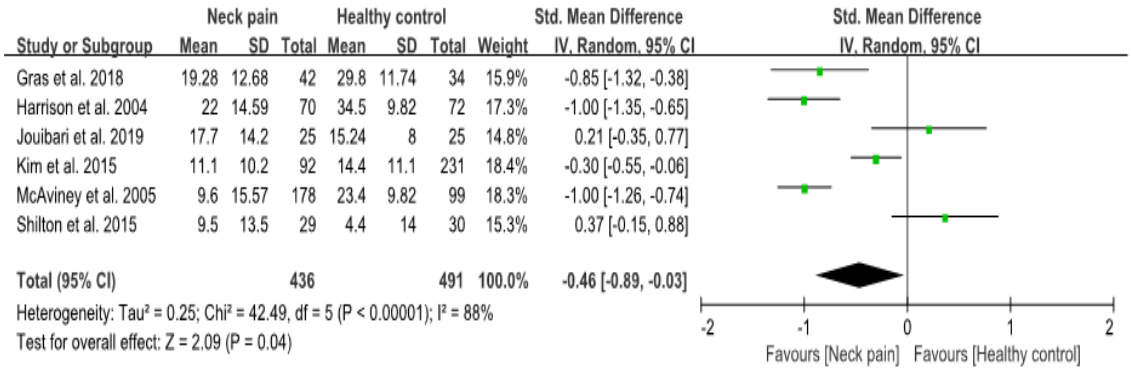

Figure 2.
Difference in cervical lordotic angle between participants with neck pain and healthy control.

4. Discussion

This review aimed to determine potential differences in CLA between patients with NP and HCs. A systematic search and subsequent meta-analysis were conducted. Six studies compared the CLA between individuals with and without NP, with the majority indicating a statistically significant reduction in CLA among those with NP.

It is notable that 4 out of 6 studies revealed a statistically significant decrease in CLA among patients with NP compared to HCs. In general, when studies in a meta-analysis examine the same population, any variation in results is attributed solely to sampling error. However, that is rarely scenario, as there is generally innate variation among studies [30]. Despite setting strict criteria to ensure qualitative homogeneity, we could not avoid statistical heterogeneity. There was a statistically significantly high level of heterogeneity (I^2= 88%) among the studies, which reduces the confidence in the results.

The meta-analysis showed patients with NP to have smaller CLA compared to HCs. A previous systematic review could not conclude that there is a difference in CLA between patients with NP and HCs due to conflicting results from the retrieved studies [31]. Among the four studies included in the systematic review, one study encompassed all cases of cervical spondylosis, including individuals who underwent cervical discectomy or laminectomy, or laminoplasty [32]. As previous studies have shown that CLA increases with age [11,33], it is difficult to rule out the effect of age on CLA, however another study was restricted to a cohort of older adults, with an average age exceeding 67 years [18]. Another study compared CLA in all subjects to subjects without craniocervical symptoms [16], which may be inappropriate for inclusion in a meta-analysis comparing CLA in patients with and without NP.

The studies integrated into this meta-analysis demonstrated an acceptable control over exclusion criteria and confounding variables, reflecting a diligent methodological approach. Although the heterogeneity among the included studies prevents making general assumptions about the association between NP and CLA, this result suggests a significant association between reduced CLA and NP.

Further research is needed to investigate the relationship between CLA and NP in various population groups in the future. Particularly studying the relationship between neck usage and load among different occupational groups may elucidate causality. Based on the observed relationship between CLA and NP in this study, further research is warranted to investigate whether cervical lordosis rehabilitation is effective for NP, cervical radiculopathy, and other related conditions, as well as to elucidate the effectiveness of specific therapeutic approaches.

This meta-analysis had several limitations. It included studies of low and moderate methodological quality, and there was considerable heterogeneity among the studies. In the meta-regression analysis, gender, age, measurement methods of CLA, and quality of the studies were not found to be factors influencing heterogeneity. This result is probably due to the small sample size of studies included in the meta-regression analysis. This precluded subgroup analysis by gender, cervical lordosis angle measurement method, and study quality.

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Most studies did not describe whether the CLA measurements were conducted by blinded evaluators, and inter-rater reliability was not reported in most cases. Nevertheless, observational studies generally exhibit less intended bias compared to interventional studies, where lower quality can compromise the reliability of the findings.

5. Conclusion

Various levels of heterogeneity were observed among the included studies. Despite this heterogeneity, our meta-analysis (six published reports, encompassing a collective of 436 individuals with NP and 491 HCs) suggests a trend wherein patients experiencing NP exhibited reduced CLA compared to HCs. This finding highlights the potential importance of assessing and addressing cervical spine alignment as part of a comprehensive rehabilitation approach for patients with neck pain. While the causal relationship remains to be elucidated, the observed association underscores the need for further research investigating the biomechanical implications of cervical lordosis and the potential benefits of interventions aimed at restoring optimal cervical curvature in the management of neck pain conditions.

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