The Change of Cervical Spine Alignment Along with BMI in Asymptomatic Population: A Preliminary Analysis

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Abstract

Study design:

A cross-sectional study

Objective:

Describe the difference in the cervical sagittal alignment between various BMI people.

Summary of Background Data:

Cervical sagittal imbalance is implicated in the development of various spinal disorders, and obesity was recognized as a global epidemic. But there were few studies focusing on the correlation between cervical sagittal alignment and body mass index (BMI).

Methods:

This study enrolled 140 asymptomatic volunteers from July 2016 to July 2019. Demographic data included gender, age and BMI, and radiographic parameters included chin–brow vertical angle (CBVA), occipital slope (OS), orbital tilt (OrT), orbital index (OI), occiput-C2 lordosis (O-C2), cervical lordosis (CL), C2-C7 sagittal vertical axis (C2-C7SVA), cranial tilting (CrT), cervical tilting (CeT), T1 slope (TS), neck tilt (NT), and thoracic inlet angle (TIA). The data were analyzed by ANOVA statistical analyses.

Results:

In terms of the occipitocervical parameters, we found that there was no significant difference (OS, $P=0.970$; OrT, $P=0.970$; OI, $P=0.798$); In terms of cervical parameters, we found significant correlations between BMI and parameters (C2-C7SVA, $P=0.005$; T2C2-C7, $P=0.030$; CrT, $P=0.050$; CeT, $P=0.013$), which reflected that forward head posture increases as BMI rises; In terms of thoracic parameters, we also found significant correlations between BMI and parameters (NT, $P=0.014$; TIA, $P=0.050$), which reflected that thoracic inlet lifts as BMI rises.

Conclusions:

We found that there are the correlations between cervical sagittal alignment (C2-C7SVA, T2C2-C7, CL, CrT, and CeT) and BMI, and forward head posture increases and thoracic inlet lifts in the obese, which can provide clinical advice and remind surgeons of BMI effect in reconstructive surgery for better prognoses.

Introduction

Disruption of cervical sagittal alignment was implicated in the development of various spinal disorders[1–3]. And severe cervical sagittal imbalance declined the patient's health-related quality of life [4, 5] and even lead to disability through compressing the spinal cord [6, 7]. Therefore, cervical sagittal

imbalance ought to be attached attention, and factors affecting cervical sagittal balance must be defined and identified before the diagnosis and treatment.

Hence, a number of studies have focused on the factors and the morphology of cervical spine [8, 9], and some previous studies[10–12] demonstrated cervical sagittal alignment was related to age and gender in asymptomatic population. Meanwhile, obesity was recognized as a global epidemic. In 2015, 600 million adults and 100 million children were obese in 195 countries[13]. Therefore, obese people, who accounted for a large proportion, cannot be ignored. And our previous studies implied that BMI is relative to cervical sagittal alignment[14]. However, there were few studies focusing on the correlation between cervical sagittal alignment and body mass index (BMI), which is a parameter to define obesity.

Does cervical sagittal alignment changes as BMI rises in asymptomatic population? Are the standard of diagnosis and treatment different in people with various BMI? To answer these questions, we hypothesized there is a relationship between BMI and cervical sagittal parameters. We grouped asymptomatic volunteers according to different BMI to investigate the correlation of cervical spine alignment changes as BMI rises.

Materials And Methods

Asymptomatic Population

The institutional review board of the hospital approved this study, and all volunteers approved this study by written informed consent. To begin with, 160 asymptomatic volunteers were recruited from July 2016 to July 2019. During the study, 3 volunteers were excluded due to the history of bony diseases, spinal diseases or myelopathy, 10 volunteers were excluded due to the history of obvious neck or back pain and 2 volunteers dropped out. In addition, 2 radiographs were excluded due to the loss of corresponding demographic data and 3 radiographs were excluded due to the criteria of radiograph. There were totally 140 plain radiographs to explore the correlation between BMI and cervical sagittal alignment.

As for criteria, the inclusion criteria included Cobb angle less than 10° [15, 16] in the coronal position, a chin–brow vertical angle (CBVA) less than 10° [9, 10, 12] in the sagittal position. The exclusion criteria included the history of bony diseases, spinal diseases, or myelopathy, and the history of neck or back pain. In the study, volunteers stood in an erect comfortable position, with elbows fully flexed and fists resting on clavicles. Because fists-on-clavicles position was deemed as a more functional sagittal profile, yielding less negative shift[8]. Radiographs were stored at the Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University. The equipment and software used in this study included an AGFA computed radiography system (AGFA Gevaert NV, Mortsel, Belgium), a Siemens 500 mA imaging machine (Siemens Corp., Germany), and a picture archiving and communication system.

Radiographic Parameters

Demographic data included gender, age and body mass index (BMI), was recorded. Radiographic parameters were measured by two researchers in a same screen and a third researcher would participate when disagreements occurred between two researchers. Radiographic parameters included chin–brow vertical angle (CBVA), occipital slope (OS), orbital tilt (OrT), orbital index (OI), occiput-C2 lordosis (O-C2), cervical lordosis (CL), C2-C7 sagittal vertical axis (C2-C7SVA), cranial tilting (CrT), cervical tilting (CeT), T1 slope (TS), neck tilt (NT), and thoracic inlet angle (TIA). The definitions of all radiographic parameters were described in Table 1 and Fig. 1.

Table 1
Definition of the radiographic parameters

OS	Angle between a horizontal line and the McRae line
OrT	Angle formed by the plumbline and a line connecting the orbit centre and the centre of McRae's line
OI	Angle formed by a line perpendicular to the McRae's line and a line connecting the orbit centre and the centre of McRae's line
O-C2	Angle between the McRae line and the lower plate of C2
CL	Angle between the lower plate of C2 and the lower plate of C7
C2-C7SVA	The horizontal offset from the posterosuperior corner of C7 to the vertebral body of C2
TZC2-C7	The horizontal offset from the posterosuperior corner of C7 to the posterosuperior corner of C2
CrT	Angle formed by the plumb line and the line connecting the centre of T1 upper end plate with the tip of the dens
CeT	Angle formed by the vertical line of upper end plate and the line connecting the centre of T1 upper end plate with the tip of the dens
TS	Angle between a horizontal line and the superior endplate of T1
NT	Angle formed by the plumb line and a line connecting upper end of the sternum and the center of T1 upper end plate
TIA	Angle formed by a line perpendicular to the superior endplate of T1 and a line connecting the centre of the T1 upper endplate and the upper end of the sternum
OS, Occipital slope; OrT, orbital tilt; OI, orbital index; O-C2, Occiput-C2 lordosis; CL, cervical lordosis; C2-C7SVA, C2-C7 sagittal vertical axis; CrT, cranial tilting; CeT, cervical tilting; TS, T1 slope; NT neck tilt; TIA, thoracic inlet angle; TK, thoracic kyphosis	

Statistical Analysis

All statistical analyses were performed with a SPSS version 19.0 (SPSS Inc, Chicago, IL, USA) and GraphPad Prism software Version 5 (GraphPad Software, Inc, 220 San Diego, CA), and descriptive parameters were in form of mean $\pm$ standard deviation. Correlations between BMI and other parameters

were analyzed by ANOVA statistical analyses. A probability (*P*) value < 0.05 was considered statistically significant.

Results

Demographic data and radiographic data in asymptomatic volunteers

All 140 asymptomatic volunteers were recruited and imaged. From group A to group D, the mean age were 42.3 ± 10.6 , 40.7 ± 13.2 , 41.8 ± 12.5 , and 44.7 ± 10.9 years; the mean CBVA were 1.9 ± 4.7 , 2.4 ± 3.3 , 2.2 ± 4.2 , and $1.4 \pm 2.4^\circ$; the mean MALD were 5.7 ± 2.9 , 5.8 ± 2.2 , 6.0 ± 2.9 , and 5.5 ± 3.1 mm, which reflected that there was no significant difference between groups in this cohort. (Table 2)

Table 2
Demographic data of volunteers in four groups

	Group A: Underweight N = 30	Group B: Normal weight N = 50	Group C: Overweight N = 30	Group D: Obese N = 30
Female	19	25	15	13
Male	11	25	15	17
Age (years)	42.3 ± 10.6	40.7 ± 12.4	41.8 ± 12.5	44.7 ± 10.9
CBVA (°)	1.9 ± 4.7	2.4 ± 3.3	2.2 ± 4.2	1.4 ± 2.4
CBVA, chin–brow vertical angle				

Anova Statistical Analyses Of Radiographic Data

To explore the differences among four groups, we performed ANOVA statistical analyses. In terms of the occipitocervical parameters, we found that there was no significant difference (OS, *P*= 0.970; OrT, *P*= 0.970; OI, *P*= 0.798). (Table 3 & Fig. 2)

Table 3
Average value of all parameters and the difference among four groups by *P* value

	Group A: Underweight N = 30	Group B: Normal weight N = 50	Group C: Overweight N = 30	Group D: Obese N = 30	<i>P</i> value
OS (°)	14.1 ± 5.5	14.7 ± 5.7	14.3 ± 6.2	14.3 ± 5.2	0.970
OrT (°)	64.8 ± 4.6	64.4 ± 5.7	64.5 ± 6.8	64.1 ± 4.8	0.970
OI (°)	78.9 ± 4.5	78.8 ± 4.9	78.1 ± 3.1	78.1 ± 4.1	0.798
O-C2 (°)	19.0 ± 6.9	18.4 ± 7.8	18.2 ± 8.7	18.1 ± 7.5	0.970
CL (°)	10.1 ± 10.3	12.8 ± 6.4	13.3 ± 10.7	15.7 ± 7.5	0.100
C2-C7SVA (mm)	17.4 ± 6.0	17.8 ± 7.2	19.6 ± 8.1	23.2 ± 7.1	0.005*
TZC2-C7 (mm)	13.5 ± 7.1	14.9 ± 8.1	17.3 ± 8.8	19.2 ± 8.4	0.030*
CrT (°)	4.1 ± 4.2	5.0 ± 4.3	6.3 ± 4.4	6.9 ± 4.4	0.050*
CeT (°)	14.0 ± 8.1	11.7 ± 5.9	9.6 ± 5.8	9.2 ± 5.2	0.013*
TS (°)	17.0 ± 5.3	17.3 ± 5.3	17.4 ± 5.6	17.5 ± 5.3	0.986
NT (°)	50.4 ± 6.9	51.1 ± 7.0	54.1 ± 5.1	54.9 ± 6.8	0.014*
TIA (°)	68.5 ± 7.7	68.5 ± 7.3	70.2 ± 7.6	72.8 ± 6.3	0.050*
OS, Occipital slope; OrT, orbital tilt; OI, orbital index; O-C2, Occiput-C2 lordosis; CL, cervical lordosis; C2-C7SVA, C2-C7 sagittal vertical axis; CrT, cranial tilting; CeT, cervical tilting; TS, T1 slope; NT neck tilt; TIA, thoracic inlet angle; * <i>P</i> < 0.05					

In terms of cervical parameters, we found significant correlations between BMI and parameters. From group A to group D, the mean C2-C7SVA were 17.4 ± 6.0, 17.8 ± 7.2, 19.6 ± 8.1, and 23.2 ± 7.1 (*P* = 0.005); the mean TZC2-C7 were 13.5 ± 7.1, 14.9 ± 8.1, 17.3 ± 8.8, and 19.2 ± 8.4 (*P* = 0.030); the mean CrT were 4.1 ± 4.2, 5.0 ± 4.3, 6.3 ± 4.4, and 6.9 ± 4.4, (*P* = 0.050); the mean CeT were 14.0 ± 8.1, 11.7 ± 5.9, 9.6 ± 5.8, and 9.2 ± 5.2, (*P* = 0.013). (Table 3 & Fig. 2)

In terms of thoracic parameters, we also found significant correlations between BMI and parameters. From group A to group D, the mean NT were 50.4 ± 6.9 , 51.1 ± 7.0 , 54.1 ± 5.1 , and 54.9 ± 6.8 ($P = 0.014$); the mean TIA were 68.5 ± 7.7 , 68.5 ± 7.3 , 70.2 ± 7.6 , and 72.8 ± 6.3 ($P = 0.050$). (Table 3 & Fig. 2)

Comparisons Among Four Groups Of All Significantly Different Parameters

After analysis, we derived clear connections between BMI and C2-C7SVA, TZC2-C7, CrT, CeT, CL, NT, TIA, and we performed further analyses among four groups of all significantly different parameters.

Interestingly, compare group B (Normal weight) with group D (Obese), we found that there are significantly different, whereas there was no significant difference between the group B (Normal weight) with group C (Overweight) expect NT, which mean that only significant increase of BMI leads to cervical sagittal imbalance. (Table 4)

Table 4
Average value of all significantly different parameters

Statistic comparison among groups						
	A/B	A/C	A/D	B/C	B/D	C/D
C2-C7SVA (mm)	0.799	0.237	0.001*	0.305	0.002*	0.072
TZC2-C7 (mm)	0.436	0.071	0.006*	0.218	0.026*	0.396
CrT (°)	0.364	0.052	0.015*	0.198	0.062*	0.599
CeT (°)	0.147	0.019	0.008*	0.125	0.059*	0.780
NT (°)	0.665	0.022*	0.014*	0.045*	0.020*	0.608
TIA (°)	0.988	0.393	0.021*	0.324	0.009*	0.155
C2-C7SVA, C2-C7 sagittal vertical axis; CrT, cranial tilting; CeT, cervical tilting; NT neck tilt; TIA, thoracic inlet angle; $P < 0.05$						
and comparisons among four groups by P value						

In addition, there was no significant difference between the group B (Normal weight) with group A (Underweight), which mean the cervical sagittal alignment of underweight people is normal; even though we also found there are significantly different compare group A (Underweight) with group D (Obese), whose difference may come from the difference between group B and group D, not from group A and group B. (Table 4)

Discussion

Cervical sagittal imbalance is implicated in the development of various spinal disorders[1, 2] and associated with patient's health-related quality of life [4, 5]. However, there were few studies focusing on the correlation between BMI and cervical sagittal alignment. After analysis, we derived clear connections between BMI and C2-C7SVA, T2C2-C7, CrT, CeT, CL, NT, TIA (Fig. 2), which indicated that surgeons should take BMI into consideration in reconstructive surgery of cervical sagittal alignment.

Forward Head Posture Increases As Bmi Rises

Several studies[1, 9, 11, 17] testified that C2-C7SVA is a crucial parameter in cervical sagittal balance, which was related to clinical symptoms. In study, C2-C7SVA were positive correlated with BMI, which reflected forward head posture increases as BMI rises. In line with our result, Oe et al[9] implied the correlation between C2-C7SVA and BMI in the result of his study. T2C2-C7 is a good addition for C2-C7SVA[18], and we also found T2C2-C7 increases as BMI rises.

CrT is an angle formed by the plumb line and the line connecting the center of T1 upper end plate with the tip of the dens, which is contacted to the flexion state of the cervical spine[19]. In study, we found CrT increases as BMI rises, which also reflected the status of forward head posture. Similar to CeT, CeT is also a common parameter to reflect cervical sagittal alignment, and CeT decreases as BMI rises[11, 19].

Combining C2-C7SVA, T2C2-C7, CrT, and CeT, we assessed forward head posture increases as BMI rises. This phenomenon may be caused by two reasons. On the one hand, we guessed that the pathological fat infiltration in paraspinal muscle lead to forward head posture. Accumulating evidences demonstrated that BMI was positive associated with fatty infiltration of paraspinal muscle[20–22], and previous studies showed that pathological muscle influences the cervical sagittal alignment[23] and quality of life[24]. On the other hand, the anterior shift of the center of gravity may be an explanation of the compensatory increasement of forward head posture. Accumulating evidences reported that obese individuals have significantly greater trunk mass and BMI is positively correlated with increased abdominal fatness[25, 26]. And increased abdominal fatness leads to anterior shift of the center of gravity. Previous articles showed that the anterior shift of the center of gravity is compensated with the posterior tilt in the pelvis and the thoracic region[27, 28], which explains the anterior tilt in cervical region.

In line with our observed phenomenon, Brink et al.[29] pointed out that overweight or obese students have more neck flexion than thinner students, when working on desktop computers in their school computer classroom. And the clinical studies certified that obese negatively effect on postural stability, not only in one leg standing but also moving from sit to stand[30, 31]; Excessive forward head posture and increased abdominal fatness were regarded as the potential factor of postural instability[32, 33].

Thoracic Inlet Lifts As Bmi Rises

As the important element of cervicothoracic junction, thoracic inlet is a circle, made up by T1 vertebral body, first ribs and the upper part of sternum. As previous studies[34–36] described, parameters of thoracic inlet, such as TIA and NT, were significant correlative with cervical sagittal balance.

TIA is formed by a line perpendicular to the superior endplate of T1 and a line connecting the center of the T1 upper end plate and the upper end of the sternum. Different from TS, there is no significant change of TIA in different positions[37, 38], which is an advantage to guide surgery when patients lay, not stand, on the operating table. And TIA was found to markedly increase with age by previous studies[11, 12, 39], which was consistent with our result. As for BMI, we found there was a correlation between BMI and TIA. Like TIA, NT is also positively related to BMI, which reflect the phenomenon thoracic inlet lifts as BMI rises, and Oe et al.[9] study also implied that NT was correlative with BMI in the result.

Combining the tender of TIA and NT, we assessed thoracic inlet lifts as BMI rises and the change came from sternum, not T1 vertebral body. We guessed that a rising position of manubrium related to the level of T1 leads to a larger TIA and NT. Shi et al. and Kent et al. certified that as BMI rises, the ribs became more perpendicular to the spine and rib cage depth increased, which lead to a rising position of manubrium related to the level of T1[40, 41].

Combining our results with those of previous studies, we assessed that forward head posture increases and thoracic inlet lifts, as BMI rises, in asymptomatic population (Fig. 3). corresponding to our result, Fabris et al[25] showed that postural changes in morbidly obese patients, and Koller et al[42] showed that the risk for revision of adult scoliosis surgery was increased, as BMI rises. Of course, the role of BMI cannot be further exaggerated. Because we found that only significant increase of BMI, such as obese, leads to cervical sagittal imbalance, and the cervical sagittal alignment of underweight people is normal.

This is the first preliminary analysis of the change of cervical spine alignment along with BMI in asymptomatic population. In clinic, we advise obese patients with neck pain to lose weight to maintain cervical sagittal balance and reduce neck pressure. In surgery, surgeons can properly evaluate cervical alignment of obese patients with cervical disorders, and map out more precise cervical realignment parameters in obese patient with cervical deformity in infusion operation.

This study has several limitations in fact. First, the number of volunteers can be more to support our conclusions and a larger scale study is our next proposal. Second, our volunteers are all Asians, for which a multi-ethnic study is need in our future. Third, besides fists-on-clavicles position, lying position and sitting position are the next aim.

Conclusion

There are the correlations between cervical sagittal alignment (C2-C7SVA, TZC2-C7, CL, CrT, and CeT) and BMI, and forward head posture increases and thoracic inlet lifts in the obese, which provide clinical advice and remind surgeons of the primary influencers of reconstructive surgery for better prognoses.

Abbreviations

BMI: body mass index; CBVA: chin–brow vertical angle; OS: occipital slope; OrT: orbital tilt; Ol: orbital index; O-C2: occiput-C2 lordosis; CL: cervical lordosis; C2-C7SVA: C2-C7 sagittal vertical axis; CrT: cranial tilting; CeT: cervical tilting; TS: T1 slope; NT: neck tilt; TIA: thoracic inlet angle.

Declarations

Acknowledgements

Not applicable.

Authors' contributions

(I) Conception and design: Xiangyang Wang, Ai-Min Wu, and Xiaolei Zhang; (II) Administrative support: Zhenxuan Shao; (III) Provision of study materials or patients: Gaole Dai, Ben Wang; (IV) Collection and assembly of data: Qingqian Zhao, Jiajie Lu; (V) Data analysis and interpretation: Zhenxuan Shao, Rui Wen; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors

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Availability of data and materials

The datasets used and or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All patients signed the informed consent form, and the use of the specimens was approved by the Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University Ethics Committee.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

References

1. Iyer S, Nemani VM, Nguyen J, Elysee J, Burapachaisri A, Ames CP, Kim HJ. Impact of Cervical Sagittal Alignment Parameters on Neck Disability. *Spine (Phila Pa 1976)*. 2016;41:371–7.
2. Zhang JT, Li JQ, Niu RJ, Liu Z, Tong T, Shen Y. Predictors of cervical lordosis loss after laminoplasty in patients with cervical spondylotic myelopathy. *Eur Spine J*. 2017;26:1205–10.
3. Blizzard SR, Krishnamoorthy B, Shinseki M, Betsch M, Yoo J. The magnitude of angular and translational displacement of dens fractures is dependent on the sagittal alignment of the cervical spine rather than the force of injury. *Spine J*. 2017;17:1859–65.
4. Protopsaltis TS, Scheer JK, Terran JS, Smith JS, Hamilton DK, Kim HJ, Mundis GM Jr, Hart RA, McCarthy IM, Klineberg E, Lafage V, Bess S, Schwab F, Shaffrey CI, Ames CP. How the neck affects the back: changes in regional cervical sagittal alignment correlate to HRQOL improvement in adult thoracolumbar deformity patients at 2-year follow-up. *J Neurosurg Spine*. 2015;23:153–8.
5. Youn MS, Shin JK, Goh TS, Kang SS, Jeon WK, Lee JS. Relationship between cervical sagittal alignment and health-related quality of life in adolescent idiopathic scoliosis. *Eur Spine J*. 2016;25:3114–9.
6. Belanger TA, Milam RA, Roh JS, Bohlman HH. Cervicothoracic extension osteotomy for chin-on-chest deformity in ankylosing spondylitis. *J Bone Joint Surg Am*. 2005;87:1732–8.
7. Etame AB, Wang AC, Than KD, La Marca F, Park P. Outcomes after surgery for cervical spine deformity: review of the literature. *Neurosurg Focus*. 2010;28:E14.
8. Yukawa Y, Kato F, Suda K, Yamagata M, Ueta T. Age-related changes in osseous anatomy, alignment, and range of motion of the cervical spine. Part I: Radiographic data from over 1,200 asymptomatic subjects. *Eur Spine J*. 2012;21:1492–8.
9. Oe S, Togawa D, Nakai K, Yamada T, Arima H, Banno T, Yasuda T, Kobayasi S, Yamato Y, Hasegawa T, Yoshida G, Matsuyama Y. The Influence of Age and Sex on Cervical Spinal Alignment Among Volunteers Aged Over 50. *Spine (Phila Pa 1976)*. 2015;40:1487–94.
10. Moon Soo P, Seong-Hwan M, Hwan-Mo L, Seok Woo K, Tae-Hwan K, Seung Yeop L, Riew KD. The effect of age on cervical sagittal alignment: normative data on 100 asymptomatic subjects. *Spine (Phila Pa 1976)*. 2013;38:458–63.
11. Chen Y, Luo J, Pan Z, Yu L, Pang L, Zhong J, Li Z, Han Z, Cao K. The change of cervical spine alignment along with aging in asymptomatic population: a preliminary analysis. *Eur Spine J*. 2017;26:2363–71.
12. Iyer S, Lenke LG, Nemani VM, Fu M, Shifflett GD, Albert TJ, Sides BA, Metz LN, Cunningham ME, Kim HJ. Variations in Occipitocervical and Cervicothoracic Alignment Parameters Based on Age: A Prospective Study of Asymptomatic Volunteers Using Full-Body Radiographs. *Spine (Phila Pa 1976)*. 2016;41:1837–44.
13. Ashkan A, Mohammad HF, Marissa BR, Patrick S, Kara E, Alex L, Laurie M, Ali HM, Maziar M-L, Mohsen N, Joseph SS, Theo V, Kalkidan HA, Cristiana A, Muktar BA, Ziyad A-A, Ala'a A, Rajaa A-R, Azmeraw TA, Alemayehu A, Adeladza KA, Erfan A, Stephen MA, Ranjit MA, Johan Ä, Hamid A, Amitava B, Aleksandra B, Estifanos B, Derrick AB, Addisu SB, Sibhatu B, Stan B, Espen B, Dube JB,

- Ismael C-N, Juan JC, Pedro C, Kelly C, Liliana GC, Leslie C, Solomon AD, Lalit D, Rakhi D, Samath DD, Bruce BD, Babak E, Alireza E, Valery LF, João CF, Thomas F, Tsegaye TG, Audra G, Philimon NG, Atsushi G, Tesfa DH, Kokeb TH, Nima H-N, Simon IH, Masako H, Farhad I, Ritul K, Amir K, Srinivasa VK, Andre PK, Chandrasekharan NK, Yousef SK, Young-Ho K, Jagdish K, Daniel K, Yun JK, Yohannes K, Soewarta K, Tiffany K, Barthelemy Kuate D, Kumar GA, Heidi JL, Mall L, Xiaofeng L, Stephen SL, Patrick L, Alan DL, Rafael L, Azeem M, Reza M, Deborah CM, Mohsen M, Colm M, Stephen TM, Desalegn TM, George AM, Gert BMM, Haftay BM, Erkin MM, Ulrich OM, Jean JN, Carla MO, Felix AO, Mayowa OO, George CP, Farshad P, Mostafa Q, Anwar R, Rajesh KR, Chhabi LR, Nikolas R, Saeid S, Joshua AS, Juan RS, Itamar SS, Benn S, Monika S, Josef S, Aletta ES, Maria IS, Sadaf GS, Moretza S, Sara S, Min-Jeong S, Rahman S, Ivy S, Hirbo SR, Diego ASS, Jonathan IS, Jasvinder AS, Saverio S, Soumya S, Rafael T-S, Fentaw T, Bemnet AT, Balewgizie ST, Abdullah ST, Thakur JS, Marcello T, Roman T-M, Stefanos T, Kingsley NU, Olalekan AU, Masoud V, Tommi V, Vasiliy VV, Stein EV, Elisabete W, Andrea W, Joshua W, Ronny W, Yuichiro Y, Naohiro Y, Gerald Y, Zoubida Z. *N Engl J Med*. 2017;377:13–27. Zerihun MZ, Ben Z and Christopher JLM. Health Effects of Overweight and Obesity in 195 Countries over 25 Years.
14. Shao ZX, Yan YZ, Pan XX, Chen SQ, Fang X, Chen XB, Wu AM, Wang XY. Factors Associated with Cervical Spine Alignment in an Asymptomatic Population: A Preliminary Analysis. *World Neurosurg*. 2019;122:e48–58.
 15. Steven DG, Sigurd B, Keith B, William H, John RD. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine (Phila Pa 1976)*. 2005;30:682–8.
 16. Suk KS, Kim KT, Lee SH, Kim JM. Significance of chin-brow vertical angle in correction of kyphotic deformity of ankylosing spondylitis patients. *Spine (Phila Pa 1976)*. 2003;28:2001–5.
 17. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, Lafage V, Shaffrey CI, Schwab F, Ames CP. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. *Neurosurgery*. 2015;76(Suppl 1):14–21. discussion S21.
 18. Harrison DE, Harrison DD, Cailliet R, Troyanovich SJ, Janik TJ, Holland B. Cobb method or Harrison posterior tangent method: which to choose for lateral cervical radiographic analysis. *Spine (Phila Pa 1976)*. 2000;25:2072–8.
 19. Le Huec JC, Demezon H, Aunoble S. Sagittal parameters of global cervical balance using EOS imaging: normative values from a prospective cohort of asymptomatic volunteers. *Eur Spine J*. 2015;24:63–71.
 20. Fortin M, Videman T, Gibbons LE, Battié MC. Paraspinal muscle morphology and composition: a 15-yr longitudinal magnetic resonance imaging study. *Med Sci Sports Exerc*. 2014;46:893–901.
 21. Sebro R, O'Brien L, Torriani M, Bredella MA. Assessment of trunk muscle density using CT and its association with degenerative disc and facet joint disease of the lumbar spine. *Skeletal Radiol*. 2016;45:1221–6.
 22. Crawford RJ, Volken T, Ni Mhuiris Á, Bow CC, Elliott JM, Hoggarth MA, Samartzis D. Geography of Lumbar Paravertebral Muscle Fatty Infiltration: The Influence of Demographics, Low Back Pain, and

- Disability. *Spine (Phila Pa 1976)*. 2019;44:1294–302.
23. Saeed K, Olivia AK, Dale S, Robert MH, Leonard IV, Alexander JG, Avinash GP. Cervical Spine Muscle-Tendon Unit Length Differences Between Neutral and Forward Head Postures: Biomechanical Study Using Human Cadaveric Specimens. *Phys Ther*. 2017;97:756–66.
 24. Imagama S, Matsuyama Y, Hasegawa Y, Sakai Y, Ito Z, Ishiguro N, Hamajima N. Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. *Eur Spine J*. 2011;20:954–61.
 25. Fabris de Souza SA, Faintuch J, Valezi AC, Sant'Anna AF, Gama-Rodrigues JJ, de. Batista Fonseca IC and de Melo RD. Postural changes in morbidly obese patients. *Obes Surg* 2005; 15: 1013–1016.
 26. Rodacki AL, Fowler NE, Provensi CL, Rodacki Cde L, Dezan VH. Body mass as a factor in stature change. *Clin Biomech (Bristol Avon)*. 2005;20:799–805.
 27. Beckers L, Bekaert J. The role of lordosis. *Acta Orthop Belg*. 1991;57(Suppl 1):198–202.
 28. Barrey C, Jund J, Nosedà O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. *Eur Spine J*. 2007;16:1459–67.
 29. Brink Y, Louw Q, Grimmer K, Jordaan E. The spinal posture of computing adolescents in a real-life setting. *BMC Musculoskelet Disord*. 2014;15:212.
 30. King AC, Challis JH, Bartok C, Costigan FA, Newell KM. Obesity, mechanical and strength relationships to postural control in adolescence. *Gait Posture*. 2012;35:261–5.
 31. McGraw B, McClenaghan BA, Williams HG, Dickerson J, Ward DS. Gait and postural stability in obese and nonobese prepubertal boys. *Arch Phys Med Rehabil*. 2000;81:484–9.
 32. Hue O, Simoneau M, Marcotte J, Berrigan F, Doré J, Marceau P, Marceau S, Tremblay A and Teasdale N. Body weight is a strong predictor of postural stability. *Gait Posture*. 2007;26:32–8.
 33. Sung Min S. Influence of Obesity on Postural Stability in Young Adults. *Osong Public Health Res Perspect*. 2016;7:378–81.
 34. Sang-Hun L, Ki-Tack K, Eun-Min S, Kyung-Soo S, Yoon-Ho K, Eun-Seok S. The influence of thoracic inlet alignment on the craniocervical sagittal balance in asymptomatic adults. *J Spinal Disord Tech*. 2012;25:41–7.
 35. Weng C, Wang J, Tuchman A, Wang J, Fu C, Hsieh PC, Buser Z, Wang JC. Influence of T1 Slope on the Cervical Sagittal Balance in Degenerative Cervical Spine: An Analysis Using Kinematic MRI. *Spine (Phila Pa 1976)*. 2016;41:185–90.
 36. Wang ZL, Xiao JL, Mou JH, Qin TZ, Liu P. Analysis of Cervical Sagittal Balance Parameters in MRIs of Patients with Disc-Degenerative Disease. *Med Sci Monit*. 2015;21:3083–8.
 37. Xing R, Zhou G, Chen Q, Liang Y, Dong J. MRI to measure cervical sagittal parameters: a comparison with plain radiographs. *Arch Orthop Trauma Surg*. 2017;137:451–5.
 38. Jun HS, Jang IB, Song JH, Kim TH, Park MS, Kim SW, Oh JK. Is It Possible to Evaluate the Parameters of Cervical Sagittal Alignment on Cervical CT scan? *Spine (Phila Pa 1976)* 2014.

39. Yokoyama K, Kawanishi M, Yamada M, Tanaka H, Ito Y, Kawabata S, Kuroiwa T. Age-related variations in global spinal alignment and sagittal balance in asymptomatic Japanese adults. *Neurol Res.* 2017;39:414–8.
40. Kent R, Lee SH, Darvish K, Wang S, Poster CS, Lange AW, Brede C, Lange D, Matsuoka F. Structural and material changes in the aging thorax and their role in crash protection for older occupants. *Stapp Car Crash J.* 2005;49:231–49.
41. Shi X, Cao L, Reed MP, Rupp JD, Hoff CN, Hu J. A statistical human rib cage geometry model accounting for variations by age, sex, stature and body mass index. *J Biomech.* 2014;47:2277–85.
42. Koller H, Pfanz C, Meier O, Hitzl W, Mayer M, Bullmann V, Schulte TL. Factors influencing radiographic and clinical outcomes in adult scoliosis surgery: a study of 448 European patients. *Eur Spine J.* 2016;25:532–48.

Figures

Figure 1

The definitions of all radiographic parameters. OS, Occipital slope; OrT, orbital tilt; OI, orbital index; O-C2, Occiput-C2 lordosis; CL, cervical lordosis; C2-C7SVA, C2-C7 sagittal vertical axis; CrT, cranial tilting; CeT, cervical tilting; TS, T1 slope; NT neck tilt; TIA, thoracic inlet angle; * $P < 0.05$

Figure 2

The line charts of cervical sagittal parameters. There are significantly different compare group B (Normal weight) with group D (Obese), whereas there was no significant difference between the group B (Normal weight) with group C (Overweight) expect NT; and there was no significant difference between the group B (Normal weight) with group A (Underweight).

Figure 3

Forward head posture increases, and thoracic inlet lifts as BMI rises. The change of C2-C7 sagittal vertical axis (C2C7SVA), T2C2C7, cranial tilting (CrT), and cervical tilting (CeT), which reflect the phenomenon forward head posture increases; the increase of thoracic inlet angle (TIA) and neck tilt (NT), which reflect the phenomenon thoracic inlet lifts as BMI rises.