Original Article

The efficacy of sagittal cervical spine subtyping: Investigating radiological classification methods within 150 asymptomatic participants

ABSTRACT

Aims: The aim of this study is to (1) compare and contrast cervical subtype classification methods within an asymptomatic population, and (2) identify inter-methodological consistencies and describe examples of inconsistencies that have the potential to affect subtype classification and clinical decision-making.

Methods: A total of 150 asymptomatic 18–30-year-old participants met the strict inclusion criteria. An erect neutral lateral radiograph was obtained using standard procedures. The Centroid, modified Takeshima/Herbst methods and the relative rotation angles in cases of nonagreement were used to determine subtype classifications. Cohen's kappa coefficient (κ) was used to assess the level of agreement between the two methods.

Results: Nonlordotic classifications represented 66% of the cohort. Subtype classification identified the cohort as, lordosis (51), straight (37), global kyphosis (30), sigmoidal (13), and reverse sigmoidal (RS) (19). Cohen's kappa coefficient indicated that there was only a moderate level of agreement between methods (κ = 0.531). Methodological agreement tended to be higher within the lordotic and global kyphotic subtypes whereas, straight, sigmoidal, and RS subtypes demonstrated less agreement.

Conclusion: This is the first study of its type to compare and contrast cervical classification methods. Subtypes displaying predominantly extended or flexed segments demonstrated higher levels of agreement. Our findings highlight the need for establishing a standardized multi-method approach to classify sagittal cervical subtypes.

Keywords: Asymptomatic, cervical classification, kyphosis, lordosis, sigmoidal

INTRODUCTION

The cervical spine is naturally lordotic,[1,2] contributing to the spine's overall sagittal balance in association with the interconnected alignment variabilities within the thoracolumbar spine, pelvis, and lower limbs.[3,4] A distinction must be made between methods that are used to classify cervical alignment subtypes and methods that produce angular measurements. The Centroid,[5,6] Kamata's line drawing,[7,8] Takeshima *et al*.[9] and Herbst[10] methods are commonly used to classify cervical subtypes. The Cobb, Posterior Tangent (relative rotation angle [RRA]),[5,11-14] Cervical Centroid Lordosis and Ishihara methods[5] all produce angular measurements that quantify the curve, but not its specific subtype.

Descriptive assessment of the various cervical alignment subtypes has improved considerably. Ruangchainikom *et al*.[6] introduced the term global kyphosis to describe both a global flexed segmental arrangement and also the concept of focal kyphotic sections within the lower or upper cervical spine of sigmoidal-types. Harrison *et al*.[15] described various subtypes

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Website: www.jcvjs.com	**Quick Response Code**
DOI: 10.4103/jcvjs.JCVJS_84_17	

How to cite this article: Daffin L, Stuelcken MC, Sayers MG. The efficacy of sagittal cervical spine subtyping: Investigating radiological classification methods within 150 asymptomatic participants. J Craniovert Jun Spine 2017;8:231-8.

within the cervical spine. These subtypes are typically classified as lordotic (L-type), straight (St-type), global kyphotic (GK-type), sigmoidal (S-type), and reverse sigmoidal (RS-type). Cervical subtype classification involves identifying and using numerous radiological landmarks to develop an overall impression of the cervical spine's sagittal alignment. A variety of visual and numerical methods have been developed and modified over time to fulfil this requirement.[5,9,10]

The Centroid method[5,6] involves visually determining the location and numerical distance of centrally located points within the vertebral bodies of C3–C6 to a central line connecting C2 and C7. The Takeshima method[9] involves visually identifying the inherent sequential alignment of the posterior vertebral body margins (PVBMs) from C2 to C7. The generated PVBM conformational shape (CSh) is classified according to its relative subtype. Conversely, the Herbst method[10] requires visual interpretation of the convergence or divergence posteriorly of five lines that equally transect the intervertebral discs between C2 and C7. At present, no single "gold standard" methodology exists to classify sagittal cervical alignment subtypes. However, these are the most accepted methods within the literature.

Considerable advances have been made regarding the various nonlordotic subtypes and their contribution to the pathogenesis of degenerative cervical myelopathy (DCM), and the significant impact that this has on the quality of life of the elderly.[2,4,16-18] Two recent reports have independently determined that approximately one-third of asymptomatic participants displayed nonlordotic subtypes.[19,20] The mounting evidence that nonlordotic subtypes are increasing within apparently healthy populations is concerning considering the detrimental effects of DCM.[2,4,21,22] As DCM is the leading cause of spinal cord dysfunction worldwide,[16] an increase in nonlordotic subtypes could indicate a potential future rise in DCM symptomatology in the general population.

Cervical subtyping is essential within research and clinical environments[5,7,8,13] to establish baseline and postintervention alignment classifications. Pre- and post-operative decision making relies on an accurate understanding of the various cervical alignment subtypes, as sagittal alignment influences operative outcomes.[7,13,23,24] Scheer *et al.*[13] suggested the necessity for a comprehensive approach to assess global cervical-pelvic relationships. Therefore, a precise understanding of the limitations within cervical subtyping methodologies is critical to achieve this future direction.

Accordingly, the purpose of this research is to (1) compare and contrast cervical subtype classification methods within an asymptomatic population, and (2) identify inter-methodological agreement and describe areas of disagreement that have the potential to affect subtype classification and clinical decision-making. It is hoped that this will stimulate further research and discussion that leads to the development of a standardized sagittal subtyping classification method.

METHODS

The sample population consisted of 61 male and 89 female participants [Table 1]. The tools that were used to assess participant eligibility were a self-reporting questionnaire (SRQ),[25-29] 36-item short-form health survey (SF-36),[30] neck disability index (NDI),[31] and a physical examination.[32,33] The SRQ was formulated from published criteria to exclude participants that could negatively influence asymptomatic measures. All included participants demonstrated an asymptomatic SRQ, with all health and neuromusculoskeletal SF-36 scores above the National Health Survey SF-36 population norms.[34] In addition, the NDI upper limit inclusion score was 12, where a score >15 was likely to indicate neck pathology.[35] The physical examination excluded participants that demonstrated positive neurological and/or orthopaedic findings.

Approval was obtained from the Institutional Research Ethics Committee (S/14/607), with written informed consent obtained from all eligible volunteers in accordance with the institutional human research ethics requirements. The current study is one component of a larger project investigating the influence of cervical alignment on postural sway. This accounts for the radiographic procedures on asymptomatic subjects.

Radiographic procedures, instruments, and measurements

A single lateral radiograph was taken with a tube-to-wall mounted Bucky distance of 1.5 m. The central ray was aligned approximately at the level of C4. Each participant was positioned with their right shoulder touching the Bucky and instructed to adopt a relaxed neutral erect stance position with their head looking toward the horizon. The participant's shoulder girdles and arms hung relaxed by their sides, while

Table 1: Cohort demographic measures shown as means±1standard deviation

Parameter	Cohort (*n*=150)	Male (*n*=61)	Female (*n*=89)
Age (years)	22.5±3.6	22.7±3.6	22.5±3.6
Height (m)	1.71±0.09	1.78±0.07	1.66±0.06
Range (m)	1.49–1.96	1.62–1.96	1.49–1.89
Mass (kg)	70.1±14.4	79.1±14.0	63.9±11.1
Range (kg)	45.0–128.0	53.3–128.0	45.0–95.5

their body weight was distributed evenly over both feet.[36] The assumed position was not guided by the radiographer, and postpositioning movements were kept to a minimum.[37-41] All radiographs were taken by the same radiographer and digital capturing unit. The principal researcher classified all modified Takeshima/Herbst Method curvatures on standard radiographic software (Genesis OmniVue® Genesis Digital Imaging, Inc., Los Angeles, CA, USA), with all images digitized at a scale of 1.0 then printed for Centroid classification.

Modified Takeshima/Herbst method

The Takeshima and Herbst methods have been combined, as both individual visual methods complement each other's subtype classification criteria. A continuous posterior vertebral body line (PVBL) was drawn connecting the posterior inferior corner of the C2 vertebral body to the posterior superior corner of the C7 vertebral body.[9] Intervertebral disc lines (IVDL) were established within the intervertebral disc spaces from C2/3 to C6/7 by drawing lines that equally transected the intervertebral disc along its anterior to posterior axis. The five transecting lines were interpreted depending on their visual convergence or divergence posteriorly to the PVBL.[10] The PVBL CSh and IVDL alignments were compared to the subtype classification guidelines to finalize classification. In the modified Takeshima/Herbst method subtype classification guidelines. L-type: The PVBL CSh is lordotic, all the IVDL converge posteriorly. St-type: The PVBL CSh indicates linearity, all the IVDL are parallel. GK-type: The PVBL CSh is kyphotic, all the IVDL diverge posteriorly. S-type: The upper sub-axial spines (C2/C4) PVBL CSh is lordotic while the lower sub-axial spine (C5/C7) is kyphotic. The upper sub-axial IVDL converge. RS-type: The upper sub-axial spines (C2/C4) PVBL CSh is kyphotic while the lower sub-axial spine (C5/C7) is lordotic. The upper sub-axial IVDL converge posteriorly while the lower sub-axial IVDL converge posteriorly [Figure 1].

Centroid method

The Centroid method utilizes a combination of numerical and visualization techniques to classify alignment. Centroids represent the intersection point of two lines within the vertebral bodies of C3–C6. The first line connected the anterior inferior corner of the vertebral body to the posterior superior corner of the vertebral body while the second line connected the anterior superior corner of the vertebral body to the posterior inferior corner of the vertebral body. The C2–C7 Centroid determination line (CDL) was generated by connecting two points. The first point was located centrally on the inferior endplate of C2 while the second point was located centrally on the superior endplate of C7.[5,6] Measured relationships of the Centroids to the CDL are outlined within the subtype classification guidelines. In the Centroid method, subtype classification guidelines. L-type: All Centroids are located anteriorly to the CDL; at least, one Centroid is ≥2 mm from the CDL. St-type: The Centroids can be located anterior or posteriorly to the CDL however, all Centroids must lay ≤2 mm from the CDL. GK-type: All Centroids are located posteriorly to the CDL; at least, one Centroid is ≥2 mm from the CDL. S-type: One upper cervical Centroid must be located anteriorly to the CDL while one lower cervical Centroid must be located posteriorly to the CDL. One Centroid regardless of location must be ≥2 mm from the CDL. RS-type: One upper cervical Centroid must be located posteriorly to the CDL while one lower cervical Centroid must be located anteriorly to the CDL. One Centroid regardless of location must be ≥2 mm from the CDL [Figure 2].

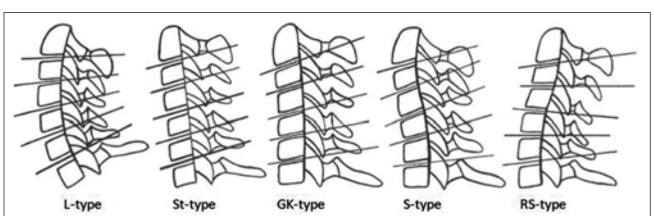

Figure 1: Modified Takeshima/Herbst method subtype classification guidelines

Relative rotation angle

When methodological inconsistency occurred, five individual RRA were generated from C2/3 to C6/7. These intersegmental angles are measured at the intersection of consecutive PVBLs [Figure 3].[5,14,15]

Final classification subtyping

Subtyping was performed separately on different copies of the same radiographs to limit the influence of previously determined classifications derived from the alternative method. Classification difficulties occurred when methods tended not to agree. Selecting a specific subtype to represent the participant involved simultaneously reviewing both marked radiographs in conjunction with the RRA measures, then comparing the collective findings with their relative guidelines. Final subtype classification was only achievable once the RRA flexion and extension findings were matched with the guidelines.

Statistical evaluation of methodological agreement

Cohen's kappa coefficient (κ) was used to assess the level of agreement between the two methods, taking into account the agreement occurring by chance. The magnitude of the kappa coefficient was evaluated according to the criteria established by Landis and Koch.[42] (<0 no agreement, 0–0.20 slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1 almost perfect agreement).

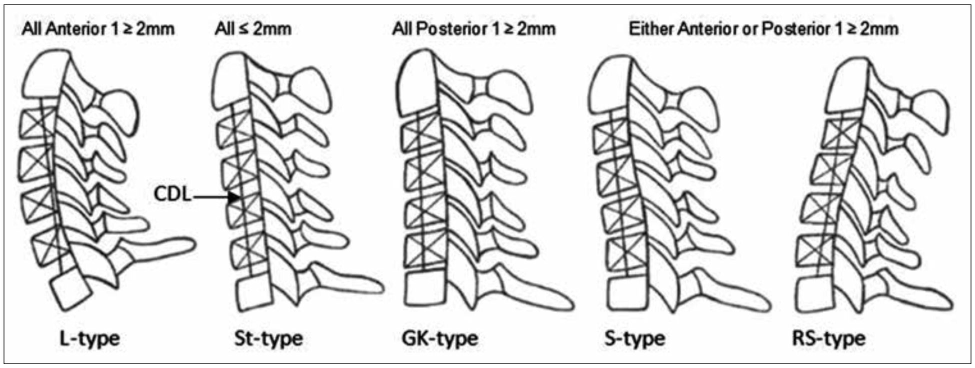

Figure 2: Centroid method subtype classification guidelines

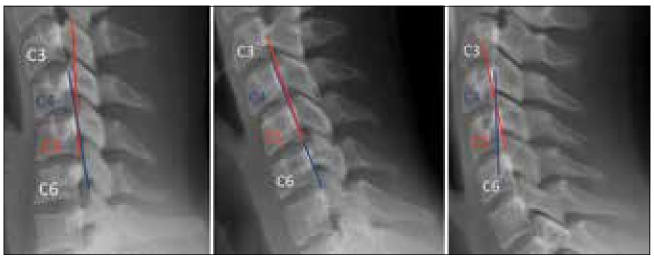

Figure 3: C4/5 relative rotation angle guidelines. Segmental flexion (positive angle) is indicated when the inferior posterior vertebral body line projects posteriorly after intersecting the superior posterior vertebral body line. Segments measuring ≤2° were considered parallel. Segmental extension (negative angle) is indicated when the inferior posterior vertebral body line projects anteriorly after intersecting the superior posterior vertebral body line

RESULTS

Subtype numbers and percentages for each sex and the cohort as a whole are outlined within Table 2. The largest percentage (34.0%) of the cohort was classified in the L-type.

Statistical evaluation of methodological agreement

Methodological consistency occurred on 94 (62.7%) occasions while methods tended not to agree 56 (37.3%) times. When agreement by chance was taken into account only a moderate level of agreement was identified, $\kappa = 0.531$ (53.1%).

The method used to select each participant's subtype is outlined in Table 3. Methodological consistency was greater within the L and GK-type curves. Conversely, in approximately 60% of cases, St, S, and RS-types were selected by a single method alone [Figures 4-6]. In cases where a subtype was classified by only a single method Tables 4 and 5 show how the classification of each subtype differs between the two methods. Figures 4-6 provide specific examples of single method subtype classifications.

DISCUSSION

Cervical spine subtype classification methods must be reliable, interchangeable, and reduce bias.[5,14] Several investigators have performed comparative[5,12,14] and reliability[11] studies on commonly performed cervical angular measures. However, this is the first study, to our knowledge, that has compared and contrasted established cervical subtype classification methods within an asymptomatic population. When comparing cervical subtype classification methods, it was surprising to observe only a moderate level of agreement (53.1%). Our findings indicate that both methods display bias, the Centroid method selects St-types over S and RS-types whereas the modified Takeshima/Herbst method selects S and RS-types over St-types [Tables 4 and 5]. Therefore, depending upon the classification method used to assess a single presentation, different cervical subtypes may be selected. This has implications for clinical decision-making.

The three factors responsible for most of the inconsistencies in subtype classification were, (1) segmental flexion (their number, location, and degree), (2) the large segmental extension angles located at the upper (C2/3) and lower (C6/7) sub-axial spine, and (3) the S and RS-type transitional region (either C3/4, C4/5 or C5/6) between the upper and lower sub-axial cervical curves. In cases where inconsistencies arose, further investigation of the radiographs RRA flexion and extension findings and subtyping guidelines was undertaken. A classification decision was reached when the collective methodological and RRA evidence supporting the selection of one method's subtype could not be refuted by the alternative.

Consistency between classification methods appears to be enhanced when there is a greater number of extended (L-type 90.2%) or flexed (GK-type 85.7%) segments in sequence. Importantly, complete segmental extension is only observed within the L-type classification, a fact that appeared to account for the greater consistency between the two methods when classifying this subtype. Conversely, none of the GK-type classifications displayed complete segmental flexion throughout the entire cervical spine. Our data indicate that the upper (C2/3) and lower (C6/7) segments within the

Table 2: The number of female (*n*=89; 59.3%) and male (*n*=61; 40.7%) participants within each of the subtype classifications

Subtype	Female		Male		Total (%)
	Female cohort (%)	Percentage of total cohort	Male cohort (%)	Percentage of total cohort	
L-type	22 (24.8)	14.7	29 (47.5)	19.3	51 (34.0)
St-type	23 (25.8)	15.3	14 (22.9)	9.3	37 (24.6)
GK-type	26 (29.2)	17.3	2 (3.3)	1.3	28 (18.6)
S-type	9 (10.1)	6.1	4 (6.6)	2.6	13 (8.7)
RS-type	9 (10.1)	6.1	12 (19.7)	8.0	21 (14.1)

Data presented as *n* (% of cohort). GK - Global kyphotic; L - Lordotic; St - Straight; S - Sigmoidal; RS - Reverse sigmoidal

Table 3: Quantification of cervical subtype classifications according to each method

Subtype	Selected by both methods (%)	Selected only by Centroid method	Selected only by modified Takeshima/Herbst method
L-type	46 (90.2)	4	1
St-type	13 (35.1)	24	0
GK-type	24 (85.7)	4	0
S-type	4 (30.8)	0	9
RS-type	7 (33.3)	1	13

GK - Global kyphotic; L - Lordotic; St - Straight; S - Sigmoidal; RS - Reverse sigmoidal

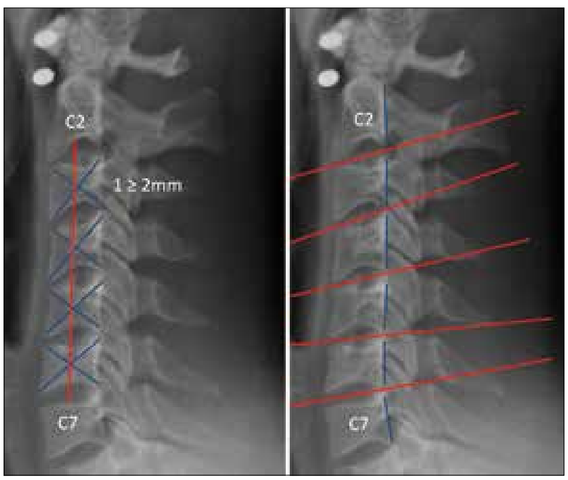

Figure 4: Global kyphotic type selected by the Centroid method and how the modified Takeshima/Herbst method selected and classified the same curvature as a reverse sigmoidal

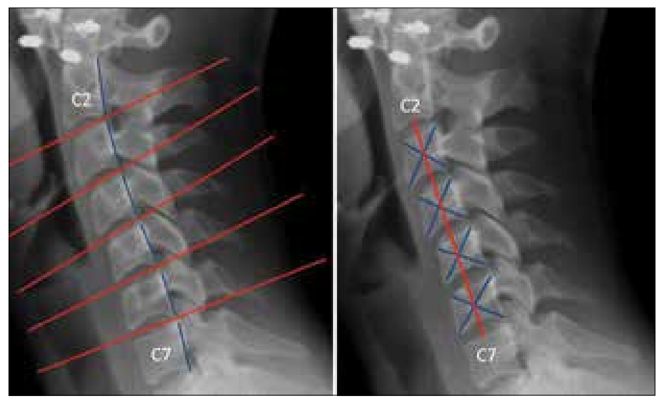

Figure 5: Sigmoidal type selected by the modified Takeshima/Herbst method and how the Centroid method selected and classified the same curvature as a straight

GK-type typically display extension. The combination of extended and flexed cervical segments in a region of the vertebral column that should display predominately extension may contribute to the moderate level of classification inconsistencies observed between the two methods. Specific differences in the classification guidelines for the nonlordotic subtypes resulted in classification inconsistencies in approximately two-thirds of the participants demonstrating St, S, and RS-types.

The Centroid method [Figure 2] uses numerical distances and visual placement of the Centroids to a CDL whereas the modified Takeshima/Herbst method [Figure 1] uses visual recognition of the PVBL's CSh and the posterior convergence or divergence of the IVDLs. PVBM is a highly reliable spinal landmark however, the vertebral endplates exhibit inter-participant angular variability.[11] The Cobb method reliably uses vertebral endplates to assess and regularly report cervical angular measures.[4] Our findings are consistent with those from Ohara *et al.*,[5] who concluded correlations were strong within all angular measures related to the L-type and weaker among the nonlordotic classifications.

The Centroid method's classification guideline for the GK-type allowed the identification of all the Centroids posteriorly to the CDL with one Centroid ≥2 mm from the CDL indicating all GK-type cases. Conversely, the modified Takeshima/Herbst method appeared to be influenced by the segmental extension located at the upper (C2/3) or lower (C6/7) segments. Accordingly, the PVBL and posteriorly converged C2/3 on C3/4 or C5/6 on C6/7 IVDL were identified as either an S or RS-type [Figure 4]. This no doubt contributed to the modified Takeshima/Herbst methods over selecting these two subtypes and under selecting the GK-type. However, in pronounced

Table 4: Subtypes selected by the Centroid method and how the alternative method selected and classified the same curvature

Selected only by the Centroid method	Total	How the modified Takeshima/Herbst method select the same curve				
		L-type	St-type	GK-type	S-type	RS-type
L-type	4				2	2
St-type	24			1	11	12
GK-type	4				1	3
S-type	0					
RS-type	1	1				

GK - Global kyphotic; L - Lordotic; St - Straight; S - Sigmoidal; RS - Reverse sigmoidal

Table 5: Subtypes selected by the modified Takeshima/Herbst method and how the alternative method selected and classified the same curvature

Selected only by the modified Takeshima/Herbst method	Total	How the Centroid method select the same curve				
		L-type	St-type	GK-type	S-type	RS-type
L-type	1		1			
St-type	0					
GK-type	0					
S-type	9	4	4	1		
RS-type	13	4	7	2		

GK - Global kyphotic; L - Lordotic; St - Straight; S - Sigmoidal; RS - Reverse sigmoidal

S or RS-type curves, the consistency between each method increases markedly. The Centroid method has a propensity to over select the number of St-type classifications within shallow S and RS-type curvatures, leading to an under selection within these two classifications [Table 4]. The Centroids within these shallow sigmoidal types fell either anterior or posterior to the CDL but at no location were the Centroids ≥2 mm from the CDL.

While classifying the St-type one problem was that all cases with Centroid locations ≤2 mm from the CDL were selected into this subtype. In contrast, the extremely rigid St-type guidelines for the modified Takeshima/Herbst method allows only a linear PVBL CSh and parallel IVDL to be selected, potentially contributing to a smaller number of this subtype selected by this method [Tables 4 and 5]. Conversely, within shallow curvatures, these small visual discrepancies in the PVBL and the nonparallel IVDL appear to allow over selection of S and RS-type classifications by the modified Takeshima/Herbst method [Table 4]. Anteriorly located Centroids (at least one Centroid ≥2 mm from the CDL) permitted an L-type classification [Figure 2]. However, when inconsistencies arose, the modified Takeshima/Herbst method classified these curves as S or RS-types [Table 4]. In contrast, an opposite scenario was observed when using the modified Takeshima/Herbst method [Table 5] whereby the PVBL CSh and the nonparallel IVDL allowed the selection of S or RS-types rather than the Centroid method's St-type classification [Figures 5 and 6]. Our research highlights that shallow sigmoidal curves with small focal kyphotic regions are difficult to classify consistently with either method.

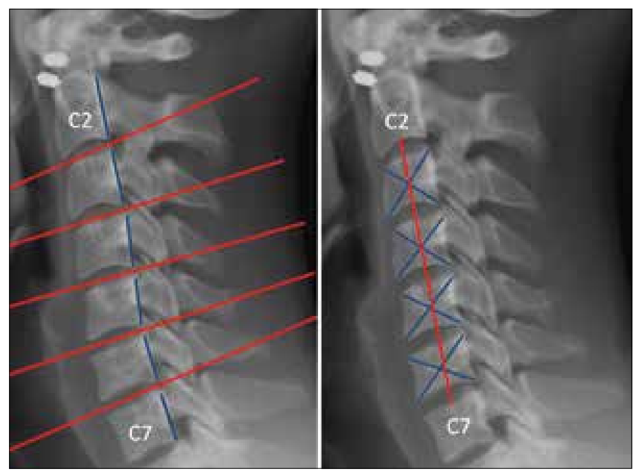

Figure 6: Reverse sigmoidal type selected by the modified Takeshima/Herbst method and how the Centroid method selected and classified the same curvature as a straight

A potential limitation of the current study was that only one researcher was responsible for classifying all subtypes through both methods and the final subtype selection. To mitigate any potential errors, all images were assessed on three occasions to formulate the final selected subtype. This comparative methodological investigation has revealed the likelihood for considerable differences in the classification of certain cervical subtypes depending on which one of the two methods is applied. The Centroid method is well suited to determine L, St, and GK-types, whereas, the modified Takeshima/Herbst method is suited to determine L, GK, S, and RS-types. The Centroid methods use of the Centroid to CDL measurement adds a level of numerical analysis not present within the modified Takeshima/Herbst method, however the visualization of the PVBL and IVDL utilized by the modified Takeshima/Herbst method offers an alternative alignment perspective not offered by the Centroid method.

CONCLUSION

Our research reinforces the need for multimethod contrasting in conjunction with the RRA measure to accurately assess and report non-lordotic subtypes. Clinical decision-making and prognostic determination require establishing precise baseline cervical subtype classifications to permit reliable pre- and post-image contrasting during postintervention appraisal. With an increasing trend toward non-lordotic alignment,[19,20] evidence-based care will encourage the reporting of therapeutic interventions and outcomes with ever increasing alignment accuracy. To increase reliability, validity, and cross correlation of clinical and research findings, our study highlights the need for establishing a standardized multi-method approach to classify sagittal cervical subtypes.

Key points

- Non-lordotic subtypes were demonstrated by 99 out of the 150 (66.0%) participants
- Methodological consistency occurred on 94 (62.7%) occasions while inconsistency was identified 56 (37.3%) times. When agreement by chance was taken into account, only a moderate level of agreement was identified, $\kappa = 0.531$ (53.1%)
- Consistency was higher while classifying the L and GK-types. Conversely, classification of non-lordotic patterns varies depending on the method selected
- The challenges presented to clinicians to correctly classifying cervical sagittal alignment may be reduced when a multi-method approach is undertaken, thus strengthening classification validity
- A classification decision in cases of inconsistency can be reached when methodological and RRA measures are considered together
- Our research provided a detailed descriptive appraisal that could be used to standardize cervical alignment classification for reporting purposes.

Acknowledgment

The authors would like to thank,

- Rebecca Mellifont (PhD) for her assistance with the project.
- Dr. David Shahar, DC for performing radiological services.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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