

Comparison of Current ATDs with China's Adult Population in Anthropometry

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Abstract: Crash test dummies are full-scale anthropomorphic test devices (ATDs) that simulate the dimensions, weight proportions and articulation of the human body, and are used to measure human injury potential in vehicle crashes. The Hybrid-III dummy family which is widely used currently refers to selection of the respective percentiles of U.S. adult males and females as design targets. Based on the Chinese National Physical Fitness Surveillance for the year 2000, 2005, 2010 and Chinese standard GB/T 10000-1988, a series of anthropometric parameters for Chinese adults were obtained, and data analysis was conducted between the population of China and of ATDs design targets. The results show that there are obvious distinctions between the current ATDs and the recent China population in anthropometry. For 50th-percentile female, the stature is about 2.6% shorter than the ATDs design targets and the body weight is about 8.03% lighter. For 50th-percentile male, the stature is about 3.59% shorter and the body weight is about 10.52% lighter, despite there is a tendency that Chinese adults are becoming higher and heavier with time goes on. The implications of these differences will provide an important reference for designing and optimizing vehicle restraint system for Chinese passengers.

Keywords: anthropomorphic test devices, anthropometry, China's adult population, ATDs design targets

1 Introduction

In order to evaluate the vehicles' ability to protect occupants in motor-vehicle crashes, anthropomorphic test devices (ATDs) of different titular percentile values are used in crash tests. For example, the Hybrid-III family is involved in crash tests of FMVSS, NCAP and other standards or regulations all over the world. Likewise, the Hybrid-III 50th-percentile male dummy is the most widely used ATD for frontal collision testing in China, which simulates the dimensions, weight proportions and articulation of the midsize American male body^[1]. There is no doubt that human dimensions of Chinese adults are different from those of American adults, but the quantitative analysis of the difference between current ATDs with china's adult population in anthropometry has not been presented.

The anthropomorphic test devices (ATDs) are usually developed in a 4-step process ^[2]. First, the reference population is selected. For the Hybrid-III adult dummy family, the general American adult population was used, both males and females. Second, among these reference dimensions, stature and body weight are chosen. Third, target percentiles are selected based on the desired size of the ATD ^[3]. The Hybrid-III adult dummy family was designed to target the 5th, 50th, 95th percentiles of U.S. population, separately, for stature and body weight. Forth, besides stature and body weight, other dimensions of the ATD are obtained from detailed anthropometric data from individuals similar in size to the reference dimensions.

Although the reference dimensions of the Hybrid-III adult dummy family are based on the anthropometric parameters of American adult population, there are still some disparity between the dimensions of the ATDs and the reference dimensions for manufacturing technique reasons. For example, the weight of the 50th-percentile male design target is 77.0 kg, but for that reasons the hybrid-III 50th-percentile male is 77.65±1.18kg. In order to eliminate this influence, the data of the hybrid dummy family design target were used rather than the real dummies' parameters in comparisons.

In this article, general trends of stature and body weight for Chinese adults are presented using data from surveys

in 1988, 2000, 2005, 2010 (current). The current Chinese adults' anthropometric parameters are compared with the reference values for the Hybrid-III family of ATDs.

2 Materials and Methods

The data which were used to design the Hybrid-III dummy family were obtained in 1974 by collecting the dimensions of U.S. adult population, and the corresponding data of China's adult population were obtained from the Chinese National Physical Fitness Surveillance (CNPFS) and Chinese standard GB/T 10000-1988 (Human Dimensions of Chinese Adults).

The Chinese National Physical Fitness Surveillance (CNPFS) is a continuing probability of China's population that gathers several anthropometric dimensions among hundreds of health-related variables, such as stature, body weight and so on. The CNPFS release data every 5 years, beginning in 2000.

In this article, the CNPFS data of 2000 were got from *Report on National Physical Fitness Surveillance (2000)*, number of samples is 25,687. The CNPFS data of 2005 were got from *Report on the second National Physical Fitness Surveillance*, number of samples is 163,448, which were published by PEOPLE'S SPORTS PUBLISHING HOUSE OF CHINA. The CNPFS data of 2010 were obtained from *Bulletin on National Physical Fitness Surveillance (2010)*, which presented on the website of the General Administration of Sport of China, number of samples is 155,054.

To assess the trends of China population anthropometry over time, the stature and body weight of 50th percentile male and female were selected from Chinese standard GB 10000-1988 for year of 1988, and CNPFS reports for year of 2000, 2005, and 2010 (current). In order to compare the stature and body weight of the Hybrid-III adult dummy family with the dimensions of China's adult population, the statures and body weights of dummy design targets were obtained from published tables for the 1974 National Health and Nutrition Examination Survey II (Abraham et al. 1978).

The reference stature and body weight for each Hybrid-III adult ATD were the dummy design targets size of 1974. CNPFS reports have only stature and body weight of 50th percentile male and female, so that this article only compare these data of the Chinese with the U.S. population's data of 1974. Although 50th percentile female Hybrid-III ATD is not available currently, midsize female is also an important part in evaluation the injury risks for the female in the frontal collision, so 50th percentile male and female are all included in comparison.

3 Results

Table 1 lists the 50th percentile male and female values of stature and body weight for Chinese adults of year 1988, 2000, 2005, and 2010. For 50th-percentile female, stature raises only 0.4% (6mm) during 22 years. But for male, stature raises 0.7% (12mm). For the change of body weight, the 50th-percentile male and female increased 16.78% (9.9kg) and 10.19% (5.3kg) respectively. Comparatively speaking, the 50th-percentile population's body weight values increased markedly; especially from year 1988 to 2000. The fact that the dimensions of Chinese adults are changed rapidly during the past two decades provides a huge influence on the automotive safety system design.

Table 1. Stature and body weight of Chinese adults

Year	50 th -percentile female		50 th -percentile male	
	Stature*	Body weight**	Stature*	Body weight**
1988	1570	52.0	1678	59.0
2000	1574	56.1	1685	65.5
2005	1574	55.8	1687	66.4
2010	1576	57.3	1690	68.9

* The unit of stature is millimeter.** The unit of body weight is kilogram.

Table 2 lists the stature and body weight for the Hybrid-III adult dummy design targets. Table 3 describes the ratios which show the distinction of stature and body weight values between Chinese adult population with the target stature

and body weight for the Hybrid-III ATDs.

Table 2. Reference stature and body weight for the Hybrid-III adult ATDs (U.S. population data)

Year	50 th -percentile female		50 th -percentile male	
	Stature*	Body weight**	Stature*	Body weight**
1974	1618	62.3	1753	77.0

* The unit of stature is millimeter.** The unit of body weight is kilogram.

Table 3. Comparison of reference stature and body weight for the Hybrid-III adult ATDs with Chinese 50th adults

Year	50 th -percentile female		50 th -percentile male	
	Stature variance*	Body weight variance**	Stature variance*	Body weight variance**
1988	2.97%	16.53%	4.28%	23.38%
2000	2.72%	9.95%	3.88%	14.94%
2005	2.71%	10.43%	3.76%	13.77%
2010	2.60%	8.03%	3.59%	10.52%

*The formula of stature variance is.**The formula of body weight variance is.

Analyzing these data listed above, the current stature percentile values for Chinese adults are slightly lower than the reference values. For example, the reference stature for the midsize male ATD is 1753mm, and Chinese male midsize stature is 1690mm in 2010, the variance of stature is only 3.59%. Same to the midsize male stature, the midsize female stature also maintains about 3% shorter than the reference midsize women stature. Even though the diversity of stature is small, the difference is larger for the body weight. The U.S. 50th-percentile male body weight is 77.0kg in 1974, compared with the Chinese value for the midsize male of 68.9kg in 2010. The variance is 10.52%, the body weight of U.S. midsize men is much heavier than that of same percentile Chinese men and same to the 50th-percentile women. Even though with time going, Chinese population is become heavier and taller, and the anthropometric values are closer to the reference values of current Hybrid-III ATDs, but is still lighter and shorter than the Hybrid-III adult ATD.

Table 4. Comparison of stature and body weight for the Chinese 50th males with the U.S. 50th males

Year	Stature*			Body weight**		
	Chinese 50 th males	U.S. 50 th males***	variance*** *	Chinese 50 th males	U.S. 50 th males***	variance*** *
1990s	1678	1755	4.4%	59.0	79.8	26.1%
2010s	1690	1761	4.0%	68.9	85.4	19.3%

* The unit of stature is millimeter.** The unit of body weight is kilogram.*** The values from .Reed et al. (2013)**** The formula of variance is.

Table 5. Comparison of stature and body weight for the Chinese 50th females with the U.S. 50th females

Year	Stature*			Body weight**		
	Chinese 50 th females	U.S. 50 th females***	variance**** *	Chinese 50 th females	U.S. 50 th females***	variance**** *
1990s	1570	1618	3.0%	52.0	65.5	20.6%
2010s	1576	1622	2.8%	57.3	71.0	19.3%

* The unit of stature is millimeter.** The unit of body weight is kilogram.*** The values from .Reed et al. (2013)**** The formula of variance is.

Table 4 and Table 5 list the comparisons of Chinese 50th males and Chinese 50th females with U.S. 50th males and U.S. 50th females, respectively. The main difference lies in body weight the same as what is discovered above.

Although as time goes on, the difference decreases, there is still an obvious divergence (about 19%) in body weight between Chinese 50th adults and U.S. 50th adults.

4 Discussion

Different percentile ATDs used in the vehicles or restraint systems testing must in some way represents the whole population of vehicle drivers and passengers. Superficially, ATDs can only accurately represent the individuals whose dimensions are similar to those of ATDs. Currently the most widely used ATDs for frontal collision in China is the Hybrid-III adult dummy family. According to analysis in this article, the anthropometry parameters for which the Hybrid-III adult dummies were designed have significant difference with the dimensions of Chinese population, which suggests that these ATDs may not be sufficiently representative of the Chinese population.

Discovering the difference of anthropometry parameters between the currently used ATDs and the Chinese adult population has a positive influence on the vehicle design and testing efforts. If a certain percentile ATD is considered to represent some individuals during design efforts, the optimal design could be fit these people well. That is to say, if engineers are clear about the difference between the current ATDs and the Chinese population, the designs of vehicles and restraint systems can focus on fitting Chinese population, the real users in China roads.

The difference in body weight between the China population and the ATDs design targets over the past 20 years have become smaller and smaller, but also maintain 10% disparity, and the main difference is lay on the body weight. For a particular crash scenario, the ATD's body weight is associated with the passive safety device, such as energy dissipation of power-absorbing, compliance of the car seat, belt restraints, air bag, and other vehicle components. If the passive safety device designed for a heavier ATD, they may not fit the lighter passenger. The air bag inflators may become higher-output, and the pre-tightening load of belt system may become bigger. From this perspective, vehicle safety performance engineers should not underestimate the difference of body weight when design vehicles for markets in China.

Chinese adults are about 3%~4% shorter than the ATDs design targets for different percentile. Different statures between Chinese adults and ATDs design targets leads to different dimensions of upper limbs, lower limbs and other parts. All of these dimensions determine the locations of the body regions that are targeted by the restraint systems, particularly the head, knees, and torso^[3]. Even though the difference in body dimension between Chinese adults and the Hybrid-III dummy design targets is small, the difference of somatotype is obvious, particularly in the pelvis and chest regions. The current ATD shapes represent people who are more obese than Chinese adults, with wider shoulder and longer torso.

The future research for occupant protection in China should focus on reducing injury risks by optimizing currently used ATDs to meet Chinese population dimensions, and protections for obese occupants should be pay more attention because there is a prominent increase for Chinese adults body weight in past two decades.

Acknowledgements

This study was sponsored by the National High Technology Research and Development Program of China “863 Program” No. 2012AA111802 and Independent Research Topic of State Key Laboratory of Advanced Design and Manufacture for Vehicle Body, Hunan University No. 51275001.

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