Concordance and Reliability of Photogrammetric Protocols for Measuring the Cervical Lordosis Angle: A Systematic Review of the Literature

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Abstract

Objective: The aim of this study was to examine and interpret the concordance, accuracy, and reliability of photogrammetric protocols available in the literature for evaluating cervical lordosis in an adult population aged 18 to 59 years.

Methods: A systematic search of 6 electronic databases (MEDLINE via PubMed, LILACS, CINAHL, Scopus, ScienceDirect, and Web of Science) located studies that assessed the reliability and/or concordance and/or accuracy of photogrammetric protocols for evaluating cervical lordosis, compared with radiography. Articles published through April 2016 were selected. Two independent reviewers used a critical appraisal tool (QUADAS and QAREL) to assess the quality of the selected studies.

Results: Two studies were included in the review and had high levels of reliability (intraclass correlation coefficient: 0.974-0.98). Only 1 study assessed the concordance between the methods, which was calculated using Pearson's correlation coefficient. To date, the accuracy of photogrammetry has not been investigated thoroughly.

Conclusion: We encountered no study in the literature that investigated the accuracy of photogrammetry in diagnosing hyperlordosis of cervical spine. However, both current studies report high levels of intra- and interrater reliability. To increase the level of evidence of photogrammetry in the evaluation of cervical lordosis, it is necessary to conduct further studies using a larger sample to increase the external validity of the findings. (J Manipulative Physiol Ther 2018;41:71-80)

Key Indexing Terms: *Photogrammetry; Radiography; Reproducibility of Results; Spine*

Introduction

The cervical spine is the upper region of the vertebral column, which appears concave posteriorly when viewed in the sagittal plane and for which the normal curvature angles range between 20° and 40°.[1-4] Knowledge of this angle is useful for diagnostic purposes, for monitoring postural change and the effectiveness of therapeutic interventions in postural alignment.[5,6]

Among the techniques used to measure cervical lordosis, radiography is the most accurate and is considered the gold standard for facilitating visualization of the position of the vertebrae, without the influence of soft tissues.[7,8] The 2 most common methods of measuring the cervical curvature angle via radiography described in the literature are the Cobb and posterior tangent methods. The Cobb angle in the neck is measured through the intersection of lines drawn over the center of the upper cervical vertebral body (C1) and the inferior endplate of the lowest cervical vertebra (C7). The posterior tangent method, on the other hand, considers the angle formed by a line drawn through the apex of the odontoid process and the extremity of the posterior-inferior region of the body of the C4 vertebra, with a line that crosses the posterior inferior region of the C4 to C7 bodies (Fig 1).[1,9]

Although the described methods are the most accurate for diagnosing postural changes, their repeated use is limited because continuous and repeated exposure to radiation is harmful to human health and should therefore be avoided when monitoring the development of postural changes.[10,11] Thus, for the quantitative assessment of cervical lordosis, it is necessary to develop accurate,

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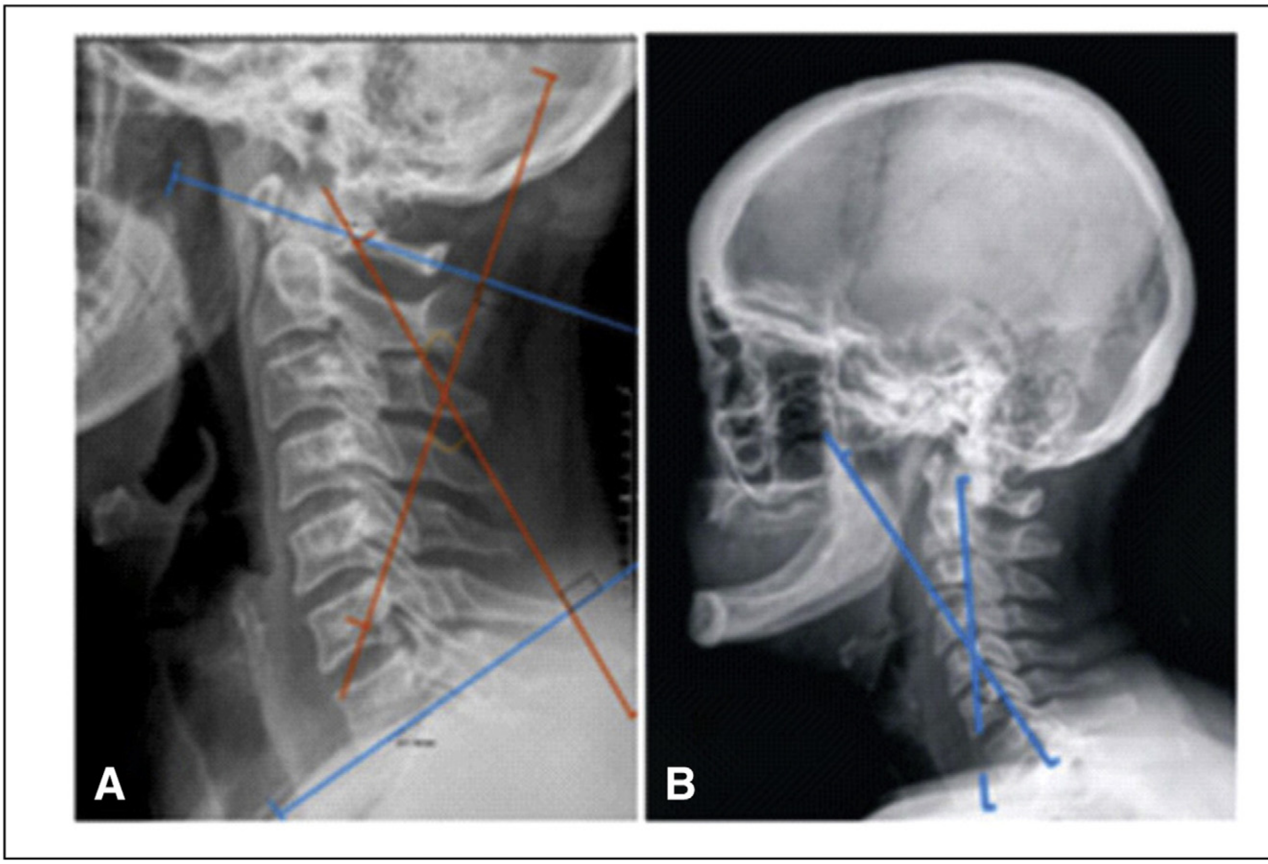

Fig 1. *Cervical lordosis angle. A, Cobb angle method. B, Posterior tangent method.*

noninvasive techniques that provide valid information when compared with the gold standard.[12]

Among the available noninvasive techniques, photogrammetry associated with the use of software such as CorelDraw and ALCimagem is an outstanding method for tracing and measuring angles and horizontal and vertical distances.[3-6] This method may be considered superior to other non-invasive methods because of the low costs involved, its easy transportation and photo-interpretation, and its capacity to measure small postural changes and register the monitoring of progression, stabilization, or reduction of postural asymmetries in adults over time.[4,13] However, to date, there has been no consensus on the best protocol for photogrammetric evaluation and no reports regarding its sensitivity and specificity in diagnosing cervical hyperlordosis and rectification.[14]

Therefore, it is important to summarize the evidence regarding the accuracy, concordance, and reliability of computerized photogrammetry protocols for measuring the angle of cervical lordosis. This information could contribute to a more specific clinical assessment, which, in turn, would assist in monitoring the development of patients with cervical pain and posture disorders, as well as verifying the effectiveness of interventions over time, and hence create normal parameters of cervical lordosis. Late diagnosis and rehabilitation may result in cervical pain, postural changes, or severe deformities, affecting physical appearance, cardiopulmonary function, and psychological well-being.[8-10]

The objective of this literature review was to investigate whether computerized photogrammetry protocols that measure the angles of cervical concavity are in concordance with radiography, are able to accurately diagnose cervical hyperlordosis and rectification in adults aged between 18 and 59 years, and have good intra- and interrater reliability. This review may also provide guidance on planning future studies that assess cervical lordosis, considering the shortcomings of articles published in the literature.

Methods

This systematic review was structured using the guidelines from Preferred Reporting Items for Systematic Reviews and Meta-Analysis.

Search Strategy in the Databases

The survey was conducted through April 2016 in MEDLINE via PubMed, LILACS, CINAHL, Scopus, ScienceDirect, and Web of Science. The search was performed using terms from 3 distinct study areas: cervical posture (cervical, posture, craniocervical, evaluation, lordosis, "cervical angle," "spine curvatures," "cervical spine," "cervical posture," and "posture evaluation"); psychometric properties of diagnostic accuracy studies (reliability, validity, and accuracy), and methods for evaluating the cervical lordosis angle (photogrammetry and radiography).

The Boolean operators "OR" and "AND" used to match the terms of each study area and search strategies were as follows: Posture AND Lordosis (Spine Curvatures) NOT scoliosis; (cervical AND posture) and photogrammetry AND lordosis; Posture AND Lordosis (Spine Curvatures) NOT scoliosis; (cervical AND posture) and photogrammetry AND lordosis; photogrammetry AND Craniocervical AND posture; (Cervical AND posture) AND photogrammetry; Evaluation AND photogrammetry AND (craniocervical posture); ((cervical angle) AND photogrammetry) AND reliability; ((posture evaluation) AND (cervical spine)) AND photogrammetry; ("cervical posture") AND photogrammetry; ((evaluation) AND photogrammetry) AND (craniocervical posture); (craniovertebral angle) AND validity.

Eligibility Criteria, Selection of Studies, and Concordance Analysis of the Selection by Reviewers

The method for the systematic review followed an available protocol previously discussed with the authors but not registered on any database. This protocol encompassed research aspects such as eligibility criteria; search method; selection of studies; and degree of methodological quality, data extraction, and synthesis.

We used observational study designs with no restrictions on language and dated before March 2016. All studies had to have investigated quantitative evaluation of the cervical lordosis angle in the sagittal plane, by photogrammetry, as a primary or secondary outcome. No restrictions were imposed regarding the software used to analyze the photos. Although no restrictions were imposed on the sample with respect to race or nationality, it was necessary to include males and/or females aged between 18 and 59 years.

Initially, 2 independent reviewers removed all repeated items from the selection list. An analysis was undertaken of those that remained based on the title of each item, excluding studies that did not include adult samples, did not evaluate the cervical region, did not use at least 1 of the methods discussed (photogrammetry or radiography), and did not investigate reliability, concordance, and/or accuracy. Next, in cases where article titles had not explicitly expressed the desired information, the abstracts were read to certify the inclusion criteria.

The index test under examination was the computerized photogrammetry protocol of the lateral profile, in which we evaluated the anatomical palpatory method used, the anatomical landmarks selected, the design of the angle lines, and the software used. The gold standard was radiographic assessment of the standing posture in sagittal plane. The outcomes analyzed were inter- and intrarater reliability, agreement between the angle values obtained by photogrammetry and radiography, and information regarding the accuracy of the method (sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios).

The gold standard was radiographic assessment of the standing posture in the sagittal plane. Excluded were studies that evaluated patients with diseases or disorders that prevented orthostatism and had been diagnosed with scoliosis with an angle greater than 20°; did not quantitatively assess the cervical lordosis angle and only verified other angles related to cervical posture, such as the craniocervical angle and anteriorization of the head; measured the cervical curvature angle with only 1 method, either the index test or the gold standard (computed photogrammetry and radiography, respectively); included a population of children or older people; and were obtained from thesis databases or conference proceedings. These eligibility criteria were chosen to ensure that the objectives and original data of the articles for measuring the cervical lordosis angle in the sagittal plane could be generalized to a broader population using the photogrammetric assessment protocol (index test) in clinical practice.

Risk of Bias in Selecting the Individual Studies

The κ coefficient was calculated so that the reviewers could analyze the eligibility of the articles with respect to concordance.[15] To do this calculation, for each selected article, the reviewers were requested to classify the following eligibility criteria as being present, absent, or unclear: samples of adults; postural analysis of the cervical region; use of radiography and photogrammetry to assess the cervical angle; and concordance, accuracy, and/or reliability analyses. The 2 reviewers were blinded to each other's results.

Any discordance that occurred during the process was settled through consensus and discussion on the review protocol. However, no discordance was experienced regarding the eligibility of the articles. The identification, selection, and inclusion processes were presented by means of a flowchart, based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines, which guide the transparent reporting of systematic reviews and meta-analyses.[16]

The full texts of the potentially relevant articles were retrieved for data extraction, and their reference lists were verified independently by 2 reviewers to identify other possible studies that could be included in the review but had not been identified in the electronic search.

Assessing the Methodological Quality of the Articles Included

The methodological quality of the selected studies was evaluated with the use of 2 tools. The first is used for evaluating the quality of diagnostic accuracy studies—QUADAS II; and the second evaluates the quality of diagnostic reliability studies—QAREL. These tools consist of 14 and 11 items, respectively, which are rated as "yes," "no," or "unclear." The tools evaluate 4 domains: patient selection, the index test, the gold standard, and flow and timing between tests. The quality of each domain is verified by assessing the risk of bias or internal validity, applicability, or external validity and reporting. Further evaluation is carried out at the level at which the estimates of diagnostic precision were not reported, as well as the level at which the results of a study may be applied to patients in clinical practice.[17,18]

Thus, a single table was created that summarized the items originating from QUADAS and QAREL together with other criteria suggested by the Standards for Reporting Studies of Diagnostic Accuracy (STARD), which were used as a guide for the article and transparency of the accuracy studies.[19] Of the 14 items contained in QUADAS, items 3, 6, and 12 were excluded. Item 3 asks whether the gold standard is recommended for the situation in question, and item 6 asks whether the entire sample was subjected to the same gold standard. However, the review protocol clearly stated that only studies in which radiography was the gold standard should be included; therefore, these 2 questions became redundant. Item 12 asks whether the patient's clinical data were the same as those made available when the test results were interpreted in clinical practice so that there is no influence on its outcome. However, because the outcome analyzed is the angle of cervical lordosis, this information is of no relevance because it is a numeric variable and does not allow for predicting the angle.

In addition, items 8 and 9 from QUADAS, which question whether the study provided sufficient details to reproduce the gold standard and the index test, respectively, were removed into 2 isolated topics for further elaboration. The first item calls for a description of the experience and/or training of the raters for each evaluated test. The second question calls for a description of the procedure for each test. This was accomplished based on STARD requirements, which also made it necessary to add items 23, 24, and 25.[20]

Items 1, 2, 5, and 10 in QAREL are similar to those in QUADAS and were therefore excluded. Items 3, 4, 8, 9, and 11, which were added to the analysis of the methodological quality of the review, ask if raters were blinded to the findings of other raters, if raters were blinded to their first evaluations, if the order of evaluation varied, if there was a sufficient interval between the measurements, and if an appropriate statistical method was used, respectively. Items 6 and 7 of QAREL were excluded for the same reason that item 12 of QUADAS was excluded.

As the QUADAS and QAREL instruments do not determine a priori scores to define the quality of studies, this analysis of the evidence was not performed.[17,18,21] However, the strategy of adding items from guidelines other than QUADAS that complement and answer specific questions is recommended within the validation of the instrument itself, and was undertaken in the present study.[21]

A quality assessment was conducted on the items selected for this study, as described above, by 2 independent reviewers at different times. After this, any disagreements that occurred were settled through discussion, and all items were clarified.

Meta-analysis

A meta-analysis was not conducted because of the heterogeneity of the tests, the participants, and the analyses of the studies selected for this review. Similarly, it was not possible to conduct a subgroup analysis because of the limited number of studies that measured the cervical lordosis angle in the same manner and with comparisons similar to the gold standard.

Results

Study Selection

The flowchart illustrates the process of identifying, selecting, and including the studies that make up this review (Fig 2). It should be noted that of the 430 articles identified in the initial search, only 2 met the inclusion criteria and were therefore analyzed. Our findings indicated that there was a high level of concordance (κ) between reviewers with respect to the selection and eligibility of articles, with a score of 1.[15]

Characteristics of Studies and Participant Types

A descriptive analysis was performed for the 2 studies included,[22,23] with general characteristics such as size, age, and sex of the sample; place of recruitment; sample calculation; description of the anatomical landmarks; type of marker used; angle layout; objectives; and outcomes analyzed, as delineated in Table 1.

Quality of Studies

The items used to assess the methodological quality of each study are listed in Table 2.

There was a high level of concordance (κ) between the reviewers regarding methodological quality, with a score of 1.[15]

Reliability and Concordance

The results of the reliability and validity analyses for each study, as well as an interpretation of the statistical adjustment, are summarized in Table 3. Neither study[22,23] presented any values for cervical lordosis angles with either photogrammetry or radiography. Only 1 study[22] examined

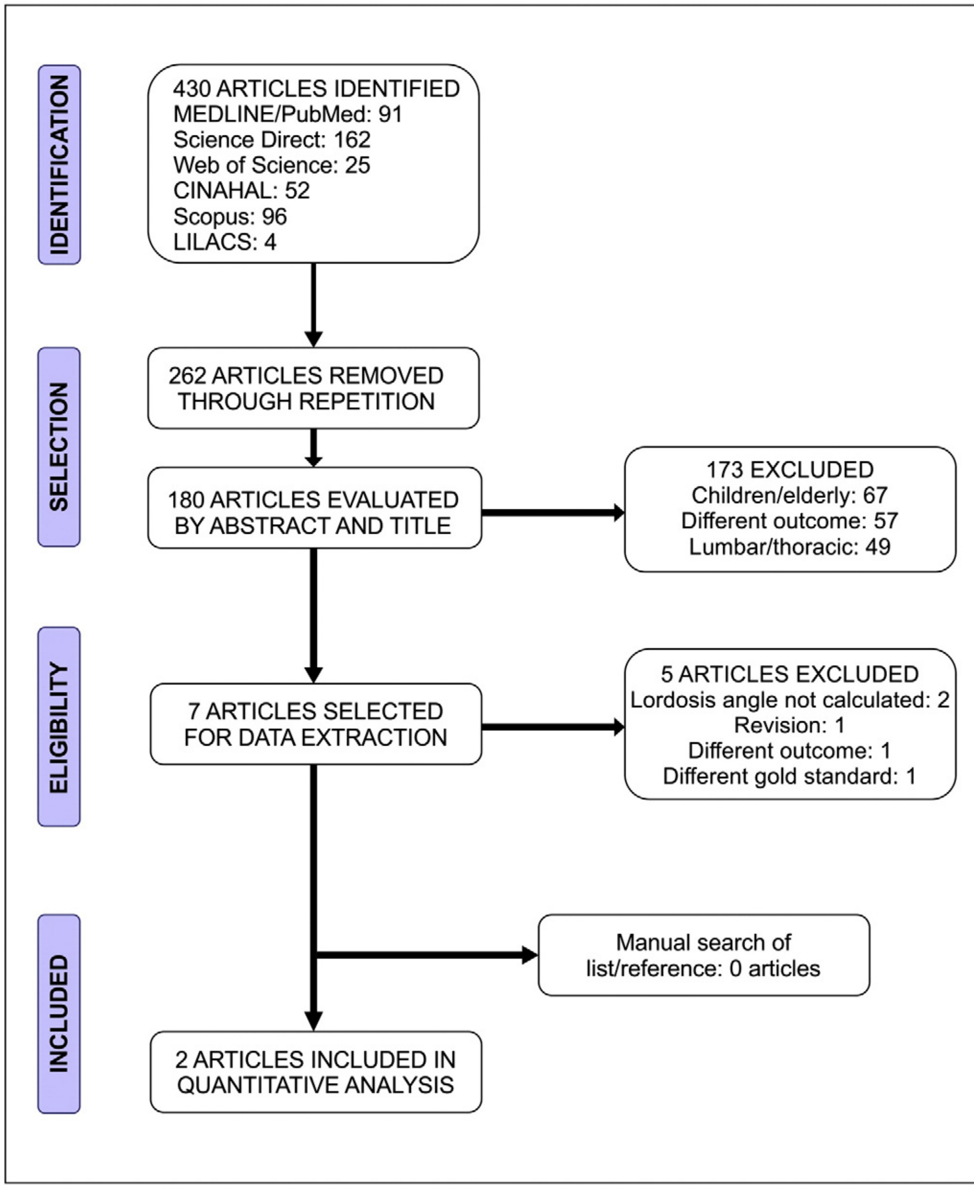

Fig 2. *Flowchart of Preferred Reporting Items for Systematic Reviews and Meta-analysis.*

the concordance between photogrammetry and radiography; however, an inappropriate statistical analysis was used for the evaluated outcome.

Discussion

The aim of this systematic review was to summarize and interpret accuracy, concordance, and reliability studies on computerized photogrammetry for measuring the cervical lordosis angle, as compared with radiography. However, none of the papers we encountered during the study mentioned the accuracy of computerized photogrammetry in diagnosing hyperlordosis or cervical rectification. This would seem to indicate that very little research has been conducted on this issue, not because it is considered unimportant, but rather because of the methodological difficulties concerning the accuracy of studies and aspects related to research ethics, which do not allow permit frequent exposure to radiation. For this reason, there has often been a greater number of investigations evaluating other cervical spine angles, such as the Rocabado and head anteriorization angles, which do not require comparison with radiography.[24]

Only 2 studies were included,[22,23] and according to QUADAS and QAREL, they presented some methodological biases; for example, the sample was not representative of the population to which the index test would be applied.

Table 1. *Characterization of Included Studies*

	Gadotti et al, 2013[23]	Weber et al, 2012[22]
Description of sample	39 healthy females	80 females
Age, y, mean (SD)	33 (8)	23.8 (3.65)
Body mass index, kg/m^2, mean (SD)	22.7 (6)	22.4 (3.83)
Place of recruitment	Glen Sather Clinic, University of Alberta	Not specified
Sample calculation undertaken	Yes (α = 0.05, power = 0.8) (n = 21)	No
Eligibility criteria	Normal craniocervical region, defined as normal range of motion and no pain; patients excluded if they presented with frequent pain in cervical region, history of surgery or trauma to the head/neck, or systemic disease	Voluntary recruitment through printed media; patients excluded if they had a history of facial and/or craniocervical trauma, presence of acute and severe musculoskeletal pain, musculoskeletal deformities (scoliosis, congenital bone malformation), and craniomandibular and/or neck orthopedic surgical procedures and previous diagnosis of cervical disk herniation
Methodologic description for palpation of anatomical landmarks	No	No
Type of marker used	Marker made of light metal fixed with double-faced adhesive tape	White polystyrene balls covered in reflexive double-faced tape fixed on the body
Form of obtaining the cervical lordosis calculated by photogrammetry	CA (cervical lordosis); formed by the line linking C2 to C4 with the line linking C4 to C7; measured in degrees	Cervical lordosis measured as the horizontal distance from a vertical tangent line that passes through the apex of the point of the thoracic kyphosis to the vertex of the cervical lordosis; measured in cm
Form of obtaining the cervical lordosis by X-ray	ARA; CA is measured using centers of the vertebral bodies of C2, C4, and C7 and PE of C2, C4, and C7; measured in degrees	CVT/EVT: CVT line intersects vertex of odontoid process of C2 with the most posterior-inferior point of the body of C4, whereas EVT line intersects the most posterior-inferior points of the body of C4 to C6; measured in degrees
Software for posture evaluation	ALCimagem	SAPO
Main outcome	Intra- and interrater reliability of photogrammetry and X-ray SEM; concordance of visual analysis of posture	Concordance between biophotogrammetry and radiography; intra- and interrater reliability of photogrammetry and X-ray
Study objectives	To determine intra- and inter-rater reliability of craniocervical posture in sagittal plane using quantitative measurements in photography and radiography, and to determine concordance of the visual assessments of raters	To investigate correlations between measurements of craniocervical posture obtained by biophotogrammetry and radiography

CVT/EVT, the CVT line intersects the apex of the tooth of the second cervical vertebra with the most posterior-inferior point of the body of the fourth cervical vertebra, while the EVT line intersects the most posterior-inferior points of the body of the fourth and sixth cervical vertebrae.
ARA, absolute rotation angle; *CA*, cervical angle; *CVT*, cervical vertebrae tangent; *CVT/EVT*, cervical lordosis angle; *SD*, standard deviation; *SEM*, standard error of the mean.

Both studies[22,23] evaluated only healthy women within a narrow age range, without specifying the place of recruitment. Moreover, they failed to include spectral variables of the disease, which is an essential aspect of application of the test to other situations.[17,19] One study[22] however, contained a convenience sample, enlisting volunteers only.

One further important methodological aspect neglected by 1 of the studies[23] is related to the description of the experience and/or training sessions of the reviewers for both diagnostic tests (index and gold standard), as well as their implementation. If the tests were to be performed differently, the results would be influenced, thereby affecting their interpretation.[17] Moreover, it is important

Table 2. *Evaluation of Quality of the Studies*

	Evaluation Criteria Based on QUADAS/QAREL and STARD	Gadotti et al, 2013[23]	Weber et al, 2012[22]
Items From QUADAS			
1	Is the patient spectrum representative of the population who will receive the test in practice? (Spectrum bias)	No	No
2	Were there adequate descriptions of the study population and selection criteria?	Yes	Yes
3	Is there a short time period between the gold standard and the index test?	Yes	Unclear
4	Did all participants undergo the gold standard? (Verification bias)	Yes	Yes
5	Was the index test part of the gold standard? (Incorporation bias)	No	No
6	Was there an adequate description of the profession, experience, and/or training of the raters of the index test?	Yes	No
7	Was there an adequate description of the profession, experience, and/or training of the raters of the gold standard?	Yes	No
8	Was there an adequate description of the index test procedure?	Yes	Yes
9	Was there an adequate description of the gold standard?	Yes	Yes
10	Were raters blinded for the index test and gold standard (Revision bias)	Yes	Unclear
11	Is there a cross-table with the results of each test and its interpretation?	Yes	Yes
12	Was the statistical method appropriate?	No	No
13	Were withdrawals from the study explained?	No	No
14	Was the test analyzed by professionals representing those for whom the authors intended to apply?	Yes	Unclear
Items From QAREL			
15	Were raters blinded for the index test? (Interrater)	Yes	No
16	Were the findings of the first evaluation blinded? (Intrarater)	No	Unclear
17	Was there a minimum interval of 1 week before repeating the evaluation? (Intrarater)	Yes	Yes
18	Was the statistical method appropriate?	Yes	Yes
Items From STARD			
19	Were the index test raters different from those of the gold standard?	No	Unclear
20	Was a flowchart provided for the selection and recruitment of participants?	No	No
21	Was there a discussion on the applicability of the index test?	Yes	Yes
22	Was there a sample calculation?	Yes	No
23	Was there an adequate description of the palpation method used?	No	No

ICC, intraclass correlation coefficient; *QAREL,* a tool for evaluating the quality of diagnostic reliability studies; *QUADAS II,* tool for evaluating the quality of diagnostic studies; *STARD,* Standards for Reporting Studies of Diagnostic Accuracy.

that these tests should be applied by professionals who are representative of those who will actually apply the test in clinical practice. However, the professions of the reviewers were not specified in this study.[18]

Interpretation of the results of the index test may be influenced by knowledge of the gold standard test results, and vice versa. This is known as review bias and may lead to exaggerated measurements of diagnostic accuracy.[17] Hence, blinding is a factor that must be guaranteed in accuracy studies. However, only 1 of the studies clarified or discussed this aspect.[23]

There is still an element of confusion regarding the different concepts of concordance and reliability and which are important factors for classifying and developing assessment tools, thus ensuring their quality. Concordance is calculated when there is a need to conduct a study on the different methods of evaluating a clinical measure that is presented quantitatively, which, in the present study, would be the cervical lordosis angle. This test is conducted to discover if 2 measurements are the same and if one could replace the other, which is useful for verifying the accuracy and consistency of new less invasive instruments that do not cause adverse effects and that are easy to apply and less expensive than the gold standard.[25-27]

In most cases, concordance was calculated in the studies through the correlation observed in 1 of the studies.[22] Another factor that should be highlighted is that a concordance analysis must compare the same units of measurement. However, the correlation coefficient does not evaluate concordance, but rather the association between different variables.[28]

Bland and Altman[26] evaluated the agreement between 2 variables on a scatter graph from the difference and mean values of 2 variables. On this graph, it is possible to observe bias (the manner in which the differences deviate from zero) and error (the dispersion of the points of difference around the mean values), as well as the outliers and trends. The basis for calculating a sample size on which the agreement analysis is performed, with precise bias and concordance limits, is 100 volunteers to estimate the values with a confidence interval of 95%.[29,30]

It was observed that neither of the selected studies[22,23] achieved or reached the sample suggested by the Bland-Altman calculation, in fact this statistical resource received no mention. This is an important condition for the external validity of the findings, which is decreased in these articles because the sample was not representative.[31] With

Table 3. *Results of Reliability and Validity Studies*

	Gadotti et al, 2013[23]		Weber et al, 2012[22]	
Analysis of outcome (method)	Reliability Concordance	Inter- and intrarater ICC Nothing	Reliability Concordance	ICC intrarater Correlation
Value	Intrarater (rater 1) ICC 0.98 (0.37) Intrarater (rater 2) ICC 0.98 (0.22) Inter rater ICC 0.91 (7.06)	ICC (SEM) 95% 0.96-0.99 ICC (SEM) 95% 0.96-0.99 ICC (SEM) 95% 0.79-0.96	Intrarater ICC 0.974 Correlation $r = 0.07$	ICC 95% 0.936-0.989 CVT/EVT x HD $P = .52$
Statistical adequacy	Reliability	Yes	Reliability	Medium (the inter-rater was missing and the intra-rater was not calculated by the observer)
	Concordance	Not calculated	Concordance	No

CVT/EVT, the CVT line intersects the apex of the tooth of the second cervical vertebra with the most posterior-inferior point of the body of the fourth cervical vertebra, while the EVT line intersects the most posterior-inferior points of the body of the fourth and sixth cervical vertebrae. HD, the horizontal distance from a vertical line tangent by the apex of the thoracic kyphosis (thoracic plane) and the point of the apex of the cervical concavity.
CVT, cervical vertebrae tangent; *CVT/EVT*, cervical lordosis tangent; *ICC,* intraclass correlation coefficient; *SEM*, standard error of the mean.

respect to reliability, 1 of the studies evaluated[23] conducted a sample calculation for this outcome, thus increasing the consistency of the findings.[24]

One study[22] did not identify a significant correlation in relation to the variable measuring cervical curvature with radiography (CVT/EVT) and photogrammetry. It is also important to highlight that the correlation does not assess whether a measurement may be used to replace another. The author contrasted angular measurements (CVT/EVT) with other linear measurements, calculated in different units, therefore making it impossible to compare. Thus, the authors' suggestion that radiography is the only method for examining cervical curvature is inconclusive.[32]

The articles[22,23] did not provide the angle values encountered within each evaluation method, thus making it impossible to calculate the Bland-Altman concordance.

With respect to reliability, the evaluated studies had intraclass correlation coefficients ranging from 0.79 to 0.99, presenting little variability between the angle results obtained with the instrument under investigation (photogrammetry). Iunes et al[33] confirmed these findings, concluding that computerized photogrammetry is a reliable method for use by different raters. However, it should not be used as a reference in visual analysis, because there is no evidence to sustain a comparison between the 2 methods.

Gadotti et al[23] also evaluated the intra- and interrater reliability for the visual analysis of cervical curvature in photogrammetry and radiography, obtaining poor intrarater reliability, thus illustrating the subjectivity of this type of evaluation and the real need for quantitative assessment in clinical practice.

It is important to highlight that, for a study to be reproducible, its protocol should be described in its methods. Information on the palpation method used, patient positioning, software, distance and height of the camera, and the angle lines is essential for the procedure to be repeated and consistently obtain the same results. Among the aforementioned factors, the palpation method used was the only method not described by any of the studies, especially because C2 was used as a reference and is difficult to palpate.[23]

Palpation of the spinous processes is the most important step and condition with which to conduct a valid, consistent evaluation. Errors at this stage may determine possible false deviations and changes in the spine in the sagittal and frontal planes. Properly executed, this step allows professionals to perform postural assessment with more confidence. Accurate palpation varies depending on the rater's experience and training, the presence of anatomical abnormalities, and the clinical characteristics of each participant. Furthermore, precision in locating referential anatomical landmarks is important in investigating concordance and interrater reliability studies.[10,34]

We discovered that the SAPO and ALCimagem software used in the studies are both validated and described in the literature and are commonly used in studies on the validity of photogrammetry. Thus, the software was not considered a factor that may influence the consistency of the results for the evaluated items.[33,35,36]

Limitations

It was not possible to estimate the prevalence of cervical hyperlordosis because the studies did not find the mean value of the lordosis angle measured by photogrammetry and radiography, and none of the studies had examined the accuracy of photogrammetry in detecting cervical lordosis and rectification. Furthermore, the sample was not representative of people who are subjected to examination daily, as both studies recruited only asymptomatic individuals. The statistical resources for calculating concordance between the values of cervical curvature encountered through photogrammetry and radiography were not appropriate. Thus, the initial aim of analyzing concordance and accuracy could not be achieved, because there were failings in the quality of methodology and statistical analysis in the available studies.

Conclusions

At present, studies in this area are scant. The results of 2 papers suggest that photogrammetric quantitative analysis of the cervical lordosis angle has high levels of intra- and interrater reliability. The concordance of the technique was wrongly evaluated using the correlation coefficient instead of the Bland-Altman concordance, without presenting measurements of the lordosis angle obtained by each method.

Practical Applications

- No study evaluated the ability of photogrammetry to diagnose dysfunctions of the cervical spine in the sagittal plane, such as hyperlordosis and rectification.
- The studies used inappropriate statistical methods (correlation coefficient) to evaluate the concordance between the values of the cervical lordosis angle obtained by photographic and radiographic methods, for which the Bland-Altman plot is the most suitable.
- There was no methodological consensus on biophotogrammetric protocols for evaluating cervical lordosis angle.
- The biophotogrammetric protocols for evaluating the cervical lordosis angle have good intra- and interreliability and may be used only as a measure for monitoring the course of treatment.

This review has also revealed a lack of validity and reliability studies using computerized photogrammetry for measuring the cervical lordosis angle, as well as a lack of analyses on the ability of the method to diagnose dysfunctions in the cervical spine (hyperlordosis and rectification). It is necessary to carry out further research that focuses on the use of appropriate statistical techniques, with equivalent sample calculations, corresponding angle lines, transparent methodological presentation, clear and objective descriptions of evaluator masking, technical specifications, and descriptions of each rater's experience.

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No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): P.M.N.M.d.A., G.R.d.S.
Design (planned the methods to generate the results): P.M.N.M.d.A., G.R.d.S., G.G.d.A.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): P.M.N.M.d.A., D.A.d.O., G.R.d.S.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): P.M.N.M.d.A., G.G.d.A.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): P.M.N.M.d.A., G.G.d.A., G.R.d.S.
Literature search (performed the literature search): P.M.N.M.d.A., G.G.d.A.
Writing (responsible for writing a substantive part of the manuscript): P.M.N.M.d.A.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): D.A.d.O., G.R.d.S

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