Int J Clin Exp Med 2015;8(1):1129-1136
www.ijcem.com /ISSN:1940-5901/IJCEM0003912

Original Article

Morphometry of lumbar spinous process via three dimensional CT reconstruction in a Chinese population

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Received November 17, 2014; Accepted January 9, 2015; Epub January 15, 2015; Published January 30, 2015

Abstract: To investigate the morphometric data of the lumbar spinous process dimensions in Chinese population. Forty-six adult subjects (22 males, 24 females, age range 26-45 years) were studied using the method of the three dimensional CT reconstruction in our hospital. The following parameters were measured: the distance between two adjacent spinous processes (DB), distance across the two adjacent spinous processes (DA), thickness of central of spinous processes (TC), thickness of the superior margin of spinous processes (TS), thickness of the inferior margin of spinous processes (TI), and height of spinous processes (H). Variance and correlation analysis were conducted for these data. Data met with normal distribution and homogeneity of variance. Similar variation trend of the parameters of lumbar spinous process for male and female was found. DB became shorter gradually from L_{1-2} to L_{4-5}, and increased at the L_5-S_1. DA became larger from T_{12}-L_1 to L_{1-2} for male and L_{2-3} for female, and then became shorter from L_{1-2} for male and L_{2-3} for female, respectively. The largest H of male and female were both noted at L_3. TS of the adjacent spinous processes were lower than that of TI for male and female. Statistical significance between male and female were found in H, TC, TS, TI (L_1, L_3 and L_4), and DA (except for L_{4-5}). Compared to male, the spinous processes of female were shorter, thinner and lower. These data may be useful for clinical application and the design of interspinous implant in Chinese population.

Keywords: Spinous process, lumbar spine, morphometry, computed tomography reconstruction

Introduction

Lumbar degenerative disc disease (LDDD) is an age-related disease associated with deteriorated discs of lumbar spine, which is one of the causes of low back pain [1]. The symptomatic LDDD can cause magnificent disability and depression to patients, which greatly affect the living quality of them [2]. It is commonly acknowledged that surgical treatment should be considered for late phase of LDDD, or when the traditional conservative treatment has no obvious effect for LDDD. At present, there are many different kinds of surgical procedures for LDDD, and the number is increasing [3, 4]. Among the diverse surgical methods performed for LDDD, the fusion surgery has been identified as the "gold standard" for the LDDD surgical treatment, which is the performance of jointing two bones [4]. However, various studies have shown that fusion surgery could promote the presentation of adjacent segment degeneration after surgery because of more motion of the above or below fusion vertebrae and more pressure on the adjacent discs from the fusion site [5, 6]. The secondary adjacent segment degeneration may cause pain and disability again, increasing the need for second surgery [7].

Interspinous process implant is a novel surgical procedure known to be minimally invasive due to the simple operating protocol and shortened operating time [8]. Several biomechanical studies have shown that interspinous stabilizing implant could offer non-rigid fixation without affecting adjacent segments significantly and decrease the pressures of anulus and central nucleus [9-11]. Although this surgery procedure presented with many advantages, complications may still occur after surgery, such as implant device migration and spinous fracture [12, 13]. Too small size device may lead to the dislocation of implant, while too large size device may result

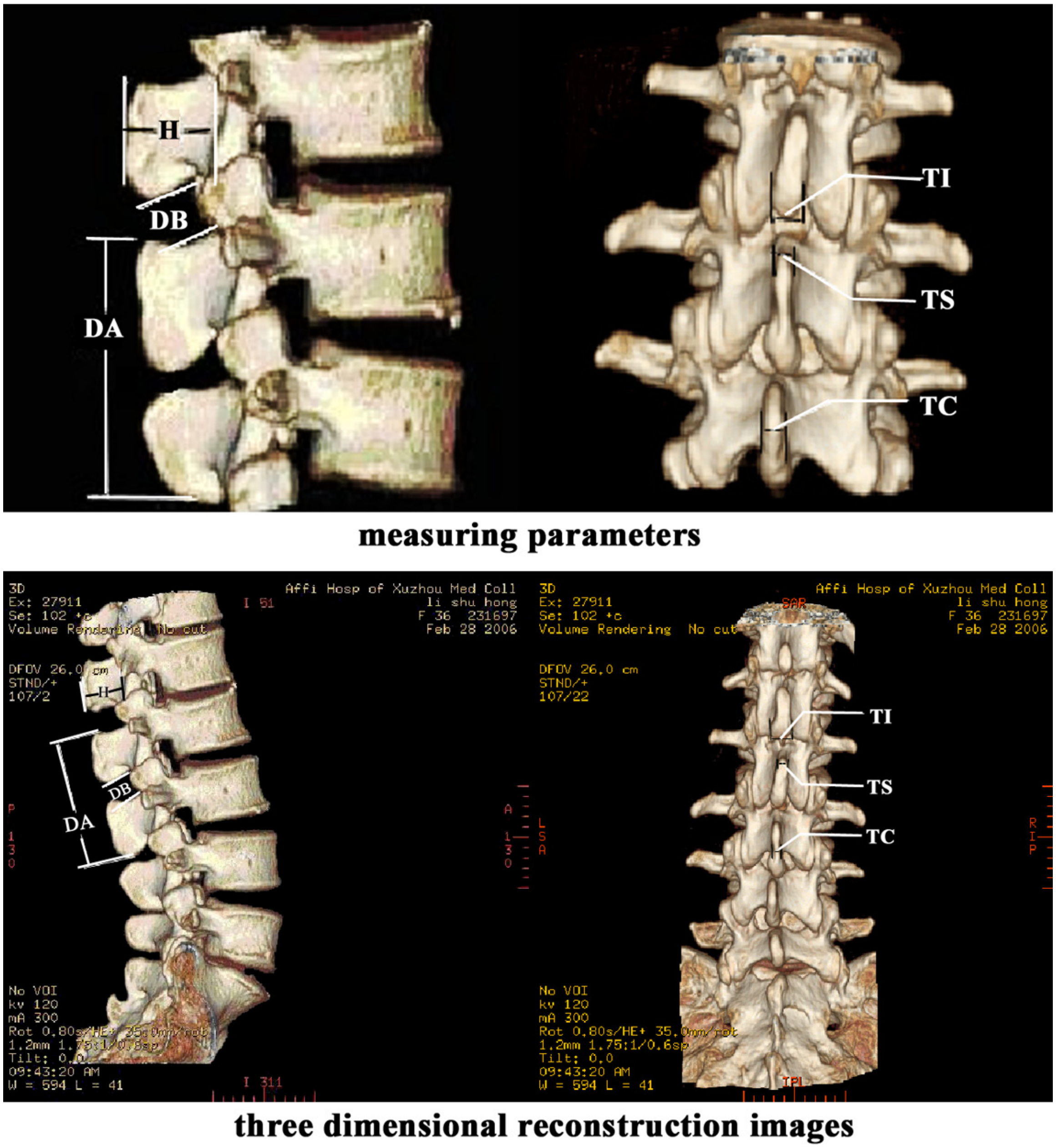

Figure 1. Illustration of measuring parameters. The upper picture: schematic diagram of DA, DB, TS, TI, TC and H. The lower picture: three dimensional reconstruction images of DA, DB, TS, TI, TC and H. DB, distance between the two adjacent spinous processes); DA, distance across the two adjacent spinous processes; TC, thickness of central of spinous processes; TS, thickness of the superior margin of spinous processes; TI, thickness of the inferior margin of spinous processes; H, height of spinous processes.

in the breakage of implant. Thus, detailed information of lumbar spinous process morphometry is critically important for the appropriate interspinous process implantation to prevent the post-operative complications [13, 14].

Emerging evidence has indicated that the morphometric dimension of spine is diverse in different populations, suggesting racial differences [15-18]. Our previous study has reported the anatomical measurement data of lumbar spinous process on cadavers in Chinese population [19] (in press). In order to confirm our previous data obtained from the cadavers, the present study defined the morphometric dimension of lumbar spinous process in Chin-

Table 1. CT scanning measurement data of lumbar spinous process in males and females

Items	Male (n = 24)	Female (n = 22)	F value	*P* value
DB				
L_{1-2}	8.26 ± 2.48 (3.60-13.80)	7.22 ± 2.04 (3.80-10.70)	1.28	0.26
L_{2-3}	7.99 ± 2.86 (2.90-13.80)	7.08 ± 2.19 (2.00-11.20)	1.46	0.23
L_{3-4}	7.33 ± 2.51 (2.10-12.30)	6.96 ± 2.32 (2.70-11.60)	0.28	0.60
L_{4-5}	5.66 ± 2.08 (1.00-9.80)	5.34 ± 1.95 (1.20-8.90)	0.29	0.59
L_5-S_1	5.68 ± 2.22 (1.20-10.30)	6.52 ± 2.10 (2.40-10.60)	1.75	0.19
DA				
T_{12}-L_1	54.91 ± 7.49 (37.60-68.40)	48.73 ± 6.47 (35.40-62.50)	8.94	< 0.01
L_{1-2}	60.00 ± 7.80 (43.20-75.40)	52.10 ± 5.80 (40.20-63.40)	12.59	< 0.01
L_{2-3}	59.35 ± 6.46 (46.50-72.30)	52.24 ± 5.41 (40.10-62.80)	16.37	< 0.01
L_{3-4}	52.22 ± 6.13 (39.60-64.60)	48.64 ± 5.74 (36.50-61.20)	4.18	< 0.05
L_{4-5}	47.13 ± 6.16 (36.40-63.20)	47.10 ± 6.12 (35.20-58.50)	0.20	0.65
H				
L_1	20.53 ± 4.03 (13.60-28.90)	17.49 ± 2.78 (12.30-23.60)	8.87	< 0.01
L_2	21.37 ± 3.66 (14.10-28.50)	17.44 ± 2.81 (12.70-23.60)	16.71	< 0.01
L_3	21.56 ± 5.38 (8.90-31.40)	17.67 ± 5.39 (7.60-28.40)	6.88	0.01
L_4	21.40 ± 6.116 (9.20-33.50)	17.24 ± 4.98 (8.50-27.60)	8.72	< 0.01
L_5	19.53 ± 4.71 (10.10-31.50)	15.07 ± 3.95 (7.80-25.60)	12.51	< 0.01
TS				
L_2	5.40 ± 2.22 (1.90-11.60)	4.00 ± 0.97 (1.80-6.00)	7.71	< 0.01
L_3	5.73 ± 2.23 (2.30-11.90)	4.33 ± 1.11 (1.80-6.70)	7.22	0.01
L_4	6.55 ± 2.19 (2.90-12.60)	4.56 ± 1.12 (2.00-6.90)	15.01	< 0.01
L_5	7.03 ± 2.13 (3.10-12.40)	5.12 ± 1.31 (2.60-7.90)	13.45	< 0.01
S_1	6.81 ± 2.15 (2.90-11.80)	5.00 ± 1.33 (2.60-7.80)	11.86	< 0.01
TI				
L_1	8.27 ± 2.60 (3.20-13.40)	6.73 ± 2.05 (3.40-11.20)	4.95	0.03
L_2	9.24 ± 2.23 (4.90-13.50)	8.43 ± 2.08 (4.20-12.80)	0.07	0.79
L_3	9.67 ± 2.37 (5.00-14.90)	7.40 ± 1.09 (4.20-11.50)	12.30	< 0.01
L_4	9.11 ± 2.35 (4.70-13.50)	7.13 ± 1.83 (4.00-10.80)	10.21	< 0.01
L_5	8.78 ± 2.81 (3.70-14.10)	7.95 ± 1.69 (4.80-11.50)	1.42	0.24
TC	7.75 ± 2.43 (1.80-12.51)	6.35 ± 2.47 (1.70-11.30)	3.75	< 0.05

The data were represented as, $\overline{X}$ ± SD, and the measurement unit was mm. DB, distance between the two adjacent spinous processes); DA, distance across the two adjacent spinous processes; TC, thickness of central of spinous processes; TS, thickness of the superior margin of spinous processes; TI, thickness of the inferior margin of spinous processes; H, height of spinous processes.

ese population by the radiographic measurement on the living subjects. We compared the radiographic data with our previous data from the cadavers. Besides, the gender difference with the data was also analyzed.

Materials and methods

Forty-six patients (24 males and 22 females; average age, 32 ± 3.7 years) with no abnormalities, injures or degeneration in the lumbar spine were enrolled in this study. All human studies were approved by the Hospital Ethics Committee and performed in accordance with the ethical standards. After the informed consent was obtained from all patients, all patients underwent the CT scanner using the 16-slice spiral CT machine (Light Speed, GE Medical System, Waukesha WI, USA). The scanning parameters were tube voltage 80 KV, tube current 50 mA, slice thickness 1.25 mm, slice interval 1.25 mm and beam pitch 1.375:1. Images are reconstructed with slice thickness of 0.625 mm and slice interval of 0.3 mm. The reconstructed CT images were transferred to a remote GE Advantage Workstation, equipped with commercial navigator software (ADW 4.4 version, GE) capable of performing volume rendering (VR) and multiple planar reformatting (MPR) [20]. The following parameters were obtained on the CT radiographs: 1) DB (distance between the two adjacent spinous processes): L_{1-2}, L_{2-3}, L_{3-4}, L_{4-5} and L_5-S_1; 2) DA (distance across the two adjacent spinous processes): T_{12}-L_1, L_{1-2}, L_{2-3}, L_{3-4} and L_{4-5}; 3) TC (thickness of central spinous processes); 4) TS and TI (thickness of the superior and the inferior margin of spinous processes); 5) H (the height of spinous processes). The measuring methods are illustrated in **Figure 1**. Three times were measured for each distance with a single investigator.

All data were expressed as mean ± standard deviation and analyzed by SPSS 8.0 software (SPSS Inc, Chicago, Illinois, USA). One-sample Kolmogorov-Smirnov test and one-way ANOVA analysis of variance were used to evaluate the normal distribution and the homogeneity of variance among data in each group. $P < 0.05$ was considered statistically significant.

Results

CT scanning measurement

One-sample Kolmogorov-Smirnov test confirmed the approximately normal distribution among data in each group, and one-way ANOVA analysis of variance indicated the homogeneity of variance among data in each group. There were no statistical significance among TC and TI of male and TC, TI and H of female by variance analysis, respectively (**Table 1**).

The data of DB became shorter gradually from L_{1-2} (male: 8.26 ± 2.48 mm; female: 7.22 ± 2.04 mm) to L_{4-5} (male: 5.66 ± 2.08 mm; female: 5.34 ± 2.95 mm) and then increased slightly from L_{4-5} to L_5S_1 (male: 5.68 ± 2.22 mm; female: 4.03 ± 2.57 mm). For males, DA increased from $T_{12}L_1$ (54.91 ± 7.49 mm) to L_{1-2} (60.00 ± 7.80 mm) and then followed by decrease from L_{1-2} to L_{4-5} (47.13 ± 6.16 mm). For females, the data of DA increased from $T_{12}L_1$ (48.73 ± 6.47 mm) to L_{2-3} (52.24 ± 5.41 mm) and then followed by decrease from L_{2-3} to L_{4-5} (47.10 ± 6.12 mm). The largest H was noted at L_3 (male: 21.56 ± 2.38 mm; female: 17.67 ± 5.39 mm). TS of the adjacent spinous process were lower than that of TI at all levels (**Table 1**). The parameters of lumbar spinous process of male and female indicated approximately similar variation trend.

Comparison of the lumbar spinous process size between males and females

The comparison of each parameter between male and female are shown in **Figure 2**. The DB values of females were shorter than that in males except at L_5S_1 but there was no significant difference ($P > 0.05$). The values of males in the terms of DA were larger than that in females at all levels, and the significance difference was seen ($P < 0.05$) except at level of L_{4-5} ($P > 0.05$). Analyzing H data, the values in males were significantly higher than that in females at all levels ($P < 0.05$). In addition, TS in males were significantly thicker than that in females at all levels (P < 0.05). The similar phenomenon was also found in TI, but there was significant difference only at L_1 L_3 L_4 ($P < 0.05$). For TC, the value of males were larger compared with that in females with significant difference ($P < 0.05$). The above results suggested that the spinous processes of female were shorter, thinner and lower than that of male.

Comparison of the radiographic data and the direct measurement data from our previous study

The CT scanning measurement values and our previous direct measurement values were comparatively similar and the absolute majority of the comparisons showed no significant difference with a few exceptions. For DB, the direct measurement value were significantly less than CT value in males ($P = 0.0175$), while the same phenomenon was found at L_{3-4} in female ($P = 0.0068$). The data of H using the direct method were larger than that using the CT scanning measurement method in males at levels of L_3 and L_4 ($P < 0.05$) (**Table 2**).

Discussion

Different kinds of interspinous implant devices have been applied in the treatment of various lumbar spine diseases favorably, such as lumbar neurogenic intermittent claudication, lumbar spinal stenosis and degenerative lumbar spinal diseases [21-24]. At present, it is acknowledged that the instability of the lumbar spine, disappearance of the intervertebral space and the decrease in the area of the spinal canal will occur after traditional laminectomy [25]. And it has been reported that the interspinous implant presents with the increase of the spinal canal area to avoid the secondary symptom of compressing the nerves [21]. The evaluation of the morphometric data of the interspinous process is of great importance to the preoperative preparation of interspinous implantation. The results of our present study showed the special characteristics of the lumbar spinous process dimensions in the subset of Chinese population using radiographic methods. Furthermore, we also found the

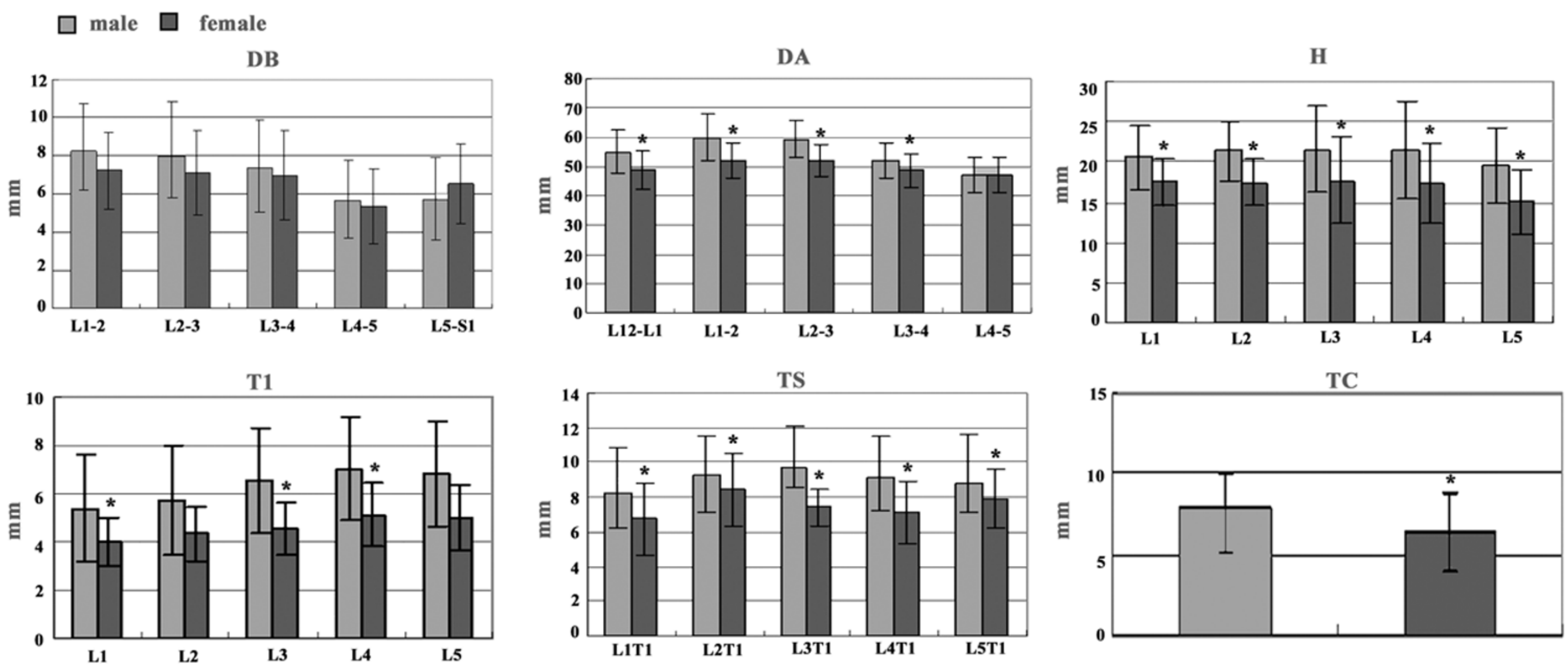

Figure 2. Comparison of each parameter of DA, DB, TS, TI, TC and H between male and female. *$P < 0.05$ female *vs.* male DB, distance between the two adjacent spinous processes); DA, distance across the two adjacent spinous processes; TC, thickness of central of spinous processes; TS, thickness of the superior margin of spinous processes; TI, thickness of the inferior margin of spinous processes; H, height of spinous processes.

Table 2. Comparison of the radiographic data and our previous direct measurement data

	Direct measurement		3D-CTR measurement		t		P	
	M	F	M	F	M	F	M	F
DB								
L_{1-2}	7.61 ± 2.44	7.75 ± 1.65	8.26 ± 2.48	7.22 ± 2.04	-0.95	0.96	0.35	0.35
L_{2-3}	6.80 ± 2.57	7.58 ± 1.94	7.99 ± 2.86	7.08 ± 2.19	-0.96	0.81	0.12	0.42
L_{3-4}	6.00 ± 2.27	5.17 ± 1.87	7.33 ± 2.51	6.96 ± 2.32	-2.02	-2.84	0.05	0.01
L_{4-5}	4.90 ± 2.17	5.68 ± 2.62	5.66 ± 2.08	5.34 ± 1.95	-1.29	0.50	0.20	0.62
L_5-S_1	4.03 ± 2.57	6.49 ± 2.78	5.68 ± 2.22	6.52 ± 2.10	-2.56	-0.04	0.02	0.97
DA								
T_{12}-L_1	54.63 ± 6.50	49.88 ± 7.33	54.91 ± 7.49	48.73 ± 6.47	-0.15	0.56	0.89	0.58
L_{1-2}	60.13 ± 6.56	52.83 ± 3.90	60.00 ± 7.80	52.10 ± 5.80	0.07	0.49	0.95	0.62
L_{2-3}	60.18 ± 6.11	53.64 ± 4.38	59.35 ± 6.46	52.24 ± 5.41	0.48	0.95	0.64	0.35
L_{3-4}	53.76 ± 6.37	45.68 ± 5.31	52.22 ± 6.13	48.64 ± 5.74	0.89	-1.80	0.38	0.08
L_{4-5}	45.07 ± 5.89	49.40 ± 7.05	47.13 ± 6.16	47.10 ± 6.12	-1.24	1.17	0.22	0.25
H								
L_1	21.63 ± 3.28	17.08 ± 2.83	20.53 ± 4.03	17.49 ± 2.78	1.10	-1.03	0.28	0.31
L_2	24.09 ± 3.95	17.59 ± 3.01	21.37 ± 3.66	17.44 ± 2.81	2.00	0.17	0.05	0.86
L_3	25.45 ± 5.96	18.42 ± 4.98	21.56 ± 5.38	17.67 ± 5.39	2.46	0.48	0.02	0.63
L_4	25.00 ± 5.03	18.71 ± 4.50	21.40 ± 6.12	17.24 ± 4.98	3.35	1.04	0.02	0.31
L_5	21.41 ± 4.41	17.44 ± 3.75	19.53 ± 4.71	15.07 ± 3.95	1.49	2.00	0.14	0.05
TS								
L_2	5.97 ± 2.11	4.39 ± 0.94	5.40 ± 2.22	4.00 ± 0.97	0.95	1.37	0.35	0.18
L_3	6.12 ± 1.89	4.48 ± 1.92	5.73 ± 2.23	4.33 ± 1.11	0.69	0.32	0.50	0.75
L_4	7.83 ± 2.39	6.76 ± 1.64	6.55 ± 2.19	4.56 ± 1.12	2.00	5.28	0.06	< 0.01
L_5	6.97 ± 2.25	6.03 ± 1.24	7.03 ± 2.13	5.12 ± 1.31	-0.11	2.39	0.92	0.02
S_1	7.93 ± 2.86	6.82 ± 0.96	6.81 ± 2.15	5.00 ± 1.33	1.57	5.24	0.12	< 0.01
TI								
L_1	8.42 ± 1.52	6.27 ± 2.01	8.27 ± 2.60	6.73 ± 2.05	0.26	-0.76	0.79	0.45
L_2	9.57 ± 2.63	8.26 ± 2.06	9.24 ± 2.23	8.43 ± 2.08	1.48	-0.28	0.63	0.78
L_3	9.64 ± 2.56	7.72 ± 1.87	9.67 ± 2.37	7.40 ± 1.09	-0.04	0.71	0.97	0.49
L_4	8.72 ± 2.17	7.25 ± 2.40	9.11 ± 2.35	7.13 ± 1.83	-0.63	0.19	0.53	0.85
L_5	8.61 ± 3.11	7.40 ± 1.04	8.78 ± 2.81	7.95 ± 1.69	-0.21	-1.31	0.84	0.20
TC	7.94 ± 1.90	6.18 ± 1.16	7.75 ± 2.43	6.35 ± 2.47	0.38	-0.29	0.75	0.77

The data were represented as $\overline{X}$ ± SD, and the measurement unit was mm. 3D-CTR, three dimensional CT reconstruction; DB, distance between the two adjacent spinous processes); DA, distance across the two adjacent spinous processes; TC, thickness of central of spinous processes; TS, thickness of the superior margin of spinous processes; TI, thickness of the inferior margin of spinous processes; H, height of spinous processes.

gender difference in the dimensions of lumbar-spinous process region.

In our opinions, there are variations between the data from the cadavers and the real normal data due to the long immersion in the fixed liquid of the specimen, which may affect the physiological state of the bone tissues. Compared with the direct measurement method on cadavers, the three dimensional CT reconstruction method can be more easy to obtain the data close to the physiological state and large quantities of in vitro studies [26, 27]. Thus, our present study measured the data of lumbar spinous process on the living subjects using the three dimensional CT reconstruction method (**Figure 1**). Compared with our previous data on cadavers [19], it was found that the CT scanning measurement values and our previous direct measurement values were comparatively similar and the absolute majority of the comparisons between parameters at different levels showed no significant difference with a few exceptions (**Table 2**). To our limited knowledge, one potential explanation for this may be due to the difference of subjects and the position during examination. Another reason may be the different methods of measurement. The reconstruction of CT images may be affected by many factors, such as the degree of the removed soft tissues. To sum up, our radiographic data could confirm our previous direct measurement data and provide the more accurate anatomy basis for the clinical application of inspinous implantation.

Ihm *et al.* has reported the spinous process morphometry in Korean patients using lateral radiographic images [16]. The changing trend of interspinous distance from our data was comparatively similar compared with the Korean data by Ihm and his coworkers. Another report also showed the similar trend [28]. In contrast, Ihm *et al.* showed that the largest height was at L_2, while our data indicated at L_3 (**Table 1**). This phenomenon may suggest racial difference of the lumbar spinous process. In addition, we found the gender difference with the spinous process size: the spinous processes of female were shorter, thinner and lower than that of male (**Figure 2**). Our finding suggested that the gender difference should be considered in the design of the inspinous implant device.

We would like to discuss some limitations in this study that we are aware of. The number of the subjects was small. The relationship of age with the lumbar spinous process was not considered in this study, because many studies has demonstrated that the size of lumbar spinous process changes with age [16, 28]. Therefore, a large quantity of Chinese population should be studied in the future to provide the more accurate measurement data of lumbar spious process. Meanwhile, the factor of age should be taken into consideration in the future study.

In conclusion, our results defined the dimensions of lumbar spinous process in the subset of Chinese population using the three dimensional CT reconstruction method on the living subjects. These data may be useful to design the interspinous implant devices fit for the characteristics of the Chinese population and provide the theoretical anatomy basis for the clinical application of this surgical procedure in a Chinese population. Meanwhile, gender difference should be considered in the design of the inspinous implant device.

Disclosure of conflict of interest

None.

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