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REVIEW

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Relationship of sagittal thoracic postural and inlet parameters with nontraumatic neck pain: a systematic review and meta-analysis

Babina Rani[1*] and Abhijit Paul[1]

Abstract

Objectives Neck pain (NP) is associated with substantial disability as well as economic and psychological distress. T1 slope (T1S) and thoracic inlet angle (TIA) reflect cervical sagittal imbalance, which can have clinical/surgical implications. Evidence of the relationship between the sagittal thoracic posture and inlet parameters and pain and functional status is inconclusive. This review aimed to determine whether these parameters differ between NP and pain-free subjects and to critically appraise their correlation with NP measures.

Methods The review consists of 15 studies that evaluated thoracic postural and/or inlet parameters on adult NP patients, after a comprehensive literature search from EBSCO, PubMed, Scopus, Embase, and Web of Science databases. Statistical heterogeneity, mean pooled difference (MPD), and effect size were calculated to establish a relationship among studies and to assess the correlation of thoracic postural and inlet parameters with NP measures, positional variation, and NP predictors. Sensitivity analysis was performed in case of high between-studies heterogeneity. The risk of bias was assessed using the Newcastle-Ottawa Quality Assessment Scale. Certainty of evidence was graded using GRADE approach.

Results Only TIA had a significant MPD of 2.12 (0.48, 3.75). The other measures, namely T1S, neck tilt (NT), high thoracic angle, and thoracic kyphosis angle, were not different between NP and asymptomatic subjects. NP population had a 3.14° higher TIA, 4.12° higher NT, and 2.26° lower T1S in lying position (relative to upright). Only thoracic kyphosis and T1S predicted the presence of NP. Very low to low certainty of evidence exists for most of the outcome measures assessed.

Conclusion Limited evidence is available for the association between the sagittal thoracic postural and inlet parameters in nontraumatic cervical dysfunction. Test-position differences reflect marginally lower T1S, and higher TIA, NT in lying than the upright. The existing evidence is insufficient to prove a minor, if any, association of thoracic posture with NP.

Keywords Neck pain, Kyphosis, Posture, Spine, Radiography, Thoracic

Introduction

An increasing number of people suffer from neck pain, which is associated with substantial disability as well as economic and psychological distress [1]. Neck pain ranks fourth among the most prevalent causes of disability, with a prevalence rate exceeding 30% every year [2].

Neck pain is a common manifestation of musculoskeletal disorders of the upper quadrant, including the

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scapular region, and cervical and upper thoracic spines. Considering the thoracic spine, various postural and inlet parameters have been previously researched in both asymptomatic and symptomatic subjects for neck pain but with conflicting results. A recent review highlighted a positive moderate correlation between age and kyphosis in healthy adults. The authors reported that kyphosis increases with aging, with significant variability between 40 and 60 year-olds [3].

A growing body of research suggests the importance of maintaining spinal sagittal balance to keep spinal pain-related issues at bay, and to maintain a balanced upright posture with a horizontal gaze, thus minimizing the energy expenditure for keeping the line of gravity aligned [4–6]. However, evidence is scarce regarding the relationship between thoracic postural alterations and neck pain, with even lesser emphasis on the functional status.

Moreover, an expanding body of evidence links poor posture to neck pain [7–10]. However, the specific thoracic posture-related factors that contribute to neck pain are still not fully understood. The craniocervical region of the body is positioned over the thoracic inlet (or outlet), which is anatomically bound by the manubrium of the sternum, first thoracic vertebra (T1), and first rib on either side [11]. So, it is likely that the orientation of T1 (T1 slope) can influence the sagittal balance of the craniocervical region, which in turn can reflect onto the symptoms related to cervical spine degeneration, or the possible mechanical impact on the surrounding muscles (e.g., sternocleidomastoid, semispinalis) [6]. An altered thoracic inlet angle (TIA) has been reported to be a risk factor for spine degeneration [6, 12]. In addition, T1S has been established as an important parameter in the planning of spinal surgeries, owing to its direct relationship with the cervical sagittal axis [13]. Likewise, postural alterations such as increased thoracic kyphosis have also been reported to result in a risk of fall [14] and reduced physical function [15]. Thus, considering their impact on posture, function, and surgical outcomes, it becomes imperative to study these thoracic parameters as a crucial factor in the development and severity of neck pain.

As per the available literature, no comprehensive analysis has been carried out regarding the influence of cervical spine problems on the existence or intensity of thoracic postural and inlet variables. Therefore, the objectives of this review were as follows: (1) investigate the relationship between (a) the sagittal thoracic postural and inlet parameters and (b) the measures of neck pain and the sagittal thoracic postural and inlet parameters and (2) ascertain the impact of test position and age on the thoracic spinal malalignment in subjects with non-traumatic neck pain.

Methodology

This systematic review and meta-analysis was registered on PROSPERO (PROSPERO 2022 CRD42022342274) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Data sources and search strategy

A comprehensive literature search was conducted in multiple databases, including EBSCO (via CINAHL complete), PubMed, Scopus, Web of Science, and Embase in December 2022, along with a manual search of the reference lists of the available articles. The database search was rerun with the same search words in August 2023, for inclusion of any recent publications. The relevant articles published from inception until July 2023 were included.

The search was performed using the search keywords (including MeSH) "cervical pain", "neck pain", "posture", "neck-shoulder pain", "thoracic kyphosis", "thoracic angle", and "thoracic inlet". Details of the search strategy are summarized in Supplementary Table 1. The longitudinal, cohort, and cross-sectional studies that examined the neck pain subjects (using standard scales to measure intensity and disability) with either or all the sagittal thoracic postural and/or inlet measures, with or without a control group for comparison, were identified. The included studies assessed the static/neutral thoracic posture of human subjects with neck pain. The studies with available English language full text were included. The studies were excluded if the full-text article could not be retrieved. Studies that assessed dynamic or working position posture; posture with external weight held; studies with neck pain pertaining to trauma, temporomandibular joint dysfunction, neurological conditions (e.g., myelopathy), migraine, etc.; and any kind of intervention studies, conference proceedings, and editorials were not considered part of this review.

Study selection

After screening the titles and/or abstracts in the primary search, all the retrieved articles were imported into the software EndNote 20.3 (Clarivate Analytics) and checked for duplicates by both authors. All full-text articles were then independently assessed by two reviewers (B. R., A. P.) for relevance, based on inclusion and exclusion criteria. Secondary/hand searching was done from the reference list of available articles. Using both reviewers' lists of relevant studies, a comparison was drawn. Both reviewers independently then extracted data and assessed the risk of bias in the included studies. Any difference in opinion was resolved by consensus.

Data extraction

Relevant data from all the studies was included, in the form of study design, sampling methods; sample characteristics; inclusion criteria for the neck pain group and control group; outcome measures for neck pain, sagittal thoracic posture, and thoracic inlet; results; and conclusion. Corresponding authors of included studies were contacted via email, wherever additional data was required.

Quality assessment

Quality assessment for all the included studies was done through the Newcastle-Ottawa Quality Assessment Scale (NOS) (adapted for cross-sectional studies) [16] independently by two reviewers (B. R., A. P.). Any disagreement was resolved through a mutual consensus. The NOS investigates the possibility of bias in three distinct domains: selection (maximum five stars), comparability (maximum two stars), and outcome (maximum three stars), thus allowing for a total score of 10 (10 stars). All studies included in the review were assessed for quality, regardless of their inclusion in the meta-analysis.

Grading the certainty of evidence

The certainty of evidence was graded by the two authors independently using GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach (http://gdt.gradepro.org). Any difference in opinion was resolved through mutual consensus. The grading was done to incorporate the following key domains: (a) risk of bias, (b) inconsistency, (c) indirectness, and (d) imprecision, along with other optional ones.

Statistical analysis

Mean differences (MDs) with 95% confidence intervals (CIs) for continuous outcomes (T1S, TIA, NT, HTA, TKA) were used to estimate the pooled effects. Using the data extracted from the eligible studies, the continuous variables were expressed as the mean value and standard deviation of the outcome measures assessed in pain and pain-free groups, along with the number of participants for which the variables were measured in each group. The I^2 test assessed the statistical heterogeneity between studies, whereas heterogeneity across the studies was analyzed using Cochran's Q test and then transformed into I^2 percent with its p-value. The Review Manager (RevMan v5.4.1, The Cochrane Collaboration, Software Update, Oxford, UK) was used for meta-analyses. The analysis for outcome measures of all thoracic postural and inlet parameters was done using RevMan, for a comparison among neck pain and asymptomatic subjects. The random-effects model was used owing to the heterogeneity of participants. The heterogeneity of I^2 value above 25%, 50%, and 75% is regarded as low, moderate, and high, respectively [17]. In case of high heterogeneity for any variable, sensitivity analysis was performed, using sequential and combinatorial algorithms as suggested by Patsopoulos et al. [18]. The positional variation (upright vs. lying position) for assessment of thoracic inlet parameters was analyzed using Stata 16 (Stata Corp. LLC, 4905 Lakeway Drive College Station, TX 77845-4512, USA). As there were a limited number of included studies per variable (< 5), publication bias was not assessed.

Results

Study selection and characteristics

Out of a total of 311 studies identified in the primary search, finally, 15 studies were found relevant for the review as per the eligibility criteria. However, owing to a lack of appropriate data, only 12 studies were included in the meta-analysis for association of sagittal thoracic postural and inlet parameters with the presence and severity of neck pain and related disability or for test position difference among the inlet parameters. PRISMA flowchart is described in Fig. 1. Relevant data extracted from individual studies are described in Tables 1, 2, and 3.

Thoracic inlet parameters

The data for thoracic inlet parameters from 710 subjects across 5 studies [12, 25–27, 29] presented the pooled mean difference between neck pain and asymptomatic subjects to be significant for TIA [2.12 (0.48, 3.75); $p = 0.01$] but insignificant for T1S [−0.86 (−5.73, 4.01); $p = 0.73$] and NT [2.37 (−1.74, 6.49); $p = 0.26$]. There was a significantly high heterogeneity for NT and T1S ($I^2 = 92$, 97% respectively), while it was low for TIA ($I^2 = 44\%$) (Figs. 2, 3 and 4). The single study removal using a sequential algorithm did not help much with reducing the between-study heterogeneity for T1S and NT to sub-threshold. Therefore, the combinatorial algorithm was applied. The omission of two studies [25, 29] effectively cut down the heterogeneity to $I^2 = 65\%$ and 48% for T1S and NT respectively. For TIA, however, a single study [27] omission successfully brought down the heterogeneity to nil ($I^2 = 0\%$) and indicated significantly higher TIA for neck pain group subjects (Supplementary Fig. 1).

Sagittal thoracic postural parameters

The outcome measures used to assess the sagittal thoracic curvature included photographically measured high thoracic angle (HTA) [7, 8] and its complementary measure called upper thoracic angle (UTA) [22], thoracic kyphosis angle (TKA) [9, 21] and index (TKI) [20], and midthoracic curve (MTC) [19].

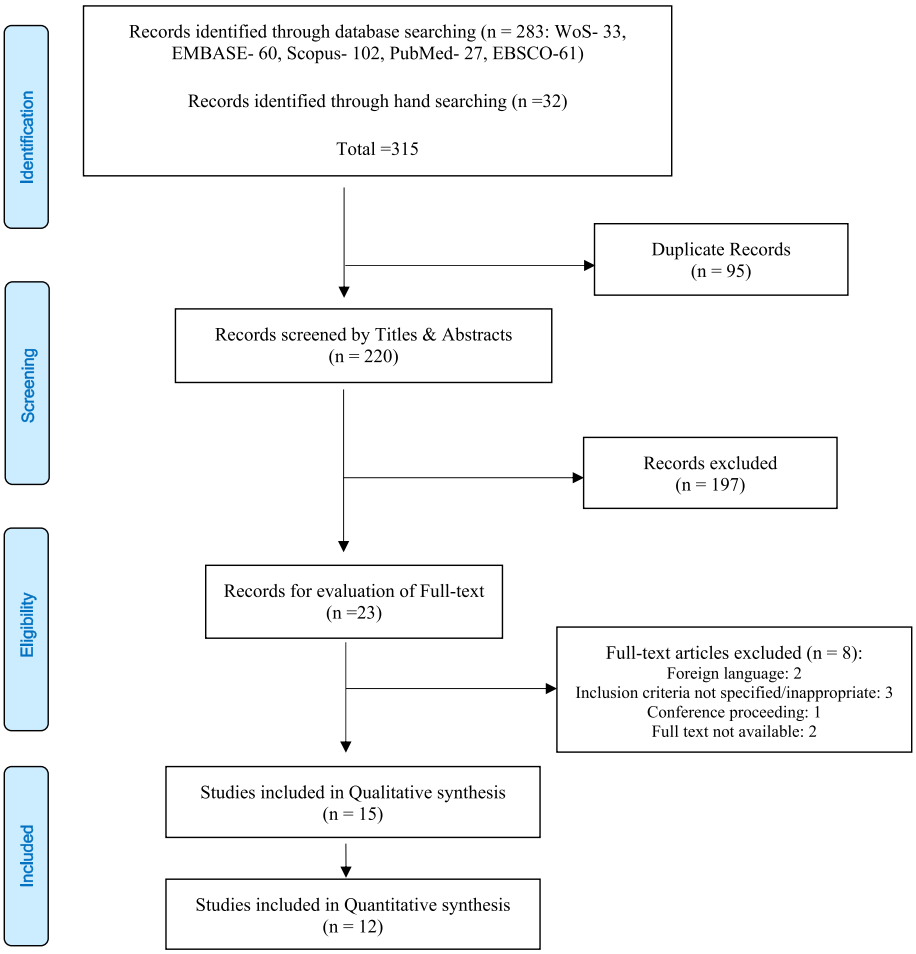

Fig. 1 Prisma flow chart for systematic review and meta-analysis of included studies

The two studies [7, 8] measuring high thoracic angle ($N=161$) reported an insignificant pooled mean difference of 4.42 (−1.50, 10.34); $p=0.14$ (Fig. 5). There was a high statistical heterogeneity of $I^2=88\%$ and chi-square = 8.51. The complementary measure of HTA, i.e., upper thoracic angle (UTA), was examined by Kanda et al. in young and elderly female subjects [22]. The study reported that subjects with neck-shoulder pain had larger UTA than control, and young subjects had smaller UTA than elderly.

The use of a spinal mouse to measure thoracic kyphosis had an insignificant pooled mean difference of 4.91 ((−3.72, 13.54); ($p=0.26$)) among the neck pain and asymptomatic subjects [21, 22] (Fig. 6). TKA was reported by two studies ($N=438$) having a high statistical heterogeneity ($I^2=94\%$, chi-square = 16.99). Quek et al. used flexicurve to analyze the thoracic kyphosis index in elderly neck pain subjects, without comparison to a control group [20]. Increased thoracic kyphosis was significantly correlated with age, but not with neck pain-related disability.

Though Helgadottir et al. reported no significant difference in MTC ($p=0.99$) between the neck pain and control groups, the exact data was not reported [19]. We tried communicating with the authors, but no response was received.

Positional difference for inlet parameters

Six studies [12, 23, 24, 26–28] were included in the analysis for the positional variation (lying vs. upright) in thoracic inlet parameters. Data from 516 subjects revealed a 3.14° higher TIA, 4.12° higher NT, and 2.26° lower T1 slope in lying position (relative to upright) for neck pain subjects. There was no significant between-study heterogeneity ($I^2=0\%$; $p=0.9$) for positional variation as depicted in Figs. 7, 8 and 9.

Table 1 Data extraction for thoracic postural studies

Study ID	Inclusion criteria		Neck pain measures	Thoracic postural measures		Results & conclusion
	NP Gp	Control Gp		Outcome measure	Equipment	
Lau K. T. (2010) [7]	Minimum 3 on NPRS; > 10% on NPQ	No NP in past 6 months; 0 on NPRS, < 10% on NPQ	NPRS, NPQ	HTA	Photographic measurement	HTA: Significantly associated with the presence and severity of NP and disability HTA: Good predictor for the presence of NP
Helgadottir et al. (2011) [19]	A score of at least 10 on the NDI and neck symptoms of > 6 m	No cervical or shoulder dysfunction	NDI, VAS	MTC	Digitizing stylus connected to the magnetic tracking device, FasTrak	- No difference in the midthoracic curve ($p = 0.99$) among the groups - Weak correlation between dependent variables & scores on NDI & VAS ($r < 0.50$)
Quek J. et al. (2013) [20]	Cervical spine dysfunction (cervical pain with or without referred pain, numbness or paraesthesia)	-	NDI	TKI	FlexiCurve	Increased age was associated with reduced cervical ROM - TKI: significantly associated with CVA, age, but not NDI
Tsunoda et al. (2013) [21]	If subjects answered "yes" to the question for NSP occurrence over previous 2 weeks	If subjects answered "no" to the question for NSP occurrence over previous 2 weeks	Question to report the occurrence of NSP over the previous 2 weeks	TKA	Spinal mouse	- No significant association between TKA & NSP Age and gender were significantly associated with NSP
Nejati P. et al. (2014) [8]	Chronic NP between C0 and T1, from > 3 m	No ache or soreness in a region between C0 and T1	Pain location & duration, working hours, driving hours	HTA	Photographic analysis	Statistically significant difference in HTA ($p = 0.02$) between NP Gp and control Gp only during computer work; no difference during neutral position
Kaya D. O. et al. (2017) [9]	Persistent NP for > 3 m	No previous NP (lifetime to date)	VAS	Sagittal thoracic spinal curvature and mobility	Spinal mouse	- Sagittal thoracic curvature and mobility—different significantly for NP Gp vs control Gp - NP intensity: significantly associated with sagittal thoracic curvature & mobility

Table 1 (continued)

Study ID	Inclusion criteria		Neck pain measures	Thoracic postural measures		Results & conclusion
	NP Gp	Control Gp		Outcome measure	Equipment	
Kanda M. et al. (2021) [22]	Symptom duration of > 1 year	-	Questionnaire for intensity, location, & duration of symptoms	UTA	Photographic method	- No significant age-by-group interactions for any variable - Significant main effect of group on the UTA ($p < 0.01$): NSP > non-NSP - Significant main effects of age on UTA ($p < 0.01$): young < elderly

Gp Group, *HTA* High thoracic angle, *MTC* Midthoracic curve, *NDI* Neck Disability Index, *NP* Neck pain, *NPQ* Northwick Park Neck Pain Questionnaire, *NPRS* Numeric pain rating scale, *NSP* Neck-shoulder pain, *ROM* Range of motion, *TKA* Thoracic kyphosis angle, *TKI* Thoracic kyphosis index, *UTA* Upper thoracic angle, *VAS* Visual analog scale, *m* Month, *yr* Year, ~ Similar

Table 2 Data extraction for thoracic inlet studies

Study ID	Inclusion criteria		Neck pain measures	Thoracic inlet measures		Results & conclusion
	NP Gp	Control Gp		Outcome measure	Equipment	
Zhao-Lin W. (2015) [12]	Outpatients with disc degenerative disease C3–C7 The presence of NP with or without neurologic symptoms	Asymptomatic volunteers	-	T1S, NT, TIA	MRI	TIA in NP Gp ~ control group. T1S, however, differed remarkably Age: significant association with T1S, TIA, NT in NP Gp
Janusz P. (2015) [23]	One-level cervical radiculopathy symptoms	-	-	T1S, NT, TIA	Lateral cervical radiographs in neutral, flexion, extension	Neck tilt measurements: not influenced by cervical spine position T1S: significantly influenced by neck flexion/extension
Paholpak (2017) [24]	Diagnosis of degenerative cervical spondylolisthesis (DCS)	-	-	T1S, NT, TIA	Kinematic MRI in neutral, flexion, extension	Neutral position: T1S differed significantly for antero- vs retrolisthesis, but not NT and TIA
Quanbing W. (2018) [25]	Diagnosis of degenerative cervical spondylolisthesis (DCS)	Healthy participants	-	T1S, NT, TIA	Cervical CT	T1S, TIA: significant difference among NP Gp vs control Gp Preoperative T1S > 22.0°: significant diagnostic value for the incidence of DCS T1S: risk factor for DCS
Xing R. (2018) [26]	Symptomatic adults with degenerative cervical discs (≥ 1 and ≤ 3)	Asymptomatic volunteers with no history of diagnosis or treatment related to any part of spine and no evidence of degenerative cervical discs on MRI	-	T1S, NT, TIA	Cervical lateral radiograph in neutral standing, looking straight ahead, and cervical MRI	T1S, NT: significant difference among NP Gp vs control Gp
Jouibari (2019) [27]	Nonspecific neck pain	No NP at least for 1 year before enrolment	VAS	T1S, NT, TIA	Lateral cervical radiograph	VAS: 74 ± 14 T1S: significant difference among NP Gp vs control Gp
Wanli Li (2020) [28]	Diagnosis of degenerative cervical spondylosis	-	-	T1S, NT, TIA	MRI	Significantly higher thoracic inlet parameters in M > F Age: significant association with TIA, NT, and T1S Association of age with TIA, T1S, and NT was stronger in M > F, especially in NT
Jia Li (2020) [29]	Patients with cervical kyphosis, axial NP VAS ≥ 3	Patients with cervical kyphosis, VAS < 3	VAS	T1S, NT, TIA	MRI and radiograph	T1S: significant difference among NP Gp vs control Gp T1S (but not TIA, age)—independent predictor of ANP

DCS Degenerative cervical spondylolisthesis, *Gp* Group, *T1S* T1 slope, *NP* Neck pain, *NT* Neck tilt, *TIA* Thoracic inlet angle, *VAS* Visual analog scale, *yr* Year

Table 3 Demographic details of included studies

Study ID	Setting	Study design	Population	NP group				Control group		
				N	Age	F, M	Pain duration	*N*	Age	F, M
Lau K. T. (2010) [7]	Hospital, clinics	Cross-sectional	Patients	30	36.77 + 9.83 (20–50)	20 F, 10 M	-	30	34.50 ± 9.95 (20–50)	13 F, 17 M
Helgadottir (2011) [19]	PT clinics	-	Patients	21	35.23 ± 8.41 (25–54)	19 F, 2 M	> 6 months	20	29.70 ± 7.75 (21–51)	17 F, 3 M
Quek J. (2013) [20]	Hospital	Cross-sectional	Elderly patients	51	66 + 4.9 (60–78)	29 F, 22 M	-	-	-	-
Tsunoda (2013) [21]	-	-	Villagers	171	63.4 ± 11.9	119 F, 52 M	> 2 weeks	158	67.9 ± 9.8	85 F, 73 M
Nejati P. (2014) [8]	University	Cross-sectional	Office workers	55	39 ± 8	-	> 3 months	46	39 ± 8	-
Zhao-Lin W. (2015) [12]	Hospital	Retrospective	Outpatients	125	50.3 ± 9.19 (26–69)	69 F, 56 M	-	50	44.76 ± 13.72 (21–69)	31 F, 19 M
Janusz P. (2015) [23]	-	Retrospective	Patients	60	53 (40–72)	36 F, 24 M	-	-	-	-
Paholpak (2017) [24]	-	Retrospective cross-sectional	Patients	52	51.7 ± 8.64	28 F, 24 M	-	-	-	-
Kaya D. O. (2017) [9]	Polyclinic	-	Patients & healthy volunteers	56	38.30 ± 12.20 (18–65)	45 F, 11 M	> 3 months	53	34.30 ± 12.15	39 F, 14 M
Quanbing W. (2018) [25]		Retrospective	Patients	60	48.6 ± 7	36 F, 24 M	-	62	46.1 ± 5.9	35 F, 27 M
Xing R. (2018) [26]	Hospital	Retrospective	Patients & control subjects	50	35.02 ± 5.46 (20–50)	20 F, 30 M	-	50	32.14 ± 9.19 (20–50)	25 F, 25 M
Jouibari (2019) [27]	Clinic	Comparative cross-sectional	Patients & controls	25	42.6 ± 11.6	21 F, 4 M	-	25	44.7 ± 12.1	18 F, 7 M
Wanli Li (2020) [28]	Hospital	Retrospective	Patients	204	M = 56.33 ± 10.493 F = 55.540 ± 10.866	78 F, 126 M	-	-	-	-
Jia Li (2020) [29]	Hospital	Retrospective	Patients	92	43.5 ± 12.9	53F, 39 M	-	171	40.8 ± 13.6	81 F, 90 M
Kanda (2021) [22]	-	-	Young females	21	20.6 ± 0.8	21 F	> 1 year	18	20.6 ± 0.8	18 F
			Elderly females	22	71.1 ± 4.5	22 F	> 1 year	11	71.1 ± 4.5	11 F

NP Neck pain *N* Sample size, *F* Female, *M* Male, *NSP* Neck-shoulder pain

Study or Subgroup	Neck pain Mean	SD	Total	Asymptomatic Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Jia Li et al 2020	73.5	5.6	92	70.2	7	171	33.7%	3.30 [1.75, 4.85]
Jouibari et al 2019	75.3	14.1	25	79.7	8.2	25	5.8%	-4.40 [-10.79, 1.99]
Rong Xing et al 2018	71.5	8	50	70.22	6.8	50	19.1%	1.28 [-1.63, 4.19]
Wang Quanbing et al 2018	76.11	5.52	60	72.86	7.31	62	24.8%	3.25 [0.96, 5.54]
Wang Zhao-Lin et al 2015	75.7	9.4	125	74.45	10.17	50	16.5%	1.25 [-2.02, 4.52]
Total (95% CI)			**352**			**358**	**100.0%**	**2.12 [0.48, 3.75]**

Heterogeneity: Tau² = 1.44; Chi² = 7.13, df = 4 (P = 0.13); I² = 44%
Test for overall effect: Z = 2.53 (P = 0.01)

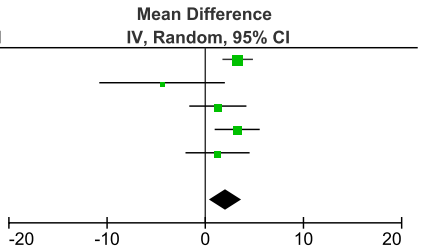

Fig. 2 Forest plot for TIA in neck pain subjects compared to asymptomatic subjects

Study or Subgroup	Neck Pain Mean	SD	Total	Asymptomatic Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Jia Li et al 2020	26.3	6.2	92	21.5	7.6	171	20.5%	4.80 [3.10, 6.50]
Jouibari et al 2019	27.7	6.29	25	32.5	8	25	18.4%	-4.80 [-8.79, -0.81]
Rong Xing et al 2018	22.9	7	50	25.8	5.1	50	20.0%	-2.90 [-5.30, -0.50]
Wang Quanbing et al 2018	24.33	2.85	60	19.59	2.04	62	20.9%	4.74 [3.86, 5.62]
Wang Zhao-Lin et al 2015	22.56	6.88	125	29.31	6.04	50	20.2%	-6.75 [-8.81, -4.69]
Total (95% CI)			**352**			**358**	**100.0%**	**-0.86 [-5.73, 4.01]**

Heterogeneity: Tau² = 29.39; Chi² = 141.26, df = 4 (P < 0.00001); I² = 97%
Test for overall effect: Z = 0.35 (P = 0.73)

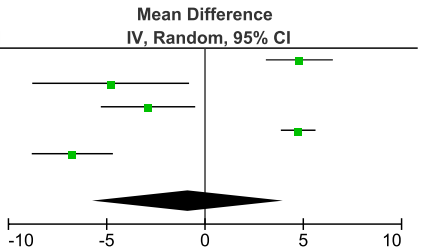

Fig. 3 Forest plot for T1 slope in neck pain subjects compared to asymptomatic subjects

Study or Subgroup	Neck Pain Mean	SD	Total	Asymptomatic Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Jia Li et al 2020	47.1	5.1	92	49.6	6.8	171	21.8%	-2.50 [-3.96, -1.04]
Jouibari et al 2019	52	9.8	25	47.9	7	25	17.3%	4.10 [-0.62, 8.82]
Rong Xing et al 2018	48.6	6.8	50	44.6	6.2	50	20.6%	4.00 [1.45, 6.55]
Wang Quanbing et al 2018	48.33	8.05	60	49.16	8.12	62	20.2%	-0.83 [-3.70, 2.04]
Wang Zhao-Lin et al 2015	52.94	8.92	125	45.21	9.05	50	20.1%	7.73 [4.77, 10.69]
Total (95% CI)			**352**			**358**	**100.0%**	**2.37 [-1.74, 6.49]**

Heterogeneity: Tau² = 19.71; Chi² = 49.54, df = 4 (P < 0.00001); I² = 92%
Test for overall effect: Z = 1.13 (P = 0.26)

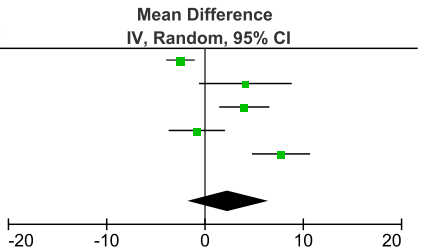

Fig. 4 Forest plot for neck tilt in neck pain subjects compared to asymptomatic subjects

Study or Subgroup	Neck Pain Mean	SD	Total	Asymptomatic Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
KT Lau 2010	123.67	4.81	30	116.33	4.81	30	51.6%	7.34 [4.91, 9.77]
P Nejati 2014	118.3	7.9	55	117	8.6	46	48.4%	1.30 [-1.95, 4.55]
Total (95% CI)			**85**			**76**	**100.0%**	**4.42 [-1.50, 10.34]**

Heterogeneity: Tau² = 16.10; Chi² = 8.51, df = 1 (P = 0.004); I² = 88%
Test for overall effect: Z = 1.46 (P = 0.14)

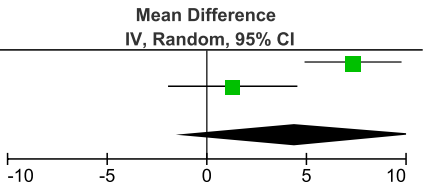

Fig. 5 Forest plot for high thoracic angle in neck pain subjects compared to asymptomatic subjects

Study or Subgroup	Neck Pain Mean	SD	Total	Asymptomatic Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Kaya DO 2017	47.76	9.25	56	38.35	9.19	53	48.9%	9.41 [5.95, 12.87]
Tsunoda 2013	40.6	10.8	171	40	11	158	51.1%	0.60 [-1.76, 2.96]
Total (95% CI)			**227**			**211**	**100.0%**	**4.91 [-3.72, 13.54]**

Heterogeneity: Tau² = 36.52; Chi² = 16.99, df = 1 (P < 0.0001); I² = 94%
Test for overall effect: Z = 1.11 (P = 0.26)

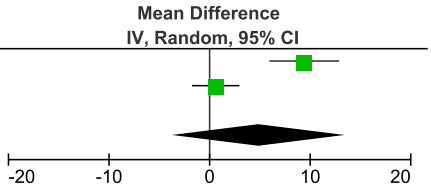

Fig. 6 Forest plot for thoracic kyphosis angle in neck pain subjects compared to asymptomatic subjects

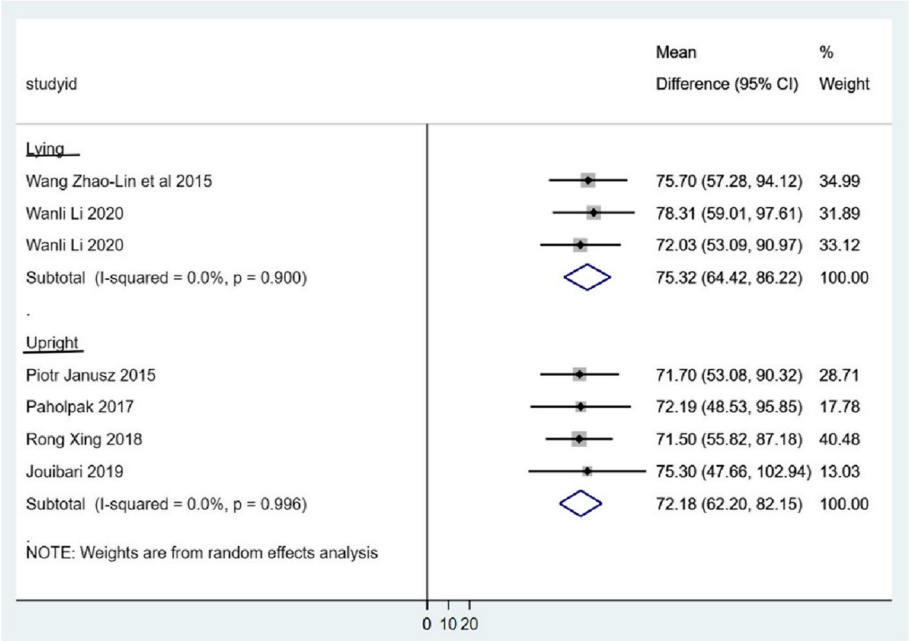

Fig. 7 Meta-analysis for test-position difference (lying vs upright) in TIA, for neck pain subjects

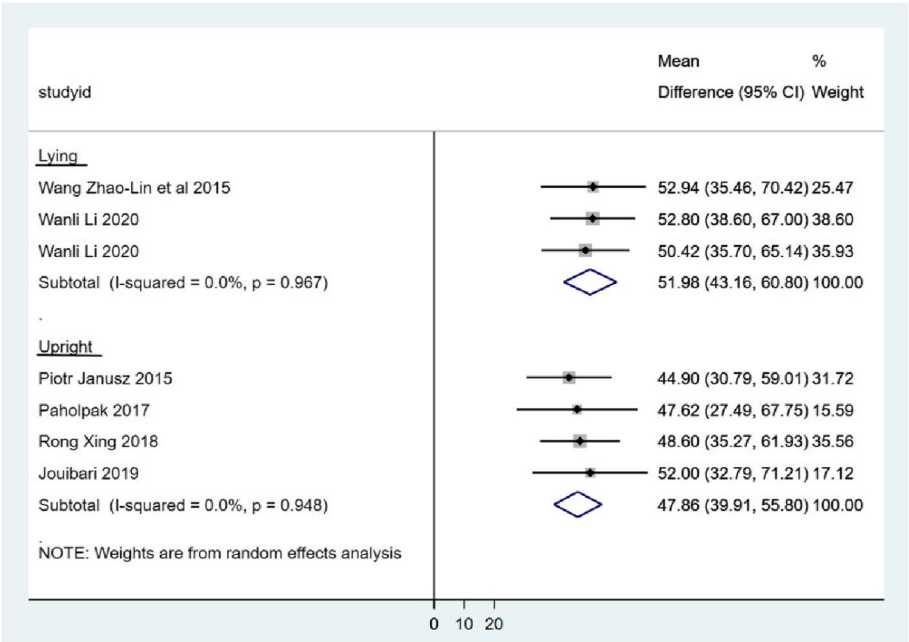

Fig. 8 Meta-analysis for test-position difference (lying vs upright) in neck tilt, for neck pain subjects

Correlation of inlet and postural parameters with neck pain

In a sample of 101 office workers examined at the desk between the 4th and 5th h of work, Nejati et al. reported a significant association between HTA and neck pain when in the working posture but not when in the neutral position. The authors, however, failed to measure it statistically in terms of correlation coefficient [8]. Lau et al. observed HTA to be positively correlated with neck pain intensity ($r=0.43$) and disability ($r=0.44$) [7]. Similar results were reported by Kaya and Celenay who found a

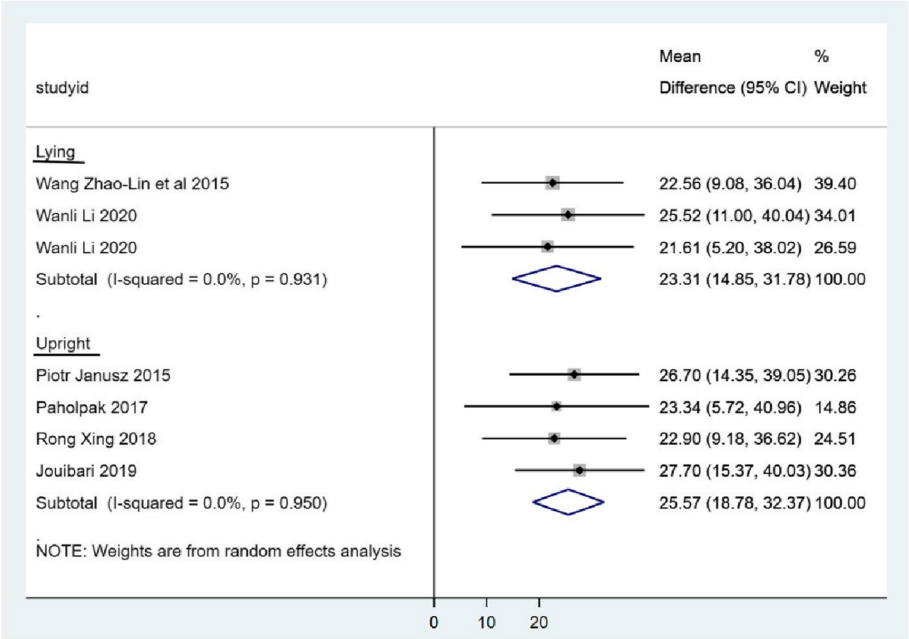

Fig. 9 Meta-analysis for test-position difference (lying vs upright) in T1 slope, for neck pain subjects

positive correlation between TKA and neck pain intensity ($r = 0.391$) [9]. However, Tsunoda et al. did not ascertain an association between TKA and neck-shoulder pain [21], for there were negligible differences in the two groups. In the study on elderly female subjects with neck pain, Quek et al. reported a negligible negative correlation of TKI with neck disability index (NDI) ($r = -0.05$) [20].

While three included studies [6, 24, 26] reported a significant correlation among the inlet parameters (T1S, TIA, NT), no study analyzed for correlation of inlet parameters with neck pain measures. Also, the authors did not find any study to date looking for a correlation between sagittal thoracic postural and inlet parameters.

Neck pain predictors

The thoracic kyphosis was a significant predictor for the presence of neck pain [7, 9] but insignificant for neck pain intensity and disability [7]. As reported by Kaya and Celenay [9], the cutoff for sagittal thoracic curvature and mobility to detect neck pain was 45.5° and 30°, respectively. Using multiple logistic regression with age and gender adjustment, HTA was found to be a good predictor for the presence of neck pain ($OR = 1.37$, $p < 0.01$) [7]. T1 slope (but not TIA) was reported to be a significant risk factor for degenerative neck pains [25, 29]. A > 22° of T1S (pre-operative) was shown to be of significant diagnostic value for degenerative cervical spondylolisthesis. However, age as a neck pain predictor was quite contrarily reported, with an insignificant relation outlined by two studies [25, 29]. On a conflicting note, Tsunoda et al. reported both age and gender to be significant predictors of neck-shoulder pain [21].

Risk-of-bias assessment

The risk of bias in the included studies was assessed using the NOS, the results of which are shown in Table 4. All the studies were assessed for quality grouped into three domains (selection, comparability, and outcome). The quality scores of included studies varied from 4 to 9, with a median score of 6. The quality of the studies was categorized based on the method described in a previous study [30]. The study quality ranged from poor ($n = 12$) to fair ($n = 1$) to good ($n = 2$). The score did not affect the inclusion or exclusion of any study from the review, it instead dictated the strength of the reported results.

Certainty of evidence

We found certainty of evidence to be very low to low for all outcome measures, except TKA which had moderate certainty of evidence for differentiating between neck pain and asymptomatic subjects. Supplementary Table 2 summarizes the certainty of evidence using GRADE.

Discussion

This review aimed to investigate the association between thoracic spine dysfunction and neck pain. We identified 15 studies that met our eligibility criteria, and

Table 4 Quality scores for risk-of-bias assessment

Study ID	Selection	Comparability	Outcome	Final score (out of 10); quality rating[a]
K. T. Lau (2010) [7]	3	1	2	6; fair
Helgadottir (2011) [19]	4	1	2	7; good
Quek J. (2013) [20]	2	2	2	6; poor
Tsunoda (2013) [21]	3	0	2	5; poor
Nejati P. (2014) [8]	3	0	1	4; poor
Zhao-Lin W. (2015) [12]	2	1	3	6; poor
Piotr Janusz (2015) [23]	2	0	2	4; poor
Paholpak (2017) [24]	2	1	3	6; poor
Kaya D. O. (2017) [9]	4	2	3	9; good
Quanbing W. (2018) [25]	2	1	3	6; poor
Rong Xing (2018) [26]	1	1	3	5; poor
Jouibari (2019) [27]	0	2	2	4; poor
Wanli Li (2020) [28]	1	1	3	5; poor
Jia Li (2020) [29]	1	1	3	5; poor
M. Kanda (2021) [22]	1	1	2	4; poor

[a] Quality of the studies was graded as poor, fair, and good based on Newcastle-Ottawa scale (adapted for cross-sectional studies) as following: Good: 4–5 stars in the selection domain, 1–2 stars in the comparability domain, and 2–3 stars in the outcome domain. Fair: 3 stars in the selection domain, 1–2 stars in the comparability domain, and 2–3 stars in the outcome domain. Poor: 1–2 stars in the selection domain or 0 star in the comparability domain or 0–1 star in the outcome domain

subsequently, 12 of them were subjected to meta-analysis to examine the impact of nontraumatic neck pain on sagittal thoracic postural and inlet parameters. Low- and very low-certainty evidence indicates that findings of the available literature on thoracic inlet and postural parameters must be viewed with caution, given that number of studies per postural parameter ranged from 1 to 2.

The included studies examined the thoracic inlet variables in subjects with various types of nontraumatic neck pain (including non-specific, cervical degenerative disc conditions, spondylolisthesis, spondylosis, and others). These findings suggest that cervical sagittal balance and postural alterations are present across different types of neck pain. Various thoracic postural measures determining the increased thoracic kyphosis included higher thoracic kyphosis angle and index and greater UTA (or lower HTA). The studies focusing on analyzing these parameters also associated neck pain with sagittal thoracic posture and other factors like age and gender. However, it is worth noting that there is a lack of high-quality research to support these associations. Another parameter of interest to authors was the correlation of the inlet parameters (TIA, T1S, NT) with the thoracic postural and neck pain measures. Surprisingly, none of the studies investigated these crucial connections.

All included studies reported postural and inlet variables recorded during the neutral position in neck pain subjects, with or without comparison to a control group. Our review suggests that inlet parameters like neck tilt and T1 slope, as well as the sagittal postural parameters for thoracic kyphosis, did not significantly differ in neck pain subjects relative to asymptomatic individuals. However, TIA was significantly higher in the neck pain subjects, compared to the controls, corroborating previous observations [12, 25, 26, 29], though it reached the level of significance in only one study [25]. We obtained lower T1S in neck pain subjects, which was, however, not statistically significant. The diminishing T1S in neck pain subjects is likely in response to compensatory mechanism to pull back the line of gravity axis, thereby decreasing the muscle work required to maintain an upright position [27]. Also, the lower T1S value causes a reduction in cervical lordosis, which further accelerates disc degeneration [26]. However, it is important to note that the insignificant difference for T1S obtained in our review contradicts the results documented in the included pieces of literature [12, 25–27, 29] wherein the T1 slope has been shown to differ significantly between symptomatic and asymptomatic groups. This astounding discrepancy in the outcomes resulted from the pain group's inconsistently different T1S value (greater or lower relative to the control group) [12, 25–27, 29].

We also found that radiographically evaluated TIA, T1 slope, and neck tilt showed slight variations between the lying and upright positions. The test position can be substantive while expressing these parameters as the compressive forces are exerted on the cervical and thoracic spine by the skull's weight in an upright position, as against the lying position. We described a 3.14° higher TIA, 4.12° higher NT, and 2.26° lower T1 slope in lying

position (relative to upright) for subjects with cervical dysfunction. However, results from a previous study on asymptomatic subjects [31] contradicted these findings, reporting no significant positional difference for TIA, for the latter being a constant parameter similar to pelvic incidence. This discrepancy may be attributed to the presence or absence of pain, as the symptomatic neck pain subjects tend to have an altered cervical spine alignment, influencing the thoracic inlet angle.

This comprehensive review represents the first attempt to examine how thoracic inlet and postural measures relate to neck pain characteristics, with subgrouping based on test-position differences. However, due to a lack of reported data, we were unable to evaluate the correlation of inlet parameters with thoracic postural and neck pain parameters.

Physiotherapy care is often recommended for patients with nontraumatic neck pain, but the influence of thoracic inlet and postural dysfunction on treatment outcomes remains unclear. The implication of treatment of cervical dysfunction on the restoration of clinically seen faulty thoracic posture or radiographically assessed thoracic inlet parameters is fundamental for a clinician and surgeon's point of view. The limited research available suggests cervical kyphosis as a risk factor for the presence and severity of neck pain [32, 33], cervical lordosis as an independent risk factor for the effective conservative treatment, and a higher T1S and cervical lordosis in the effective treatment group [34]. TIA has been assumed to be a constant morphologic parameter like pelvic incidence; hence, TIA can be the basis of planning surgical treatment to restore spinal alignment [6, 35].

The first thoracic vertebra at the cervicothoracic junction is of paramount importance, as being at the base of the neck it reacts to the tilting of the neck in any direction or under any stress. Thus, T1 responds to the physiological changes in the cervical spine above, and NT responds to maintain a horizontal gaze [12]. Slope changes in T1 reflect global spinal alignment as well as T1 vertebral motion. T1 slope and TIA have been linked with cervical lordosis [31, 36]. Altered cervical sagittal alignment therefore in the most likelihood impacts the thoracic kyphosis as well. However, further investigation is needed to explore this connection in more detail. Deviation of inlet parameters, particularly T1S, is indicative of cervical sagittal imbalance [6, 36, 37], and consequently, it can impact the outcomes of spinal surgery [13]. The preoperative cervical sagittal imbalance, which includes thoracic inlet parameters, plays a crucial role in determining postsurgical outcomes, such as pain, quality of life [38], and the reduction in cervical lordosis [39]. However, as evident from the results of this meta-analysis, T1 slope and NT had a difference of 0.86° and 2.37° respectively among the asymptomatic and symptomatic subjects with neck pain. Nevertheless, these differences were not statistically significant. It is important to note that the limited evidence available restricts the generalizability of these outcomes. Further studies are warranted before asserting the clinical relevance of T1 slope and NT in determining the effectiveness of any treatment.

It is essential to consider factors beyond pain when investigating postural dysfunction. Occupational exposure, nature/duration of routine work, sports participation, sitting elements, screen addiction, and psychosocial factors can all contribute to spinal mal-alignment owing to their repetitive/prolonged nature [40–42]. The analysis of the included studies does not provide sufficient evidence to definitively determine whether poor thoracic posture is a result of neck pain or a contributing cause. This uncertainty arises from substantial variability in the reporting of posture- and neck pain-related parameters in these studies.

Among the 15 studies included, a significant portion exhibited low to fair quality, thus indicating a high risk of bias. The predominant sources of bias were associated with sample representativeness, ascertainment of exposure, and nonrespondents subsection within the selection domain of the quality assessment scale. It is plausible that the outcomes of these lower-quality studies may lead to an overestimation of effects, potentially diminishing the overall impact of conclusive evidence that could be derived from this review.

The substantial heterogeneity observed in inlet and postural variables across the included studies stems from the wide range of inclusion criteria and individual characteristics of both patients and healthy participants in these studies. High heterogeneity carries the drawback of potentially attributing computed effects to variations in research design or the populations assessed rather than true changes in the outcome of interest. To account for this heterogeneity and obtain a more robust estimate of the effect size, we employed a random-effects model for our analysis [43].

This review underscores the limited evidence supporting T1 slope and thoracic kyphosis as significant predictors of neck pain. However, the absence of prospective trials in this field renders thoracic kyphosis, inlet parameters, age, and gender inadmissible as risk factors for developing neck pain. Additionally, it remains unclear whether poor posture serves as a risk factor for the onset of neck pain or whether neck pain leads to postural changes.

Furthermore, the results of this meta-analysis can serve as a foundation for future research, particularly long-term prospective studies that can delve deeper into the relationship between thoracic posture and cervical

dysfunction/pain. Additionally, there is a pressing need for research that explores the association between thoracic posture and inlet parameters. Besides, cervical spine conditions that limit cervical movement may also influence the thoracic inlet parameters. Conducting further cross-sectional studies to examine the implications of thoracic inlet parameters in relation to sagittal thoracic kyphosis and the severity of cervical pain is essential to ascertain their influence on the necessity and outcomes of conservative and surgical treatment options.

This study has few limitations, including the lack of consideration for symptoms and functional limitations in the evaluated thoracic inlet studies, the absence of clear definitions for most thoracic postural variables, the methodological variability in assessment of postural variables, and the predominance of low to fair-quality studies. The variability in equipment used to evaluate sagittal thoracic posture also reduces the likeliness of the results to be pooled, thus contributing to reduced effect estimates and lower certainty of evidence. The methodological and statistical heterogeneity for the outcome measures analyzed could limit the generalization of the results to some extent. A very low or low level of certainty of evidence for the analyzed parameters suggests that future studies could have a significant impact on effect estimates. Future research should aim for a clearer scope, higher methodological quality, and consistent outcome measures to reduce the methodological and statistical heterogeneity and thereby improve the generalizability of results.

Conclusion

This review highlights the limited and heterogenous evidence of low to fair quality, available with regard to the relationship between the sagittal thoracic postural and inlet parameters to pain variables in nontraumatic cervical dysfunction. TIA was the only thoracic inlet variable to be significantly different for symptomatic and asymptomatic subjects. With insufficient evidence, if thoracic posture and neck pain are associated, it is minuscule. Test-position difference reflected marginally lower T1 slope, and higher TIA and neck tilt in lying compared to upright, for neck pain patients. Also, only thoracic kyphosis and T1 slope could predict the presence of neck pain. There is a lack of evidence for associating the inlet and postural parameters in subjects with neck pain.

Defining the key terms

Thoracic inlet parameters [12, 23–29]

- Thoracic inlet angle (TIA)—Angle formed by a line perpendicular to the superior end plate (SEP) of T1 and a line connecting the center of SEP of T1 and the upper end of the sternum
- Neck tilt (NT)—Angle formed by reference vertical line drawn in the upper end of the sternum and a line connecting the center of the SEP of T1 and the upper end of the sternum
- T1 slope (T1S)—Angle formed between the reference horizontal line and the SEP of T1

Thoracic postural parameters

- High thoracic angle (HTA)—Angle between a line connecting C7 to T7 and a horizontal line from T7 [7, 8]
- Upper thoracic angle (UTA)—Angle between a line connecting C7 to T5 and a vertical line from T5 [22]
- Thoracic kyphosis angle (TKA)—The sum of the angles T1/2 to T11/12 [21]
- Thoracic kyphosis index (TKI)—Thoracic width/horizontal thoracic length × 100 [20]
- Midthoracic curve (MTC): 4 × [arctan (2 × thoracic height/thoracic length)] [19]

Abbreviations

CI	Confidence interval
HTA	High thoracic angle
MD	Mean difference
MPD	Mean pooled difference
MTC	Midthoracic curve
NDI	Neck Disability Index
NOS	Newcastle-Ottawa Quality Assessment Scale
NT	Neck tilt
T1S	T1 slope
TIA	Thoracic inlet angle
TKA	Thoracic kyphosis angle
TKI	Thoracic kyphosis index
UTA	Upper thoracic angle

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43161-023-00166-3.

Additional file 1: Supplementary Table 1. Details of Search Strategy. **Supplementary Figure 1.** Sensitivity Analysis Forest Plots of a) T1S, b) NT and c) TIA.

Additional file 2: Supplementary Table 2. Certainty-of-evidence ratings for all outcome measures.

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Authors' contributions
Both authors were involved in conceptualization, data extraction and meta-analysis, drafting, and revising the manuscript for important intellectual content.

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Availability of data and materials
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Declarations

Ethics approval and consent to participate
Not applicable as this is a review article.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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