An analysis of the negative asymmetry in the coronal body shape of the old people in South Korea

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Research article

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Abstract

Background Existing positive shape models are based on values for the right side of the body. To the best of our knowledge, this is the first comparative study to analyze both left- and right-side data to explore asymmetrical body characteristics, considering that most older people are not able to maintain a healthy spinal vertical tilt presentation. In this study, 3D scanning and 3D measurement were used to analyze and study the asymmetry of the elderly in South Korea to provide more complete basic size data for the development of clothing patterns for the elderly.

Methods The calculated values were analyzed by ANOVA and correlation analysis, and the paired sample t-test was performed to find asymmetrical characteristics of the older adult body. Finally, we used the independent t-test to analyze sex differences. Geomagic Design X software was used to record the coordinates of the measured points to reconstruct 3D models of the older adult body. We present a new method based on analysis of the vertex-anterior neck plane, the anterior neck-omphalion plane, and the omphalion-crotch point plane as benchmarks for the center of the head, the upper torso and the lower torso, respectively, to determine lateral asymmetry.

Results The Kolmogorov-Smirnov normality test indicated the tendency of the torso to tilt to the right in older men and women. Compared with the inclination of the head, the inclination of the lower torso is more obvious. The correlation analysis results show that the tilt of the head does not affect the asymmetrical characteristics of the trunk.

Conclusions This study did not use the traditional median sagittal plane as a central datum plane, instead separating the model according to the structure of the human body into the head, upper body, and lower body, with three independent central datum planes. Therefore, this study contributes an analysis of human asymmetry, thus providing more complete basic size data for the development of clothing patterns for the elderly in South Korea.

Background

1.1 Review of literature

During normal human aging, the upper body becomes bent, the waist and viscera tend to become obese, and the upper limbs become thinner, leading to reductions in height, width, thickness and weight[16,5,20]. At the same time, the curvature of the waist, the thoracic vertebrae and the cervical spine present a relatively obvious flatback shape. Due to deformation of the spine, the contour of the trunk, as well as of the neck and shoulders, are important factors in body shape analysis. Most of the existing literature is classified and compared in terms of sagittal hunchback types[19,21].

In addition to athletes and disabled people, who require clothing with extremely demanding ergonomic standards, the elderly also present ergonomic challenges for clothing. [24] With the increase in the average lifespan and the reduction in the birth rate, increased aging of the population is a growing social problem. According to the Korea Statistics Information Service (KOSIS) [1], elderly people accounted for 14.9% of the total population in 2019, and those over 65 years old are projected to account for 40% of the total population by 2050. Such a sharp increase in the proportion of elderly people forces us to pay more attention to age-related research. The increase in aging is accompanied by an increase in the number of aging workers. Compared with young people, old people have more serious injuries and diseases[23]. In Korea, many older workers aged 65 to 79 have to continue working because of their livelihood. According to OECD research, the employment rate of South Korea's 50- to 74-year-old population (62.1% in 2016) is much higher than the OECD average (50.8%). Similarly, more older women are employed in Korea than in many other OECD countries, and the proportion of working women among those aged 70-74 is higher in Korea than in any other OECD country.

Recently, worldwide studies on the convenience of clothing size for older people have been conducted. Traditional direct measurement methods in the past have limited anthropometric studies of older people to weight, height, BMI and some simple dimensional data. The requirements of ergonomic design make it necessary to first accurately grasp the body shape and size of the wearer[21,24]. Older people show abdominal obesity and limb muscle atrophy, as well as physical symptoms of the bones and other phenomena that intensify with age. The bodies of older people take on very different shapes than those of younger people. Therefore, it is necessary to conduct separate human body size studies for older people. Studies have shown that the phenomenon of lumbar protrusion increases significantly with age[14]. Moreover, the lateral curvature of the spine is accompanied by an increase in posterior curvature. [5,22]. The stretched posture of Koreans can cause a pelvic list, resulting in scoliosis. The muscle atrophy and the walking posture of older people leads to coronal asymmetry in their body shape [9], and this trend of asymmetry increases with age.

1.2 Purpose of the study

Earlier studies on coronal plane body types have focused on adult women (20 to 59 years old) or adolescents[4,13]. Studies on the coronal plane body shape in older people have been limited to analyses based on the right-side size or overall size and have also been limited to width items[15]. To compensate for the limitation of using only the right side as the research object, this study used 3D scanning and 3D measurement technology to analyze the asymmetry of elderly people in South Korea, aiming to provide more complete basic size data for the development of ergonomic clothing patterns for older people. Research for better aging provides a reference to prevent social problems and reduce health problems in elderly people. Accordingly, a feasible prediction scheme for the clothing size of older people was developed.

Methods

2.1 Data collection

This study used 3D images of the human body collected by SizeKorea, in which 329 elderly people aged 70 to 85 who could stand autonomously without the aid of crutches were scanned using indirect 3D measurement technology. The landmarks on the 3D image provided by SizeKorea were only found on the right side. According to SizeKorea, the method of direct landmark generation was used. We used 3D reverse modeling software to simulate direct measurement when the landmark was also attached to the left side of the human body.

The coordinates (x,y,z) of the measured points in the 3D scans of the human body were measured using Geomagic Design X 64 reverse modeling software (reference: right sole =(0,0,0)). The width, height, and angle of all coordinate points were calculated using the following formula (Fig. 1):

$$\text{Width}=Xc-Xa,\ \text{Height}=Zc-Zd,\ \theta = \tan^{-1}\left(\frac{Xa-Xb}{Za-Zb}\right)$$

The width is the distance between the point coordinates on the x-axis, and the height is the distance on the z coordinate axis. The height is calculated using the point of contact of the right foot with the floor as the reference point and applying the tan function to calculate the angle. Most older probands have an asymmetrical body shape, so the traditional median sagittal plane cannot be used as the baseline for analyzing positive body shape. Consequently, we measured the lateral asymmetry using the plane between the vertex and the anterior neck, the plane between the anterior neck and the omphalion, and the plane between the omphalion and the crotch point (Fig. 2) as the central datum plane for the head, the upper body and the lower body, respectively. Previous studies eliminated minimum and maximum measurements (3 standard deviations). Here, the extremes were not removed because we also wanted to reflect the diversity of body types in the older people in this study. A total of 12 width items (Fig. 2), 11 angle items (Fig. 2), and 11 height items (Fig. 2) were selected among the most common items in the pilot study on positive body shape. The study was approved by the Seoul University Bioethics Committee (IRB No. 1903/003–014).

2.2 Statistical analysis

In this study, InBody measurement items (body weight, BMI, body fat, body fat percentage) and direct measurement items (shoulder tilt angle (left/right)) were used together with 10 height items, 12 width items, and 8 angle items. The differences were calculated via subtraction using indirect 3D measurement. To analyze the asymmetry of the body types of the elderly, the data on the left and right were compared using the paired sample t-test in SPSS 23.0 software (IBM Corp., USA). Regarding the angle of the trunk and cross-analysis of lateral asymmetry, the Kolmogorov-Smirnov normality test was implemented after comparing the inclination angle of the trunk with the difference between the left and right sides. Cross-analysis and chi-squared tests were performed to determine the correlation between the angle of the trunk and the difference between the left and right sides. To examine whether lateral asymmetry is affected by age, the probands were divided into three 5-year age cohorts of 70–74, 75–79, and 80–85 years old. According to the Asian classification criteria in the WHO report from 2004, the probands were divided into 4 BMI categories of low ($BMI < 18.50$), normal (BMI 18.50-22.99), overweight (BMI 23.00-24.99), and obese ($BMI \geq 25.00$).

Results

3.1 Torso features

The normality test showed that the average central 50% of the normal distribution was as follows: angle between the vertex and anterior neck for males and females, -2.125 ~ 0.956 and − 2 ~ 0.9, respectively; angle between the anterior neck and omphalion for males and females, -0.917 ~ 2.154 and − 0.56 ~ 2.58, respectively; and angle between the anterior neck and crotch for males and females, -0.130 ~ 1.813 and 0.08 ~ 2.2, respectively. Among them, the proportion of men and women with a vertex-anterior neck angle less than 0 was 58% and 62%, respectively; that of men and women with an anterior neck-omphalion angle greater than 0 was 68% and 62%, respectively; and that of men and women with an angle between the anterior neck and crotch greater than 0 was 80% and 71.5%, respectively. There was an average inclination of the torso to the right in older men and women, whereby the tilt of the navel and crotch was more pronounced than that of the head. There was a tendency of the torso to tilt to the right in older men and women. Compared with the inclination of the head, the inclination of the line between the navel and crotch was more obvious. Table 1 shows an example of the tilt of the central torso of the elderly. We conducted a regression analysis of the crotch point tilt angle and the omphalion tilt angle, which yielded the following result (Fig. 3):

$\theta_{navel} = -0.387 + 1.208 * \theta_{crotch}$ ($R^2 = 0.625$)

(θcrotch: tilt angle of crotch point, θnavel: tilt angle of navel point)

The angle from the anterior neck point to the omphalion and from the anterior neck point to the crotch point had a certain influence on the lateral asymmetry of the trunk from shoulder to waist. However, the central body angle was not associated with an increase in age or BMI, indicating that age and obesity did not affect lateral asymmetry. The correlation analysis of the trunk tilt angle showed that the correlation coefficient between the angle of the anterior neck-omphalion line and the angle of the anterior neck-crotch point line was highly positive for both male (.820***) and female (.76***) probands. To analyze the relationship between the tilt of the trunk and the asymmetry of the left and right sides, we analyzed the correlation between the tilt angle of the trunk and the lateral difference and found that the anterior neck-omphalion angle and nipple height difference (-.531**), as well as the shoulder width difference (-.526**), presented a negative correlation in aging males. Furthermore, the waist width difference (.402**) showed a positive correlation with the anterior neck-omphalion angle, and this correlation was most prominent for the side waist point width difference (.504**) and the waist upper angle (.442**). In the female probands, there was a negative correlation with the posterior shoulder width difference (-.550***) and a positive correlation with the most prominent waist point width difference (.418***). The angle of the anterior neck-crotch point was negatively correlated with the height difference of the nipple point (-.511**) and the posterior shoulder width difference (-.557**) in aging males but was positively correlated with the angle difference of the upper waist (.488**). Negative correlations were found in women with the highest side waist height difference (-.453***), posterior shoulder width difference (-.514***), and waist bottom angle (-.509***).

3.2 Features of the upper and lower body

We carried out a paired sample t-test of the left and right measurements (Table 2), and the results showed that there were significant differences in posterior shoulder width, bust breadth, and shoulder angle between the elderly men and women, which could be used as a basis for judging lateral asymmetry. Compared to the traditional use of the shoulder slope as the sole decision basis, we believe that the width of the shoulders is more responsive to the asymmetry of features. Consistent with this idea, we found that spinal flexion viewed from the side presents the form of a C or S in most women. However, severe scoliosis appears to cause asymmetry of the trunk, pelvis, and knees. There was a significant difference in knee height between men and women, and there was significant asymmetry in the bending angle of the knee in older men. The results of the correlation analysis of the degree of inclination of the trunk and lateral asymmetry show that the degree of inclination of the head does not affect the asymmetrical features of the trunk, and the asymmetry of the shoulder width and waist width is mainly related to the angle of the anterior neck-omphalion and anterior neck-crotch lines.

3.3 Relation between age and asymmetry

We used ANOVA to assess the contribution of different measured items to the observed differences, and the results show that height presented an obvious decreasing trend with increasing age, but there were no significant changes in trends in asymmetry. Therefore, we found no statistically significant relationship between leaning of the spine or asymmetry and increasing age in this study. Therefore, we believe that the personal management of posture in daily life is quite important. Outward bending of the knee tended to increase with age, especially in those over 80 years of age compared to those aged 70–74.

3.4 Relationship between BMI and asymmetry

Overall, obese older women accounted for 53.4% of the total, while older males with obesity accounted for 39.4%. With increasing BMI, the weight and width of the body presented an increasing trend, but there was no statistically significant correlation between asymmetry and BMI. The cross-analysis did not find any statistically significant correlation between the age and BMI groups.

3.5 Analysis of body type by sex

We performed the independent sample t-test on the male and female datasets (Table 3), and the results of the comparison of male and female measurement items show that men had a higher average height and width than women. In contrast, the average values of BMI, body fat percentage, body fat mass, left and right posterior shoulder width difference, left and right chest breadth difference, omphalion tilt angle, crotch tilt angle, upper waist angle (left, right), and median malleolus-mid-patella angle (left, right) were greater in women than in men.

Discussion

4.1 Sex differences

In old age, the spine of both men and women tends to tilt to the right. However, scoliosis and posterior curvature are more pronounced in older women than in older men; additionally, women also tend to bend their knees to the outside more because they could not stand upright[8]. Measurements of the sagittal plane of 226 people between the ages of 20 and 89 showed significant differences in the angles of the neck, chest, and buttocks between men and women. The asymmetrical loading of spinal segments due to asymmetry of the intervertebral discs and facet joints at different levels is caused by common metabolic bone diseases, such as osteoporosis, especially in postmenopausal women[18]. It was found that 35.5% of 1347 older volunteers had scoliosis, and the incidence was higher in women[10]. Older women showed a lower average body weight than men but a higher BMI, body fat ratio and body fat mass. These changes are consistent with an increased incidence of osteoporosis and increased body fat.

4.2 Effects of aging on the spine

A study of the sagittal body planes of 226 people aged 20 to 89 showed that the angles of the neck, chest, and knee were affected by aging, and the changes in older women were more pronounced[8.7]. Eguchi Y et al showed that in the process of aging, patients with muscle atrophy had a higher incidence of degenerative lumbar scoliosis, and the trunk muscles, in turn, affected the bending posture, further causing forward pelvic tilt and vertebral body rotation. Decreased trunk muscle mass is also associated with osteoporosis[14]. Studies have shown that asymmetry in the cross-sectional area of the paravertebral and psoas muscles is caused by muscle hypertrophy in patients with degenerative scoliosis[17]. This suggests that the high rate of disc herniation in Korea may be due to the traditional Ondol floor heating system and the lifestyle of sitting cross-legged on the floor. [18] The effects of sitting position on the lumbosacral spine and pelvis were examined in four postures: upright, sitting in a chair, using a Japanese-style cabinet, and Korean-style cross-legged. The results showed that among the four sitting postures, in Korean cross-legged sitting, the sacral slope was significantly reduced and the pelvic tilt was the largest.

4.3 Reasons for using 3D measurements and comparison with previous studies

It is well known that direct measurement is more accurate than 3D measurement, but it requires the measured person to hold the posture for a long time. However, due to the declining health of older people, most cannot maintain the upright posture for the long time required for direct measurement. Although a large number of previous studies have adopted automatic 3D measurement software to measure the body, due to the severe curvature of the spine in older people, the standing posture is not as straightforward as that in middle-aged adults, leading to large errors in the landmarks points of the automatic 3D measurement software. Anthropometric studies of older people in other countries have largely been based on the maximal values of the basic dimensions of the investigation. For example, Chinese researchers surveyed more than 65 older people and measured 47 anthropometric dimensions[12]. A Polish scholar measured 33 anthropometric characteristics in 106 women aged 60 and above. Most studies have investigated the progression of spinal deformities and have not concentrated on the asymmetry of anthropometric characteristics due to spinal deformities.

4.4 Research limitations and future significance

This study used only the coronal plane to compare and analyze the changes and differences in the body shape of elderly men and women. Shape changes in the sagittal plane cannot be ignored. Some studies have shown that deformities of the spine on the coronal plane may affect the direction of pelvic and sagittal spine alignment[11]. Future studies can further explore whether changes in the sagittal and coronal planes are correlated. Noninvasive assessments are also of significance for the future development of anthropometry in older people.

Conclusions

Symptoms of scoliosis and retroflection in the elderly result in a tendency of the entire trunk to lean to the right, whereby women on average develop greater spinal deformity than men. Moreover, obesity is more severe among elderly women than among elderly men, but we did not find a statistical correlation between increasing age and BMI. Hence, obesity is not affected by age, nor does it directly lead to spinal inclination or body asymmetry. Notably, obesity is not correlated with age and does not lead to spinal inclination or asymmetry of the body.

Declarations

-**List of abbreviations-Not applicable**

-**Ethics approval and consent to participate**-The study was approved by the Seoul University Bioethics Committee (IRB No. 1903/003-014).

-**Consent for publication-** Data availability statement: The authors obtained data from this dataset: https://sizekorea.kr/

-**Availability of data and material**- The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

-**Competing interests**-The authors declare that they have no competing interests

-**Funding**-Not applicable.

-**Authors' contributions**- LC, SML, YJN and JHP: involved in the design of the study; LC: performed the statistical analyses and wrote the initial manuscript; all authors: contributed to the interpretation of the data, critically revised the manuscript, and All authors read and approved the final manuscript.

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Tables

Table 1 An example of the tilt of the central torso of the elderly man and woman.

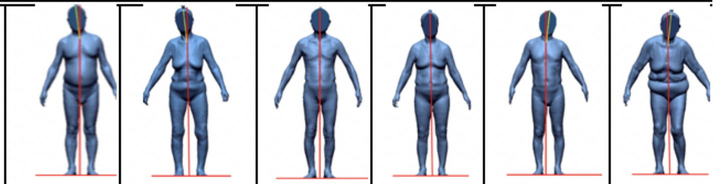
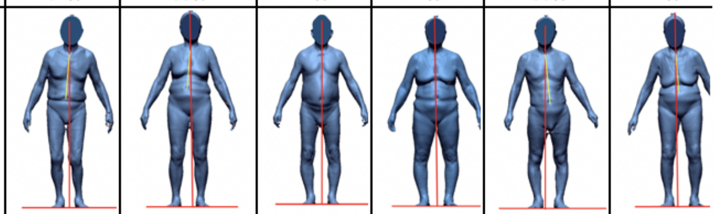
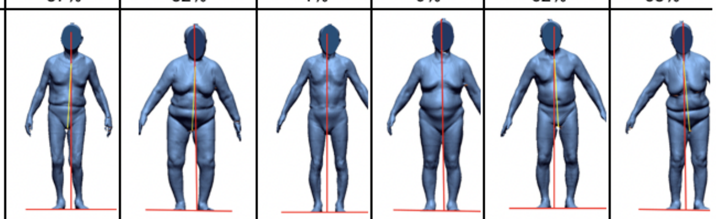
Tilt degree		right		normal		left	
		m	f	m	f	m	f
Anterior Neck_ Vertex angle	subject						
	n	224	191	9	2	131	136
	%	62%	58%	2%	1%	36%	41%
Anterior Neck _ Anterior Waist angle	subject						
	n	134	105	5	1	225	223
	%	37%	32%	1%	0%	62%	68%
Anterior Neck _ Crotch angle	subject						
	n	102	63	2	4	260	262
	%	28%	19%	0.5%	1%	71.5%	80%

Table2 Paired-sample t-test of the left and right measurements. (unit：mm)

		Mean		Mean±SD		t-value	
		M (n=364)	F (n=329)	M (n=364)	F (n=329)	M (n=364)	F (n=329)
Width	Posterior Shoulder width (right)	155.70	139.817	10.69	13.55	-6.515***	-12.807***
	Posterior Shoulder width (left)	159.80	148.622	11.29	12.42		
	Posterior Shoulder width (right)-Posterior Shoulder width (left)	-4.10	-8.8045	12.00	12.47		
	Bust Breadth (right)	96.41	92.940	9.86	13.83	-7.571***	-2.180*
	Bust Breadth (left)	101.12	94.845	11.82	12.10		
	Bust Breadth (right)- Bust Breadth (left)	-4.71	-1.90	11.88	15.85		
angle	Shoulder Angle (right)	17.15	13.40	4.03	3.91	5.030***	4.671***
	Shoulder Angle (left)	15.96	16.29	4.44	4.16		
	Shoulder Angle (right)- Shoulder Angle (left)	1.19	1.12	4.52	4.33		

Table3 The independent sample t-test by gender.

Variable	Male (n=364) Mean (S.D.)	Female (n=329) Mean (S.D.)	t
Body Weight	63.79 (8.32)	56.27(8.15)	11.991***
BMI	24.28(2.82)	25.25(3.14)	-4.266***
Body fat percentage	25.42(5.95)	35.02(5.72)	-21.092***
Body fat mass	16.41(5.26)	19.94(5.40)	-8.507***
Stature	1639.34(56.98)	1513.39(57.46)	28.941***
Shoulder Height (right)	1358.22(54.24)	1243.63(48.85)	29.736***
Shoulder Height (left)	1360.03(52.03)	1243.82(49.23)	30.118***
Nipple Height (right)	1159.16(48.31)	1031.33(52.01)	33.543***
Nipple Height (left)	1160.73(48.43)	1131.50(52.31)	33.768***
most prominently for the side waist point height (right)	978.76(42.07)	897.35(40.38)	25.926***
most prominently for the side waist point height (left)	979.89(41.17)	898.65(40.95)	25.998***
Hip Height (right)	825.76(38.43)	757.05(36.76)	23.990***
Hip Height (left)	829.05(37.61)	759.05(52.51)	20.313***
Knee Height (right)	459.52(21.07)	424.51(19.74)	22.512***
Knee Height (left)	458.61(20.41)	423.41(19.40)	23.205***
Nipple Height (right) - Nipple Height (left)	-1.57(8.45)	-0.17(9.86)	-1.988*
Neck Base Width (right)	65.82(6.62)	58.65(6.38)	14.487***
Neck Base Width (left)	65.03(7.15)	59.58(6.48)	10.476***
Posterior Shoulder Width (right)	155.70(10.69)	139.82(13.55)	17.004***
Posterior Shoulder Width (left)	159.80(11.29)	148.62(12.42)	12.408***
Bust Breadth (right)	96.41(9.86)	93.20(12.98)	3.630***
Bust Breadth (left)	101.12(11.82)	94.84(12.10)	6.901***
Hip Width (left)	168.09(9.51)	166.28(10.66)	2.352*
Neck Base Width (right)- Neck Base Width (left)（mm)	0.79(11.13)	-0.93(10.35)	2.099*
Posterior Shoulder Width (right)- Posterior Shoulder Width (left)	-4.10(12.00)	-8.80(12.47)	5.058***
Bust Breadth (right)- Bust Breadth (left)	-4.71(11.88)	-1.64(15.33)	-2.926**
Anterior Neck _ Anterior Waist angle	0.62(2.26)	1.01(2.31)	-2.258*
Anterior Neck _ Crotch angle	0.85(1.43)	1.14(1.56)	-2.638**
Upper waist angle (right)	6.45(3.66)	4.09(6.67)	5.671***
Upper waist angle (left)	5.33(3.50)	3.82(5.48)	4.264***
Lower waist angle (right)	7.64(4.23)	15.82(6.51)	-19.401***
Lower waist angle (left)	9.89(5.52)	17.25(6.28)	-16.311***
Medial Malleolus_ Midpatella angle (right)	8.54(2.54)	9.14(3.08)	-2.778**
Medial Malleolus_ Midpatella angle (left)	8.24(2.59)	9.23(2.85)	-4.823***
Upper waist angle (right)- Upper waist angle (left)	1.13(4.81)	0.27(6.41)	2.003*
most prominently for the side waist point width (left)	157.96(14.27)	160.66(15.32)	-2.398*

BMI group	1.04(0.88)	1.28(0.86)	-3.701***

Figures

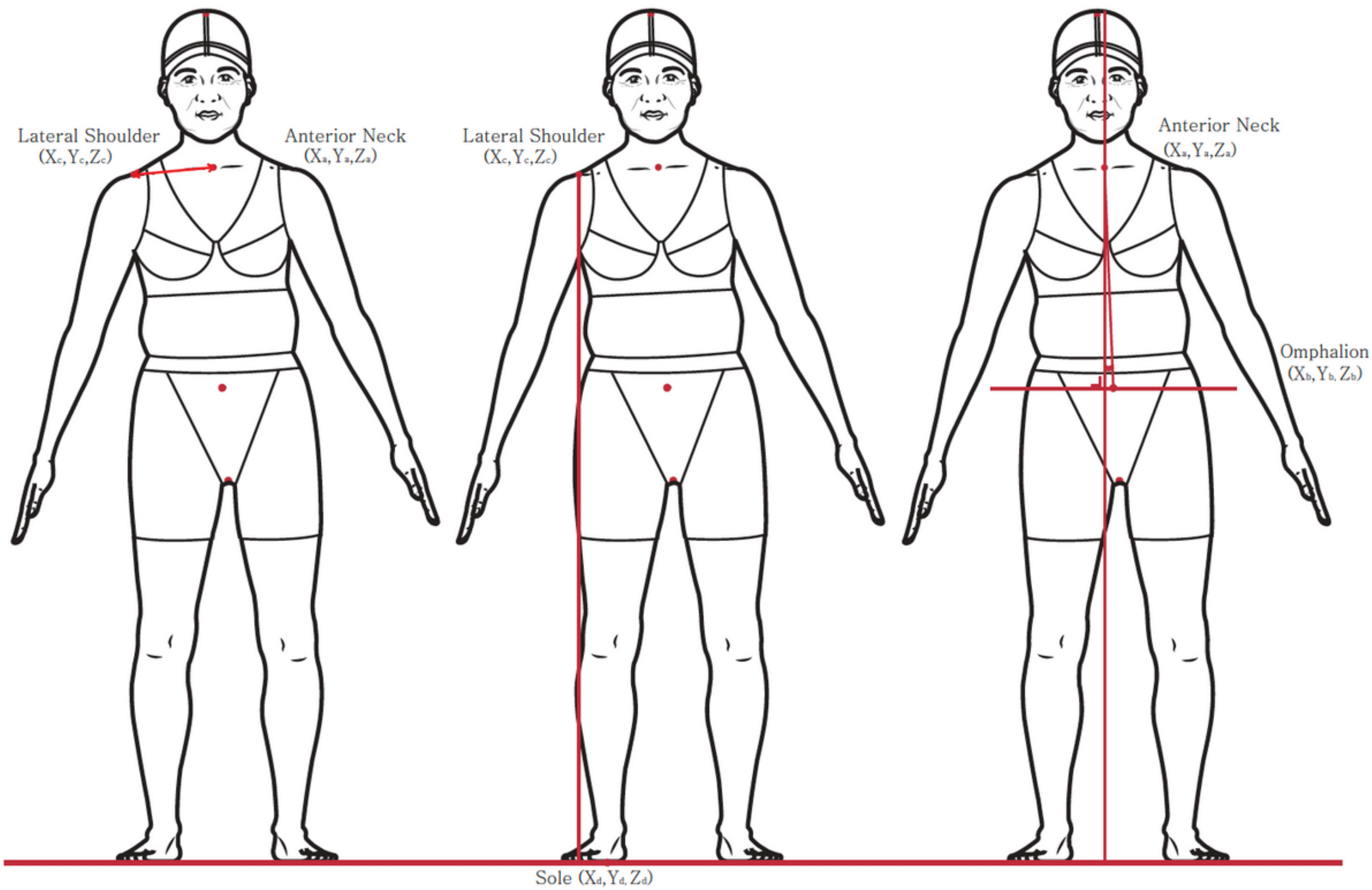


Figure 1

The width, height, and angle of all coordinate points were calculated using the formula.

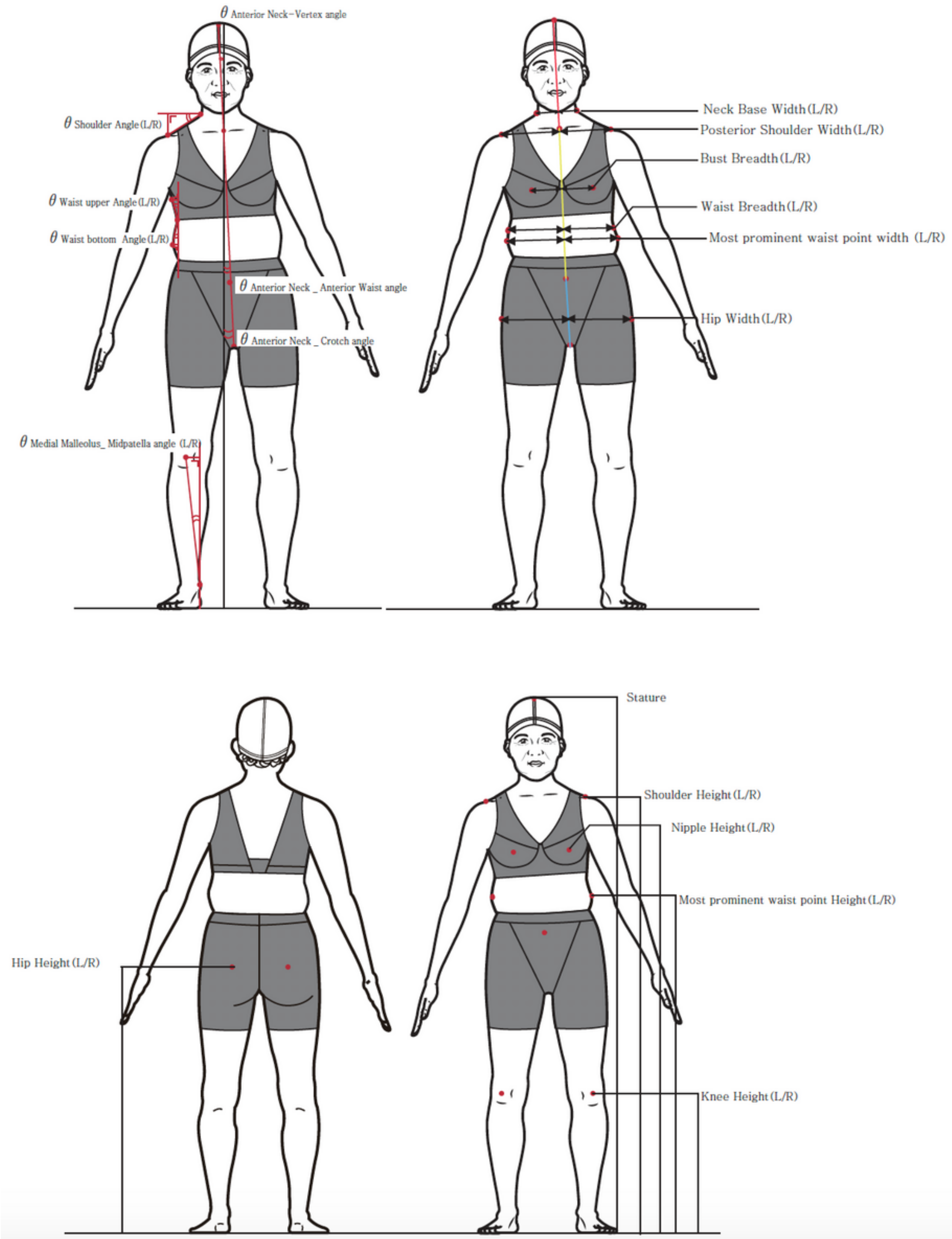


Figure 2

12 width items, 11 angle items, and 11 height items.

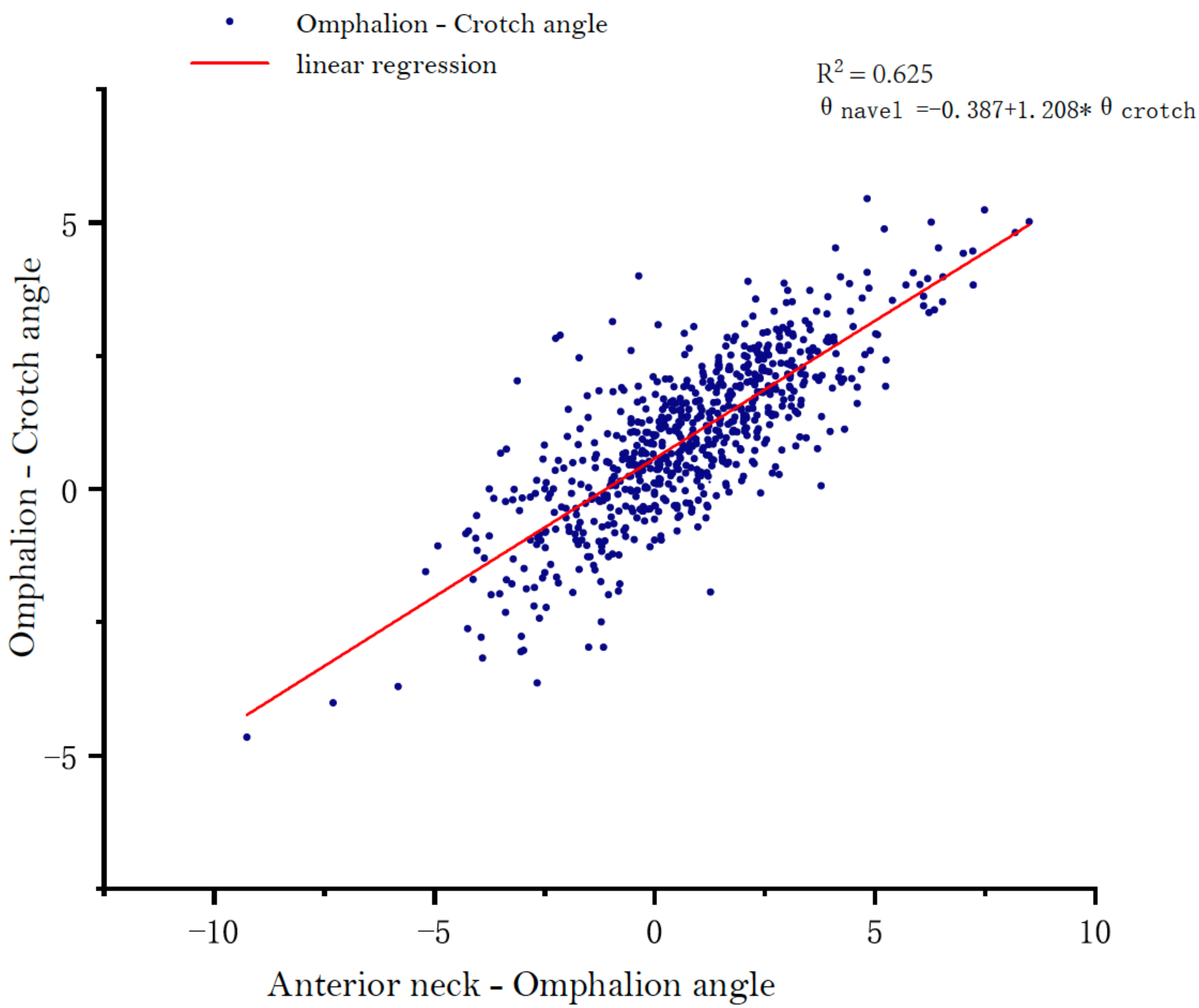


Figure 3

Regression analysis fitting graph of the crotch point tilt angle and omphalion tilt angle.