ESTABLISHMENT OF NATIONAL STANDARD FOR INERTIAL PARAMETERS OF CHINESE ADULTS

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Utilizing the database of human body measurement of Chinese adults, 128 regression equations of inertial parameters of adult human body segments were established in the study on the base of research on inertial parameters of young human body segments using the CT method. These equations includes: the binary and plural regression equations that calculate segmental mass and center of mass of adult male or a female; the binary and plural regression equations that calculate segmental and the whole body inertial moments of adult male or female. A measuring system consisting of a three-wire pendulum instrument and center of gravity plank is also devised in the study. After measuring the selected Chinese adults (80 males and 40 females), the regression equations of inertial parameters of Chinese adults are verified. A national standard was subsequently established.

KEY WORDS: national standard of Chinese adults, inertial parameters of human body, center of mass measurement, three-wire pendulum instrument, regression equations

INTRODUCTION: In order to catch up with the pace of modernization in China, the Chinese standard about inertial parameters of adults for some fields and production design in some industries is imperative. There are two existing research studies: one is the database of human body measurement of Chinese adults (GB10000, 1988), the other is the determination of inertial parameters of young human body segments by CT method (Xiuyuan Zheng, 1993). On the basic of the inertial parameters of young Chinese people, regression equations of Chinese adult segments can be established using the index of database of Chinese adults as independent variables and the constant and coefficient of the equations can be revised. If these equations are prove to be correct that the inertial parameters of Chinese adults are calculated, we may establish a Chinese standard so that other industries of China can use it in the future.

METHODS:

Subject and method: The database of human body measurements of Chinese adults includes 11164 malès and 11150 females from 16 provinces of China. The distribution of the height and weight of these subjects is similar to that of the Chinese males and females all over the country. New regression equations of inertial parameters of Chinese adult human body segments using the CT method were established according to the index of the Chinese database. 200 males and 200 females who represent Chinese adults are selected according to the distribution. A gravity plank to measure human body center of gravity were developed. Their inertial parameters are measured by the measuring system in order to revise the regression equations for Chinese adults. The constant and coefficient of regression equations were revised according to the results of the measurement. 80 male and 40 female Chinese adults were randomly selected in order to validate the new regression equations. Their age ranges from 18 to 50 years old. The inertial parameters of these Chinese adults are measured to compare with the results calculated by the new regression equations. This allowed a standard of Chinese adult inertia parameters to be established.

Instruments: Human body rotational inertia can be measured with a three-string pendulum system which consists of four parts: three-string pendulum, light-electric period testing instrument, the equilibrium regulation system, data collection system etc. All strings and circle disc and tripods are connected with three force sensors. The force of each string can be measured and transmitted with an amplifier. When the three-string pendulum rotates through a small angle, the total time for ten rotations is measured and the average period is

tested through light-electric period instrument. The rotational inertia of dish and object can be calculated with the follow formula: $J_z = \frac{R^2T^2G}{4\pi^2H}$

R stands for the radius of the circle through the ends of three strings, T stands for the rotation period,G stands for the weight of disc and object, H stands for the length of the string.

Figure 1 Measure the frontal axis through his mass of center.

Figure 2 Measure the sagittal axis though his mass of center.

Figure 3 Measure the rotational inertia of longitudinal axis of the sitting posture.

Figure 4 Measure the mass center of the body.

Three postures are selected: lie on one's side (Figure 1), lie on one's back (Figure 2) and sitting (Figure 3). The rotational inertia of frontal axis though his mass of center is measured when the object lies on his side. The rotational inertia of sagittal axis though his mass of center is measured when the object lies on his back. The rotational inertia of longitudinal axis of the sitting posture is measured when the object is sitting on a stool. The relative error of the measurement of the three-string pendulum system is less than one-thousandth. The mass center of the body is measured with the gravity plank (Figure 4). Three pressure sensors are distributed in iso-triangle. The 2-D mass center of the body (Xc and Yc) can be measured quickly using this instrument. The average error of Xc is 3.3‰; the average error of Yc is 1.5‰. The data collection and calculation: the data collection instrument can receive and store the measure data that can also show in monitors. The software is programmed to calculate the data and make statistics.

Table 1 The mean of inertial parameters of segments and whole body of Chinese adults.

segment	Male(subject=11164)					female(subject=11150)				
	Mass	m.c.	Ix	Iy	Iz	mass	m.c.	Ix	Iy	Iz
head	5.16	117.8	32329	33827	18762	4.38	111.8	25830	25672	12438
Upper trunk	10.07	115.6	114913	66578	107599	8.73	107.4	45073	70563	58827
Lower trunk	16.30	177.8	308105	277666	123524	14.67	178.7	208697	218926	75147
thigh	8.50	254.5	135388	137902	24926	7.52	244.5	102537	105751	19832
crus	2.20	224.1	21566	21344	2412	2.36	197.6	20092	20634	2407
Upper arm	1.46	163.3	11478	11855	1552	1.42	151.4	9984	9382	1423
Fore arm	0.75	136.6	2913	2821	738	0.61	124.9	2205	2139	498
Whole body	59.90	734.2	9222809	9479466	637993	52.39	698.7	7517344	7032832	468254

Notes: The m.c. is the center of the segment, which measuring point is from the far side of the segment. The m.c. of the whole body is from the vertex. Ix is the rotational inertia through coronal axis; Iy is the rotational inertia through sagittal axis; Iz is the rotational inertia through vertical axis. Unit of the mass is kilogram. Unit of center of mass is millimeter. Unit of the rotational inertia is $kg \cdot mm^2$.

RESULTS: The standard of inertial parameters of Chinese adults includes 168 regression equations. It includes: the binary regression equations that calculate segmental mass and center of mass of adult male or female by weight and height (40); the regression equations that calculate segmental mass and center of mass of adult male or female (40); the binary and plural regression equations that calculate segmental and the whole body inertial moments of adult male or female (88). The independent variables of the plural regression equations are total 31. The inertial parameters of 80 Chinese males and 40 Chinese females were calculated through the regression the standard equations and compared with the current results measured by the instruments. The average relative error of the mass of the males was 0.531% and that of the females was 0.470%; The average relative error of the center of mass (vertical axis) of the males was 0.405% and that of the females was 2.138%; The average relative error of rotational inertia through coronal axis of the males was 4.049% and that of the females was 4.124%; The average relative error of rotational inertia through sagittal axis of the males was 4.455% and that of the females was 3.732%; The average relative error of rotational inertia about the longitudinal axis in the sitting posture of the males was 9.244% and that of the females was 8.419%. The mean of inertial parameters of segments of the 11164 Chinese males and the 11150 Chinese females are shown in table 1.

CONCLUSION: This standard is established on many national standards of China, which have the same measurement items and independent variables of regression equations. It has better compatibility and applicability and can be used in many industries and fields conveniently. It has been proved to be valid and correct in the fields of aeronautics, astronautics and sports. It is suggest that more industries and research fields use this national standard in the future, especially in the field of scientific research of sports.

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