Collection of Basic Data on Thorax and Abdomen of Chinese 50th-Percentile Adult Males

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Abstract. Nowadays, body data model, as a powerful means for occupant crash protection against impact loads, has been widely used to measure and predict the injury degree of those occupants exposed to the crash or explosion of transportation tools such as cars, airplanes, spacecrafts and ships. The numerical model of thorax and abdomen, where vital important organs are accommodated, is one of the most important data sources of body parts. Through choosing the body samples of Chinese 50th-percentile adult males, this paper has, by means of CT and MRI, obtained the density data of vertebras (across both thorax and abdomen), ribs and sternums, as well as the dimensional data of main organs such as heart, liver, spleen, lung, kidney and stomach. These data are expected to serve as basic data of dummies and simulation models of Chinese 50th-percentile adult males, thus applying to the collision injury tests of motor vehicles for occupant protection.

Introduction

In the evaluation of body injuries caused by car crashes, biomechanics is the theoretical basis, and body model is an important evaluation means. Internationally, European countries, the United States and other developed countries have successively developed a series of body data models based on a large number of body feature data and a collection of collision biomechanical tests, and established the injury limit criteria based on European and American body features, thereby introducing various regulations on car crashes. However, the body data models based on European and American body features, which are much different from Chinese body features, are not completely applicable to our country's vehicle safety design. Through statistical analyses, Ren Jindong, Chen Jinghui, Lu Shanbin and Du Xiaoming obtained the main elements of male and female body size distribution in some countries, and proposed a method of describing the boundary of body size distribution and choosing key body data for ergonomic design in the light of the distribution of main elements among the multi-element body data. [1] Hu Huimin, Li Xianxue, Ding Li and Zhao Chaoyi established a finite element model for thorax and abdomen in car collision, and conducted the frontal crash tests. [2] Yin Yan, Ma Chunsheng and Lü Fang, through the thorax/abdomen MRI scanning of Chinese 50th-percentile adult male volunteers, extracted different gray values of bones and internal organs from the scans for 3D CAD geometric modeling, and thus provided basic data for body data modeling. [3] But the above studies failed to acquire basic data of thorax and abdomen. At present, the lack of body data modeling based on Chinese body features makes our country unable to formulate the regulations on impact and collision of the vehicles in collision and of other high-speed transport vehicles, thus imposing serious constraints on the competitiveness of Chinese auto makers in passive safety. Therefore, it is of great significance to develop such a model.

Body Size of Subjects

The body size data of Chinese adults lay an important foundation for the 3D numerical FEM based on Chinese body features. At present, the body size data in wide use are the data released by the relevant

national standard in 1988 and the CNIS measurements in 2009. This study takes the body features of Chinese 50th-percentile adult males as an example to compare the database established in 2009 with that in 1988, as shown in the Table 1. The result shows that, over 20 years, the body sizes of 50th-percentile adult males have changed significantly. This study will adopt the sizes in the database established by CNIS in 2009.

Tab. 1 Body Sizes of Chinese 50th-Percentile Adult Males in 1988 and in 2009

Data and year	Height /cm	Weight /kg	Bust /cm	Waist /cm	Hip /cm	Shoulder breadth /cm
Data released by the national standard in 1988	167.80	59.0	86.7	73.5	87.5	37.50
CNIS measurements in 2009	169.25	64.5	93.2	81.3	93.2	38.53

Among various body size features, height, weight and the resulting BMI index shall be given top priority. Therefore, this study takes 169.25cm (height) and 64.5kg (weight) as the basic features of 50th-percentile adult males to screen the samples of subjects. The subjects were subject to field measurement of 11 body dimensions, as shown in the Table 2.

Tab. 2 Body Size Measurements of Subjects

Height /cm	Weigh /kg	Bust /cm	Waist /cm	Hip /cm	Shoulder breadth /mm
168.20	63.3	93.0	80.2	93.1	390.2
Chest breadth /cm	**Chest depth /cm**	**Shoulder height in sitting posture /cm**	**Hip breadth in sitting posture /cm**	**Hip-knee distance in sitting posture /cm**	
33.5	23.5	56.4	36.7	53.5	

Dimensional comparison between subjects and 50th-percentile adult males

The Table 3 shows the deviations of the subjects' 6 body dimensions (height, weight, bust, waist, hip and shoulder breadth) from 50th-percentile, 45th-percentile and 55th-percentile body dimensions of Chinese adult males measured by CNIS in 2009. Meanwhile, the sample parameters of Toyota THUMS model and GM GHBMC model are compared with the statistical data of American body dimensions, as shown in the Table 4.

Tab. 3 Dimensional Comparison Between Samples and Chinese 50th-Percentile Adult Males

Data and year	Height /cm (Deviation)	Weight /kg (Deviation)	Bust/cm (Deviation)	Waist/cm (Deviation)	Hip/cm (Deviation)	Shoulder breadth/cm (Deviation)
Chinese body dimensions in 1988	167.8	59.0	86.7	73.5	87.5	37.5
Chinese body dimensions in 2009	169.3	64.5	93.2	81.3	93.2	38.5
Sample	168.2 （0.6%）	63.3 （1.8%）	93.0 （0.2%）	80.2 （1.4%）	93.1 （0.1%）	39.0 （1.2%）

Tab. 4 Dimensional Comparisons between THUMS/GHBMC Models and American 50th-Percentile Adult Males

Data and year	Height /cm (Deviation)	Weight /kg (Deviation)	Bust/cm (Deviation)	Waist/cm (Deviation)	Hip/cm (Deviation)	Shoulder breadth/cm (Deviation)
American body dimensions	175.8	79.5	100.7	87.2	101.7	41.8
THUMS	173.0 (1.6%)	77.3 （2.7%）	\	\	\	\
GHBMC	174.9 （0.5%）	78 （1.9%）	99.7 （1.0%）	92.1 （5.6%）	\	47.8 （14.3%）

The comparisons show that, the maximum deviation of the subjects' 6 body dimensions from those of Chinese 50th-percentile males is 1.4% (waist). The subjects selected by CNIS are better representative than THUMS and GHBMC, which deviate more significantly from American 50th-percentile adult males.

Density measurement of main bones in thorax and abdomen

Currently, CT and MRI are two methods used most widely in the world to obtain the sectional images of human bodies or creatures and even their stereoscopic images through the relevant techniques.

Measurement of vertebra density

The vertebras involved in this study include 12 thoracic vertebras (T1-T12) and 5 lumbar vertebras (L1-L5). The calculation formula of cancellous bone density is as follows:

$$\text{Density}=47+1.122*\text{CT, in kg/m}^3$$

To acquire the average density of cancellous bone, this study chose 6 different vertebras for measurement. For every vertebra, the CT image at the middle section was chosen, and 3 points on that section were measured. According to the results of all the measuring points, this study calculated and determined the cancellous bone density of vertebras, as shown in the Table 5.

Tab. 5 Results of Vertebra Measurement Points

Vertebra	Point 1		Point 2		Point 3		Average density
	CT value	Density	CT value	Density	CT value	Density	
1	436.42	536.6632	386.91	481.113	270.88	350.9274	456.2345
2	296.36	379.5159	331.80	419.2796	426.62	525.6676	441.4877
3	298.49	381.9058	321.23	407.4201	467.94	572.0287	453.7848
4	374.58	467.2788	359.54	450.4039	793.91	937.767	618.4832
5	472.84	577.5265	489.96	596.7351	849.38	1000.004	724.7553
6	485.49	591.7198	391.01	485.7132	804.29	949.4134	675.6155

Measurement of rib density

For the ribs consisting of both compact bone and cancellous bone, this study measured and calculated the densities of the two elements in the same way as vertebras.

For cancellous bone, the calculation formula of its density is as follows:

$$\text{Density}=114+0.916*\text{CT, in kg/m}^3$$

For compact bone, its longitudinal modulus of elasticity shall be calculated by using the following equation before determining its density:

$$E3=296+5.20*\text{CT, in MPa}$$

On this basis, the density of compact bone can be calculated according to the relationship between E3 and the density given in the literature, as shown below:

$$E3=-3.842+0.013*Density$$

The results are given in the Table 6.

Tab. 6 Results of Rib Measurement Points

Rib	Point 1			Point 2			Average density of cancellous bone	Average density of compact bone
	CT value	Density of cancellous bone	Density of compact bone	CT value	Density of cancellous bone	Density of compact bone		
1	563.1	629.7996	1543.5477	738.05	790.0544	1526.1917	709.927	1534.87
2	678.61	735.6076	1458.7477	547.01	615.0617	1449.7757	675.335	1454.26
3	559.03	626.0723	1410.9157	606.69	669.7283	1517.3157	647.900	1464.12
4	679.06	736.0201	1415.2597	587.63	652.2699	1422.3557	694.145	1418.81
5	719.78	773.3196	1431.5477	712.92	767.0358	1428.8037	770.178	1430.18
6	440.57	517.5621	1494.5357	543.46	611.8096	1492.0237	564.686	1493.28

Measurement of sternum density

The calculation results of sternum density are obtained in a way similar to rib density calculation by choosing the points on differnet sternum sections in proper order for measurement and then calculating the density in accordance with the formula given in the literature. The measurement results of sternum density are shown in the Table 7.

Tab. 7 Results of Sternum Measurement Points

Rib	Point 1			Point 2			Average density of cancellous bone	Average density of compact bone
	CT value	Density of cancellous bone	Density of compact bone	CT value	Density of cancellous bone	Density of compact bone		
1	635.98	696.55768	1596.86	488.25	561.237	1456.63	592.4038	1526.75
2	569.23	635.41468	1588.69	469.36	543.9338	1446.57	552.3873	1517.63
3	462.3	537.4668	1439.84	475.69	549.732	1450.24	506.5784	1445.04
4	498.6	570.7176	1485.25	600.68	664.2229	1556.28	585.6988	1520.77
5	522.3	592.4268	1490.32	597.6	661.4016	1552.78	595.0134	1521.55
6	477.6	551.4816	1446.56	587.6	652.2416	1547.39	569.5408	1496.98

Dimensions of main organs in thorax and abdomen

On the basis of MRI results, this study measured main organs in thorax and abdomen to obtain the dimensions of those organs. To ensure the measurement accuracy, the relevant work was done in Mimics, where the dimension boundaries could be determined through multi-directional section adjustment.

Heart. The heart size was measured as 92.80mm*89.87mm*137.87mm, as shown in the Fig.1.

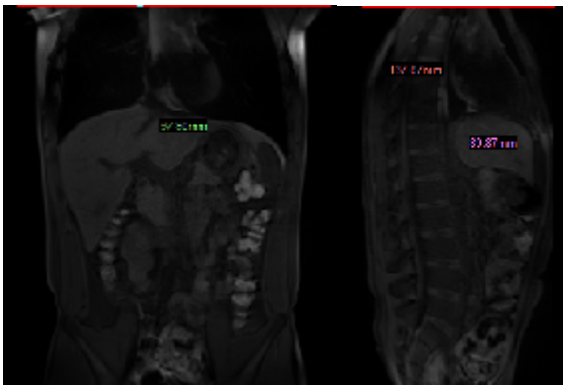

Fig.1 Measurement of Heart Size

Liver. The liver size was measured as 186.57mm*156.29mm*166.22mm, as shown in the Fig.2.

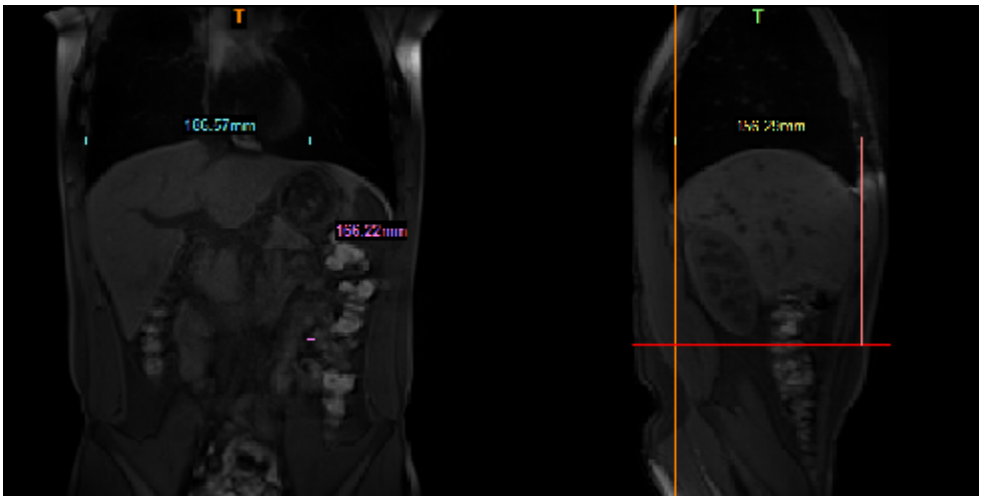

Fig.2 **Measurement of Liver Size**

Spleen. The spleen size was measured as 115.26mm*110.38mm*94.84mm, as shown in the Fig.3.

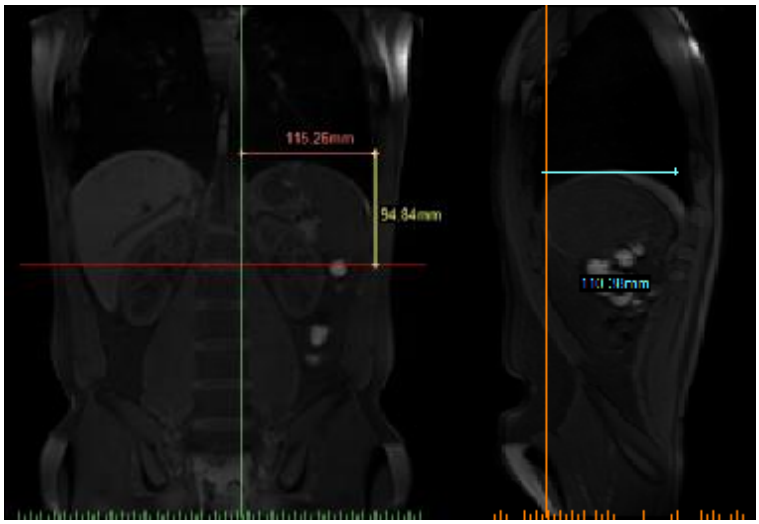

Fig.3 Measurement of Spleen Size

Lung. The lung size was measured as 111.36mm*152.38mm*163.29mm, as shown in the Fig.4.

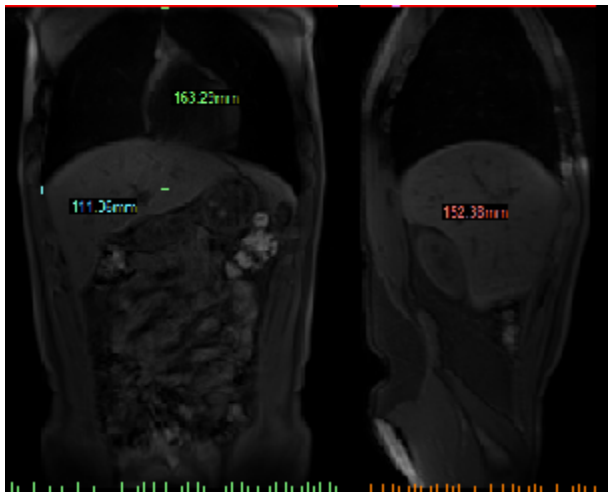

Fig.4 Measurement of Lung Size

Kidney. The kidney size was measured as 67.40mm*59.59mm*88.98, as shown in the Fig.5.

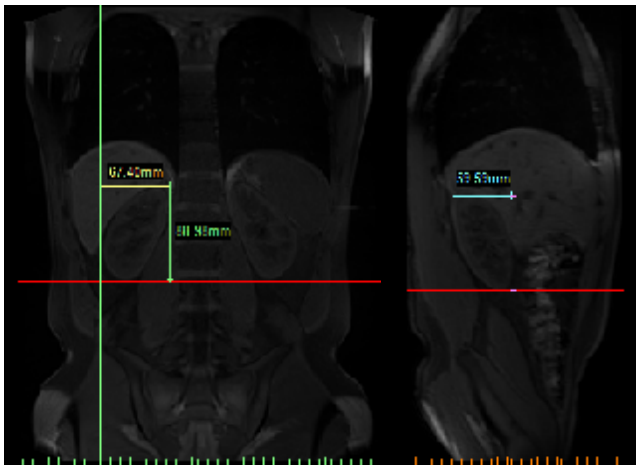

Fig.5 Measurement of Kidney Size

Stomach. The stomach size was measured as 93.77mm*36.14mm*63.56mm, as shown in the Fig.6.

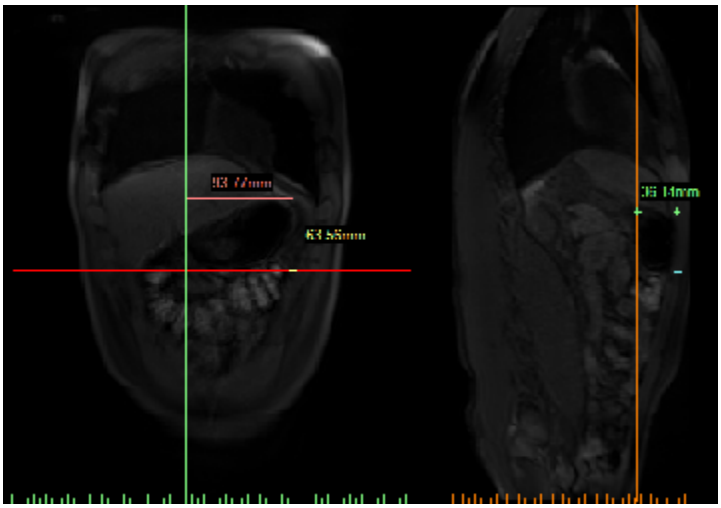

Fig.6 Measurement of Stomach Size

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