



# Size North America – The New North American Anthropometric Survey

Thorsten Kuebler<sup>(✉)</sup>, Andre Luebke, Jamie Campbell,  
and Tim Guenzel

Human Solutions of North America, Inc., Morrisville, NC 27560, USA  
contact.usa@human-solutions.com

**Abstract.** Size NorthAmerica is the new North American anthropometric survey, the latest and most representative survey of 18,000 men, women, children and elderly people of the United States and Canada. It is the largest civilian size study to date that provides over 100 body measurements, compliant with ISO 8559 and ISO 7250, and extensive socio-demographic information of all participants. For the first time ever, a representative number of children 6–18 and elderly people >65 years is collected. It is also the only size survey that includes a representative amount of people with different ethnic backgrounds from different regions of both countries.

The size survey has been conducted over the last two years by Human Solutions of North America, Inc. partnering directly with industry and universities. The United States portion is finished, and data is available. 14,460 persons have been scanned and surveyed across the USA. A data pool of 57,840 whole body scans, far more than double the number of scans compared to any other survey. These representative results form the basis for an up-to-date anthropometry database including a secular growth prognosis model which will last until 2040. All data is delivered by means of the online-portal iSize, easily accessible through [www.portal.i-size.net](http://www.portal.i-size.net). The portal provides partnering companies access to all results, with comprehensive functionality for data analysis. The purpose of this paper is to give an overview on the still on-going project and to describe the data that has been collected and processed so far for the USA population.

**Keywords:** Size NorthAmerica · Anthropometry

## 1 Introduction

Anthropometry plays an important role within the area of Human Factors and Ergonomics. It is important for consumer product design and workplace design alike. Especially in the application of Digital Human Modeling (DHM) anthropometry is one major input to build accurate virtual human representation. In the early stages of human modeling back in the 80s, available anthropometric data was insufficient for the complete definition of a comprehensive 3-D human figure model. To create the RAMSIS model Seidel 2004 reports that in the beginning they had to overlay 2 and 3-D data images and adjust length, thickness, and circumferences of each human body element until the scanned data was completely congruent with the corresponding digital human

model [1]. Today DHM tools are widely used in the industry. Various tools are available. The human figure models are based on available anthropometric data. In many cases, due to the lack of specific measurements, values to build the models have to be extrapolated.

To provide good ergonomics, safety and comfort for the end-user, the correct anthropometry layout for products and workplaces is essential. Product and workplace designers need accurate and up-to-date anthropometric data of their actual target population to provide the best solutions that are appropriate for their customer's needs.

To date, available anthropometric data sets are not satisfying. Not only in terms of accuracy for the creation of 3-D DHM. For various studies it is questionable if they are actually representative. Prior studies lack critical groups like children and elderly people. Furthermore, the population has changed significantly within the last decades. The increase in overweight and obese individuals has affected 70.7% (2013/2014) and 71.6% (2015/2016) of 20-year-old adults, as reported by the National Center for Health Statistics [18]. It can be questioned if other surveys reflect these changes especially for surveys that involve military personnel.

In order to provide the industry with representative and up-to-date anthropometric data, it is the goal of Size NorthAmerica to:

- Collect appropriate data for technical ergonomics and apparel design
- Collect data of age groups between 6–75 years
- Represent regional and ethnic diversity
- Include extensive socio-demographic information
- Surveying consumer satisfaction and trends
- New acceleration prediction for future trends
- Make data accessible from anywhere via iSize web portal

The purpose of this study is to assess the anthropometric evolution of the USA and Canadian population. A longitudinal study of nearly 18.000 men, women and children from 6 to 75 years is performed to get a comprehensive look at today's population to provide vital information of body shapes and sizes to the industry. The study will meet and exceed any requirements for products in Automotive, Apparel, Consumer, Digital, Medical and Military industries.

## 2 Methods

The objective of Size NorthAmerica is the acquisition of true, representative data for the North American population for use in technical ergonomics primarily in the apparel and transportation industries. Three key methods have been defined for the concept of the serial measurement collection [15]:

1. Measurement must take place solely with the help of body scanners in accordance with the ISO 20685. Standard body shapes must also be analyzed as a supplement to body dimensions.

2. The analysis of the body dimensions must take place in compliance with the market standards for technical ergonomics in accordance with ISO 7250 and for the apparel industry in accordance with ISO 8559.
3. The results are made available in the form of a web-based, interactive data portal, enabling companies to carry out product-specific analyses online. The guidelines of the ISO 15535 were also incorporated.

## 2.1 Assure True and Representative Data Collection

The United States of America, with a population estimate of around 330M (United States Census Bureau, population estimate, July 1<sup>st</sup>, 2018, (V2018)) [17], is the 3<sup>rd</sup> largest population in the world. Only 6.1% of the population is in the age 5 years and under, 22.6% is 6–17 years that is an interesting market of 50 Million young people. The main portion of the population is 18–65 years, 205M. Elderly people 66–80 years represent 16.7%, 37M. Consequently, these subpopulations 6–18 and >65 years represent around 30% of the consumer market. The US market is constantly growing, with a 6% growth from 2010 to 2018 and a population projection of over 400M in 2060. Natural increase in average is around 545 thousand per year (US fertility rate 1.9) and net international migration is over 1 Million per year. The United States is a country with large ethnic diversity. With further immigration the market becomes more diversified. The ethnic diversity of the US population shows regional differences from the West to the Northeast, the Midwest and the South [17].

In order to collect a representative sample size for all these different aspects of the population, the concept incorporates recommendation of the ISO 15537 (Principles for Selecting and Using Test Persons for Testing Anthropometric Aspects of Industrial Products and Designs). The population was divided into subpopulation by gender, age and region. The overall number of sampling groups is 108 (2 (gender) \* 9 (age groups) \* 6 (regions) = 108). With age strata of 6–10, 11–13, 14–17, 18–25, 26–35, 36–45, 46–55, 56–65, 66+. The regions are 4 regions in the United States (Northeast, Midwest, South and West) and two regions in Canada (Quebec and Non-Quebec).

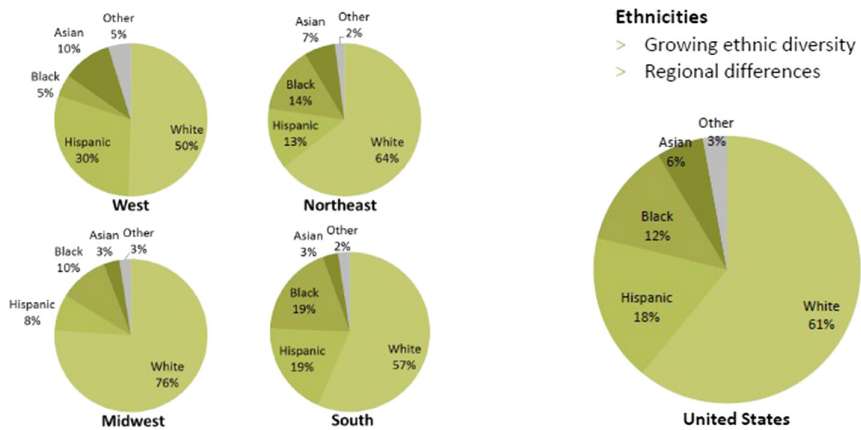
Ethnicity diversity was not a separate stratum but covered by collecting scans in different regions (see Fig. 1).

Based on the accuracy requirements of  $\alpha \pm 10$  mm for body height and 95% confidence ( $c_{\%}$  is 1.96) the minimum sample size for each subpopulation was calculated using formula 1. The total number of persons is  $n_{Size\ NA} = 17,820$  subjects (2).

$$n = \left( c_{\%} * \frac{\sigma_{stature}}{a} \right)^2, \sigma_{stature} = 65.5 \text{ mm} \quad (1)$$

$$n_{Size\ NA} = gender * age\ groups * regions * n \quad (2)$$

Each combination of gender, age and region will be kept as one category. The quality assurance reviewed the participant demographics on a regular basis to ensure that sufficient data is collected to accurately represent each group. Recruiting of the participants was done parallel through local advertisement at the scanning locations, flyers and handouts, social media, media coverage and in cooperation with partner



**Fig. 1.** United States – population facts

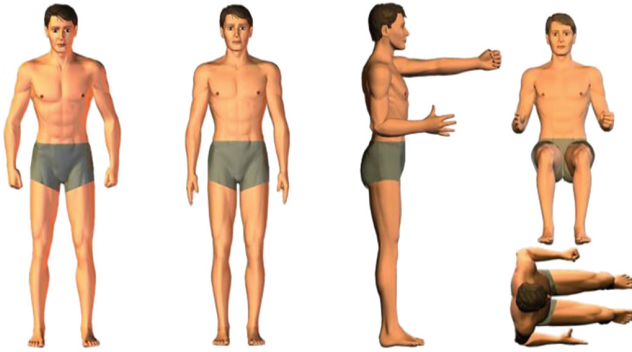
companies and market research institutions. To ensure the intended active sampling strategy, it was necessary to invite participants with specific characteristics to fill up all groups equally. The partnering market research institutions have a vast database of people who want to participate in research studies. This partnership allowed an efficient and accurate connection between Human Solutions of North America and specific test persons. Different incentives were given to each participant depending on the scanning location and specific needs.

## 2.2 Measurement Technology and Procedure

The ISO Standard 20685 (3-D scanning methodologies for internationally compatible anthropometric databases) was introduced in 2006. The standard specifies the technical requirements for the measurement equipment in the acquisition of human body shape data and measurements that can be extracted from 3-D scans [6]. The intended audience is everybody who uses 3-D scanners to create 1-D anthropometric databases as well as the users of 1-D anthropometric data from 3-D scanners.

Data acquisition is based on highly accurate 3D body scanners. All body dimensions are extracted from 3D body surface data. The scanning equipment used in the Size NA study are VITUS Smart XXL body scanners together with ANTHROSCAN software from Human Solutions. The equipment is compliant with ISO 20658 and has been used in previous size studies. The VITUS Smart XXL is a four-column, 3D body scanner which uses the optical triangulation measurement principle (laser technology and 100% safe for the eyes). The 8 sensor heads have a measuring range of 2100 mm height, 1000 mm depth and 1200 mm width (see ISO 20685). The level of accuracy of the system is very high - it has an average error (circumference) of less than 1 mm. Within just 12 s of scanning time, the sensors capture a density of 27 points/cm<sup>2</sup>; approx. 550,000 3D points for each person are thus measured. Yet another advantage the system has mobility. The weight of the measuring columns is less than 100 kg and the floor space required is only around 4.8 m<sup>2</sup>.

ISO 20685 suggests scanning poses for an accurate extraction of all necessary body measures specified in ISO and ASTM standards. Figure 2 shows the four scanning poses that were used in the study. The test persons had a visual instruction inside the scanner and the scan operators described verbally each pose. After each scan the scan PC showed the scanning result and the operator checked the result for correct posture of the test person and eventual artefacts. If a problem was found the pose was rescanned. In addition all scans were checked for correct posture and artefacts by a separate person on a daily basis. Using a standardized quality assurance document each scanning operator got a daily feedback on the results of the previous day.



**Fig. 2.** Four scanning poses: standard, relaxed, reach and sitting pose

Together with the scanning procedures all participants had to submit a questionnaire with extensive socio-demographic information. This additional data and information of the test subjects provides a realistic profile of how physical and characteristic data correlate amongst the participants.

Participants had to fill out the questionnaire prior to their scheduled scanning date. The survey questionnaire was completely anonymous, no personal data is registered during the process.

The final quality control of the scanning data and the extraction of the body measurements and data processing was done at the Human Solutions headquarters in Germany by body scanning specialists and statisticians. The ANTHROSCAN software has been used in various size surveys all over the world and has proven its capabilities to process scans and extract 1-D and 2-D measurements accurately, quickly and cost efficient. The advantage of this method compared to traditional measuring is that there is no physical contact that can lead to compression of tissue and reading errors such as parallax and estimation. The extracted measurements were compiled in a Size NorthAmerica database that is now available through the iSize web portal.

### 3 Results

#### 3.1 Survey Status

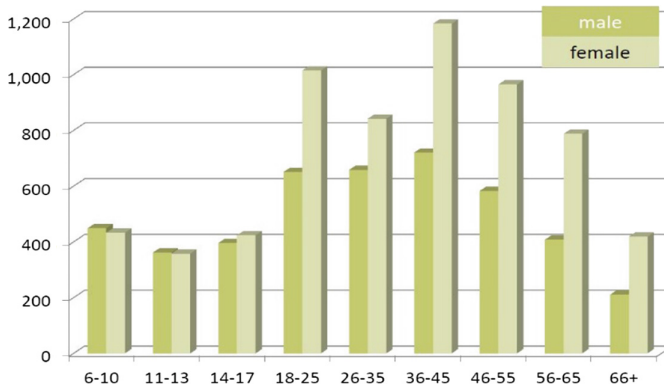
The results presented in this paper are a status report as of November 15<sup>th</sup>, 2018. Remaining data sets are currently processed, and measurements are extracted. The complete USA dataset will be available in early 2019. The vast demographic information of all test subjects and the remaining measurements will be implemented into the iSize web portal. The data for the Canadian population will be available by the end of 2019. Another 6,000 persons are to be surveyed and scanned until September of 2019.

The survey for the US population has been completed on November 3<sup>rd</sup>, 2018. 14,460 persons participated in various locations at different events across the United States.

Over two years the project raised attention of the media. Local Broadcasting stations interviewed participants and scanning operators who presented the scope of the project and the 3-D body scanning technology.

#### 3.2 Data Analysis

The following results have been analyzed based on a subset of 10,866 subjects that already have been quality assured, processed and implemented into the web portal iSize. This data is now available, partner companies of the apparel and transportation industry are already working on updating their size tables and gradings as well as their digital human models. In total the data pool contains a number of 57,840 3-D body scans. The analysis of the demographic composition of the survey data shows a higher number of female participants. 6,427 in this first data set are females, 4,439 males. This corresponds to 59% female participants and 41% male participants. Data sets with other information than male or female were not included into the results. The following diagram shows the demographic composition for the 6 adult and 3 children age groups (Fig. 3).



**Fig. 3.** Age distribution

To represent the geographic differences and the differences in the ethnical composition, body scans were gathered in 4 regions of the United States in the Northeast, Midwest, the South and the West. The following diagram shows the number of scans that were collected in these four regions (Fig. 4).

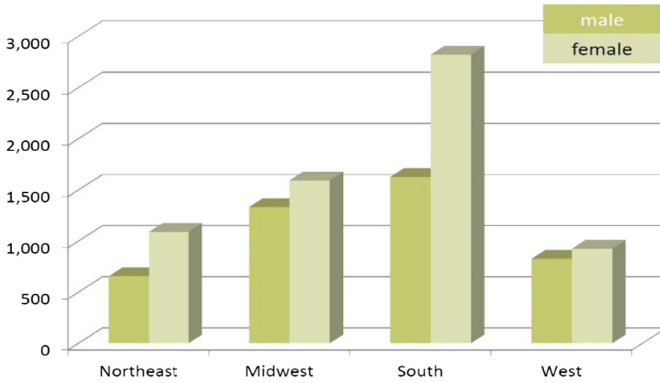


Fig. 4. Regional composition of the size survey

The largest group was the Non-Hispanic White ethnic group with 2961 females and 2220 males. The second largest ethnic group were African-Americans with 1509 females and 888 male participants. Data from 1955 Hispanic persons includes 1180 females and 775 males, 789 Americans with Asian background (454 females, 335 males) and 221 other ethnicities have participated (Fig. 5).

10,866 data sets have been processed

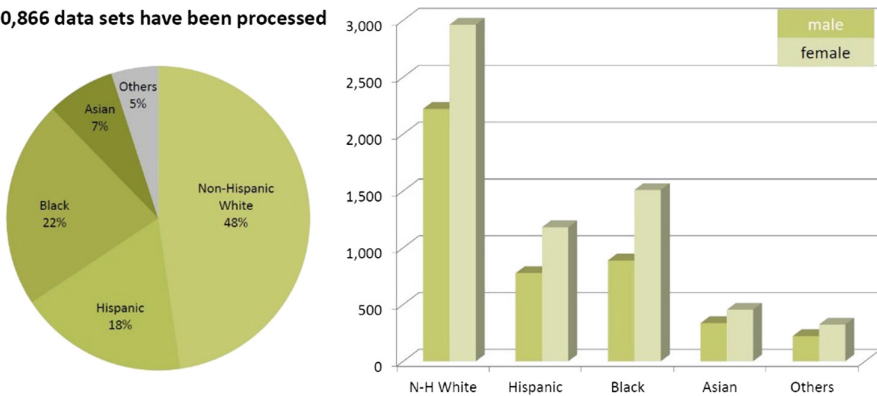


Fig. 5. Representation of ethnicity groups

Body measurements that have been extracted from the 3-D body scans are compliant with the technical standard ISO 8559 for apparel and ISO 7250 for ergonomics. In total, 38 body measurements for the application in apparel design and 42 body

measurements for ergonomics have been extracted. Furthermore, several body measurements have been extracted especially for the RAMSIS DHM software to generate 3-D digital human figure models. The following tables show the different body measurements that are available in iSize (Table 1).

**Table 1.** 38 body measurements have been extracted for application in apparel design in compliance with ISO 8559, 42 body measurements for ergonomics in compliance with ISO 7250 and to generate digital human models in the ergonomic design software RAMSIS.

Body measurements Apparel		
BMI	Knee Girth	Shoulder Slope
Back Width	Knee Height	Thigh Girth
Bust/Chest Girth	Lower Knee Girth	Total Crotch Length
Bust/Chest Height	Maximum Waist Girth	Trunk Length
Calf Girth	Middle Forearm Girth	Upper Arm Girth
Cervical Height	Middle Hip	Upper Arm Length
Cervical to Knee Hollow	Minimum Leg Girth	Upper Knee Girth
Crotch Length Front	Neck Base Diameter (front view)	Waist Girth
Elbow Girth	Neck Base Girth	Waist Height
Head Girth	Neck Girth	Waist to Hip
Height	Outside Leg Length	Weight
Hip Girth	PROP Waist Girth / Hip Girth	Wrist Girth
Inside Leg Length	Shoulder Length	
Body measurements Ergonomics		
BMI	Crotch height	Thigh clearance, sitting
Head breadth	Chest depth, standing	Knee height, sitting
Head height	Body depth, standing	Abdominal depth, sitting
Head length	Chest breadth, standing	Thorax depth at the nipple
Foot breadth	Hip breadth, standing	Buttock-abdomen depth, sitting
Upper arm length	Sitting height (erect)	Forearm-fingertip length
Foot length	Eye height, sitting	Buttock-popliteal length (seat depth)
Chest breadth	Cervical height, sitting	Buttock-knee length
Forearm circumference	Shoulder height, sitting	Neck circumference
Upper arm circumference	Elbow height, sitting	Chest circumference
Chest depth	Shoulder-elbow length	Waist circumference
Foot height	Elbow-wrist length	Wrist circumference
Stature (body height)	Shoulder (biacromial) breadth	Thigh circumference
Eye height, standing	Shoulder (bideltoid) breadth	Calf circumference
Shoulder height, standing	Hip breadth, sitting	
Elbow height, standing	Lower leg length (popliteal height), sitting	

The body measure stature (body height), which is defined as the vertical distance from the floor to the highest point of the head (vertex) according to ISO 7250, was extracted from the subject standing fully erect with feet together and the head oriented in the Frankfurt plane. The results show a range for all genders from 1039 mm to 2039 mm (3'5"–6'8"). The adult women range from 1358 to 1881 mm (4'6"–6'2") and the adult men range from 1444 to 2039 mm (4'9"–6'8").



The body weight ranges from 16.5 kg up to 199.3 kg that corresponds to 36.4 lbs and 439.4 lbs for the entire test sample presented herein. The adult women range from 37.2 kg to 199.3 kg (82 lbs–439.4 lbs) and the adult men range from 39.8 kg to 194.3 kg (87.7 lbs–428.4 lbs).

### 3.3 iSize Web Portal

One of the important innovations by Human Solutions was to provide anthropometric data for the first time in an easily accessible online portal. iSize was initiated with the Size Germany survey in 2008. iSize not only allows the user to access results but also to filter and analyze data and use the results for their product design. For industrial applications it is not suitable and not valuable to provide a pool of data and statistical numbers. iSize gives anthropologists, designers, engineers and specialists the possibility to break down the data specifically to represent the intended target market. Since its development, the iSize web portal has been established as an application for apparel design. Fashion companies use the online tool to generate up-to-date size tables and to create avatars. The results can be imported into the human simulation software Vidya and the ergonomic design software RAMSIS. For specific application various filters for demographic data and body measurements can be applied to all available databases. For each selection a representative number of persons for the target market is calculated and the user gets a qualitative feedback whether the data is representative for the market or not.

## 4 Conclusion

Size NorthAmerica is the biggest size survey of the USA and Canadian civilian population. For the first time ever a true, representative dataset of anthropometric measurements together with extensive socio-demographic information for each subject is available for the industry. In comparison with other size surveys of the US population, Size NA is the only survey that complies with important industry standards such as ISO 20685 for internationally compatible anthropometric databases and ISO 15537 for selecting and using test persons for testing anthropometric aspects of industrial products and designs. With 14,460 persons scanned in 4 postures Size NA has collected more than double the number of 3-D body scans than every other size survey of the US civilian population ever before. Body measurements extracted from the 57,848 scans are compliant with ISO 7250 for ergonomics and ISO 8559/ASTM D5219 for apparel design. Therefore, the data is better applicable for the design and development of consumer products. CAESAR reports an actual number of scanning subjects for North America of 2375 vs. a planned sample size of 3384 including 188 per strata. Ethnic groups “Black” and “Other” are low represented [14, 15]. Previous surveys collected data for adults and neglected the important market of people under 18 and over 65 which is more than 30% of the US population. Size NorthAmerica for the first time covers those age groups and provides rich data about this untouched consumer market.

Size North America is the new American anthropometric survey that replaces all former studies. For the first time, representative anthropometric important data from children 6 years and up as well as elderly people (up to 75) is available.

Human Solutions provides efficient and accurate products, as well as the expertise for sizing surveys worldwide. The anthropometric data of the Size North America study is available through the iSize web portal together with anthropometric databases from other countries around the world. The iSize web portal gives users an easy and effective overview and the ability to compare and analyze anthropometric and socio-demographic data of their target market. Major companies have already begun to use the data to optimize ergo guidelines, human figure models, size charts and target market specifications. The data will also become available within the digital human modeling software RAMSIS to create 3D virtual avatars to represent a product's end user within a human-centric product development and design validation.

For the first time, companies which offer their products worldwide will be able to use the latest anthropometric data to develop these products ergonomically - addressing the specific needs of their customers in multiple regions concurrently.

## References

1. Seidl, A.: The RAMSIS and ANTHROPOS human simulation tools. In: Delleman, N.J., Haslegrave, C.M., Chaffin, D.B. (eds.) *Working Postures and Movements – Tools for Evaluation and Engineering*, pp. 445–453. CRC Press, Boca Raton (2004)
2. DIN 33402: Koerpermaße des Menschen. Part 1–3 (1978)
3. Godil, A., Ressler, S.: Shape and size analysis and standards. In: Duffy, G.V. (ed.) *Handbook of Digital Human Modeling. Research for Applied Ergonomics and Human Factors Engineering*. CRC Press, Boca Raton (2009)
4. ISO 15535:2003. General requirements for establishing anthropometric databases
5. ISO 15537:2004. Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs
6. ISO 20685:2006. 3D scanning methodologies for internationally compatible anthropometric databases
7. ISO 7250:1996. Basic human body measurements for technological design
8. ISO 8559:1989. Garment construction and anthropometric surveys – body dimensions
9. Juergens, H.W., Aune, I.A., Pieper, U.: *Internationaler Anthropometrischer Datenatlas*. Schriftenreihe der Bundesanstalt fuer Abreitsschutz. Fb 587 (1989)
10. Juergens, H.W.: Anwendung anthropometrischer Daten. Direkte und indirekte Anwendung. In: Schmidtke, H. (ed.) *Handbuch der Ergonomie (A - 3.3.1)*. Hanser Verlag (1992)
11. Lewin, T., Juergens, H.W.: Ueber die Vergleichbarkeit von anthropometrischen Maßen. *Zeitschrift Morph. Anthropol.*, 61 (1969)
12. Robinette, K.M., Daanen, H.A.M., Zehner, G.F.: Three dimensional anthropometry. In: Delleman, N.J., Haslegrave, C.M., Chaffin, D.B. (eds.) *Working Postures and Movements*, pp. 29–49. CRC Press LLC, Boca Raton (2004)
13. Seidl, A., Bubbs, H.: Standards in anthropometry. In: Karwowski, W. (ed.) *Handbook on Standards and Guidelines in Ergonomics and Human Factors*, pp. 169–196. Lawrence Erlbaum Associates Publishers, New York (2005)

14. Blackwell, S., et al.: Civilian American and European Surface Anthropometry Resource (CAESAR), Final report, vol. 2 (2002)
15. Robinette, K., et al.: Civilian American and European Surface Anthropometry Resource (CAESAR), Final report, vol. 1: Summary (2002)
16. Seidl, A., Trieb, R., Wirsching, H.J., Smythe, A., Guenzel, T.: SizeNorthAmerica—The New North American anthropometric survey: conceptual design, implementation and results. In: Goonetilleke, R., Karwowski, W. (eds.) *Advances in Physical Ergonomics and Human Factors*. AISC, vol. 489, pp. 457–468. Springer, Cham (2016). [https://doi.org/10.1007/978-3-319-41694-6\\_46](https://doi.org/10.1007/978-3-319-41694-6_46)
17. United States Census Bureau. <https://www.census.gov/quickfacts/fact/table/US/PST045218>. Accessed 20 Jan 2019
18. CDC