Relationship between body weight and spinopelvic alignment in Chinese adult people: A preliminary study

Qing Xi Zhang
Peking University People's Hospital
Fu Qiang Gao
China-Japan Friendship Hospital
Yun Ting Wang
China-Japan Friendship Hospital
Zi Rong Li
China-Japan Friendship Hospital
Ozaki Koji
China-Japan Friendship Hospital
Wei Sun (sun887@163.com)
China-Japan Friendship Hospital

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Abstract

Background: The purpose of this study is to evaluate the correlation between spinopelvicalignment and the body weight parameters in healthy Chinese adult volunteers. That has not been systematically studied yet. Methods: 100 Chinese healthy adult volunteers (36 males and 64 females) were included in this study, which grouped according to the gender. The obesity parameters, body mass index (BMI), waist circumference (WC), sagittal abdominal diameter (SAD), transverse abdominal diameter (TAD) and RR (the ratio of SAD to TAD) were measured. The sagittal spinopelvic parameters include pelvic incidence (PI), pelvic tilt (PT), pelvic angulation (PA), sacral slope (SS), sacral inclination (SI), lumbar lordosis (LL) and the disc angle of L5/S1. The coronal spinopelvic parameters include the Cobb angle of the major curve of the spine, lumbar scoliosis (LS) and pelvic obliquity (PO). Pearson's correlation analysis was used to determine correlations between obesity index and spinopelvic alignment parameters. Results: The mean BMI and WC of the males and females was 28.7 ± 3.7 kg/m2 vs 26.8 ± 2.3 kg/m2 and 88.39 ± 9 cm vs 82.6 ± 2.7 cm respectively. In the female group, a strong correlation was found between BMI and PI, WC and PT, WC and PI. However, there was no strong correlation between the obesity and spinopelvic alignment parameters in the male group. None of the coronal spinopelvic parameters showed a correlation with the obesity parameters in two groups. The RR showed a positive linear correlation with PA and PT in both groups. Conclusions: Body weight could influence the spinopelvic alignment,especially for females. People with abdominal obesity, the sagittal spinopelvic alignment is likely to change. But there is little effect on the coronal spinopelvic alignment.

Background

The epidemic of obesity has become a serious problem in modern society, especially in the developed countries [1]. Obesity is characterized by the imbalance between energy intake and expenditure [2, 3]. There are some indicators for degrees of obesity. For example, body mass index (BMI), as a common indicator, was used to evaluate the whole status of a person’s body weight [4]. Even though it is very useful, BMI cannot represent the distribution of the fat in the body because it is determined by people’s height and weight only. Other indicators, such as the distribution of body fat (sagittal abdominal diameter (SAD), transverse abdominal diameter (TAD)) and waist circumference (WC) are used along with BMI to identify abdominal obesity [5–7]. Obesity is considered a strong risk factor for cardiovascular disease, cancer, stroke, and endocrine disorders. Besides, the increase in body weight may pose a stronger impact on musculoskeletal system, particularly the lumbar spine [2, 8]. Many studies have shown that low back pain is correlated with obesity [9–12, 28].

In the standing position, the posture of human subjects can viewed as a set of mutually articulating sections: The head is balanced on and connected to the trunk by the cervical spine; the trunk articulates with the pelvis, which in turn articulates with the lower limbs at the hip joints to maintain a stable posture and to expend the minimum amount of energy [13–16]. In the upright standing posture, the spinal load is primarily influenced by changes in body weight, especially the load on the lumbar vertebrae. Excessive mechanical load on the trunk, applied intermittently or repetitively over time, are however believed to play a causative role in injures and degeneration [8]. Multiple studies have reported the normative values for parameters associated with spinopelvic alignment in populations of varying ages, races and pathologic conditions [17–20]. However, to our knowledge, the association of BMI, WC, SAD, and TAD with spinopelvic parameters in the sagittal and coronal planes has never been studied before. Therefore, the purpose of this study is to evaluate the correlation between obesity parameters and spinopelvic alignment in healthy Chinese adult volunteers.

Materials And Methods

Participants

100 healthy Chinese adult volunteers (36 males and 64 females) were recruited from the physical examination crowd in our hospital based on the following inclusion and exclusion criteria. We included individuals of the Han race with the aged between 18 and 45 years. Another requirement was for the participants to have an occupation that involved standing most of the time, such as sales jobs. The final criterion was the availability of a standing lateral radiograph of the spine and pelvis in which the spine from T1 to S1 and both femoral heads were visible.

We excluded individuals with sitting-type jobs, such as bus drivers. Those with a history of the spine or pelvic surgery were also excluded. Furthermore, individuals with a history of degenerative spine disease, or idiopathic scoliosis and those with hip or knee joint deformities were also excluded.

All subjects signed an informed consent for the study after the study protocol was explained to them. Further, this study was approved by the Institutional Review Board of China-Japan Friendship Hospital.

Measurement of obesity parameters

BMI was computed by dividing the weight in kilograms by the square of the height in meters (kg/m2) [4]. Weight was measured using a platform scale to the nearest 0.1 kg. Height was measured using a tape to the nearest 0.1 cm. According to the classification of BMI by the World Health Organization, BMI in the range of 18.5–24.9 kg/m2 is normal, ≥ 25.0 kg/m2 is overweight.

WC was measured with a tape to the nearest 0.1 cm, with the patient wearing light garments. It was measured at the midpoint between the last rib and the highest point of the iliac crest at the end of normal inspiration. Abdominal obesity (indicated by increased waist circumference) was defined as WC 85 cm for men and 80 cm for women [7].

The anterior-posterior diameter, which is a measure of the abdominal extension along the sagittal plane in the standing position, is also called SAD. The transverse diameter, which is a measure of the abdominal extension along the coronal diameter in the standing position, is also called the TAD. SAD is determined using a radiograph, with the diameter extending from skin to skin through the center of the abdomen in the anterior-posterior direction. TAD is defined as the largest diameter from the skin to the skin through the center of the abdomen in both lateral directions in another image. These measurements were determined to the nearest 0.1 cm (Fig. 1). Relative ratio (RR), which is defined as the ratio of SAD to TAD, was also used to study the relationship between the spinopelvic parameters and abdominal obesity.

Measurement of spinopelvic alignment parameters

Participants keep an upright relaxed position, looking forward, with their knees straight, arms gently clasped in front of their trunk and a distance of 25 cm between their feet. All the subjects underwent frontal and lateral radiographs of the entire spine and hip joints. Lateral radiographs of the lumbar spine were obtained on a vertical film (30 × 90 cm) while maintaining a constant distance between the subject and the radiographic source.

The sagittal and coronal spinopelvic parameters were measured on the radiographs. The sagittal spinopelvic parameters included pelvic incidence (PI), pelvic tilt (PT), pelvic angulation (PA), sacral slope (SS), sacral inclination (SI), lumbar lordosis (LL) and the disc angle of L5/S1. The coronal spinopelvic parameters included the Cobb angle of the major curve of the spine, lumbar scoliosis (LS) and pelvic obliquity (PO). These parameters are defined and described clearly in the legend to the figures, as it is easier to understand them from the depictions in the figures (Figures. 2 and 3).

All the measurements were made by two experienced individuals who using a software program that was designed to assess the sagittal and coronal alignment of the spine and pelvis. To determine the inter-observer and intra-test reliability, two observers measured the same radiograph two times. The angular parameters were expressed in degrees.

Statistical analysis

All data analyses were performed using SPSS version 15.0 (SPSS Inc. Chicago, IL). The mean values and standard deviation (SD) were obtained for all the measurements. Continuous variables (BMI, WC, SAD, TAD) are presented as the mean ± standard deviation or the median, as appropriate, and are compared using the t-test or the Mann-Whitney U test, depending on whether the quantitative data were consistent with a normal distribution. A value of $p < 0.05$ was considered statistically significant. Pearson's correlation analysis was used to determine correlations between obesity and spinopelvic alignment parameters. A correlation coefficient (CC) of < 0.5 was considered to indicate a relatively weak correlation, while a CC of > 0.5 was considered to indicate a relatively strong correlation. Levene's test for equality of variances was used to verify the gender-based differences between the measurements. All the results are expressed as mean ± standard deviation (SD).

Results

The participants were grouped according to gender (male, n = 36; female, n = 64). The mean age of the male participants was 30.9 ± 7 years (19 to 45 years), and the female was 29.7 ± 7.3 years (18 to 44 years). As shown in Table 1, the mean BMI of the male participants was 28.7 ± 3.7 kg/m2, and the female was 26.8 ± 2.3 kg/m2. The mean WC of the male participants was 88.39 ± 9 cm, and the female was 82.6 ± 2.7 cm. In both the male and female group, there were significant differences between normal and overweight in BMI and WC respectively. Besides, all the parameters (BMI, WC, SAD, TAD) have a significant difference between the gender.

Levene's test for equality of variances showed the presence of gender-based differences in the variables. Therefore, Pearson's correlation analysis was conducted separately in the male and female groups. According to the results of Pearson's correlation analysis, in the male group, BMI, WC, and TAD were not correlated with the obesity parameters, while SAD was weakly correlated with LL (CC = 0.459) and PA (CC = 0.331) (Table 2). In the female group, PI was strongly correlated with BMI (CC = 0.521). Furthermore, WC was correlated with SI (CC = 0.435), PT (CC = 0.551), PA (CC = 0.436), and PI (CC = 0.539) respectively. No spinopelvic parameter was correlated with TAD. However, SAD was correlated with both PT (CC = 0.450) and PA (CC = 0.393) weakly (Table 3).

As shown in Table 2, RR was correlated with LL (CC = 0.562), SS (CC = 0.552), SI (CC = 0.558), PT (CC = 0.534), and PA (CC = 0.550). In Table 3, RR was correlated with PT (CC = 0.391) and PA (CC = 0.349). Contrary to the sagittal spinopelvic parameters, the coronal spinopelvic parameters did not show a strong correlation with the spinopelvic alignment parameters.

Discussion

Obesity is a medical problem which is associated with various musculoskeletal disorders, especially the spine [13, 3]. Although the interaction between spinopelvic disease and obesity is not clear, the relationship between low back pain and BMI has been demonstrated by many studies [9–12, 28]. To our knowledge, the parameters of spinopelvic have clinical implications. For example, the risk of early distal discopathy increases in patients with low PI and a flat back [21]. Patients with chronic low back pain typically have a low SS, LL, and small PI [12]. That means biomechanics play an important role in the initiation and progression of several spine pathologies, and it is imperative to understand spinopelvic alignment in obese patients. However, no study has reported the significance of spinopelvic parameters for the diagnosis and treatment of human musculoskeletal disorders. Thus, the present study made an objective analysis of the correlation between spinopelvic parameters and the obesity parameters.

Our results showed that coronal spinopelvic parameters have no correlation with both BMI and WC, which means that obesity may not affect the coronal spinopelvic arrangement. In the male group, BMI and WC were not correlated with sagittal spinopelvic parameters yet. But in the female group, the sagittal spinopelvic parameter (PI) was correlated with both BMI and WC strongly. It seems that obese female tends to have higher PI values. PI, an anatomical parameter, is unique to each individual and independent of the spatial orientation of the pelvis [22]. It has a geometrical relationship with two positional parameters, PT and SS: PI = PT + SS [23]. A study concluded that PI is significantly correlated with SS and there is a positive linear relationship between SS and LL. This implied that, in females, with the PT increasing, the balance of the sagittal spinopelvic arrangement was maintained by an increasing LL. This may explain why obese females tend to have hyperlordosis and their pelvis is usually forward-inclined.

Whitcome et al. [24] pointed out that in bipeds, the upper body is stabilized by the positioning of the center of mass (COM) on the trunk above the hips. However, in women who are pregnant, the body shape changes as a result of the extra mass, which results in a shift of the body's COM towards ahead. In a typical pregnant human female with a naturally extended back, the COM was recovered through increased lumbar lordosis, a stable positional alignment with reduced hip torque but exacerbated spinal shearing load. This indicated that the increased abdominal circumference might affect the sagittal spinopelvic alignment. The abdominal circumference can reflect the form of the abdomen, and it was an appropriate index for evaluating the influence of obesity on the spinopelvic alignment under certain conditions. However, as an abdominal circumference can only be measured in a single plane at a time, this may not suitable for evaluating changes of COM in the sagittal and coronal planes.

Kvist et al. [25] proposed the use of TAD and SAD to estimate visceral obesity. Therefore, we thought it necessary to determine the correlation of SAD and TAD with the spinopelvic parameters. The results indicated that TAD was not correlated with any of the spinopelvic parameters in the two groups. Concerning SAD, it was weakly correlated with PA and LL in the male group, and with PA and PT in the female group. Further, the results of the correlation analysis showed that SAD was linearly correlated with PA and PT in both groups, but the correlation was not strong [Figure. 4]. In the female group, a positive correlation was found between SAD and PA. As an increase in PA and PT was often associated with pelvic incline and greater LL, this may have important implications [28]. Further, RR (the ratio of SAD to TAD) had a positive linear correlation with PA and PT (Figure. 5). These results indicated that for people with abdominal obesity, SAD may have a greater impact on the spinopelvic parameters than TAD.

From the findings of our research, we can deduce that the changes in the shape of the lumbar spine caused by obesity impacts females more than males. This may be attributed to the differences in the shape of the spine between males and females. The spine and pelvis of females were more dorsally inclined, either as a whole (T1–L5–SSI) or specifically about the thoracic and thoracolumbar vertebrae. Because the biomechanical demands of pregnancy exerted an early selection pressure on the evolution of lumbar lordosis in bipedal hominins [24, 26]. The explanation can also be applied to the obese individuals with increased pressure on the spine and pelvis, which results in shifting of the COM backward to maintain standing balance. This may change the position of the lumbar spine in the long term. Hyperlordosis results in degenerative spondylolisthesis and its main symptoms are lumbago, degenerative discopathy, and Baastrup disease. It consequently leads to a disturbance of the global sagittal balance of the spine [21, 27]. Altogether, these findings highlight the importance of maintaining an appropriate body weight by incorporating an appropriate amount of exercise to keep the spine and pelvis in a healthy condition.

Conclusions

This was the first analysis to investigate the association between sagittal and coronal spinopelvic parameters and abdominal obesity parameters. Body weight could influence the spinopelvic alignment, especially for females. Further, people with abdominal obesity, the sagittal spinopelvic alignment was likely to change as a result of hyperlordosis and forward inclination of the pelvis. But there was little effect on the coronal spinopelvic alignment.

Abbreviations

body mass index	BMI
sagittal abdominal diameter	SAD
transverse abdominal diameter	TAD
waist circumference	WC
pelvic incidence	PI
pelvic tilt	PT
pelvic angulation	PA
sacral slope	SS
sacral inclination	SI
lumbar lordosis	LL
lumbar scoliosis	LS
pelvic obliquity	PO
standard deviation	SD
correlation coefficient	CC
center of mass	COM

Declarations

Ethics approval

The survey was approved by the China-Japan Friendship Hospital Health Science Center Ethics Committees.

Consent to participate

Written informed consent was obtained from all participants according to the Declaration of Helsinki.

Availability of data and material

The first author can provide all data.

Conflict of interest statement

The authors declare that they have no conflict of interest.

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Consent for publication

All authors approved the final version to be submitted.

Author contributions

Qingxi Zhang, Fuqiang Gao, Yunting Wang, Zirong Li, and Wei Sun were responsible for the conception and design of the study. Qingxi Zhang, Fuqiang Gao, Ozaki Koji acquired the data and performed data analysis and quality assessment. All authors made substantial contributions to the interpretation of the results. Qingxi Zhang drafted the article and all authors revised it critically for important intellectual content

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Tables

Table 1. Characteristics of participants.

	Male					Female				
	n	Mean±SD	Minimum value	Maximum value	Median	*n*	Mean±SD	Minimum value	Maximum value	Median
II (kg/m^2)										
Normal (<25)	8	22.3±1.9	19.1	24.5	22.2	24	20.8±2.3†	16.9	24.8	20.6
verweight (≥25)	28	30.5±2.4*	25.2	39.7	34.4	40	30.4±2.7**†	25.4	38.8	33.3
Total	36	28.7±3.7	19.1	39.7	30.9	64	26.8±2.7†	16.9	38.8	28.7
C (cm)										
Normal	8	76.3±5.5	68	85	76.5	28	68.7±10.4†	49	80	69
Abdominal overweight	28	90.5±4.8*	86	102	89	36	86.2±2.9**††	82	92	86
Total	36	88.39±9	68	102	87	64	82.6±2.7††	49	92	83
D (cm)	36	26.2±4.9	17.2	38.7	25.5	64	21.7±2.5††	15.8	27.8	21.8
D (cm)		32.8±4.5	26.1	43.6	32.2		30.1±2.7††	24.8	36.2	29.9

Number of people; BMI: Body mass index; WC: waist circumference; SAD: Sagittal abdominal diameter; TAD: Transverse abdominal diameter.
Normal vs Overweight; *<0.05, **<0.001. †: Male vs Female; †<0.05, ††<0.001.
dominal overweight: WC□85cm for male and □80cm for female.

Table 2. The results of the Pearson correlation test in the male group.

	Obesity Parameters					Sagittal Spinopelvic Parameters						Coronal Spinopelvic Parameters			RR
	BMI	WC	TAD	SAD	LL	Disc angle of L5/S1	SS	SI	PT	PA	PI	Cobb angle of L1/S1	LS	PO	
		.855**	.637*	.688**	-0.016	-0.11	0.063	0.059	-0.367	-0.232	-0.156	-0.084	-0.189	-0.162	0.358
			.569*	.645**	0.013	0.178	0.216	0.219	-0.102	-0.132	0.173	0.086	0.144	-0.181	0.379
				.880**	-0.238	0.144	-0.072	-0.03	0.03	0.081	-0.046	-0.028	-0.014	0.132	0.309
					.459**	0.016	-0.327	-0.295	0.289	.331*	-0.097	-0.071	-0.125	-0.038	.720**
ne(LL)						0.138	.751**	.773**	-.472**	-.694**	.396*	.369*	.366*	-0.092	.562**
e OF l							.423*	.448**	-0.018	-0.155	.496**	0.166	.360*	-0.015	-0.208
								.967**	-.654**	-.787**	.533**	0.285	.420*	-0.035	.552**
									-.626**	-.769**	.551**	0.296	.427**	-0.089	.558**
										.866**	0.193	-0.242	-0.197	0.061	.534**
											-0.013	-0.329	-.343*	0.138	.550**
												0.282	.464**	0.077	0.127
le of l													.848**	0.064	-0.1
														0.09	-0.224
															-0.222

f r with superscripts * or ** are valid.

ıass index; WC: waist circumference; TAD: sagittal abdominal diameter; SAD: transverse abdominal diameter; LL: lumbar lordosis; ope; SI: sacral inclination; PT: pelvic tilt; PA: pelvic angulation; PI: Pelvic incidence; LS: lumbar scoliosis; PO: pelvic obliquity; RR: the and TAD.

correlation at the level p=0.01(99%)

correlation at the level p=0.05(95%)

Table 3. The results of the Pearson correlation test in the female group.

	Obesity Parameters					Sagittal Spinopelvic Parameters						Coronal Spinopelvic Parameters			RR
	BMI	WC	TAD	SAD	LL	Disc angle of L5/S1	SS	SI	PT	PA	PI	Cobb angle of L1/S1	LS	PO	
BMI		.676**	.519**	.604**	0.1	0.175	0.246	0.316	0.311	0.313	.521**	-0.049	-0.097	-0.042	0.27
WC			.473*	.845**	0.294	0.229	0.313	.435*	.551**	.436*	.539**	-0.146	-0.119	0.165	.593**
TAD				.579**	0.026	0.097	-0.051	-0.062	0.18	0.145	0.071	0.073	0.011	0.164	-0.213
SAD					0.12	-0.002	-0.085	-0.017	.450**	.393**	0.223	-0.009	-0.025	0.133	.670**
Lumbar spine(LL)						-0.167	.515**	.543**	0.085	0.031	.441**	0.084	0.12	0.055	0.097
Disc angle OF L5/S1							.453**	.457**	-0.004	-0.198	-0.146	.265*	.338**	.520**	-0.092
SS								.956**	0.025	-0.174	.442**	0.219	.292*	.388**	-0.072
SI									0.045	-0.18	.431**	0.178	.257*	.375**	0.015
PT										.858**	.285*	-0.148	-0.163	0.076	.391**
PA											.361**	-0.166	-0.19	-0.035	.349**
PI												-0.088	-0.103	-0.138	0.182
Cobb angle of L1/S1													.955**	.595**	-0.086
LS														.658**	-0.055
PO															-0.003
RR															

The values of r with superscripts * or ** are valid.

BMI: body mass index; WC: waist circumference; TAD: sagittal abdominal diameter; SAD: transverse abdominal diameter; LL: lumbar lordosis; SS: sacral slope; SI: sacral inclination; PT: pelvic tilt; PA: pelvic angulation; PI: Pelvic incidence; LS: lumbar scoliosis; PO:pelvic obliquity; RR: the ratio of SAD and TAD.

**Significant correlation at the level p=0.01(99%)

*Significant correlation at the level p=0.05(95%)

Figures

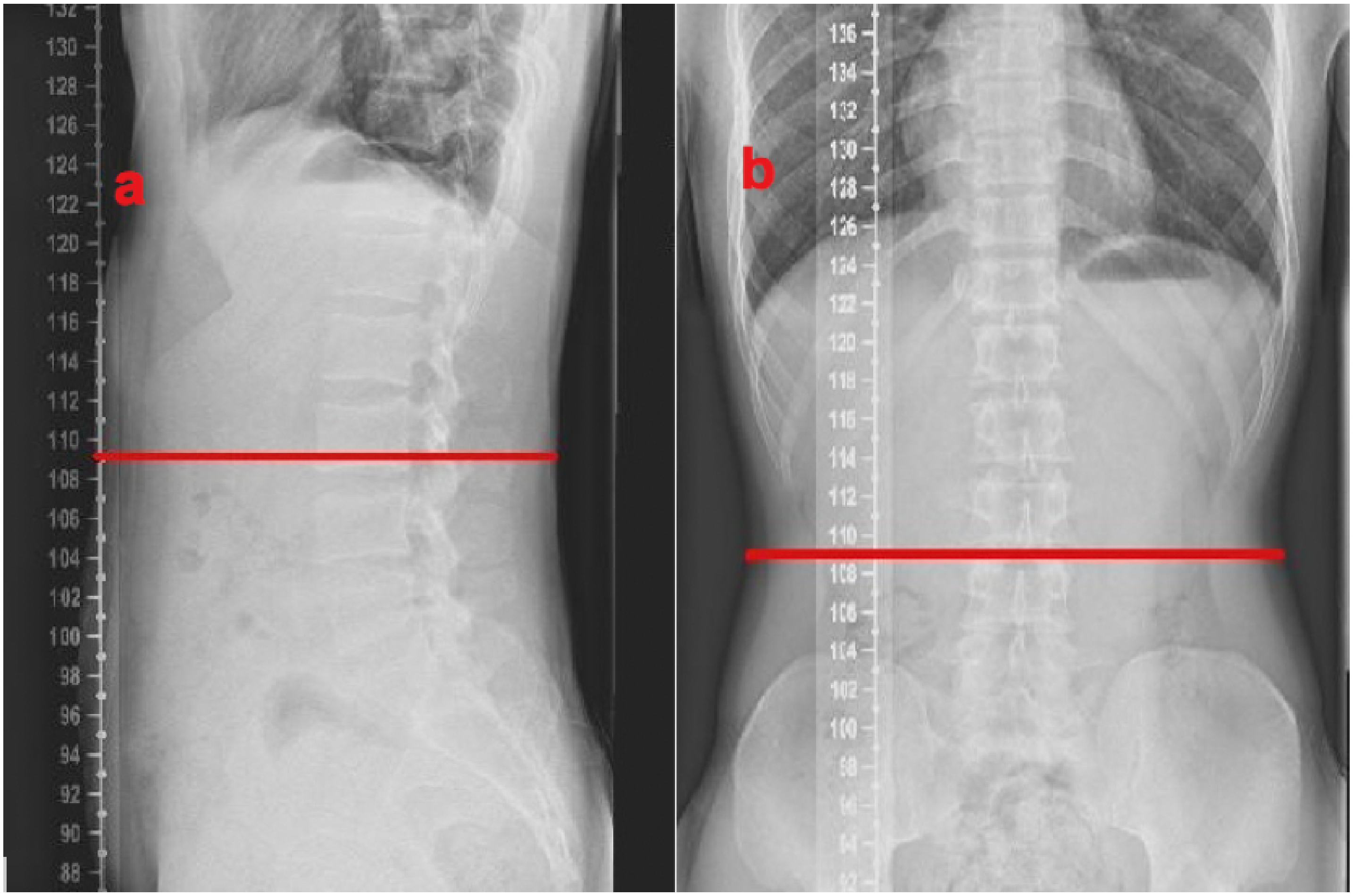

Figure 1

Measurement of anterior-posterior diameter and transverse diameter. (a)The sagittal abdominal diameter (SAD) is represented by the line drawn from skin to skin through the center of the abdomen in the anterior-posterior direction. (b) The transverse abdominal diameter (TAD) is represented by the line drawn from skin to skin through the largest spanning width of the abdomen in both lateral directions.

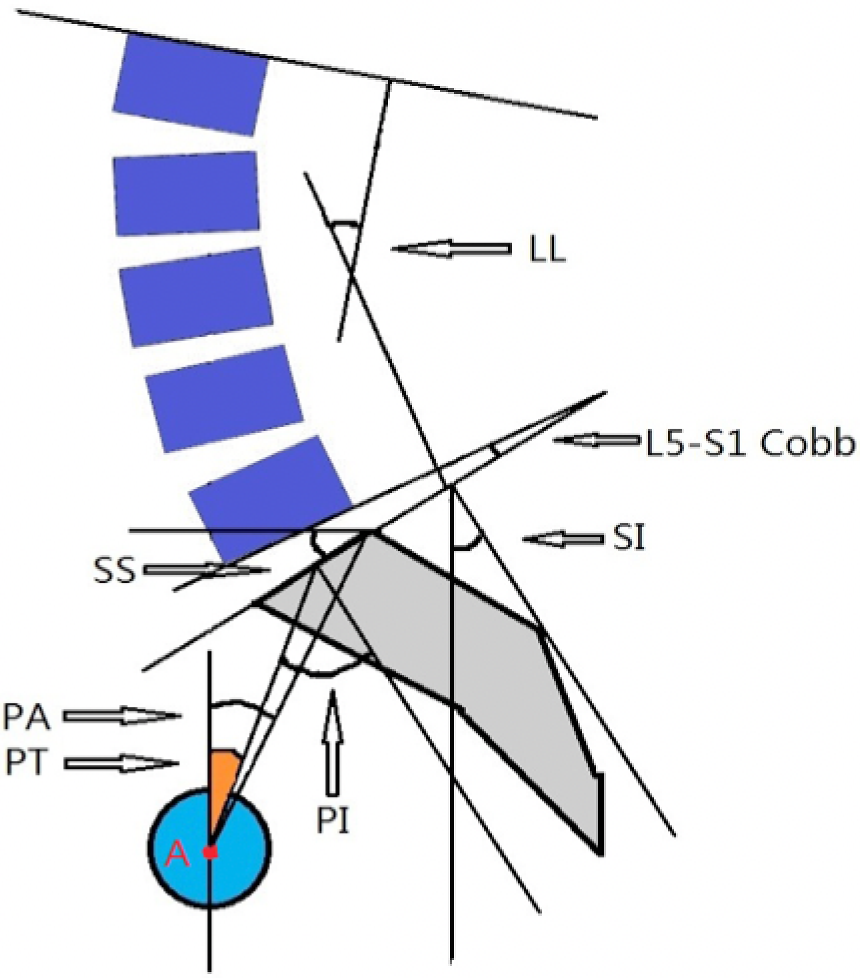

Figure 2

Measurement of sagittal spinopelvic alignment parameters. (1) Pelvic incidence (PI) is defined as the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the middle axis of the femoral heads. (2) Pelvic tilt (PT) is defined as the angle between the line connecting the midpoint of the sacral plate to the femoral head axis and the vertical line. (3) Pelvic angulation (PA) is defined as the angle between the vertical line and the pelvic radius line. The pelvic radius was drawn from the pelvic hip axis (point A) to the posterior–superior corner of S1.(4) Sacral slope (SS) is defined as the angle between the superior endplate of S1 and the horizontal axis. (5) Sacral inclination (SI) is defined as the angle subtended by a tangent to the posterior border of S1 and the vertical line. (6) The Cobb angle of L1-S1 in the sagittal plane is also known as lumbar lordosis (LL) and is measured using the Cobb method, between the upper endplate of L1 and the upper endplate of S1 in the sagittal plane. (7) The disc angle of L5/S1 is defined as the angle between the subordinate endplate of L5 and the superior endplate of S1.

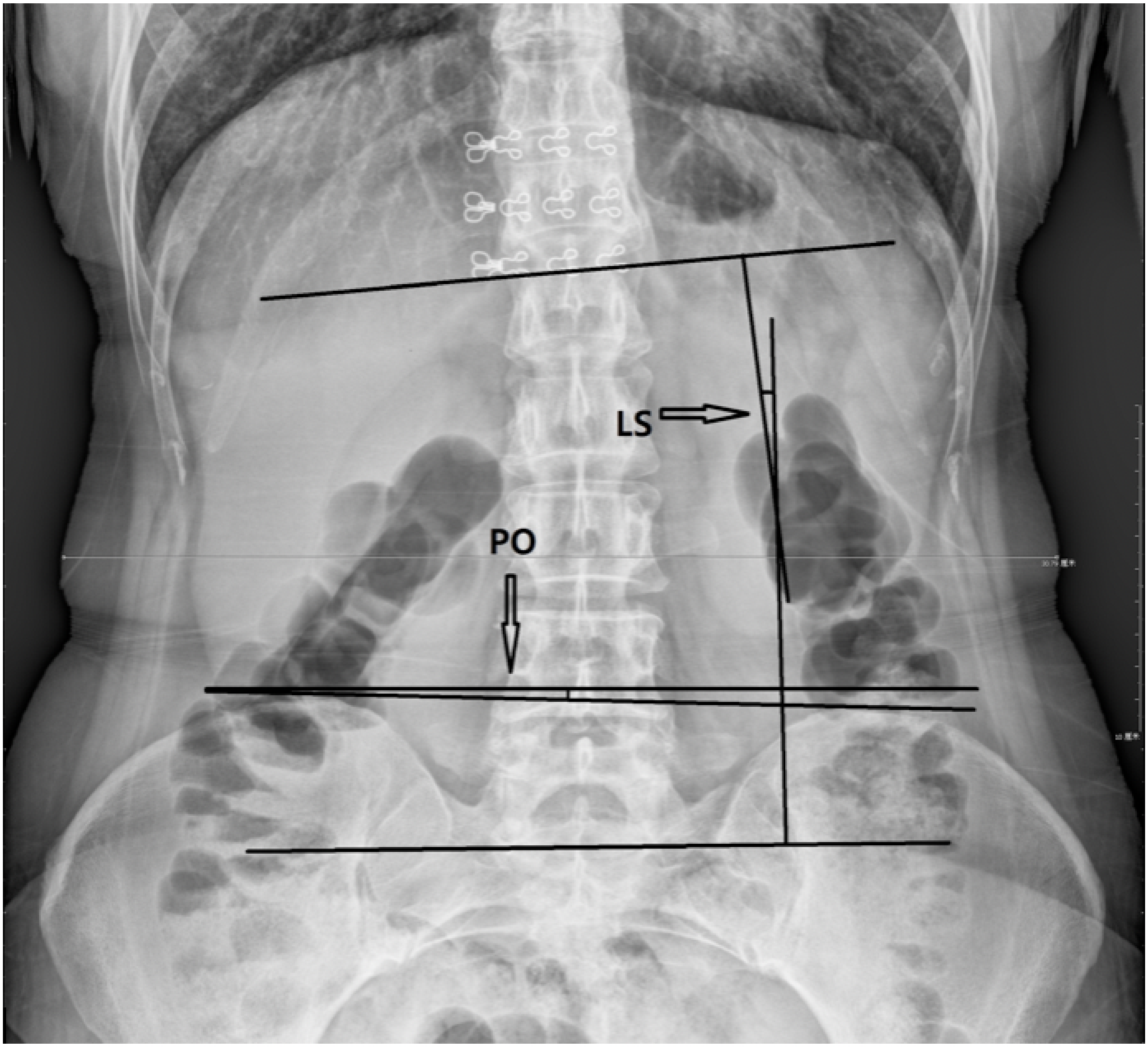

Figure 3

Measurement of coronal spinopelvic alignment parameters. (1) Lumbar scoliosis (LS) is measured using the Cobb method, between the upper endplate of L1 and the subordinate endplate of L5. (2) Pelvic obliquity (PO) is defined as the angle between the line passing through both iliac crests and the horizontal line. (3) Cobb angle of the major curve of the spines defined as the angle between the first centrum of the upper endplate of the major curve and the last centrum of the subordinate endplate of the major curve.

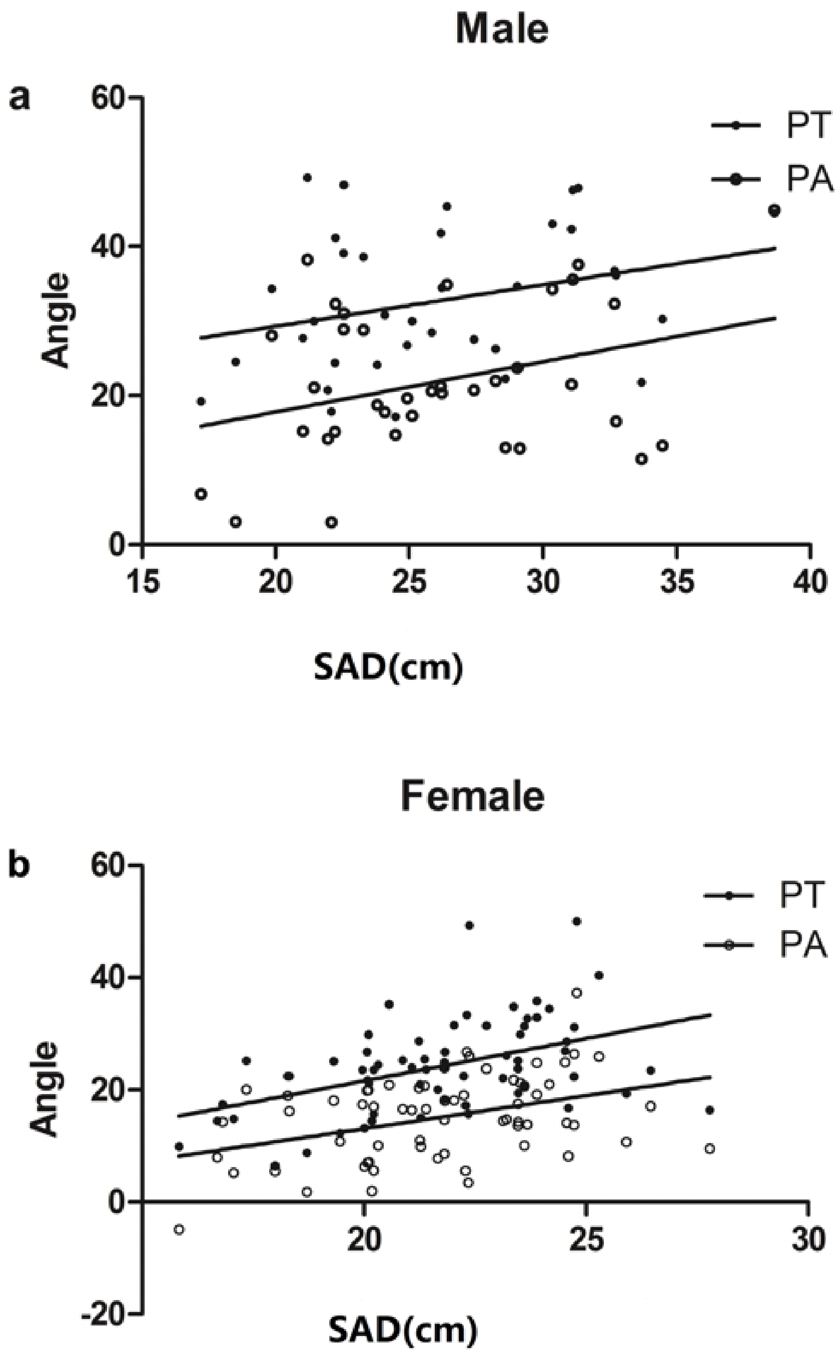

Figure 4

The relationship between sagittal abdominal diameter (SAD), pelvic tilt (PT) and pelvic angulation (PA) in the male and female groups. The graph shows that SAD is linearly correlated with PA and PT in both male and female groups.

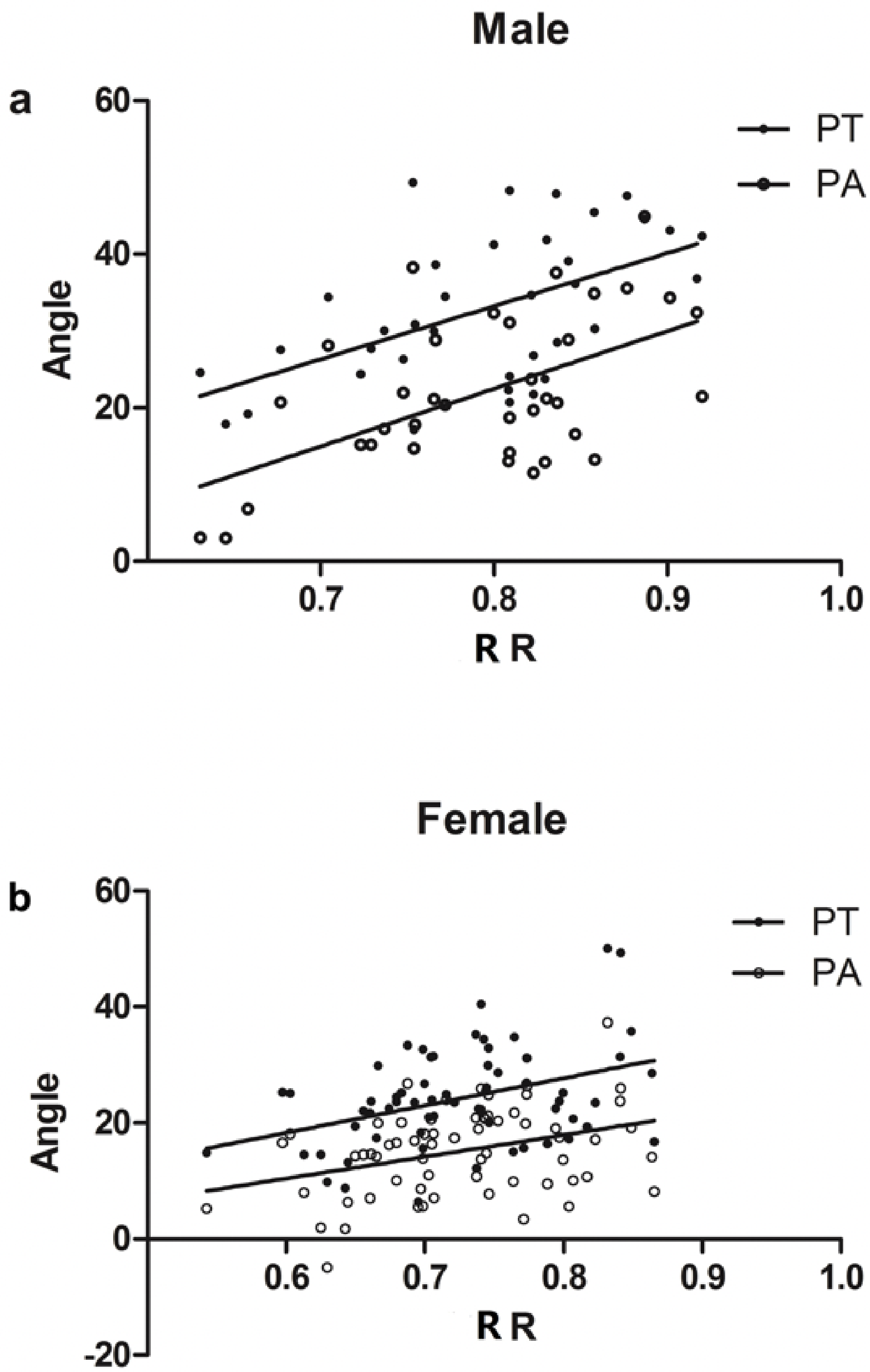

Figure 5

The relationship between RR (the ratio of sagittal abdominal diameter to transverse abdominal diameter) and pelvic tilt (PT) and pelvic angulation (PA) in the male and female groups. The graph shows that RR is linearly correlated with PA and PT in both male and female groups.