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Reference intervals of C2-C7 lateral spinous process deviation in Chinese adults

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Background: *Lateral spinous process deviation (LSPD) is a commonly used morphological parameter in the anatomical study of the cervical spinous process. However, quantitative studies on this issue are still lacking. In this study we aimed to establish reference intervals of C2-C7 LSPD in the adult Chinese population and provide decision-making information for clinical practitioners.*

Materials and methods: *This was a retrospective study of 92 adult patients who received neck computed tomography scans, including 42 females and 50 males meeting the inclusion criteria. Three-dimensional reconstruction and anatomical measurements were performed using Mimics Research 19.0 and 3-Matic Research 11.0.*

Results: *The inter-observer reliability of LSPD measurement in this study was excellent (intraclass correlation coefficient value > 0.93). Only 2 cases of LSPD angles of 90 degrees were found, which means most cervical spinous process exist deviation. The reference interval for the C2-C7 LSPD angle was (85.11, 94.75) degrees. The C2 LSPD showed the different directions to C5 and C7 ($p < 0.05$). In the C4 vertebrae, the male tends to have greater LSPD angles than the female ($T = -2.013$, $p = 0.047$). In the C2 vertebrae, there was a statistically significant but weak correlation between age and LSPD angles ($r = 0.24$, $p = 0.029$). There was no statistically significant effect of sex or age on other levels of cervical vertebrae.*

Conclusions: *Cervical spinous process deviation of less than 5 degrees on either side is a common morphological manifestation in Chinese adults. Thus, LSPD may not be an indicator for clinical care. Moreover, the vertebrae may have opposite directions of LSPD in the upper levels (C2-C4) and lower levels (C5-C7).* (Folia Morphol 2023; 82, 4: 892–897)

Key words: morphology, cervical vertebra, lateral spinous process deviation, computerized tomography, retrospective analysis

INTRODUCTION

Neck pain is one of the most common musculoskeletal complaints, with an annual prevalence of more than 30% [2]. Spinal manipulation was proved an effective therapy for neck pain compared to no treatment or sham treatment [2, 3, 7]. Identifying bony landmarks by palpation is a prerequisite procedure for many kinds of manual therapy [12, 15]. One

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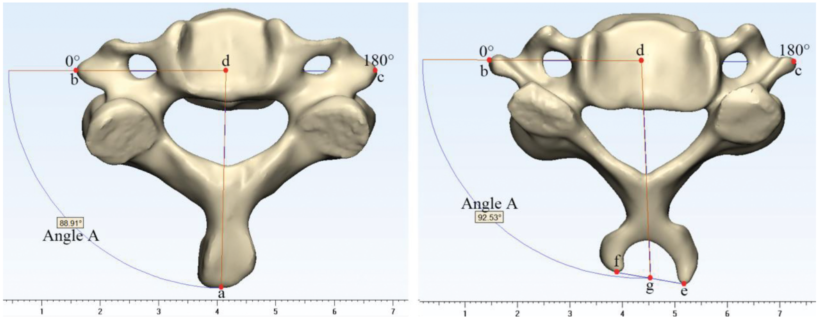

Figure 1. Measurement of lateral spinous process deviation (LSPD) in non-bifid spinous processes (SP) (left) and bifid SP (right). Anatomical landmarks: *a* — the most posterior tip of SP; *b* and *c* — the tip of the posterior tubercles of the transverse processes; *d* — the midpoint of line *bc*; *e and f* — the posterior tip of bifid SP branches; *g* — the midpoint of line *ef*. Angle *A* is the angle of LSPD.

of the most important bony landmarks in the cervical vertebra is the spinous processes (SPs) [12]. According to Mulligan's techniques, which was commonly used in musculoskeletal physical therapy, SPs are thrust points in many spinal manipulations [9, 12]. Likewise, before spinal manipulation, Maitland emphasized using the tip of the thumb to palpate the SPs for the assessment of bony outlines [14]. Theoretically, SPs of a spine should align in the posterior midline of the neck region [11, 15]. To date, the definition of the midline alignment of SPs still lacks quantitative study. According to previous research, lateral spinous process deviation (LSPD) angle is a commonly used morphological parameter in the anatomical study of the cervical spinous process, but its correlation with clinical symptoms remains doubtful [1, 4, 5]. In addition, it is still controversial regarding the static imaging measures of LSPD as indicators for clinical treatment [4, 13]. To fully understand the definition of the midline alignment of SPs, the cut-off values of LSPD in normal populations need to be determined. Also, previous studies of cervical spinous processes failed to acquire data of multiple segments of the same individuals. Therefore, in this research we aim to determine the reference intervals of C2-C7 LSPD in an adult Chinese population and provide decision-making information for clinicians and therapists.

MATERIALS AND METHODS

We collected 92 cases of patients who underwent cervical computed tomography (CT) scanning between January 2018 to December 2019 from Nanfang Hospital of Southern Medical University. The inclusion criteria were age 18 to 60 asymptomatic subjects. The exclusion criteria included vertebral malrotation, cervical deformity, chronic neck pain, tumours, infections, trauma, and any other pathological neck condition. This study had approval from the institutional review board and the requirement for informed patient consent was waived. This study also complies with current regulations in our country. Ethical approval for this study was obtained from the Chinese Ethics Committee of Registering Clinical Trials (Reference number: ChiECRCT20210191).

A US GE 16-slice spiral CT was used to perform CT scans. Mimics Research 19.0 was used for the reconstruction of all C2-C7 cervical vertebra. The 3-Matic Research 11.0 was used for anatomical measurement, performed by two independent observers. According to standard anthropometric measurements, measurements were taken using bony landmarks for reproducibility, as shown in Figure 1. The angle of LSPD was defined as the angle between line *bc* and line *ad* (angle *A*). Both examiners were blinded to the radiological data and patient data. The SP was defined as left deviation (LSPD $<$ 90 degrees), right deviation (LSPD $>$ 90 degrees), or no deviation (LSPD = 90 degrees).

Statistical analysis

The SPSS statistical software package 20.0 (IBM, New York) was used for statistical analysis. Data were expressed as mean ± standard deviation (SD), using the mean value from the two examiners. The inter-and intra-observer reliability for LSPD measurement was evaluated using intraclass correlation coefficient (ICC) and reliability was classified as inferior (0–0.39), moderate (0.4–0.74), or excellent (0.75–1) according to ICC value. The reference intervals were established using the mean ± 2×SD. A single sample t-test was used to test whether LSPD differed from 90 degrees. The chi-square test was used to analyse the differenc-

Table 1. Inter- and intra-observer reliability for spinal process deviation angles (ICCs [95% confidence interval])

Levels	Inter-observer	P	Intra-observer	P
C2	0.934 (0.868–0.963)	< 0.01	0.983 (0.966–0.991)	< 0.01
C3	0.953 (0.929–0.969)	< 0.01	0.988 (0.982–0.992)	< 0.01
C4	0.960 (0.939–0.974)	< 0.01	0.990 (0.984–0.993)	< 0.01
C5	0.957 (0.935–0.972)	< 0.01	0.989 (0.984–0.993)	< 0.01
C6	0.969 (0.953–0.979)	< 0.01	0.992 (0.988–0.995)	< 0.01
C7	0.966 (0.948–0.977)	< 0.01	0.991 (0.987–0.994)	< 0.01

Inter- and intra-observer reliability in all cervical levels were excellent (intraclass correlation coefficient [ICC] > 0.93, p < 0.01)

es in deviating directions among C2-C7 levels. One--way repeated measure analysis of variance (ANOVA) was used to compare LSPD in different cervical levels (C2-C7), and post hoc used the Bonferroni test. The sex difference was analysed using independent-sample t-tests. The correlation of LSPD angles with age was analysed using the Pearson correlation coefficient. $P < 0.05$ was considered statistically significant.

RESULTS

The study subjects consisted of 92 CT scans of Chinese adults, including 42 (45.65%) women and 50 (54.35%) men, with a mean age of 40.99 ± 9.49 (range 19–59) years old. ICCs were used to evaluate the intra- and inter-observer reliability of LSPD angles. The results of ICCs were expressed as 95% confidence intervals (CI) in Table 1. The intra- and inter-observer ICCs were excellent in LSPD angles at each cervical level (ICC > 0.93, $p < 0.01$).

The frequencies of different ranges of LSPD at all cervical levels are presented in Table 2. In this study, only 2 cases showed precisely 90 degrees in the LSPD angle measured by 1 investigator, while the majority deviated to a different extent. All experimental results in this study are expressed as mean values of 2 independent investigators. According to our results, the range of LSPD angle in C2-C7 was approximately 85 to 95 degrees, and 95% CI was (89.74, 90.13) degrees. Thus, we evaluated the frequency of various ranges of LSPD angles from a larger range (85~95 degrees) to a smaller range (89~91 degrees). As shown in Table 2, 93.12% of vertebrae presented LSPD of (85~95) degrees, while 32.97% presented LSPD of (89~91) degrees. This indicated that most SPs showed a deviation of more than one degree. But, a single sample t-test showed no significant difference between the mean LSPD and 90 degrees ($t = 0.249$, $p = 0.804$), indicating that all SPs did not deviate significantly in statistics.

Table 2. The frequency of various lateral spinous process deviation (LSPD) ranges

The range of LSPD (degrees)	Frequency (%)
89~91	182 (32.97%)
88~92	361 (65.40%)
87~93	424 (76.81%)
86~94	483 (87.5%)
85~95	514 (93.12%)

Table 3. Statistics of lateral spinous process deviation angles in C2-C7

Levels	Mean ± SD	Lower, upper limits	95% CI
C2	89.02 ± 1.97	85.16, 92.88	88.63–89.41
C3	89.75 ± 2.47	84.91, 94.59	89.25–90.24
C4	89.54 ± 2.43	84.78, 94.30	89.03–89.97
C5	90.51 ± 2.10	86.39, 94.63	90.09–90.93
C6	90.19 ± 2.49	85.31, 95.07	89.70–90.69
C7	90.56 ± 2.86	84.95, 96.17	89.97–91.12
Total	89.93 ± 2.46	85.11, 94.75	89.74–90.13

CI — confidence interval; SD — standard deviation

According to Table 3, the upper levels (C2-C4) displayed a mean LSPD angle of fewer than 90 degrees, whereas the lower levels (C5-C7) showed greater than 90 degrees. This result indicated that the LSPD presumably changed from left deviation to right deviation from C2 to C7 levels. In addition, the chi--square test showed that the LSPD direction among C2-C7 levels were different. As shown in Table 4, the pairwise comparison showed statistically significant differences in LSPD between C2 and C5, C2 and C7 ($p < 0.05$), while no statistical difference was found between other levels (Fig. 2). One-way repeated measures ANOVA showed significant differences between C2 and C5 ($p < 0.001$), C2 and C7 ($p < 0.001$), C4 and C5 ($p < 0.05$), and C4 and C7 ($p < 0.05$). No statistical differences were detected among other levels in post

Table 4. The frequency of lateral spinous process deviation directions among C2-C7 levels

Cervical levels C2-C7	Direction of spinous process deviation		Total
	Right	Left	
C2	28	64	92
C3	44	48	92
C4	44	48	92
C5	54	38	92
C6	47	45	92
C7	61	31	92
Total	278	274	552

A chi-square test ($\chi^2 = 26.487$, $p = 0.000$) indicated that the deviations of spinous processes (SPs) were different among C2-C7 levels. Pairwise comparison was statistically significant ($p < 0.05$) between the deviations of C2 SP and C5 SP, C2 SP and C7 SP.

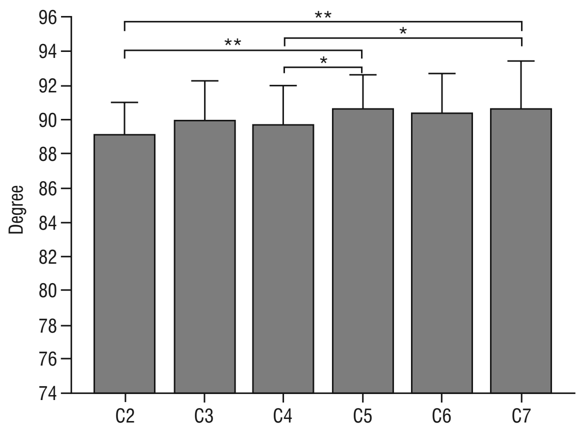

Figure 2. Statistical differences of C2-C7 lateral spinous process deviation angle; **$p < 0.001$, *$p < 0.05$.

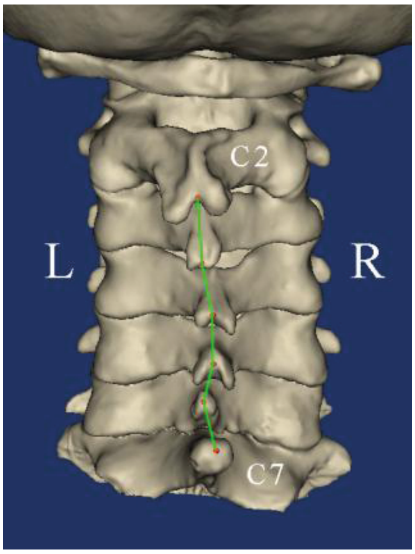

Figure 3. The posterior view of cervical vertebrae with spinal process deviation (SPD). The green line connects the tip of spinous processes, the SPD transformed from right deviation to left deviation in C7 to C2.

hoc tests. Therefore, the above results indicated that the C2 and C5, C2 and C7 have the opposite direction of LSPD (Fig. 3). Due to the opposite direction of LSPD, the overall deviation between C2 and C7 SP could be up to 1.54 degrees. Regarding sex difference, men tend to have greater LSPD angle than women at the C4 level in this study ($T = -2.013$, $p = 0.047$), while no statistically significant difference was found in other levels (Table 5). Additionally, a statistically weak correlation was found ($r = 0.24$, $p = 0.029$) between age and LSPD angles at the C2 level. When correlated with the other levels, age exhibited small correlations with LSPD ($p > 0.05$).

DISCUSSION

In this study, we introduced a method of LSPD quantification and analysed the C2-C7 LSPD in the Chinese adult population. In previous studies, there were different methods for LSPD measurements. Gradl et al. [5] defined LSPD as SPs that are not aligned with the midline of cervical anterior-posterior radiographs. Macpherson et al. [13] suggested that the LSPD is relative to the axis of the vertebral body and posterior arch. Tang et al. [16] defined the LSPD as the angle between the midsagittal line of the vertebral body and the longitudinal line of SP, using landmarks such as the centre of the vertebral body, the centre of spinolaminar junction, and the SP. Ji-Hong et al. [10] described LSPD as the midsagittal line through SP that was not coinciding with the bisector of the vertebral foramen in the horizontal plane. Liao et al. [12] performed an LSPD measurement using the angle between the line connecting two transverse processes tips and the midsagittal line through SP [12]. Zhang et al. [18] measured the LSPD with the angle between the long axis of SP and the median line of the vertebra in the superior aspect. The 6 methods mentioned above were common existing methods of LSPD measurement. We believe that quantification methods of LSPD should ensure the reliability and repeatability of measurement. Therefore, we chose the tips of transverse processes and spinous processes as reference landmarks for easy identification. In addition, previous methods often failed to address the issue of LSPD measurement in bifid SPs. We defined the midpoint of two tips of bifid branches as the end of the SP axis (*g* point), and the LSPD angle was defined as the angle between line *bc* and line *dg*. Repeated measurements with this method showed excellent reliability for two observers with ICCs. We hope this

Table 5. C2-C7 lateral spinous process deviation angles (degrees) of sex groups

Groups	C2	C3	C4	C5	C6	C7
Females	88.77 ± 2.01	90.07 ± 2.39	88.90 ± 2.42*	90.27 ± 2.33	90.26 ± 2.30	90.78 ± 2.52
Males	89.23 ± 1.94	89.48 ± 2.52	90.09 ± 2.32*	90.71 ± 1.88	90.13 ± 2.66	90.36 ± 3.14

*P < 0.05 for independent sample t-tests comparisons between the male and the female in the C4 level.

method may provide a reference for diagnosis and research in the future.

Spinous processes are often described in many works as aligned on the posterior midline but lack quantification of the midline alignment [14, 15]. Since LSPD is a common variation, the reference interval should be determined to realise the range of normal SP alignment. Although only 2 cases were found to be exact 90 degrees in the LSPD angle, our results showed no statistically significant difference between the overall LSPD angle and 90 degrees, indicating that all subjects in this study were considered to have SPs aligned in the posterior midline. Our results showed that the overall reference interval of LSPD was approximately within ± 5 degrees, which is 85~95 degrees. This reference interval covers 93.12% of our samples, approximately 95% of the subjects. This observation may support the hypothesis that 85~95 degrees were the appropriate reference interval of LSPD angle as normal variation in the asymptomatic population.

As we all know, there has been literature arguing about the reliability of LSPD measurement in static imaging as an indicator of vertebral rotation [4, 13]. According to Gradl et al. [5], in a radiograph, the SP tip deviates 1 mm from the posterior midline indicating a vertebral rotation of 1.62 degrees. However, according to our results, the reference intervals of LSPD have a difference of 5 degrees on each side, which is about 3 mm deviation on the radiograph. Thus, we recommend that researchers take into account the reference intervals of LSPD when studying the vertebral rotation in the static radiograph. The LSPD may also had an influence on the reliability of static palpation of SP in vertebral alignment assessment. Nevertheless, some researchers have already doubted the reliability of static palpation in manual therapy [8, 17]. As a matter of fact, a small deviation of SP was commonly seen in asymptomatic subjects. To study the relationship between pathological SP deviation and clinical symptoms, researchers should exclude subjects within the reference interval of 85–95 degrees LSPD to truly analyse the connection between SP deviation and clinical symptoms. We also noticed that our results of LSPD angle were slightly different from other studies, possibly due to the differences between measuring methods [5, 10, 12, 18]. Nevertheless, our results are consistent with the conclusion of other studies that LSPD is common in the asymptomatic population [10, 12, 14, 15].

Another important finding of normal cervical spinal alignment often neglected by researchers is the different directions of LSPD between the upper and lower cervical vertebra. The C2 and C7 SPs are two prominent bony landmarks in the cervical vertebra that are palpable through the surface [14, 15]. In our study, we found that C2 LSPD usually deviated in the opposite direction of C7 LSPD in a small magnitude. Based on this finding, the maximum angle between the deviation of C2 and C7 SPs could be up to 1.54 degrees. Nevertheless, such a small range of differences may not be identified through palpation, as muscles and soft tissues cover SP in the posterior neck region. Previous studies have already noted that the upper and lower cervical SPs commonly have an opposite direction of deviation [6]. Our findings echoed Greiner's research [6], that the SPs tend to deviate to the left in the C2-C4 cervical levels, whereas tend to deviate to the right side in the C5-C7 levels. Unfortunately, Greiner [6] only investigated the SPs of C3-C7. One possible explanation for such findings is that at some point in early age, muscle contractions may have had an influence on the development of SP. Most studied subjects were right-handed, resulting in the special directions of LPSD in the upper and lower cervical levels [6]. In addition, we found that age and sex have little impact on LSPD. The male consistently had greater LSPD angles in the C4 levels when compared to the female. There was a statistically weak correlation ($r = 0.24$, $p = 0.029$) between age and LSPD angles at the C2 level. No statistical difference in sex and age was found at other levels.

Limitations of the study

There are some limitations that need to be acknowledged. The study population is not strictly a normal population. The reasons for ordering the CT scans might have some unknown effects on the alignment of cervical vertebrae. Most importantly, there is no known relationship between small LSPD and current or future clinical conditions of the cervical spine that may warrant treatment for small LSPD. No palpation of the cervical spine was conducted, so the relationship between CT findings and palpation findings is unknown. It is not known to what extent a clinician can feel such small deviations of the SP.

CONCLUSIONS

Clinical practitioners should be aware of normal reference intervals for LSPD. LSPD have a weak association with age and small gender differences in the cervical spine. LSPD of small magnitude may be a normal variant without clinical implications. Further work is required to determine if LSPD has concurrent or predictive validity for identifying the need and site of spinal manipulation.

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Conflict of interest: None declared

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