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U.S. Truck Driver Anthropometric Study and Multivariate Anthropometric Models for Cab Designs

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Abstract

Objective—This study presents data from a large-scale anthropometric study of U.S. truck drivers and the multivariate anthropometric models developed for the design of next-generation truck cabs.

Background—Up-to-date anthropometric information of the U.S. truck driver population is needed for the design of safe and ergonomically efficient truck cabs.

Method—We collected 35 anthropometric dimensions for 1,950 truck drivers (1,779 males and 171 females) across the continental United States using a sampling plan designed to capture the appropriate ethnic, gender, and age distributions of the truck driver population.

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Results—Truck drivers are heavier than the U.S. general population, with a difference in mean body weight of 13.5 kg for males and 15.4 kg for females. They are also different in physique from the U.S. general population. In addition, the current truck drivers are heavier and different in physique compared to their counterparts of 25 to 30 years ago.

Conclusion—The data obtained in this study provide more accurate anthropometric information for cab designs than do the current U.S. general population data or truck driver data collected 25 to 30 years ago. Multivariate anthropometric models, spanning 95% of the current truck driver population on the basis of a set of 12 anthropometric measurements, have been developed to facilitate future cab designs.

Application—The up-to-date truck driver anthropometric data and multivariate anthropometric models will benefit the design of future truck cabs which, in turn, will help promote the safety and health of the U.S. truck drivers.

Keywords

truck driver; human body size; cab design models

INTRODUCTION

Trucking is one of the most hazardous occupations in the United States. An estimated 1.5 million workers are employed as drivers of heavy trucks and tractor-trailers in the United States (Bureau of Labor Statistics [BLS], 2010). In 2009, truck drivers experienced 16.8% (303 out of 1,795 cases) of all transportation-related fatalities (BLS, 2009b) and 2.0% of the nonfatal injuries requiring days away from work (BLS, 2009d), even though they only made up 1.0% of the U.S. workforce.

Truck drivers spend long hours behind the wheel, working an average of 41.5 hr per week (BLS, 2009a). A well-designed truck cab not only makes a significant difference in the working conditions for a truck driver but also affects the safety of truck drivers and other road users. If the design of the truck cab is poorly fitted to the size and dimensions of the driver, the road may be less visible, driving controls may be more difficult to reach, and seat belts may be less comfortable and less likely to be used—all of which increase the risk of injury to the driver and other road users.

There is a pressing need to enhance ergonomic cab designs for safe and efficient over-the-road operation. Up-to-date anthropometric data play a key role in the design. Unfortunately, anthropometric data on the U.S. truck driver population have not been collected for several decades. Truck drivers were last systematically measured in the United States in the late 1970s (Sanders, 1977) and early 1980s (Sanders, 1983; Shaw & Sanders, 1984). Demographic evidence suggests that the population is changing, with a greater representation of racial and ethnic minorities, especially the Hispanic ethnic group. In 1983, the combined category of truck drivers (heavy and light) and driver-sales workers included 11.7% African Americans, 5.6% Hispanics, and 3.5% females (BLS, 1983). In 2009, the category of driver-sales workers and truck drivers included 13.4% African Americans, 18.7% Hispanics, and 5.2% females (BLS, 2009c). This new demographic reality necessitates an updating of the anthropometric data used for the design of truck cabs because anthropometric data are related to various demographic characteristics (Bradtmiller, Ratnaparkhi, & Tebbetts, 1985; Gordon, Bradtmiller, & Ratnaparkhi, 1986; International Organization for Standardization [ISO], 2006).

In recent years, major truck manufacturers in the United States and other countries have begun a transition from the traditional percentile approach toward the multivariate accommodation model (MAM) approach in cab design. The 5th-to-95th-percentile approach has been criticized for the decrease in accommodation when two or more dimensions are involved in a design (Zehner, Meindl, & Hudson, 1993) and for its inability to generate biofidelitic models (Robinette & McConville, 1981). The MAM approach offers a superior solution to the workstation design because of its ability to circumvent both problems.

With the MAM, one uses a principal component analysis (PCA) to reduce a large number of body dimensions to a smaller number (e.g., two or three) of variables or principal components (PCs). These PCs approximate an ellipse or ellipsoid in distribution, which enables designers to select the desired level (e.g., 95%) of accommodation for the user population. Then, a small set of body models can be identified on the boundary of the ellipse or on the surface of the ellipsoid. This cadre of body models is composed of not only the overall large or small individuals but also individuals of different body configurations (Zehner et al., 1993). Designers may rely on these more realistic multivariate body models, instead of the traditional percentile values, in cab design.

In 2006, the National Institute for Occupational Safety and Health (NIOSH) initiated a 4-year nationwide anthropometric study of the U.S. truck driver population. In this report, we present the study results and examine the differences in key anthropometric dimensions between the current U.S. truck driver population and the U.S. general population and between the current truck drivers and their counterparts of 25 to 30 years ago. In addition, MAMs capable of accommodating 95% of the truck driver population were developed to facilitate the next-generation truck cab design.

METHOD

Participants

This study sample consists of 1,779 male and 171 female truck drivers measured from January 2008 to March 2009. Data were collected in 15 states across the continental United States. A sampling strategy that took into account age, sex, and race categories was used. The original sampling plan and the final sample are presented in Table 1. Other relevant information (data collection sites and location types) is provided in Table 2. Only those with a valid Class A Commercial Vehicle Driver's License (CDL) were measured. The sample size of this study has exceeded the requirement of ISO 15535 standard on minimum sample size for 95% confidence and 1% relative accuracy (ISO, 2006).

Apparatus

Standard anthropometric instruments, used in this study, were an anthropometer, beam caliper (rearranged pieces of the anthropometer), sliding calipers, and a Lufkin steel tape. Other instruments included a weight scale and a stool for seated measurement.

Procedure

The measuring team traveled to each data collection site, where a measuring station was set up. When a participant arrived, an investigator checked his or her CDL to establish eligibility before giving him or her a consent form, on which the purpose of the study and the measurement procedures were explained. If he or she agreed to participate, the participant would sign the form. The participant remained in street clothes during the measurement and was measured on two postures: standing with heels together and sitting (Figure 1). Detailed specifications on the measurement postures can be found in Gordon and associates (1989). The investigator located body landmarks by palpating the bones and placing small stickers on the clothes overlying those points or marking those points with an eyeliner pencil if they were on the skin. After the marks were properly placed on the participant's body, 33 anthropometric measurements, plus shoe length and width, were taken with the anthropometric devices. After the measurement was completed, the participant was reimbursed and dismissed.

Anthropometric Measurements

The 33 anthropometric dimensions, plus shoe length and shoe width, were chosen on the basis of their utility in facilitating truck cab design (Appendix A). Five measurements (abdominal breadth, sitting; arm length; thumb-tip reach; shoe length; and shoe width) were specifically defined for this study. Further information about the remaining variables can be found in Gordon and associates (1989) and Speyer (2007). Shoe length and width were measured only if the individual was wearing shoes that were typically worn while driving.

To ensure data quality, we trained five measurers prior to data collection; only four of them performed subsequent data collection. During the training session, 9 participants were measured. Since it was a training session, dimensions that are more difficult (e.g., chest width) were measured more often than dimensions that are less difficult (e.g., shoe length). The measuring team repeated the measurements on practice participants until the interobserver differences were at or below the levels specified in ISO 20685 (ISO, 2005). In addition, specifically designed software was employed in data entry. The software signals the operator when an unexpected value is entered. Any values flagged by the system were verified on-site by remeasuring the driver.

Data Analysis

Sample weighting—Before data were analyzed, a weighting procedure was applied to the male and female samples, respectively, to ensure that the current samples represent the current truck driver population in age, race, and ethnicity. The weights are calculated as the relative frequency of a given cell in the truck driver population, divided by the relative frequency of the same cell in the study sample. This approach is standard in anthropometric studies (Gordon, 2000; Harrison & Robinette, 2002; ISO, 2007, 2008).

Information on the racial ethnic distribution of truck drivers came from the BLS (2006). Age distribution was selected from an American Trucking Association–sponsored report (Global Insight, 2005) for lack of official government data. Samples were weighted across six age groups (<25, 25–29, 30–34, 35–44, 45–54, and 55+) and three racial ethnic groups (Non-Hispanic White, Hispanic, and Non-Hispanic Black and Others) for males and females, respectively. Note that this approach treats Hispanic as an ethnic, rather than a racial, group.

Current truck drivers compared with the U. S. general population— Measurements from the current study were compared with relevant measurements from the U.S. general population according to the National Health and Nutrition Examination Survey (NHANES). For this analysis, a male sample and a female sample between 20 and 65 years of age were taken from a combined 4-year (2003–2006) NHANES data set (McDowell, Fryar, Ogden, & Flegal, 2008). This age range consists of the majority of the U.S. working population. Before the two samples are compared, the same 20-to-65 age range criterion was applied to the NIOSH truck driver sample, resulting in a male sample of 1,749 participants and a female sample of 171 participants.

Bonferroni *t* was used to compare the relevant measurements from both studies. Most measurements in NHANES were not comparable to those taken in this study. As a result, only four comparable measurements (stature, weight, waist circumference, and thigh circumferences) were selected for comparison. With four comparisons, each *t* value was evaluated at $\alpha = .05/4 = .0125$ level.

Current truck drivers compared to those of 25 to 30 years ago—The female samples were not involved in this analysis because the number of female participants in the earlier two studies was very small (Sanders, 1977, 1983; Shaw & Sanders, 1984). As a result, this analysis compared only the male samples. There are 10 dimensions comparably measured between the current study and the two earlier studies, and these 10 dimensions were submitted to statistical analysis by Bonferroni *t*. With 10 comparisons, each *t* value was evaluated at $\alpha = .05/10 = .005$ level.

Multivariate anthropometric accommodation—The MAM method started with a PCA procedure run by SAS (Version 9; SAS Institute, Cary, NC) on the male and female samples, respectively. This procedure reduced a set of 12 dimensions, chosen on the basis of their utility in cab design, to a smaller number of variables or PCs. In the present study, a decision was made to use the first three PCs (PC1, PC2, and PC3) to define body models on the basis of a scree plot. These three PCs were found to account for 87% to 88% of the total variance.

To ensure the accuracy of body model selection, the multivariate normality of the samples was checked by inspecting Q-Q plots along with a Kolmogorov-Smirnov test for males (large sample) and a Shapiro-Wilk test for females (small sample). The Kolmogorov-Smirnov test showed that PC2 and PC3 for the male sample did not meet the normality assumption ($p < .01$). As a result, The 12 original variables were first transformed by natural log, and 1 participant (No. 488) was removed as an outlier before the PCA procedure was applied. On the other hand, the Shapiro-Wilk test showed that the female sample was able to meet the normality assumption without any transformation after just 4 participants (Nos. 408, 750, 1172, and 1529) were removed from the data set.

The PCs, which are orthogonal to one another, can be described as approximating an ellipsoid. Then, one can select the desired level of accommodation (e.g., 95%) by determining the appropriate confidence level in the ellipsoid (Zehner et al., 1993). In this study, we used the Bonferroni method to determine the 95% enclosure (Johnson & Wichern, 2007). Since the three PCs were standardized to z scores, we were able to use a single radius value ($r = 2.40$ for males and $r = 2.42$ for females) as the 95% enclosure criterion.

After the 95% enclosure criterion was determined, the next step was to identify the 14 models (six intercepts, eight octant midpoints) on the surface of the ellipsoid. The six intercept points were obtained on the ellipsoid surface where the three axes intercept. In addition, each of the eight octant midpoints was located at the surface center of each of eight sections (octants) divided by the three axes of this ellipsoid. These 14 points (8 octant points and 6 intercept points), along with the centroid of ellipsoid, were the basis for the selection of the anthropometric models (Figure 2).

We calculated the corresponding 12 anthropometric values of these 14 models first by linearly transforming the coordinates of the models scaled by the Bonferroni factor and making use of the reduced matrices of the eigenvalues and eigenvectors. Then, these calculated values were multiplied by the weighted standard deviations before being added to the weighted means to obtain the final values. These 14 participants, along with the average individual, represented 15 body models, each of which had a set of 12 derived anthropometric dimensions. To determine the closest-neighbor participants for these models, we computed the Euclidean distance from each participant to each model point. One closest-neighbor participant for each model was chosen.

Since truck cab workspace is designed for both male and female drivers, a recombined set of male and female models, after those have been derived separately, is useful for the design process (Hudson & Zehner, 2010). To obtain these recombined male and female models, the models of each gender were put into the other gender's 95% enclosure space, and those who are identified to be within the enclosure space of the opposite gender were considered redundant and discarded. For example, to identify a redundant female model, we first converted the 12 derived body dimensions of that female model into z scores using the means and standard deviations of the corresponding variables in the male sample. Then, we derived the three PCs by multiplying the set of z scores with the matrix of component score coefficients. Then, we determined the Euclidean distance of this female model to the centroid of the 95% male enclosure by using the three PCs. If the distance was smaller than the $r = 2.40$ enclosure criterion, this female model was considered redundant and discarded. Otherwise, this model was retained for the joint male and female space. After all the female models have been evaluated in this way, the male models were placed into the female 95% enclosure ($r = 2.42$) and evaluated for possible redundancy.

RESULTS

Measurement Error

Data on measurement errors (minimum and maximum absolute difference between any two measurers and the mean and standard deviation of absolute differences among all measurers) on each measurement are presented in Appendix B. The mean of the absolute differences ranged from 2 mm to 18 mm, except for weight.

Summary Statistics

Summary statistics on all body measurements are presented in Appendix C. The weighted and unweighted means for each body dimension were very close to each other, as were the weighted and unweighted standard deviations for each body dimension. Since these values were very similar, subsequent analyses were based on the weighted samples alone. The similarity between the weighted and unweighted data suggests that this study sample was reasonably representative of the truck driver population in anthropometric dimensions.

Current Truck Drivers Versus the U.S. General Population

Table 3 shows the results of Bonferroni *t* comparisons for the means of four body dimensions between the current data and the U.S. general population. For the males, differences in the means of all four dimensions were found to be statistically significant. Although the male truck drivers were on average shorter than males in the U.S. general population, they were nonetheless heavier. The truck drivers were, on average, 13.5 kg heavier than those in the U.S. general population, and their thigh and waist circumferences were larger than those of men in the U.S. general population. For the females, the mean stature was not statistically different. However, the female truck drivers were significantly heavier than those in the general population, by 15.4 kg on average. Besides, their thigh and waist circumferences were larger than those of women in the U.S. general population. These results showed that the size and physique of the truck driving population are not well represented by the U.S. general population.

Current Truck Drivers Versus Truck Drivers of 25 to 30 Years Ago

As Table 4 shows, the current male truck drivers were larger in abdominal depth, sitting; forearm-forearm breadth; hip breadth, sitting; waist circumference; and body weight as compared with the previously available male truck driver data (Sanders, 1977, 1983). The sitting height in the present study was shorter than that in earlier studies, although the stature was the same. This finding suggests that the current male drivers were different in physique from their counterparts of 25 to 30 years ago. They were heavier by 12.0 kg on average and larger in body width and girth, even though they were not taller.

Multivariate Anthropometric Models

We used the MAM approach to identify representative truck driver body models for truck cab design. Table 5 presents the PC score coefficient matrix involving 12 anthropometric dimensions for the male and female truck drivers, respectively. The PCA output for the males consisted of three PCs, the combination of which accounted for 88% of the total variation. PC1, which accounted for 53% of the total variation, predicted the overall body size. PC2, accounting for 20% of the variation, showed a contrast between dimensions correlated with body heights and those correlated with body width and depth. PC3, accounting for 15% of the variation, contrasted the measurements of stature and torso height with the remaining 7 body dimensions. The PCA output for females also consisted of three PCs, the combination of which accounted for 87% of the total variation. The three PCs, which followed the same patterns as in the male sample in revealing the relationships among body dimensions, accounted for 53%, 21%, and 13% of the total variation, respectively.

Table 6 describes the 15 representative body models and their corresponding closest-neighbor human participants for the male truck drivers. A graphical representation of these 15 male body models in both standing and sitting positions can be found in Figure 3. Model O, which was at the center of the ellipsoid, represented an average person in all body dimensions. Model U represented a small-size individual, whereas Model V represented a large-size individual. Model W had a relatively long stature but a short torso. In contrast, Model X was relatively short in stature and torso length but large in abdominal depth and hip breadth. Model C was characterized by a relatively short stature and short limbs but a long torso, whereas Model E was characterized by a relatively long stature and long limbs but a short torso (Figure 4). These 15 body models represented all body sizes and types for the male truck driver population. Table 7 describes the 15 female representative body models and their corresponding closest-neighbor human participants. Similar patterns in body dimensions found among the male representative models apply to the female representative models.

To recombine the male and female body models, we first projected the 14 female body models (excluding the female Model O) into the 95% male enclosure space. Four female models (E, H, V, and W) were found to coincide with the male space because their respective Euclidian distance to the centroid of the 95% male enclosure was smaller than the r = 2.40 criterion. These four female body models were considered redundant and were, therefore, excluded from the final set of recombined male and female body models. The remaining female models were retained. Then the 14 male body models (excluding the male Model O) were projected into the 95% female enclosure space. The Euclidian distance of four male models (B, C, U, and X) to the centroid of the 95% female enclosure was smaller than the r = 2.42 criterion. These four models were excluded from the final set of recombined male and female body models, and the remaining male models were retained. Finally, the recombination procedure resulted in a joint male and female enclosure space that included Models A, D, E, F, G, H, V, W, Y, and Z for the males and Models A, B, C, D, F, G, U, X, Y, and Z for the females.

DISCUSSION

Anthropometric Characteristics of the Current U.S. Truck Driver Population

Table 3 shows that the current U.S. truck driver population is significantly heavier than the U.S. general population of working age. The body width and circumference measurements are also larger among truck drivers than among those in the U.S. general population. The results are consistent with Hsiao, Long, and Snyder's (2002) findings that different occupational groups have distinctive anthropometric characteristics from the general population.

A comparison between this and earlier truck driver anthropometric studies (Sanders, 1977, 1983) reveals a significant change in the anthropometric profile of truck drivers across a quarter century. The current male truck drivers are, on average, 12 kg heavier than their earlier counterparts, and they are also larger in abdominal depth, sitting; forearm-forearm breadth; hip breadth, sitting; and waist circumference. This change in body width and circumference may reflect the sedentary nature of the trucking occupation and the ongoing obesity epidemic in the United States.

There is also a discrepancy between what this study and the Sanders study found on truck drivers' stature. Sanders (1983) found that both male and female truck drivers are taller than the U.S. general population. On the contrary, this study reported that male truck drivers are shorter than the general population and that female truck drivers are not significantly different from the general population in stature. The difference can be explained by the fact that this study included a more representative Hispanic subsample (14% of the total sample) whereas the Sanders study did not include any Hispanic participants. As an ethnic group, Hispanics have a shorter stature than non-Hispanic Whites. For example, for those 20 years and older, Hispanic males and females were reported to be, on average, 72 mm and 53 mm shorter than their non-Hispanic White counterparts (McDowell et al., 2008). In this study, we found that the male Hispanic truck drivers are, on average, 56 mm shorter than the male non-Hispanic White drivers ($t = 12.93$, $p < .01$, two-tailed test). The female Hispanic drivers are, on average, 44 mm shorter than the female non-Hispanic White drivers ($t = 7.0$, $p < .01$, two-tailed test). The inclusion of a representative Hispanic sample has enabled this study to yield a more accurate estimate of the true stature in the truck driver population.

The issue of female truck driver sample deserves special attention. Despite various anecdotes that more and more females are entering the trucking occupation, the BLS data consistently show that the percentage (i.e., about 4% to 5%) of female drivers has remained stable for decades in the driver-and-sales worker category. This study includes 171 female truck drivers, or about 8.8% of the total study sample. This percentage is higher than that of the actual female truck driver population. This over-sampling is needed for meaningful statistical analysis and desirable for design purposes.

Percentile Models Versus MAM Approach

Zehner and associates (1993) argued that the use of percentile models leads to a decrease in the accommodation level when two or more dimensions are involved in a design. The percentile values are univariate variables. The 5th to 95th percentiles would exclude 10% of the user population on the first dimension. With each additional dimension added, the exclusion rate would increase and the level of accommodation would decrease. The MAM approach circumvents this problem by taking a multivariate approach. In our example, instead of focusing on each of 12 individual dimensions, the MAM relies on three PCs, generated by the PCA, that are linear combinations of the 12 original variables. These PCs, which are orthogonal to each other, can approximate an ellipsoid in distribution. Then, a 95% accommodation level was chosen to exclude only 5% of the user population.

Another problem facing the percentile approach is that the percentile values are not additive (Robinette & McConville, 1981). For example, a 95th-percentile stature cannot be reassembled by adding up all the 95th-percentile body segments that make up the stature. Any attempt to reassemble a whole body based on the 95th-percentile segments would result in mathematically and anatomically incorrect models. In contrast, the MAM approach enables the generation of body models that are representative not only of the size variance but also of proportional body variance in a user population (Zehner et al., 1993). The cadre of MAM models generated in this study includes not only overall large and small persons but also individuals of different body configurations. For example, as shown in Figure 4, male Model C has a short stature (9th percentile) but a relatively tall sitting height (44th percentile). In contrast, male Model E has a tall stature (92th percentile) but relatively short sitting height (55th percentile). This variability in body sizes and configurations will help improve the biofidelity of manikins in cab workspace design.

Application to Cab Design

In this study, we used the MAM approach to select 15 body models for male and female truck drivers, respectively. Each of the 15 body models represents a unique combination of body size and physique. These models, together with the anthropometric values of their closest-neighbor participants, should benefit the design of the next-generation truck cabs. If a combined set of the male and female models are more desirable, the 20 male and female models selected in this study may be used for the same purposes. These models can be applied to truck cab design in a number of ways. Developers of ergonomic software may apply these models toward generating biofidelic digital manikins to improve the cab simulation environment. Likewise, cab designers may use these models to create cadres of manikins to evaluate or visualize different “fit” issues in truck designs. For example, a short manikin with short legs but a relatively long sitting and eye height (Model C) and a tall manikin with long legs but a relatively short sitting and eye height (Model E) may be selected to evaluate the cab and mirror design. With the manikins properly seated and their right heels placed on the accelerator heel point, the effects of cab and mirror design on drivers’ direct and indirect visibility can be assessed. These manikins provide the level of anthropometric variability that cannot be provided by the percentile models.

CONCLUSION

An anthropometric study of 1,950 male and female U.S. truck drivers was conducted to provide key human body dimension data for the design of truck cabs. In this study, we found that truck drivers are, on average, heavier in body weight and larger in body width and girth than the U.S. general population. However, the male truck drivers are shorter in stature and the female truck drivers are not different from the U.S. general population. A comparison of the male truck drivers in this and earlier studies showed important anthropometric changes, primarily related to increased width and girth, across a quarter century. Given the substantial differences in key dimensions between the truck drivers and the U.S. general population, and between the current truck drivers and those of 25 to 30 years ago, the current data will be an important resource for future truck cab designs. The PCA-based representative body models were developed to facilitate truck cab designs.

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APPENDIX A

Definition of Anthropometric Measurements and Shoe Measurements

Dimension	Posture	Definition	Compatible Sources
Abdominal breadth	Sitting	Maximum distance between the lateral points of the abdomen (abdominal point, lateral, left, right) measured in a seated posture	Defined for this study
Abdominal depth	Sitting	Horizontal distance between the most anterior point of the abdomen (abdominal point, anterior, sitting) and the back at the same level measured in a seated posture	ANSUR
Acromial height	Standing	Vertical distance between the standing surface and the acromion landmark on the tip of the right shoulder measured in a standing posture	ANSUR
Acromial height	Sitting	Vertical distance between the sitting surface and the acromion landmark on the tip of the right shoulder measured in a seated posture	ANSUR
Ankle height	Standing	Vertical distance between the standing surface and the lateral malleolus landmark on the outside of the ankle	ANSUR (lateral malleolus height)/ RAMSIS (foot height: lateral ankle)
Arm length	Standing	Distance between the acromion landmark on the tip of the right shoulder and the dactylion III landmark at the tip of the middle finger measured in a standing posture	Defined in this study
Biacromial breadth	Sitting	Distance between the right and left acromion landmarks at the tips of the shoulders measured in seated posture	ANSUR
Bideltoid breadth	Sitting	Maximum horizontal distance between the lateral margins of the upper arms on the deltoid muscles measured in a seated posture	ANSUR
Buttock-knee length	Sitting	Horizontal distance between the buttock plate and the anterior point of the right knee (knee point, anterior)	ANSUR/RAMSIS
Buttock-popliteal length	Sitting	Horizontal distance from the buttock plate to the back of the knee	ANSUR
Calf circumference	Standing	Maximum horizontal circumference of the lower leg	ANSUR/RAMSIS
Chest depth	Standing	Horizontal distance between the xiphoidale landmark on the lower edge of the body of the sternum and the dorsally most prominent point in the midline of the back at the same level	RAMSIS
Chest width	Standing	Maximum horizontal distance between the two laterally most prominent points of the	RAMSIS

Dimension	Posture	Definition	Compatible Sources
		rib cage at the level of the xiphoidale landmark on the lower edge of the bony part of the sternum	
Elbow-fingertip length	Standing	Horizontal distance between the back of the tip of the right elbow (olecranon, rear) and the tip of the right middle finger (dactylion III) when the right elbow is flexed 90°	ANSUR
Elbow rest height	Sitting	Vertical distance between the sitting surface and the bottom of the right elbow (olecranon, bottom)	ANSUR
Eye height	Sitting	Vertical distance between the sitting surface and the outer corner of the right eye (ectocanthus)	ANSUR
Forearm circumference	Standing	Horizontal circumference of the right forearm at the point of maximum prominence slightly distal to the elbow joint	RAMSIS
Forearm-forearm breadth	Sitting	Maximum horizontal distance across the upper body between the lateral margins of the forearms	ANSUR
Hand breadth	Palm on table	Breadth of the hand between the landmarks at metacarpale II and metacarpale V	ANSUR
Hand length	Palm on table	Length of the right hand between the stylion landmark on the wrist and the tip of the middle finger (dactylion III)	ANSUR
Hip breadth	Sitting	Maximum distance between the lateral points of the hips	ANSUR
Knee height	Sitting	Vertical distance between the footrest surface and the top of the right knee at the center of the widest part of the calf	ANSUR/RAMSIS
Popliteal height	Sitting	Vertical distance between the footrest surface and the back of the right knee (the popliteal fossa at the dorsal juncture of the right calf and thigh)	ANSUR
Shoulder-elbow length	Standing	Distance between the acromion landmark on the tip of the right shoulder and the bottom of the right elbow (olecranon, bottom) with the elbows flexed 90°	ANSUR
Sitting height	Sitting	Vertical distance between the sitting surface and the top of the head	ANSUR/RAMSIS
Stature with and without shoes	Standing	Vertical distance between the standing surface and the top of the head	ANSUR/RAMSIS
Thigh circumference	Standing	Maximum circumference of the thigh with the tape perpendicular to the long axis of the leg	ANSUR/RAMSIS
Thigh clearance	Sitting	Vertical distance between the sitting surface and the highest point on the top of the right thigh (thigh point, top)	ANSUR
Thumb-tip reach	Sitting	Distance between the surface of the back and the tip of the right thumb when the subject raises both arms horizontally forward with the elbows straight, the thumbs on top, and the fingers curled out of the way.	Defined for this study
Upper arm circumference	Standing	Circumference of the right arm at the biceps point, relaxed, located one-half the distance between acromion and the elbow crease	RAMSIS
Waist circumference, natural indentation	Standing	Horizontal circumference at the level of greatest indentation of the torso	ANSUR/RAMSIS
Shoe width	Standing	Breadth of the right shoe perpendicular to its long axis	Defined for this study

Dimension	Posture	Definition	Compatible Sources
Shoe length	Standing	Length of the right shoe parallel to its long axis	Defined for this study

Note. ANSUR = 1988 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics (Gordon et al., 1989); RAMSIS = RAMSIS Anthropometric Databases (Speyer, 2007).

APPENDIX B

Mean Absolute Differences of Interobserver Errors in Team Training

Dimension	*n* [a]	Min (Absolute Difference)	Max (Absolute) Difference	*M* (Absolute Difference)	*SD* (Absolute Difference)
Abdominal breadth, sitting	32	0	36	12	9.35
Acromial height	32	0	19	5	3.91
Acromial height, sitting	32	0	38	9	9.03
Abdominal depth, sitting	32	0	39	11	10.49
Ankle height	35	0	10	3	2.41
Arm length	35	0	30	5	6.78
Biacromial breadth	31	0	19	6	4.23
Bideltoid breadth	33	0	34	1	8.10
Buttock-knee length	32	2	21	10	5.00
Buttock-popliteal length	32	2	39	17	11.74
Calf circumference	36	1	23	6	5.38
Chest depth	38	0	29	8	6.48
Chest width	42	1	36	15	10.60
Elbow rest height	32	0	45	12	10.98
Elbow-fingertip length	36	0	20	6	4.99
Eye height, sitting	32	0	23	7	6.20
Forearm circumference	36	0	9	3	2.14
Forearm-forearm breadth	32	0	37	10	9.03
Hand breadth	32	0	6	2	1.52
Hand length	32	0	11	4	2.86
Hip breadth, sitting	31	0	23	8	6.47
Knee height, sitting	33	0	55	8	9.65
Popliteal height	32	0	35	8	7.032
Shoulder-elbow length	35	0	30	7	6.54
Sitting height	32	0	13	5	3.64
Stature with shoes	26	0	19	4	3.74
Stature (no shoes)	31	0	16	4	3.10
Thigh circumference	39	0	50	13	11.00
Thigh clearance	32	0	15	5	4.59
Thumb-tip reach	33	1	23	8	5.68
Upper arm circumference	38	0	24	10	7.22
Waist circumference, natural indentation	33	0	85	18	21.43
Weight (kg)	10	0	3.5	0.7	1.47
Shoe length	29	0	13	3	3.56
Shoe width	29	0	11	3	2.47

Note. Values are in millimeters except for weight.

[a] *n* indicates the number of interobserver comparisons.

APPENDIX C

Summary Statistics for Measured Dimensions in NIOSH Truck Driver Study

Dimension	*M* (*SD*), Unweighted	*M* (*SD*), Weighted	5th Percentile, Weighted	95th Percentile, Weighted	*SE* 5th and 95th Percentile, Weighted[a]	*n*
Males						
Abdominal breadth, sitting	372 (55.07)	371 (55.46)	292	471	2.02	1,779
Abdominal depth, sitting	333 (65.93)	331 (66.03)	232	452	2.40	1,779
Acromial height	1,449 (63.75)	1,449 (63.81)	1,345	1,554	2.32	1,779
Acromial height, sitting	615 (32.52)	615 (32.43)	561	669	1.18	1,779
Ankle height	74 (6.19)	74 (6.21)	64	85	0.23	1,779
Arm length	777 (37.81)	776 (37.45)	715	838	1.36	1,777
Biacromial breadth	426 (21.45)	426 (21.53)	392	462	0.78	1,779
Bideltoid breadth	537 (48.62)	537 (48.91)	469	624	1.78	1,779
Buttock-knee length	632 (35.02)	632 (35.04)	577	693	1.27	1,779
Buttock-popliteal length	520 (30.82)	520 (30.66)	473	572	1.12	1,779
Calf circumference	417 (40.97)	417 (41.42)	356	488	1.51	1,779
Chest depth	264 (41.35)	263 (41.56)	199	335	1.51	1,779
Chest width	356 (42.46)	356 (42.82)	299	435	1.56	1,779
Elbow-fingertip length	487 (23.72)	487 (23.48)	449	525	0.85	1,777
Elbow rest height	254 (33.20)	254 (33.13)	202	312	1.20	1,779
Eye height, sitting	799 (34.68)	799 (34.86)	742	858	1.27	1,779
Forearm circumference	309 (25.92)	309 (25.92)	271	353	0.94	1,779
Forearm-forearm breadth	617 (66.12)	617 (66.17)	516	730	2.41	1,779
Hand breadth	90 (4.80)	90 (4.82)	82	98	0.18	1,779
Hand length	197 (10.18)	196 (10.10)	180	214	0.37	1,779
Hip breadth, sitting	428 (45.96)	428 (46.04)	366	513	1.67	1,779
Knee height, sitting	569 (28.29)	569 (28.40)	523	615	1.03	1,779
Popliteal height	439 (25.84)	439 (25.89)	397	483	0.94	1,779
Shoulder-elbow length	362 (19.01)	362 (18.81)	331	393	0.68	1,777
Sitting height	918 (35.93)	919 (36.14)	858	978	1.31	1,779
Stature with shoes	1,785 (69.28)	1,785 (69.85)	1,672	1,900	2.74	1,522
Stature (no shoes)	1,757 (69.11)	1,757 (69.58)	1,645	1,869	2.53	1,779
Thigh circumference	634 (69.25)	635 (69.91)	535	764	2.54	1,779
Thigh clearance	181 (19.60)	181 (19.71)	152	216	0.72	1,779
Thumb-tip reach	834 (39.51)	833 (39.37)	771	902	1.43	1,778
Upper arm circumference	365 (41.05)	365 (40.98)	305	436	1.49	1,779
Waist circumference, NI	1,093 (153.37)	1,089 (154.31)	856	1,371	5.61	1,779
Weight (kg)	102.8 (23.83)	102.6 (23.93)	72.1	146.4	0.87	1,779
Shoe width	116 (6.33)	116 (6.31)	106	126	0.25	1,521
Shoe length	309 (14.46)	309 (14.50)	285	334	0.57	1,521
Females						
Abdominal breadth, sitting	372 (55.41)	374 (55.43)	283	463	1.36	171
Abdominal depth, sitting	322 (61.00)	325 (61.89)	225	430	1.52	171
Acromial height	1,338 (61.32)	1,337 (61.20)	1,236	1,450	1.50	171
Acromial height, sitting	578 (31.00)	579 (30.66)	524	630	0.75	171
Ankle height	68 (5.66)	68 (5.66)	58	78	0.14	171
Arm length	706 (36.62)	704 (35.20)	650	756	0.87	170
Biacromial breadth	385 (21.37)	385 (21.94)	344	425	0.54	171
Bideltoid breadth	498 (48.96)	499 (49.25)	421	587	1.21	171

Dimension	*M* (*SD*), Unweighted	*M* (*SD*), Weighted	5th Percentile, Weighted	95th Percentile, Weighted	*SE* 5th and 95th Percentile, Weighted[a]	*n*
Buttock-knee length	607 (33.82)	607 (32.56)	563	667	0.80	171
Buttock-popliteal length	502 (29.56)	502 (28.43)	458	551	0.70	171
Calf circumference	408 (47.77)	411 (47.91)	343	491	1.18	171
Chest depth	242 (37.85)	243 (38.03)	186	316	0.93	171
Chest width	328 (36.78)	328 (36.81)	274	399	0.90	171
Elbow-fingertip length	441 (22.11)	440 (21.86)	404	477	0.54	170
Elbow rest height	248 (32.16)	249 (31.55)	197	296	0.77	171
Eye height, sitting	751 (35.86)	752 (36.32)	691	813	0.89	171
Forearm circumference	276 (26.96)	276 (26.66)	240	323	0.65	171
Forearm-forearm breadth	570 (65.09)	574 (64.70)	475	684	1.59	171
Hand breadth	79 (3.89)	79 (3.90)	74	87	0.10	171
Hand length	177 (8.83)	177 (8.48)	163	190	0.21	171
Hip breadth, sitting	459 (51.06)	460 (51.19)	388	559	1.26	171
Knee height, sitting	525 (26.47)	526 (25.69)	487	571	0.63	171
Popliteal height	396 (25.29)	396 (25.17)	360	443	0.62	171
Shoulder-elbow length	333 (19.33)	333 (18.46)	304	364	0.45	170
Sitting height	863 (35.18)	863 (35.49)	804	922	0.87	171
Stature with shoes	1,648 (69.81)	1,647 (69.95)	1,530	1,789	1.72	130
Stature (no shoes)	1,627 (68.54)	1,626 (69.19)	1,510	1,763	1.94	171
Thigh circumference	670 (80.51)	671 (78.66)	560	798	1.93	171
Thigh clearance	174 (22.77)	174 (22.31)	143	212	0.55	171
Thumb-tip reach	770 (37.14)	771 (35.91)	716	845	0.88	171
Upper arm circumference	352 (50.78)	353 (51.14)	278	453	1.26	171
Waist circumference, natural indentation	1,014 (147.26)	1,020 (147.68)	787	1,249	3.62	171
Weight (kg)	90.3 (21.26)	91.0 (21.14)	62.6	126.1	0.52	171
Shoe width	106 (6.85)	106 (6.87)	95	118	0.19	130
Shoe length	274 (15.27)	275 (15.60)	250	303	0.44	130

Note. All values are in millimeters except for weight. NIOSH = National Institute for Occupational Safety and Health.

[a]Since the samples were weighted, the standard error of the 5th and 95th percentiles were calculated on the basis of the sum of weights, instead of *n*, for each body dimension.

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KEY POINTS

- Truck drivers are heavier than the U.S. general population, with a difference in mean body weight of 13.5 kg for males and 15.4 kg for females.
- The current truck drivers have a different anthropometric profile from their counterparts of 25 to 30 years ago, exemplified by a heavier mean body weight (by 13 kg) and larger width and girth dimensions.
- A set of multivariate anthropometric models, spanning 95% of the current truck driver population, has been developed to facilitate future cab designs.

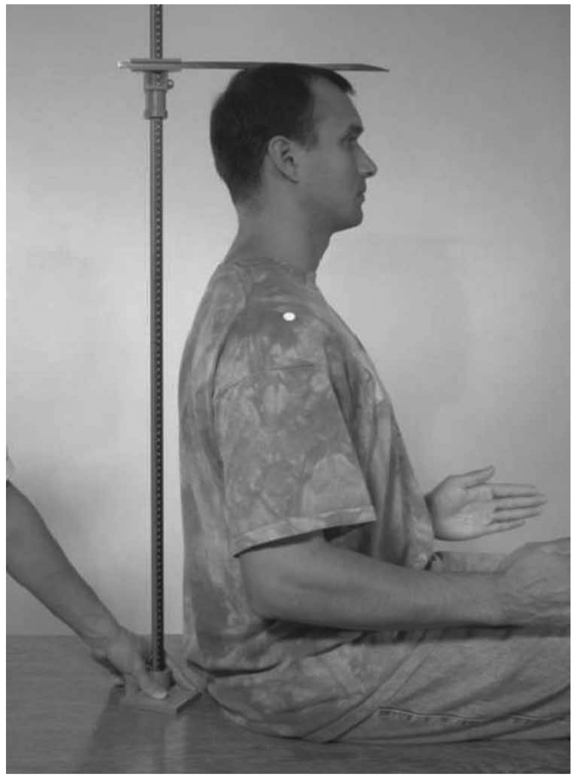

Figure 1.
Illustration of sitting height measurement.

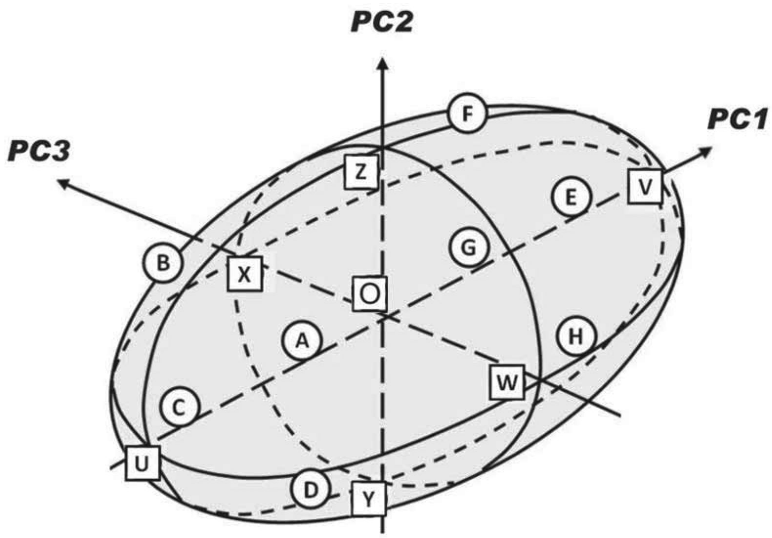

Figure 2.

The centroid, intercept points (square) and octant midpoints (circle) of a 95% enclosure ellipsoid.

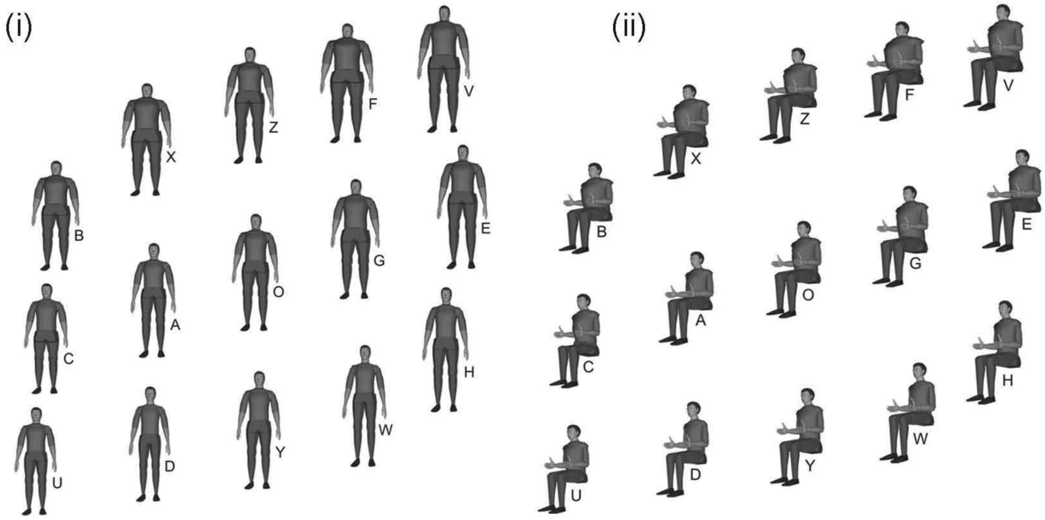

Figure 3.

The 15 male representative body models in both standing (i) and sitting postures (ii).

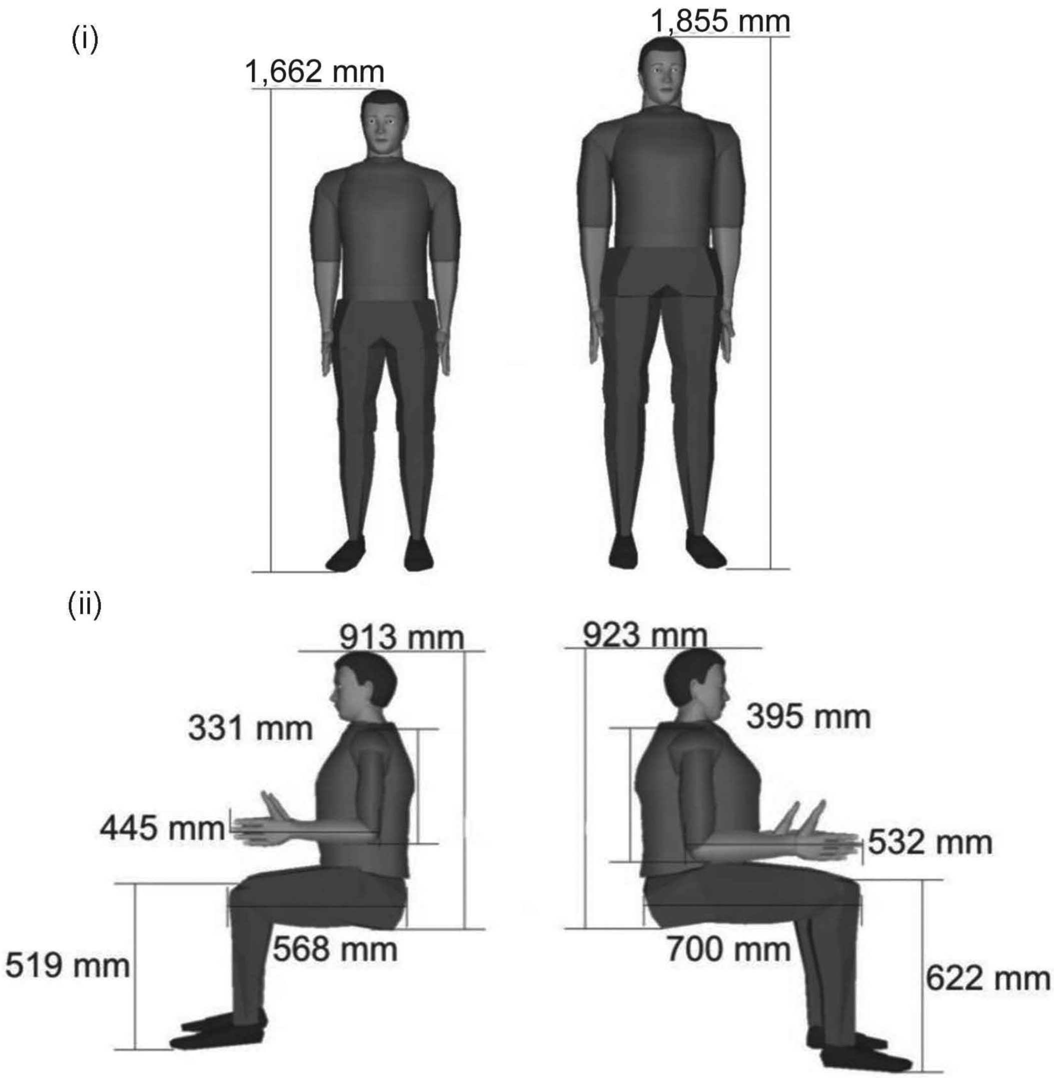

Figure 4.

Contrasting Models C, left in (i) and (ii), and E, right in (i) and (ii). Model C has a relatively short stature (1,662 mm [9th percentile]), short arm length (shoulder-elbow length = 331 mm [5th percentile]; elbow-fingertip length = 445 mm [3rd percentile]), and short leg length (buttock-knee length = 568 mm [3rd percentile]; knee height = 519 mm [3rd percentile]) but a large sitting height (913 mm [44th percentile]). In contrast, Model E has a relatively tall stature (1,885 mm [92nd percentile]), long arm length (shoulder-elbow length = 395 mm [97th percentile]; elbow-fingertip length = 532 mm [97th percentile]), and long leg length (buttock-knee length = 700 mm [97th percentile]; knee height = 622 mm [97th percentile]) but a short sitting height (923 mm [55th percentile]).

TABLE 1

Original Study Sampling Plan and Final Sample

Original Sampling Plan	Non-Hispanic White	Hispanic	Non-Hispanic Black and Others	Total
Males				
Ages 20–24	129	30	24	183
25–29	149	38	28	215
30–34	139	38	26	203
35–39	151	40	26	217
40–44	157	39	26	222
45–49	164	37	25	226
50–54	146	32	21	199
55+	241	47	27	315
Total	1276	301	201	1,780
Females				
All ages, all races				100
Grand total				1,880
Final Sample				
Males				
Age <25[a]	33	10	8	51
25–29	65	31	21	117
30–34	124	42	27	193
35–39	155	41	42	238
40–44	186	49	33	268
45–49	216	45	38	299
50–54	214	32	30	276
55+	290	25	22	337
Total	1,283	275	221	1,779
Females				
<25	2	2	0	4
25–29	3	2	0	5
30–34	9	2	0	11
35–39	18	2	2	22
40–44	20	5	2	27
45–49	32	2	3	37
50–54	26	3	1	30
55+	31	1	3	35
Total	141	19	11	171
Grand total				1,995

[a]Two drivers, ages 18 and 19, were added to the youngest age category, so it is not exactly equivalent to the youngest Bureau of Labor Studies category (which ranged from 21 to 25).

TABLE 2

Data Collection Sites and Location Type

Variable	*n*	Percentage
Region (states)		
South (Texas, Florida, Tennessee)	509	26
Midwest (Kentucky, Ohio, Missouri, Indiana)	541	28
Northeast (Pennsylvania, New York, New Jersey, West Virginia)	353	18
West (Nevada, California, Arizona, Oregon)	547	28
Total	1,950	100
Location type		
Fleet	795	41
Truck stop	566	29
Truck show	589	30
Total	1,950	100

TABLE 3

Independent *t* Tests (Bonferroni) on Four Dimensions: Truck Drivers in NIOSH Study (i) versus U.S. General Population (j)

	NIOSH (i)		NHANES (j)			
Dimension	***n***	***M* (*SD*)**	***n***	***M* (*SD*)**	$M_i - M_j$	***t***
Males						
Stature	1,779	1757 (69.58)	3,335	1,769 (98.15)	–12	–6.53*
Waist circumference	1,779	1,089 (154.31)	3,333	1,002 (266.91)	87	18.55*
Thigh circumference	1,779	635 (69.91)	3,225	545 (90.41)	90	53.59*
Weight (kg)	1,779	102.6 (23.93)	3,193	89.1 (31.18)	13.5	23.61*
Females						
Stature	171	1,626 (69.19)	3,206	1,629 (96.26)	–3	–1.09
Waist circumference	171	1,020 (147.68)	3,121	936 (290.50)	84	11.93*
Thigh circumference	171	671 (78.66)	3,067	536 (138.45)	135	39.90*
Weight (kg)	171	91.0 (21.14)	3,207	75.6 (35.68)	15.4	18.03*

Note. All values are in millimeters except for weight. NIOSH = National Institute for Occupational Safety and Health; NHANES = National Health and Nutrition Examination Survey.

* $p < .05/4 = .0125$, two-tailed test; equivalently $t_{0.05}(4, >120) = \pm 2.50$.

TABLE 4

Independent *t* Test (Bonferroni) on 10 Dimensions for Male Truck Drivers: NIOSH Study (i) Versus Sanders Studies (j)

	NIOSH (i)		Sanders (j)			
Dimension	***n***	***M* (*SD*)**	***n***	***M* (*SD*)**	$M_i - M_j$	***t***
Stature (no shoes)	1,779	1,757 (69.58)	183[b]	1,756 (62)	1	0.48
Sitting height	1,779	919 (36.14)	267[a]	927 (35)	–8	–7.51*
Buttock-knee length	1,779	632 (35.04)	183[b]	636 (32)	–4	–3.98*
Hand breadth	1,779	90 (4.82)	183[b]	89 (5)	1	6.08*
Hand length	1,779	196 (10.10)	183[b]	189 (10)	7	22.84*
Abdominal depth, sitting	1,779	331 (66.03)	183[b]	299 (45)	32	15.44*
Forearm-forearm breadth	1,779	617 (66.17)	183[b]	502 (48)	115	55.85*
Hip breadth, sitting	1,779	428 (46.04)	267[a]	353 (35)	75	53.39*
Waist circumference, natural indentation	1,779	1089 (154.31)	183[b]	1,027 (124)	62	12.76*
Weight (kg)	1,779	102.6 (23.93)	183[b]	90.6 (17.11)	12.0	16.07*

Note. All values are in millimeters except for weight. NIOSH = National Institute for Occupational Safety and Health.

[a] Sanders (1977).

[b] Sanders (1983).

* $p < .05/10 = .005$, two-tailed test; equivalently $t_{0.05}(10, >120) = \pm 3.29$.

TABLE 5

Component Score Coefficient Matrix, Eigenvalues, and Total Variance Explained for Male and Female Truck Drivers

	Principal Component (PC)		
Variable	**PC 1**	**PC 2**	**PC 3**
Males			
Stature, no shoes	0.137	–0.180	–0.055
Shoulder-elbow length	0.103	–0.229	0.081
Elbow-fingertip length	0.112	–0.209	0.131
Bideltoid breadth	0.099	0.240	0.205
Abdominal depth, sitting	0.084	0.259	0.254
Hip breadth, sitting	0.106	0.222	0.211
Sitting height	0.129	–0.017	–0.287
Knee height, sitting	0.134	–0.137	0.127
Buttock-knee length	0.126	–0.078	0.229
Elbow rest height	0.077	0.272	–0.273
Eye height, sitting	0.123	–0.013	–0.305
Acromial height, sitting	0.128	0.106	–0.236
Eigenvalue	6.333	2.417	1.813
Percentage of variation	53	20	15
Total percentage of variation	88		
Females			
Stature, no shoes	0.134	–0.178	–0.041
Shoulder-elbow length	0.099	–0.215	0.229
Elbow-fingertip length	0.109	–0.174	0.228
Bideltoid breadth	0.094	0.269	0.153
Abdominal depth, sitting	0.066	0.301	0.214
Hip breadth, sitting	0.092	0.235	0.159
Sitting height	0.133	–0.065	–0.279
Knee height, sitting	0.134	–0.086	0.184
Buttock-knee length	0.128	0.028	0.240
Elbow rest height	0.082	0.227	–0.362
Eye height, sitting	0.130	–0.067	–0.292
Acromial height, sitting	0.136	0.029	–0.262
Eigenvalue	6.426	2.531	1.526
Percentage of variation	53	21	13
Total percentage of variation	87		

TABLE 6

Multivariate Anthropometric Models and Closest-Neighbor Participants for Male Truck Drivers

Model	Abd Dp, Sit	Acro Ht, Sit	Bidelt Brth	Butt-Knee Lgth	Ebw-Fngrtip Lgth	Ebw Rest Ht	Eye Ht, Sit	Hip Brth, Sit	Knee Ht, Sit	Shldr-Ebw Lgth	Sit Ht	Stature No Shoes
Model O	324	614	535	631	486	252	798	425	568	361	918	1756
participant	323	606	534	633	473	253	797	435	562	351	923	1748
Model A	288	552	497	630	490	189	737	392	562	364	855	1,709
participant	289	533	500	628	498	176	743	391	553	352	864	1,726
Model B	387	570	563	614	462	232	734	447	540	340	851	1,640
participant	371	588	542	627	477	228	740	461	545	355	857	1,633
Model C	285	616	503	568	445	289	797	391	519	331	913	1,662
participant	277	621	498	581	460	279	783	373	528	339	901	1,667
Model D	212	596	445	582	471	235	800	342	540	355	916	1,732
participant	215	594	466	599	472	260	794	354	531	340	923	1,735
Model E	370	612	569	700	532	220	800	463	622	395	923	1,855
participant	412	618	573	693	529	234	799	449	617	386	910	1,866
Model F	497	632	644	683	502	270	797	528	598	368	919	1,780
participant	486	630	647	692	518	248	797	538	601	405	923	1,764
Model G	365	682	576	631	482	337	865	462	575	359	986	1,804
participant	375	666	562	637	472	304	869	462	580	356	978	1,820
Model H	272	661	508	647	511	274	868	404	598	385	989	1,880
participant	282	641	492	649	511	264	858	417	603	373	974	1,873
Model U	252	554	468	567	448	216	736	360	513	333	850	1,617
participant	261	567	458	560	460	236	751	360	518	333	861	1,635
Model V	417	680	612	701	528	294	866	502	629	392	991	1,906
participant	442	663	597	717	522	277	861	500	625	385	992	1,907
Model W	241	594	473	646	515	205	801	372	592	387	921	1,829
participant	257	622	488	645	518	232	799	373	594	386	916	1,810
Model X	436	634	606	615	459	310	796	486	546	337	914	1,685
participant	419	631	569	620	457	313	778	498	542	345	894	1,682
Model Y	261	648	494	597	473	294	846	387	553	355	964	1,772
participant	248	652	489	599	482	283	852	366	544	365	964	1,773
Model Z	403	581	579	666	500	216	753	468	584	368	874	1,739
participant	409	585	565	665	500	215	728	463	578	373	863	1,727

Note. All values are in millimeters. Abd = abdominal; Dp = depth; Acro = acromial; Ht = height; Bidelt = bideltoid; Brth = breadth; Butt = buttock; Lgth = length; Ebw = elbow; Fngrtip = fingertip; Sit = sitting; Shldr = shoulder.

TABLE 7

Multivariate Anthropometric Models and Closest-Neighbor Participants for Female Truck Drivers

Model	Abd Dp, Sit	Acro Ht, Sit	Bidelt Brth	Butt-Knee Lgth	Ebw-Fngrtip Lgth	Ebw Rest Ht	Eye Ht, Sit	Hip Brth, Sit	Knee Ht, Sit	Shldr-Ebw Lgth	Sit Ht	Stature No Shoes
Model O	325	580	499	606	440	251	753	460	526	333	864	1,627
participant	317	597	512	619	445	280	772	467	527	322	883	1,638
Model A	271	525	442	591	446	183	697	407	518	342	809	1,585
participant	252	515	428	589	448	167	705	410	526	345	817	1,599
Model B	386	531	523	597	423	224	682	481	504	318	795	1,509
participant	375	550	528	573	419	238	700	468	517	318	835	1,545
Model C	316	571	484	556	397	281	737	438	479	295	846	1,523
participant	318	561	460	567	383	272	735	430	486	298	832	1,510
Model D	201	566	402	551	420	239	751	364	493	320	860	1,599
participant	210	546	439	576	422	216	747	407	503	325	856	1,601
Model E	335	588	514	655	483	221	769	481	572	370	882	1,730
participant	353	585	506	655	471	225	776	476	551	354	886	1,736
Model F	449	593	596	660	460	262	754	555	558	346	868	1,654
participant	415	608	602	667	461	269	784	574	565	333	885	1,682
Model G	380	634	557	620	434	319	809	512	533	324	919	1,668
participant	381	649	555	604	457	313	809	458	544	332	909	1,683
Model H	265	628	475	615	457	277	823	438	547	348	933	1,745
participant	271	620	454	615	459	280	802	403	548	331	917	1,721
Model U	262	517	426	542	403	213	681	386	472	304	791	1,482
participant	258	528	417	538	392	226	708	388	478	293	817	1,519
Model V	389	642	572	669	477	289	825	534	580	361	937	1,772
participant	405	623	614	647	472	293	817	534	577	326	932	1,743
Model W	211	574	417	600	463	209	767	385	539	357	878	1,703
participant	261	577	435	593	454	220	753	388	532	361	880	1,690
Model X	440	585	581	611	417	292	738	534	512	309	850	1,550
participant	446	583	552	592	431	275	740	547	519	329	855	1,563
Model Y	276	608	471	577	421	291	791	429	508	317	900	1,637
participant	269	594	456	572	432	282	762	402	510	343	870	1,642
Model Z	375	551	527	634	458	211	714	490	543	349	828	1,616
participant	384	573	528	610	473	232	724	484	553	347	835	1,621

Note. All values are in millimeters. Abd = abdominal; Dp = depth; Acro = acromial; Ht = height; Bidelt = bideltoid; Brth = breadth; Butt = buttock; Lgth = length; Ebw = elbow; Fngrtip = fingertip; Sit = sitting; Shldr = shoulder.