Vehicle Occupant Nationality Study: Japanese

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University of Michigan Transportation Research Institute

Final Report

UMTRI-2017-3

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14. ABSTRACT

Few previous studies have compared postures for drivers of different nationalities. In the current study, 73 Japanese citizens who were licensed to drive in Japan participated in a laboratory study of driving posture, belt fit, and body shape using methods identical to those used in an earlier study of US drivers. The data from the two studies were pooled for analysis. As expected, the Japanese study population was shorter in stature and lower in body weight than the US study population. In general, the effects of nationality were small compared to the residual variance in the regressions. After accounting for body size, the Japanese study population placed their seats 13.5 mm further rearward than the US study population and were an average of 1.2 degrees more reclined. Importantly, no significant differences between study populations in the effects on posture of steering wheel position or seat height were found. The lap belt placement was much closer to the pelvis in the Japanese study population; most of this difference could be accounted for by lower body mass index. Statistical body shape models for standing and seated postures were developed using pooled data from 235 US and Japanese subjects. The results showed differences in body shape after accounting for stature, body weight, sitting height and age that were primarily concentrated in the torso. The results of the study are limited by the lack of Japanese individuals with high body mass and age greater than 60 years.

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CONTENTS

ABSTRACT

Few previous studies have compared postures for drivers of different nationalities. In the current study, 73 Japanese citizens who were licensed to drive in Japan participated in a laboratory study of driving posture, belt fit, and body shape using methods identical to those used in an earlier study of US drivers. The data from the two studies were pooled for analysis. As expected, the Japanese study population was shorter in stature and lower in body weight than the US study population. Regression was used to assess the effects of nationality after accounting for differences in body size and age. In general, the effects of nationality were small compared to the residual variance in the regressions. After accounting for body size, the Japanese study population placed their seats 13.5 mm further rearward than the US study population and were an average of 1.2 degrees more reclined. Importantly, no significant differences between study populations in the effects on posture of steering wheel position or seat height were found. The lap belt placement was much closer to the pelvis in the Japanese study population; most of this difference could be accounted for by lower body mass index. Torso belt placement was not significantly different between the study populations after accounting for body size. Statistical body shape models for standing and seated postures were developed using pooled data from 235 US and Japanese subjects. The results showed differences in body shape after accounting for stature, body weight, sitting height and age that were primarily concentrated in the torso. The results of the study are limited by the lack of Japanese individuals with high body mass and age greater than 60 years.

INTRODUCTION

UMTRI recently completed a large-scale study of driver and passenger posture, body shape, and belt fit (Reed and Ebert, 2013). As part of that study, the driving postures of 100 U.S. men and women, including about 60% over age 60 years, were measured in 9 laboratory conditions spanning a large range of vehicle package dimensions. Among the questions that has arisen since the completion of that study is the extent to which the results are applicable to the populations of other countries. No previous studies have systematically compared driving postures between countries using identical methods and test conditions for each country.

This report describes a parallel study conducted with Japanese drivers. The test conditions were identical to those used previously with U.S. drivers. The data analysis quantified differences in posture, belt fit, and body shape attributable to nationality after taking into account body dimensions and age.

METHODS

Participants

Seventy-three people who had been in the United States less than three years and who held Japanese citizenship and a Japanese driver's license were recruited for this study via online advertisements and posting printed in both English and Japanese at businesses, organizations, and public events that had some probability of Japanese citizen involvement. The study protocol was approved by the University of Michigan Institutional Review Board (IRB) for Health Behavior and Health Sciences (IRB# HUM00111070) and written informed consent was obtained using a form approved by the IRB.

The initial recruitment criteria required that participants had been in the US less than 12 months. The requirement was subsequently expanded to 3 years to improve recruitment. However, even with this expansion, 71% of participants reported living in the US less than 1 year, and 87% had been in the US less than 2 years.

Ability to speak English was required, but many laboratory instructions and slide show giving a study overview were professionally translated into Japanese to improve participant comfort and understanding. Evening and weekend appointments were offered and friends or relatives of the participant were invited to accompany participants or volunteer themselves for participation at the same time.

Testing Protocol in Mockup

A driver workstation mockup used in the previous study of US drivers was used in the current study. Figure 1 shows the vehicle mockup, which included a tilting steering wheel, instrument panel, brake and accelerator pedals, six-way power seat, and seat belt. The relationships between the seat, steering wheel, and pedals were adjustable to represent a wide range of different vehicle packages. The driver mockup was equipped with a six-way power seat with a power recline adjuster and a large range of vertical adjustment. The fore-aft seat track was angled 3 degrees above horizontal (higher at the front). The seat was mounted on a motorized platform that could be moved fore-aft so that all participants were able to select a comfortable seat position without being censored by the available seat track adjustment range. This was accomplished by placing the seat design H-point at a different fore-aft position for men and women (see Table 1).

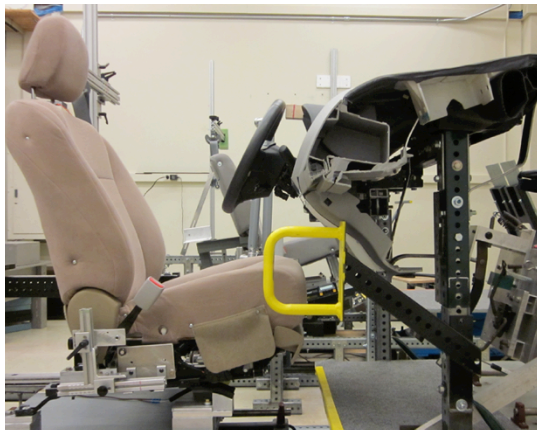


Figure 1. Vehicle mockup.

The vehicle packages chosen as test conditions listed in Table 1 and illustrated in Figures 2 and 3 were among those used in several previous UMTRI studies and are designed to span a large percentage of passenger car, light truck, minivan, and SUV packages. Testing was conducted in a range of conditions distinguished by values of steering wheel fore-aft position (SAE L6 or L11), steering wheel height above the heel surface (SAE H17), and seat height (SAE H30). The pedal plane angle was also changed according to SAE J1516 for each seat height. The steering wheel angle was varied at each seat height. Seat back and cushion angles were initially set to 23° relative to vertical and 14.5° relative to horizontal respectively (SAE J826).

Table 1
Driver Mockup Package Geometry

Package Condition Number	Initial Seat (H-point) Position			Steering Wheel				Pedal
	Z	X relative to AHP		X		Z	Angle (deg.)	Angle (deg.)
	H30	Male	Female	L11	L6	H17		
D1	180	902	755	584	650	578	23°	71°
D2*		882	735	534	600			
D3		861	714	484	550			
D4*	270	833	679	507	600	646	25°	62°
D5		813	658	457	550			
D6*		792	638	407	500			
D7	360	759	630	425	550	715	27°	51°
D8*		738	609	375	500			
D9		718	589	325	450			

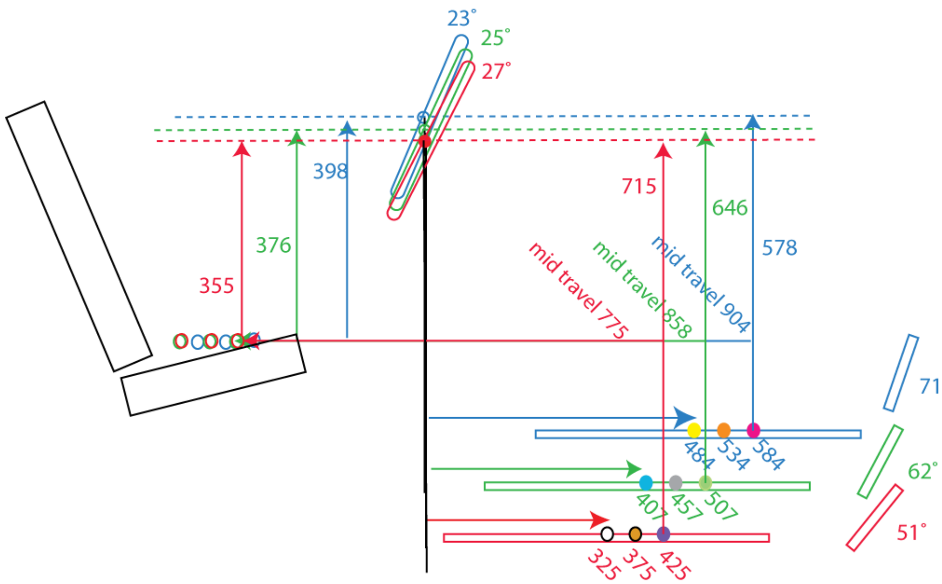


Figure 2. Illustration of driver mockup packages.

In the vehicle mockup, the orientation of the right-handed coordinate system followed SAE J1100 with +X rearward parallel to the long axis of the mockup, +Y toward the passenger/inboard side of the mockup, and +Z upward. The X-axis origin is the ball of foot reference point on the accelerator pedal. The Z-axis origin is the accelerator heel point.

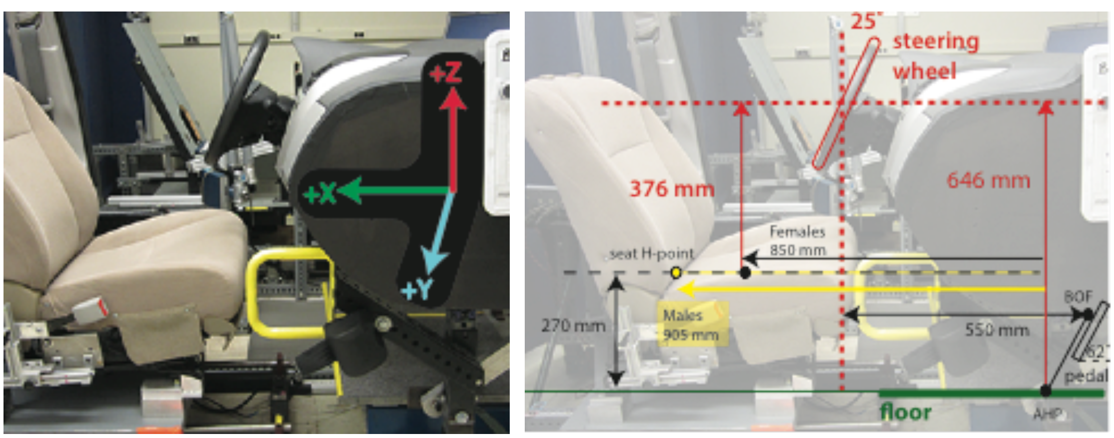


Figure 3. Package dimensions of vehicle mockup for mid condition (D5). Fore-aft and up-down H-point locations are starting positions; participants were able to adjust the seat fore-aft and up-down position, and the seat back and seat cushion angle, to obtain their preferred posture.

The driver mockup was equipped with a three-point seatbelt with a sliding latch plate. The retractor and D-ring were mounted to a fixture allowing the D-ring location to be adjusted over a wide range. With the D-ring at its typical position, the lower anchorages were adjusted to present the flattest and steepest belt angles permitted under FMVSS 213 (30 and 75 degrees). Five belt configurations were obtained by manipulating the belt anchorage locations. Table 2 lists the conditions. Because previous work showed that the D-ring location had minimal effect on lap belt fit across a range of lap belt angles, the effects of D-ring location and lap belt angle were examined separately, each at 3 levels. The shoulder belt YZ and XZ angles were manipulated together, creating three D-ring locations: one location high, rearward, and inboard, one location low, forward and outboard, and one midrange location. Figures 4 and 5 illustrate the belt configurations. The lap belt angles were set relative to seating reference point (SgRP) and were equivalent on the inboard (buckle) and outboard sides.

Table 2
Belt Restraint Conditions

Condition Number		Shoulder Belt		Lap Belt
Package	Belt	ZX Angle (deg)	YZ Angle (deg)	XZ Angle (deg)
D1	DB1	26°	21°	52°
D2				
D3				
D4				
D7				
D8				
D9				
D5	DB1	26°	21°	52°
	DB2			30°
	DB3			75°
	DB4	24.5°	17°	52°
	DB5	31.0°	24°	

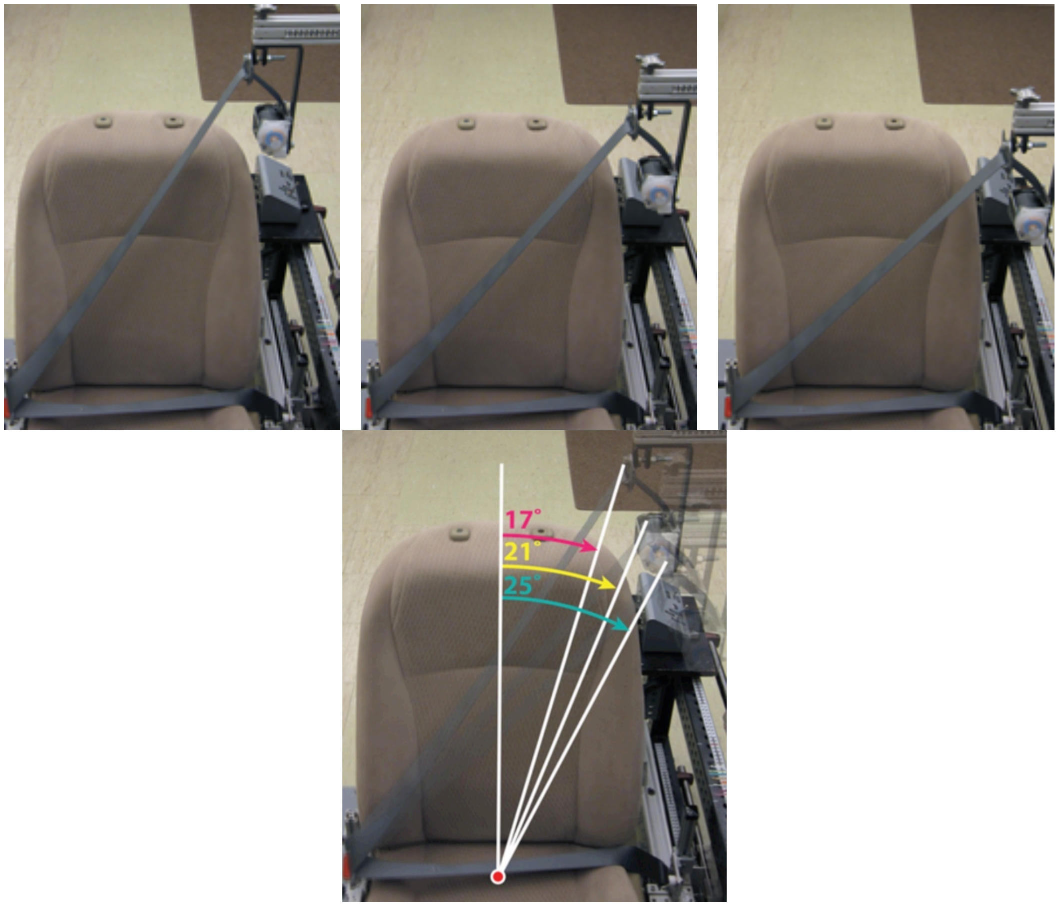


Figure 4. Illustration of shoulder belt conditions with (left to right) D-ring YZ angles of 17, 21, and 25 degrees.

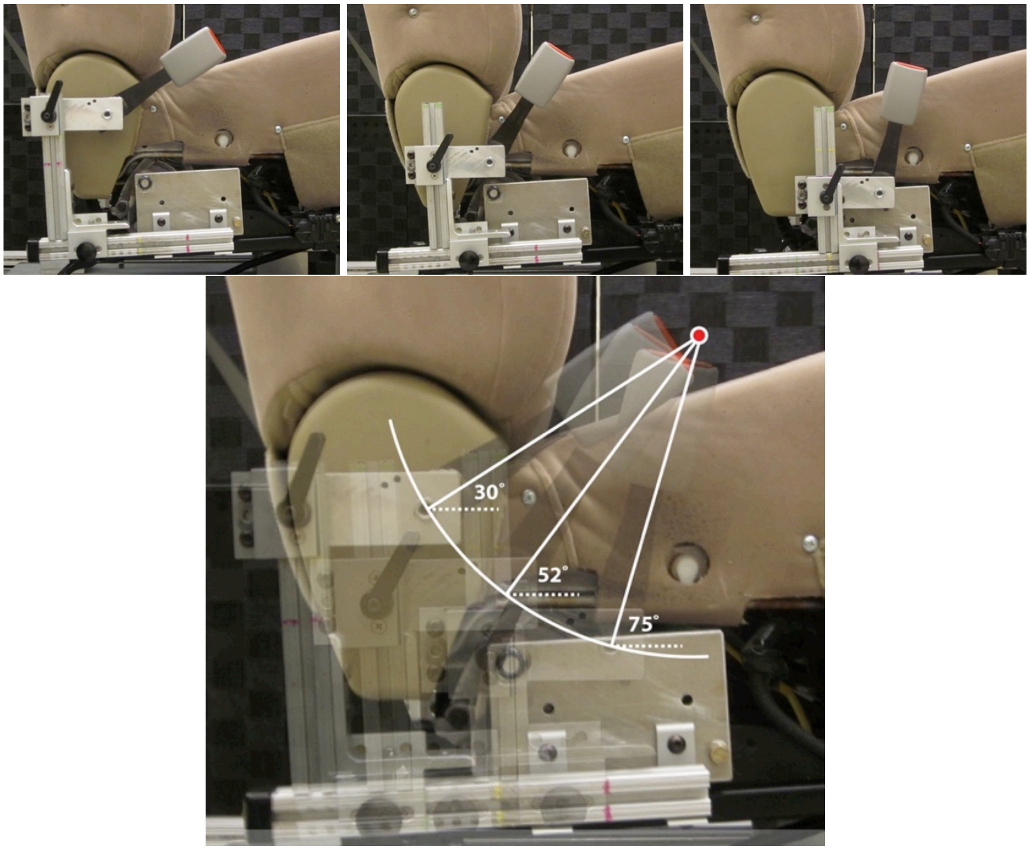


Figure 5. Lap belt buckle anchorage locations for belt fit conditions at 30, 52, and 75 degrees to horizontal.

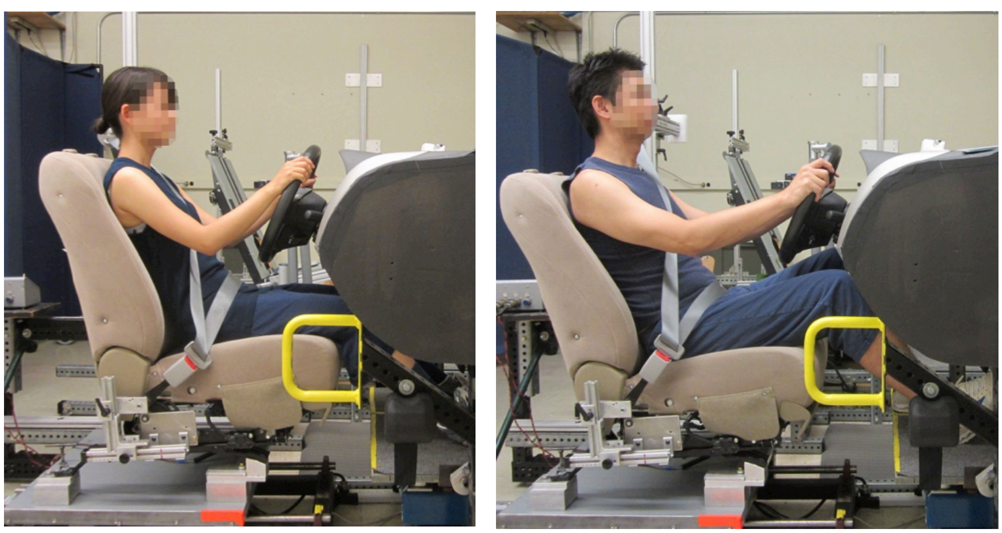


Figure 6. Participants in the mockup.

Protocol

The participant changed into test clothing and standard anthropometric measures were taken. Body landmark locations were recorded in a laboratory hardseat. While seated in the driving mockup, the participant was trained in the operation of each seat adjuster and demonstrated use of the components for the investigator. The initial positions of each participant-adjustable component were set to the same midrange values prior to each trial, except that the fore-aft position of the seat was set to different target for men and women to ensure adequate seat travel (see Table 1). The participant entered the mockup and adjusted the seat (fore-aft position, vertical position, cushion angle, backrest angle) to obtain a comfortable driving posture. The participant then donned the belt and assumed a normal driving posture. The test conditions in Table 1 were presented in random order, except that the conditions in the belt-condition block (package condition 5) were presented randomly in sequence while the package remained fixed.

The investigator used the FARO Arm coordinate digitizer to record the three-dimensional locations of landmarks on the participant's body and on the mockup, seat, and belt (Table 3). In addition, a stream of points with approximately 5-mm spacing was recorded along the edges of lap and shoulder portions of the belt between the anchorages and latch plate (Figure 7).

Due to the difficulty of locating the ASIS points on some participants, the investigator used the tool in Figure 8 to assist in digitizing the ASIS points in the vehicle mockup. The distance between the ASIS points (bispinous breadth) measured with a caliper anthropometer away from the mockup where the investigator had better access to the lap area. With the breadth marked on the tool (Figure 8), the tool was centered on the lap of the participant. The investigator then began palpating the abdomen at these locations and then firmly compressed the flesh over the ASIS while digitizing.

Table 3
Points Recorded on Participant and Vehicle Mockup

	Mockup
	Accelerator Pedal
Participant	Floor
C7 (Cervicale)	Steering Wheel Center
Back Of Head (Max Rearward)	
Top Of Head (Max Height)	Seat
Tragion Lt	Measured before and after
Ectoorbitale Lt	participant's adjustments
Infraorbitale at Pupil Center Lt	3 Points on Seat Cushion (references
Glabella	tracking up-down, fore-aft and tilt)
Suprasternale	2 Points on Seat Back (references
Substernale	tracking recline angle)
Medial Clavicle Lt	
Lateral Clavicle Lt	Restraint System
Anterior of Acromion Lt	D-ring Reference Point
Lateral Humeral Epicondyle Lt	Lower Anchorage Reference Point
Ulnar Styloid Process, Lateral Lt	Buckle Reference Point
ASIS Lt and Rt	
Suprapatella Lt and Rt	Shoulder Belt:
Infrapatellat Lt	Inboard and Outboard Edge on
Lateral Femoral Epicondyle Lt	Clavicle
Medal Femoral Epicondyle Rt	Top and Bottom Edge at Participant's
Toe (Bottom edge of sole, longest shoe point) Lt	Midline
Ball of Foot Lateral Lt	Inboard Edge at Participant's
Ball of Foot Medial Rt	Suprasternale Height
Heel (Bottom edge of sole at midline) Lt & Rt	
Lateral Malleolus Lt	Lap Belt:
Medial Malleolus Rt	Top Edge and Bottom edge at ASIS
	lateral position (Lt & Rt) and at
	Participant's Midline

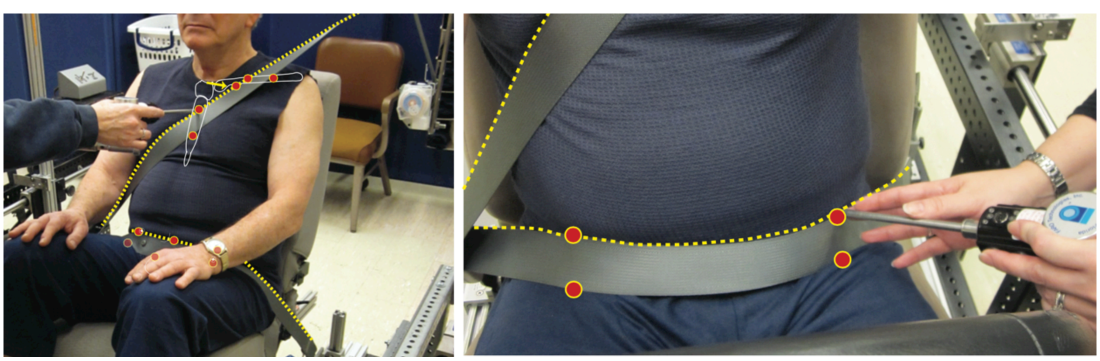


Figure 7. Continuous streams of point data (dashed line) were collected along the entire length of the webbing in addition to point data (red circles). Both the shoulder and lap belt were recorded along the upper edge of the webbing.

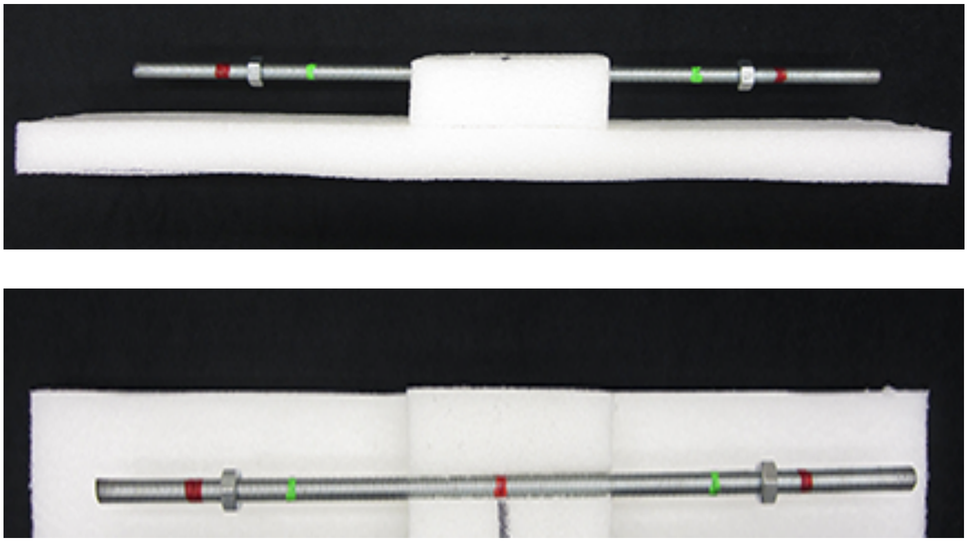


Figure 8. Tool used to aid in finding the ASIS points in the vehicle mockup. The locations of the nuts on the threaded rod were adjusted to the participants bispinous (bi-ASIS) breadth recorded during standard anthropometry

Traditional Anthropometry

Standard anthropometric dimensions, including stature, body weight, and linear breadths and depths (Table 4) were gathered from each participant to characterize the overall body size and shape, following the procedures in Hotzman et al. (2009). All measurements were obtained from the participants in minimally clad test clothing.

Table 4
Anthropometric Dimensions

Weight	Maximum Hip Breadth
Stature (with shoes)	Buttock Knee Length
Stature (without shoes)	Buttock-Popliteal Length
Erect Sitting Height	Biacromial Breadth
Eye Height (Sitting)	Shoulder Breadth
Acromial Height (Sitting)	Chest Depth (on a scapula)
Knee Height	Chest Depth (on spine)
Tragion to Top of Head	Bispinous (BiASIS) Breadth
Head Length	Chest Circumference at Axilla
Head Breadth	Waist Circumference
Shoulder Elbow Length	Hip Circumference at Buttocks
Elbow-Hand Length	Upper Thigh Circumference

Hard Seat

Body landmark locations were recorded in the laboratory hardseat shown in Figure 9. The hardseat allows access to posterior spine and pelvis landmarks that are inaccessible in the automotive seat. The hardseat has a 14.5° "cushion" (pan) angle and a 23° back angle designed to produce postures similar to those in an automotive seat. Table 5 lists the landmarks recorded in the hardseat. Using the hardseat data, the adjustment for adiposity described in Reed et al. (2013) was applied to the points recorded on the pelvis (Figure 10).

Figure 9. Hardseat

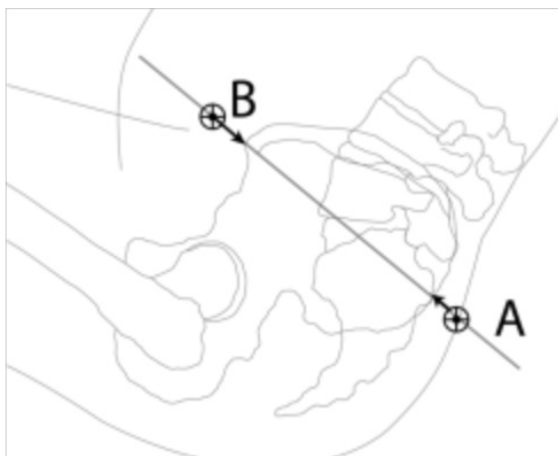


Figure 10. Compensation for adiposity at the PSIS flesh margin (A) and ASIS flesh margin (B) separating the depressed surface landmark from the underlying bone landmark

Table 5
Hardseat Landmarks and Scanning Markers

Back if Head	Lateral Femoral Epicondyle Rt and Rt	C7
Top Of Head (Vertex)	Lateral Femoral Epicondyle Marker Lt and Rt	C7 Marker
Tragion Rt and Rt	Lateral Fibular Head Lt and Rt	T4
Ectoorbitale Lt and Rt	Medial Femoral EpicondyleLt and Rt	T4 Marker
Infraorbitale at Pupil Center LT and Rt	Medial Femoral Epicondyle Marker Lt and Rt	T8
Glabella	Medial Tibial Condyle Rt	T8 Marker
Medial Clavicle Lt and Rt	Suprapatella Lt and Rt	T12
Lateral Clavicle Lt and Rt	Infrapatella Lt and Rt	T12 Marker
Acromion Lt and Rt (Anterior)	Heel Lt and Rt	L1
Acromion Lt Marker	Malleolus Lateral Lt and Rt	L1 Marker
Humeral Epicondyle Lateral Lt and Rt	Lateral Ankle Marker Lt and Rt	L2
Lateral Elbow Lt Marker	Ball of Foot Lateral Lt and Rt	L2 Marker
Humeral Epicondyle Medial Lt and Rt	Toe (Longest Tibiale) Lt and Rt	L3
Medial Elbow Lt Marker	Ball of Foot Medial Lt and Rt	L3 Marker
Ulnar Styloid Process Lt and Rt	Malleolus Medial Lt and Rt	L4
Radial Styloid Process Lt and Rt	Medial Ankle Rt Marker	L4 Marker
Wrist Mid Top Marker Lt and Rt	Rib10 Marker Lt and Rt	L5
Wrist Mid Bottom Marker Lt and Rt	Lateral Torso Ctr Marker Lt and Rt	L5 Marker
Lateral Hand Lt and Rt	Iliocristale Marker Lt and Rt	ASIS Lt and Rt
Medial Hand Lt and Rt	Torso Mid Top Marker Lt and Rt	PSIS Lt and Rt
Suprasternale	Torso Mid Bot Marker Lt and Rt	
Substernale		
Chest Triad Markers (3)		
Acromion Rt (Anterior)		
Acromion Rt Marker		

Whole-Body Scanning

Body shape and surface contours were recorded using a Vitronic Vitus XXL full-body laser scanner and Scanworx software by HumanSolutions. The VITUS XXL records hundreds of thousands of data points on the surface of the body in about 12 seconds by sweeping four lasers vertically. The two cameras on each of the four scanning heads pick up the laser light contour projected on the participant and translate the images into accurate three-dimensional data. Figure 11 shows a participant being scanned and images of the resulting data.

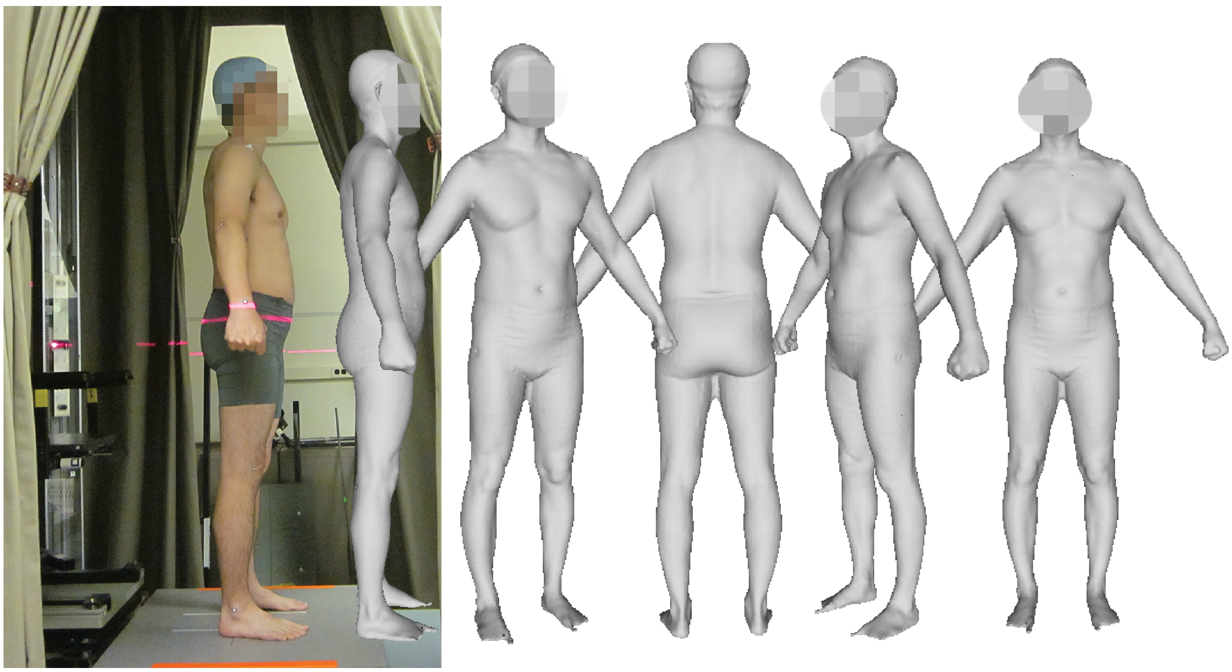


Figure 11. Participant in the scanner and several views of the resulting data.

The locations of landmarks on the participants were recorded via skin targets stamped on the skin. Body landmarks were marked on the skin using a pattern of water soluble, non-toxic, square ink stamp into which was placed a high contrast white paint dot. Figure 12 shows the landmarks schematically.

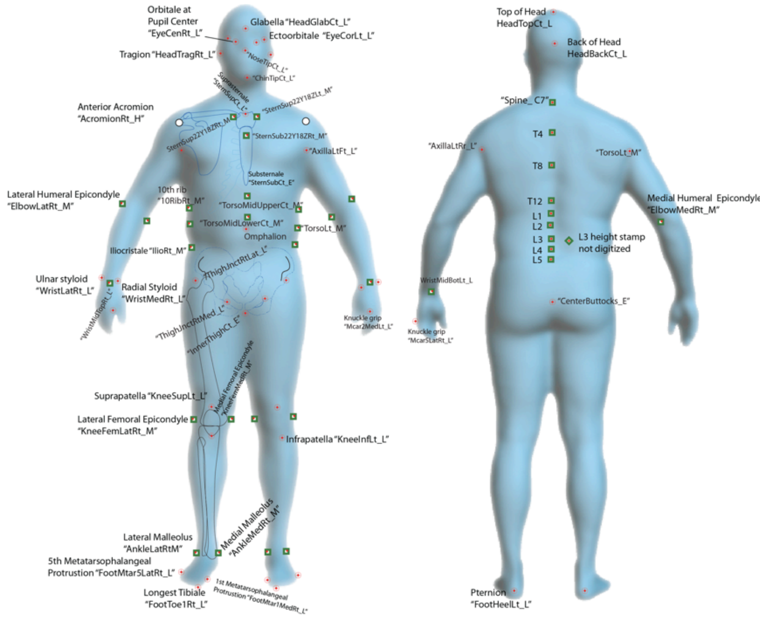


Figure 12. Targets stamped on participant to track skeletal landmarks and track changes in torso shape across postures.

The participants were scanned in range of postures that included standing, unsupported seat, driving, and several other automotive-like postures that spanned three seat back recline angles. Figures 13 to 18 show participants with a range of sizes in some of the postures.

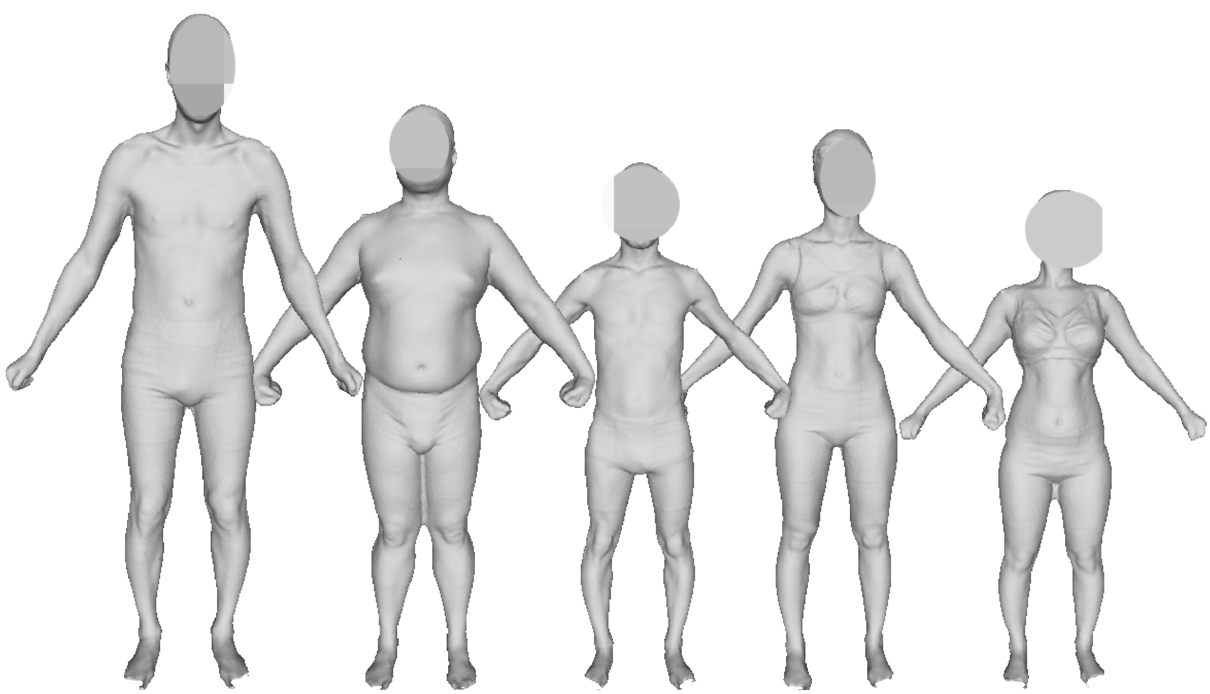


Figure 13. Scans of participants in standing posture (T2)

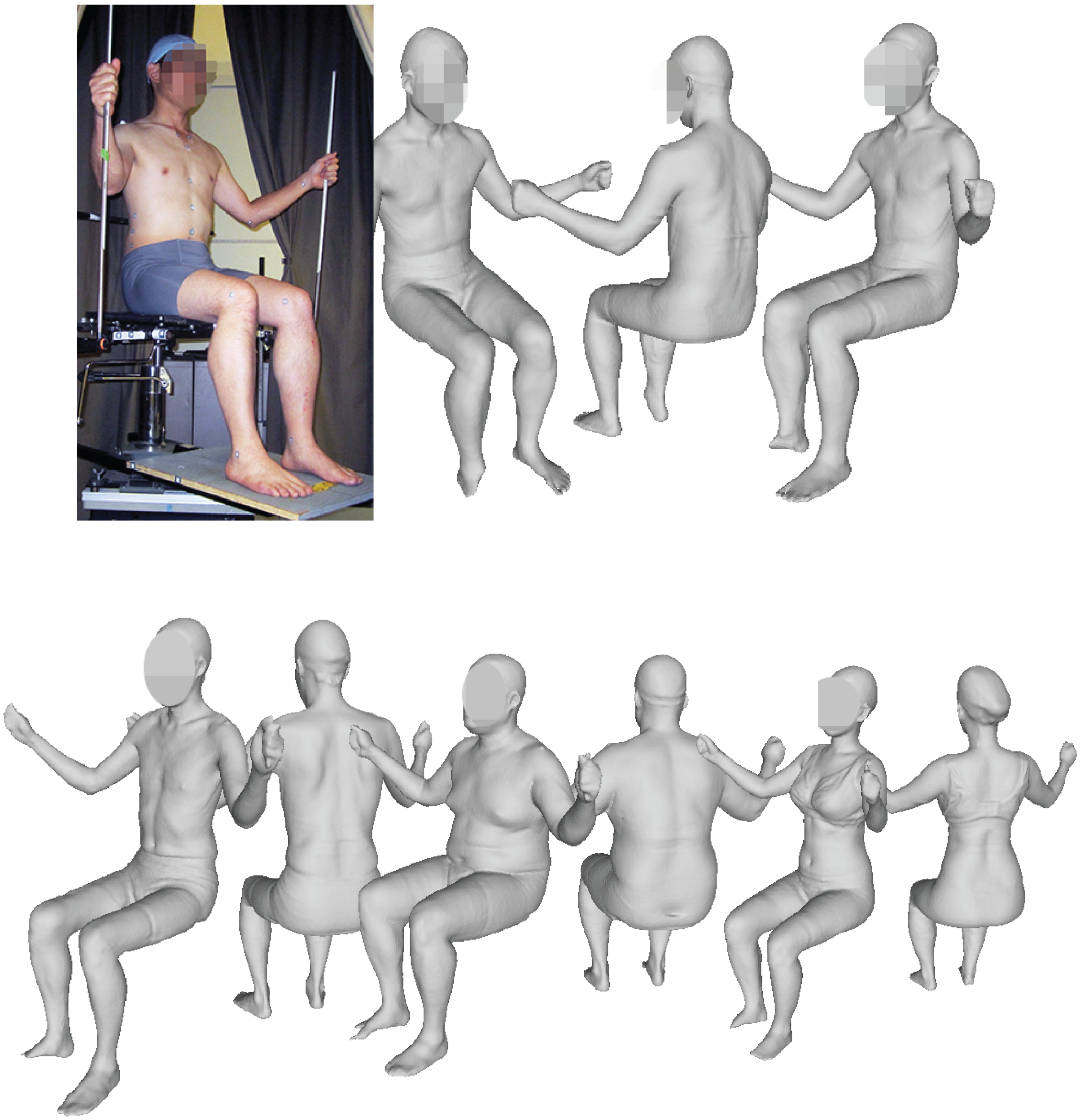


Figure 14. Scans in of participants in unsupported seated posture (L1)

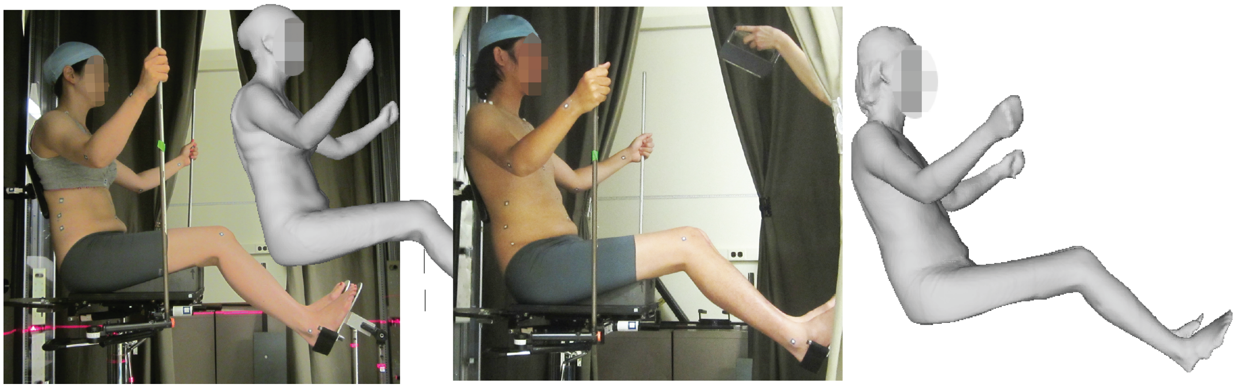


Figure 15. Participants scanned in driving posture (CB)

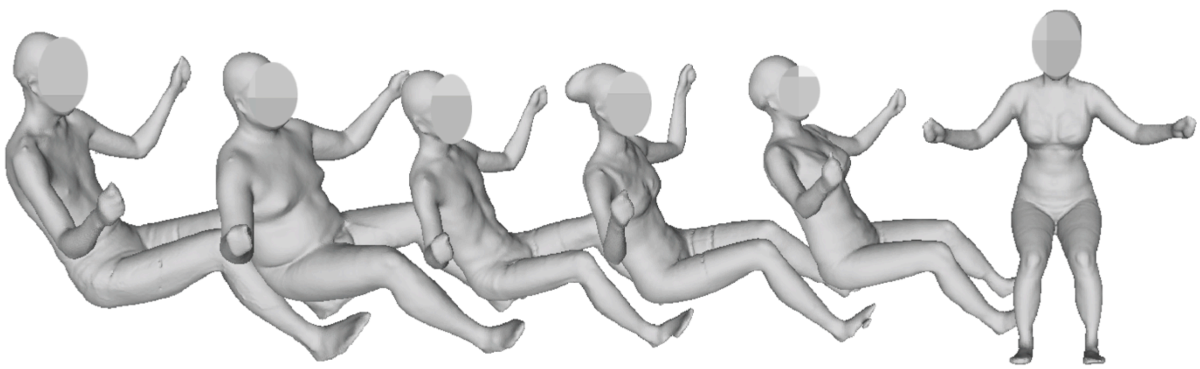


Figure 16. Examples of participant scans in driving posture (CB)

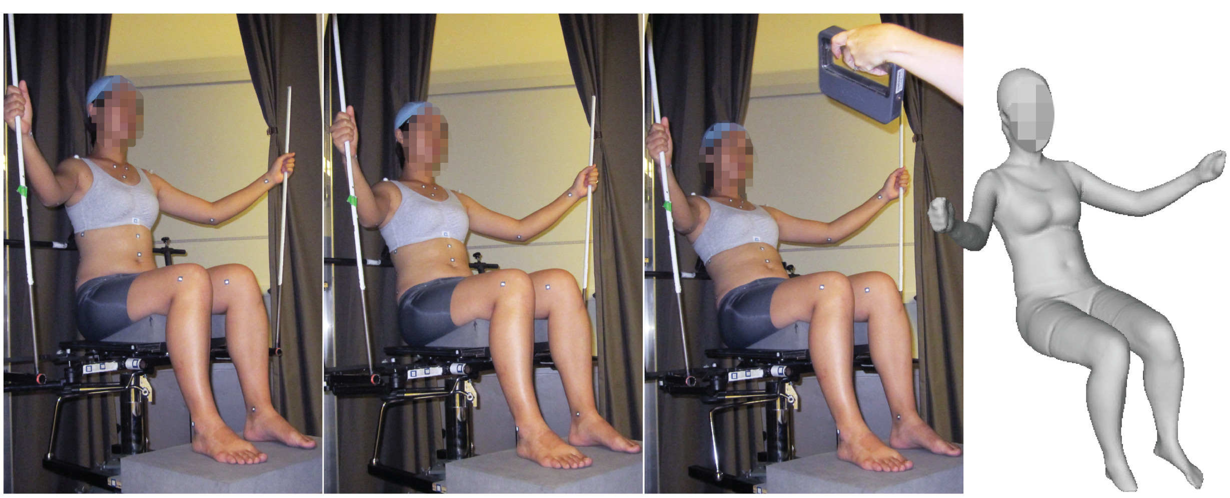


Figure 17. Participant scanned in automotive posture at several recline angles (R1, R2, R3)

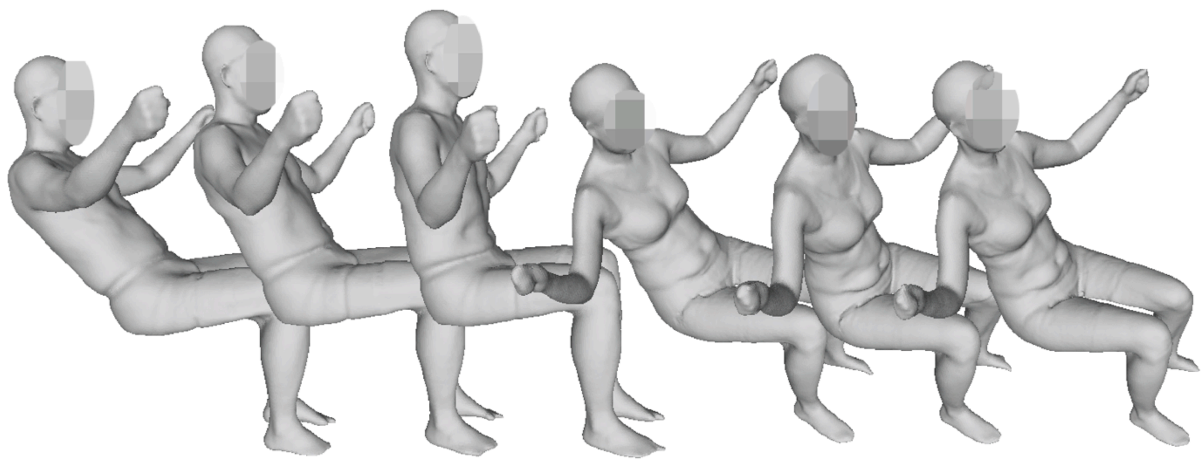


Figure 18. Examples of participant scans in automotive posture at several recline angles (R1, R2, R3).

Analysis Methodology

The primary objective of the data analysis was to identify differences in posture, belt fit, and body shape between the Japanese and US study populations, *after* accounting for difference in body dimensions and age. Several approaches were considered:

1. developing predictive models from each data set and comparing the predictions for similar generic input values (for example, selected percentiles for each population)

2. developing predictive models for each data set and comparing predictions for the individuals in the other data set to observed values

3. pooling the data from the two studies, developing prediction models, and comparing the residuals for the individuals in the two datasets.

After some investigation, **approach 3 (pooled data) was chosen**. The primary reasons were (1) the pooled dataset provides additional statistical power, and (2) the pooled database is more diverse with respect to anthropometric variables, providing better estimates of the effects of those variables.

With the pooled data, one approach is to create regression models that include nationality as a predictor and to consider interactions between nationality and other predictors. For example, the analysis can test whether the effects of stature or seat height on driver posture differ across the populations. However, the restriction of range of the anthropometric variables for the Japanese population poses a problem for that approach. For example, the range of BMI in the Japanese population is much smaller than for the US sample, in part because the US sample was deliberately constructed to have a representative level of obesity, whereas the Japanese study population is a convenience sample. Consequently, the interaction between nationality and BMI is significant for some variables because the BMI effect for Japanese drivers is minimized by the restriction of range. Consequently, interactions between nationality and anthropometric variables were examined during exploratory analyses but not included in the final models.

Interactions between anthropometric variables and vehicle package and belt geometry variables were considered, but none was important enough to include. Included variables were statistically significant ($p<0.001$) and also improved the adjusted R^2 value by at least 0.02 relative to the model without the variable.

For each dependent measure of interest, a regression model was developed using potential predictors of the package and/or belt geometry variables, anthropometric variables, and age. The ratio of sitting height to stature (SH/S) was used rather than sitting height to reduce the problems associated with collinearity of predictors. The residuals associated with the resulting model were compared across study populations and significant differences ($p<0.001$) were reported. As a result of these procedures, the results document differences between the study populations after accounting for vehicle and belt layout, anthropometric factors, and age.

The package variables used as potential predictors were H30 (seat height) and L6 (fore-aft steering wheel position – see Table 1). H30 and L6 were correlated due to the study design. To reduce issues related to collinearity in the regression predictors, L6 was expressed relative to the middle L6 value at each value of H30 (referred to as $L6_{rel}$), taking on values of -50, 0, and 50.

Posture Analysis

The primary dependent measures for posture are listed in Table 6. The variables were selected due to their importance for vehicle layout and safety applications, such as crash test dummy positioning. These are also the key variables previously analyzed for US drivers in Reed et al. (2002) and Park et al. (2016).

Table 6
Primary Driver Posture Variables (mm, deg)

Variable	Definition
SeatPositionX	Fore-aft (X) and vertical (Z) location of driver-selected seat position (translated H-point location) relative to BOF and AHP
SeatPositionZ†	Fore-aft (X) and vertical (Z) location of mean hip joint center location with respect to seat H-point
HipReHPtX	Fore-aft (X) and vertical (Z) location of eye with respect to mean hip joint center
HipReHPtZ	Angle of side-view vector from mean hip joint center to eye with respect to vertical
HipEyeX	Fore-aft distance from mean hip joint center to mean eye location
HipEyeZ	Vertical distance from mean hip joint center to mean eye location
HipEyeAngle	Sideview angle of vector from mean hip joint center to mean eye location with respect to vertical, positive rearward of vertical
EyeX	Fore-aft location of mean eye with respect to BOF.
EyeZ	Vertical location of mean eye with respect to AHP
HeadAngle	Sideview angle of vector from tragion to infraorbitale with respect to horizontal, measured on the left side, positive with infraorbitale above tragion
NeckAngle	Sideview angle of vector from C7T1 joint to atlanto-occipital joint, positive rearward of vertical
ThoraxAngle	Sideview angle of vector from T12/L1 joint to C7T1 joint, positive rearward of vertical
AbdomenAngle	Sideview angle of vector from L5/S1 joint to T12/L1 joint, positive rearward of vertical
PelvisAngle	Sideview angle of vector from mean hip joint to L5/S1 joint, positive rearward of vertical
ThighAngle	Sideview angle of vector from right hip joint to right knee joint, positive above forward horizontal
KneeAngle	Sideview included angle between the vectors from right hip to right knee and right knee to right ankle; a straight knee corresponds to 180 degrees
SeatBackAngle	Seat back angle referenced to the SAE J826 H-point manikin torso angle
SeatCushionAngle	Seat cushion angle referenced to the seat cushion angle (SAE A27) measured using the SAE J826 H-point manikin

Belt Fit Analysis

Following methods used in a previous belt fit studies (Reed et al. 2013), lap belt fit was quantified by the fore-aft and vertical location of the upper/rearward margin of the lap portion of the belt at the lateral location of the anterior-superior iliac spine (ASIS) landmarks on the left and right sides of the pelvis (Figure 19), incorporating the correction for adiposity at the ASIS from Reed et al. (2013). Shoulder belt fit was quantified by the lateral location of the inboard edge of the shoulder portion of the belt relative to the body midline at the height of the suprasternale landmarks (Figure 20). The

Y-axis (medial lateral) distance between the body midline and belt is termed shoulder belt score (Reed et al. 2009, Reed et al. 2012, Reed et al. 2013 A fifth-order Bézier curve was fit to the lap and shoulder belt stream points to smooth measurement error. The amount of belt feed out was calculated by finding the lengths of the lap belt between the lower outboard anchor and the buckle and the shoulder belt between the D-ring and buckle were calculated along the Bézier curve.

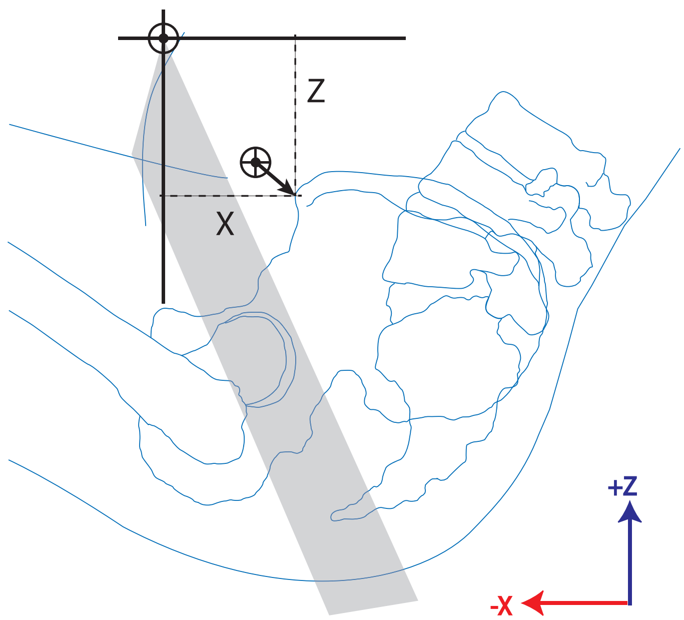


Figure 19. Locations of points recorded on the lap belt and the dimensions corresponding to the X and X lap belt scores.

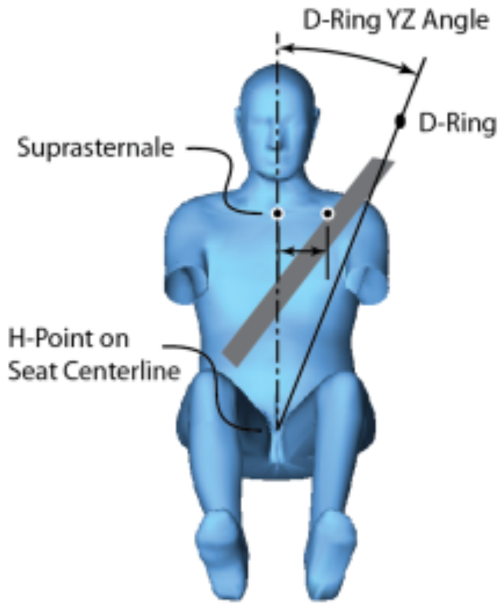


Figure 20. Torso (shoulder) belt fit measurement. Larger positive values indicate more-outboard belt placement. The definition of D-ring YZ Angle is also shown.

Body Shape Analysis

The laser scans were processed in a manner consistent with previous UMTRI studies (Reed and Ebert 2013). In brief, the scan files were edited to remove data from the seat and other hardware components. Marker locations were manually digitized using Meshlab v1.31 software (meshlab.org). Areas of missing data were filled in Meshlab using a Poisson reconstruction algorithm and the scans were decimated to 80k vertices. A homologous template was fit to the scans using methods described in Park and Reed (2015). A principal component analysis was conducted on the matrix of vertex coordinates for the pooled dataset from the US and Japanese studies. All principal components were retained for subsequent analyses. Regression analysis was conducted predicting principal component scores from anthropometric variables (stature, BMI, SH/S, and age), gender, and nationality. Interactions between gender and the anthropometric predictors and between nationality and the anthropometric predictors were included. This results in different effects of the anthropometric variables depending on the gender and nationality selected. Analysis results are reported for the relaxed standing (T2) and seated automotive postures.

RESULTS

Participant Demographics

Of the 23 women and 50 men, 100% self-reported their ethnicity as Asian, with sub group reporting to be 94% Japanese, 3% Japanese and Korean, 2% Japanese and Chinese, and 1% Arab or Middle Eastern. Participants had been in the US between 1 and 35 months with an average stay of 10 months and a median of 6 months. Sixteen of the participants reported having visited another country besides the US for longer than 12 months, of which six participants reported driving while there. Of the 70 participants who answered the question about current driving habits, 10% indicated that they were not driving in the US, 7% were driving 2-3 times per week and 56% drove three or more times per week. Of the vehicles driven in Japan, 15% were reported to be manual transmissions versus 85% automatic, whereas 100% of the vehicles driven in the U.S. were reported to have automatic transmissions. All but two of the vehicles reported to be driven in Japan were from Japanese manufacturers. In the US, 11 participants reported driving vehicles from non-Japanese manufacturers. Regarding belt use, 99% of participants reported using the seat belt when in the driver or in the front passenger position "always". However, only 42% reported using the seat belt "always" when seated in the rear, with 35% reporting "nearly always", 14% "seldom," and 9% "never."

Anthropometric Comparison

As expected, the body dimensions of the Japanese sample differ significantly from the U.S. sample. Table 7, Figure 21, and Figure 22 compare the distributions of selected variables. The median stature is similar between the two populations, but the range is greater for the US study population. Large differences are seen in the distribution of BMI, age, and SH/S.
Only one Japanese driver had a BMI greater than 30 kg/m^2 and none was above age 60 years. Approximately 75% of the Japanese drivers had BMI less than then 25th percentile of the US population distribution. All but one of the drivers in the combined population with body weight greater than 90 kg was in the US population. The median ratio of sitting height to stature is higher for the Japanese drivers, with a median of 0.54. Approximately 75% of the Japanese study population had a SH/S value greater than the 75th percentile of the US sample. For a midsize US male with a stature of 1750 mm, the difference in SH/S of 0.02 would correspond to a difference in torso length (or lower extremity length) of 35 mm. Appendix B presents additional detail on the anthropometry of the study population including separate tabulations for men and women.

Table 8 compares the study populations with the latest available data for the two national populations. The US summary statistics for stature and body weight are drawn from the National Health and Nutrition Examination Survey (2011-2014) presented by Fryar et al. (2016). The Japanese statistics are from the Size Japan survey conducted from 2004 to 2006 as reported in IOS Technical Report 7520-2 (ISO 2016).

Table 7
Study Populations (Combined Men and Women)

US (36 men, 40 women)	Mean	SD	5%	25%	50%	75%	95%
Stature	1689	113	1531	1605	1672	1782	1864
Weight (kg)	77.9	18.5	52.9	63.8	75.4	91.1	106.8
BMI (kg/m2)	27.1	4.6	20.3	24.1	26.1	30.0	35.4
Erect Sitting Height (mm)	879	57	793	837	881	920	961
SH/S (mm/mm)	0.521	0.015	0.502	0.510	0.519	0.531	0.548
Age (year)	59.3	20.0	23.9	38.8	66.6	74.0	83.0
Japanese (47 men, 24 women)							
Stature	1664	87	1519	1597	1676	1717	1787
Weight (kg)	62.7	13.2	45.7	52.2	61.6	73.2	82.4
BMI (kg/m2)	22.4	3.2	18.7	19.8	21.9	24.2	28.6
Erect Sitting Height (mm)	902	42	833	874	903	924	976
SH/S (mm/mm)	0.542	0.013	0.524	0.532	0.541	0.554	0.562
Age (year)	35.3	7.8	25.5	29.9	33.1	39.5	50.1

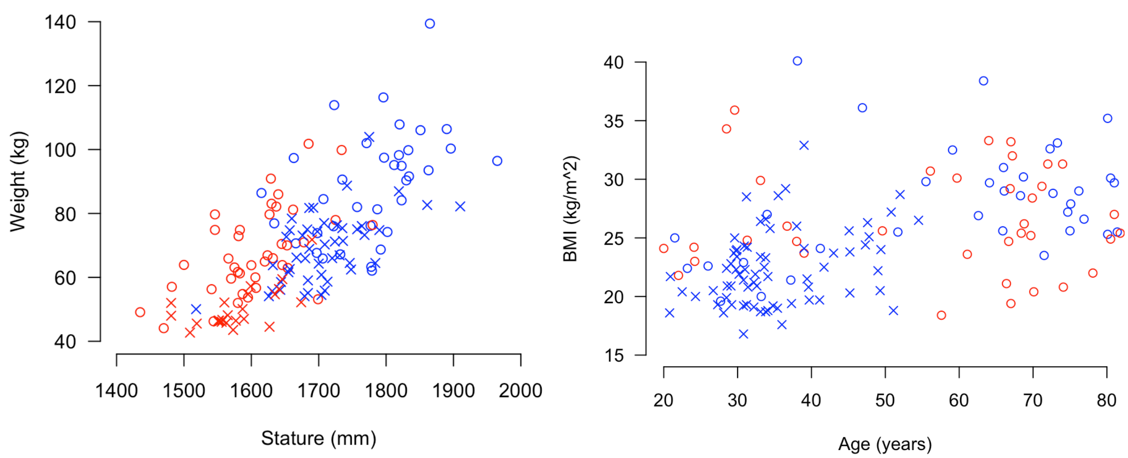


Figure 21. Comparison of stature, body weight distributions, BMI, and age distributions for US (o) and Japanese (x) study populations for men (blue) and women (red).

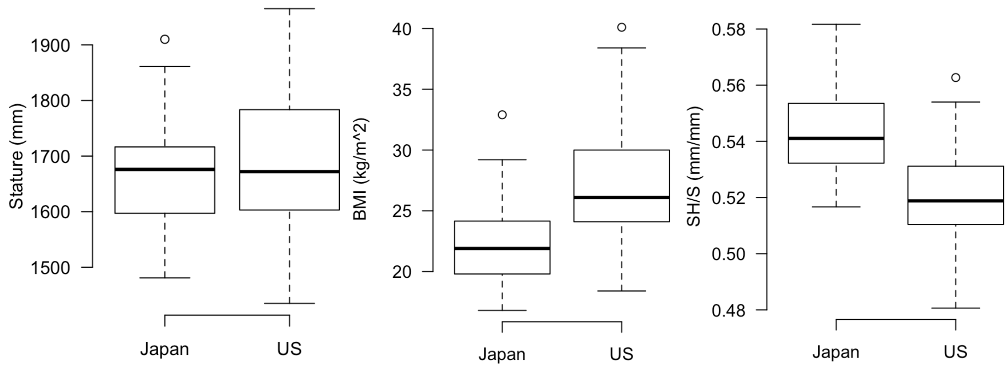


Figure 22. Comparison of the distributions of stature, BMI, and SH/S for the Japanese and US study populations (combined men and women).

Table 8
Comparison of Study Population Anthropometry to US (Fryar et al. 2016) and Japan (ISO TR 7250-2) Population Statistics

US Men (N=36)	Mean	SD	5%	50%	95%
Stature (mm): Study	1779	77.0	1656	1790	1892
Stature (mm): US	1757	75.1	1634	1756	1881
Weight (kg): Study	88.8	17.2	65.2	90.5	114.5
Weight (kg): US	88.8	19.5	61.0	85.9	125

US Women (N=40)					
Stature (mm): Study	1607	70.0	1481	1607	1725
Stature (mm): US	1618	72.0	1498	1619	1735
Weight (kg): Study	68.0	13.6	49.0	65.4	91.3
Weight (kg): US	76.4	20.3	50.1	70.1	117

Japanese Men (N=47)	Mean	SD	5%	50%	95%
Stature (mm): Study	1708	64.9	1631	1704	1810
Stature (mm): Japan	1696	59.9	1597	1696	1795
Weight (kg): Study	69.1	10.9	54.2	68.9	85.7
Weight (kg): Japan	67.5	9.8	54	67	84

Japanese Women (N=24)	Mean	SD	5%	50%	95%
Stature (mm): Study	1578	54.3	1485	1569	1670
Stature (mm): Japan	1570	55.1	1481	1570	1664
Weight (kg): Study	50.2	6.5	43.7	47.5	59.1
Weight (kg): Japan	51.9	7.0	43	51	64

Posture

Table 9 lists the regression models for the combined dataset, along with the difference between studies in the residual (after accounting for the regression predictors). After accounting for body size and age, the average Japanese driver placed the seat 13.5 mm more rearward than the average U.S. driver. This effect is somewhat less than half of the root mean square error (RMSE) from the regression.

Surprisingly, the ratio of sitting height to stature (SH/S) was not a significant predictor of fore-aft seat position. As noted above, one of the notable anthropometric differences between populations is the larger mean SH/S for the Japanese population. However, no effect was observed. Considering only the US study population, SH/S is not significant either, even though it has a large ranger than the range of the Japanese study population (see Table 7), so it is apparent that stature is a more important determinant of seat position than body proportions. Vertical seat position was essentially identical between the study populations.

The Japanese study population was slightly more reclined, on average, using the position of the eyes with respect to the hips. The hip location relative to the seat differed by less than 3 mm in the X direction. Unlike in the earlier US analysis, BMI was not a significant predictor of fore-aft hip location with respect to H-point, probably due to the large number of low-BMI subjects in the combined dataset. A vertical difference in hip location 6.5 mm was noted. The slightly greater recline for the Japanese study population (again, after accounting for body dimensions and age), is observed in the segment angles as well, except that the head angle was slightly smaller (closer to horizontal) for the Japanese drivers. No differences between study populations were observed for seat back angle, seat cushion angle, thigh angle, or knee angle, although the latter two were affected by all of the potential predictors except age.

The combination of increased recline and more-rearward seat position yields Japanese driver eye locations an average of 40 mm rearward of the values for US drivers after accounting for vehicle package geometry and body size. This is somewhat less than the RMSE for the regression, but is the largest discrepancy of any that were quantified. In contrast, no population difference for eye height relative to AHP after subtracting H30 was observed in the regression residuals. A close examination of the data reveals that this difference is due to a more reclined posture for the Japanese study population than for the US population, after accounting for body size and age. However, seat back angles were not significantly different between the studies.

Table 9
Regression Models for Combined Dataset and Study Difference in Residual (mm, deg)

Variable	Intercept	H30	$L6_{rel}$	Stature	SH/S	BMI	Age	RMSE	R^2_{adj}	Study Effect*	%
SeatPositionX	355	-0.387	0.419	0.345		1.44		29.6	0.74	13.5	2
SeatPositionZ†	54.8			-0.03				14.6	0.04	-0.6	0
HipReHPtX	-26.0									-2.9	0
HipReHPtZ	-6.7									6.5	0
HipEyeX	-335				835		-0.52	43.1	0.19	12.7	4
HipEyeZ	-273			0.332	604		0.38	24.7	0.60	-7.8	2
HipEyeAngle	-31.9				78.7		-0.048	4.1	0.19	1.2	4
EyeX	483	-0.433	0.549	0.350		-1.12		48.9	0.53	39.6	10
EyeZ**	-369			0.333	741	1.51		2.5	0.62	n.s.	0
HeadAngle	-11.1					0.36	0.083	6.8	0.14	-1.6	2
NeckAngle	3.0	-0.011				-0.15		6.9	0.02	2.0	3
ThoraxAngle	-56.0				142	-0.333	-0.092	6.5	0.33	2.2	5
AbdomenAngle	-31.8				73.3	0.971	-0.053	10.3	0.13	3.0	5
PelvisAngle	61.4					-0.504		15.6	0.02	-2.8	1
ThighAngle	17.6	-0.028	-0.03	0.024	-50.0	-0.32		4.8	0.36	n.s.	0
KneeAngle	160	-0.095	0.068	-0.029	45.4	0.53		8.7	0.48	n.s.	0
SeatBackAngle	14.5	0.006					-0.034	4.8	0.03	n.s.	0
SeatCushionAngle	12.0	-0.002				0.061		1.9	0.03	n.s.	0

* Difference for Japanese study relative to US study after taking into account regression factors. (n.s.= not significant)
† Relative to H30; stature effect reflects angled seat track (3˚)
** Relative to H30
% Change in adjusted R^2 value from adding nationality to the predictors, expressed as percentage of total variance. in the dependent measure, e.g., a change in R^2_{adj} from 0.60 to 0.62 = 2%.

Belt Fit

Figure 23 shows the lap belt scores (left side only) for belt condition DB1 (midrange). Figure 24 compares the distributions of lap belt scores across all 5 belt conditions for the two studies. Both figures demonstrate that the lap belt scores for the Japanese drivers are clustered near the bottom of the range, indicating belt placements closer to the pelvis, on average, in both the horizontal and vertical directions.

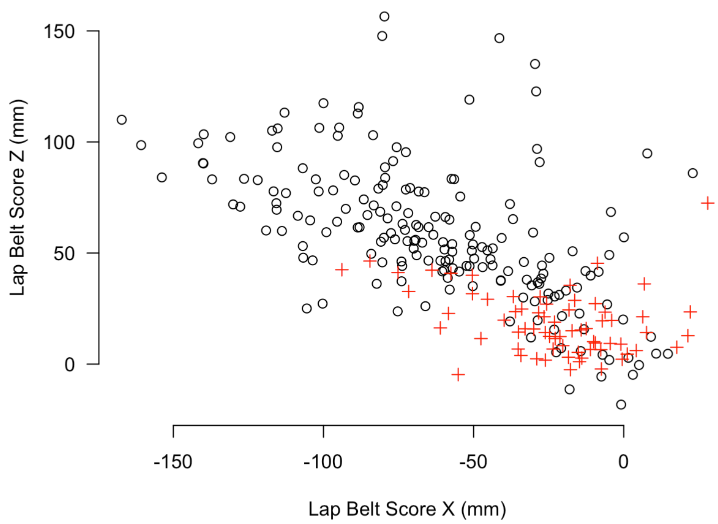


Figure 23. Lap belt scores for US (o) and Japanese (+) drivers in the midrange vehicle and belt condition.

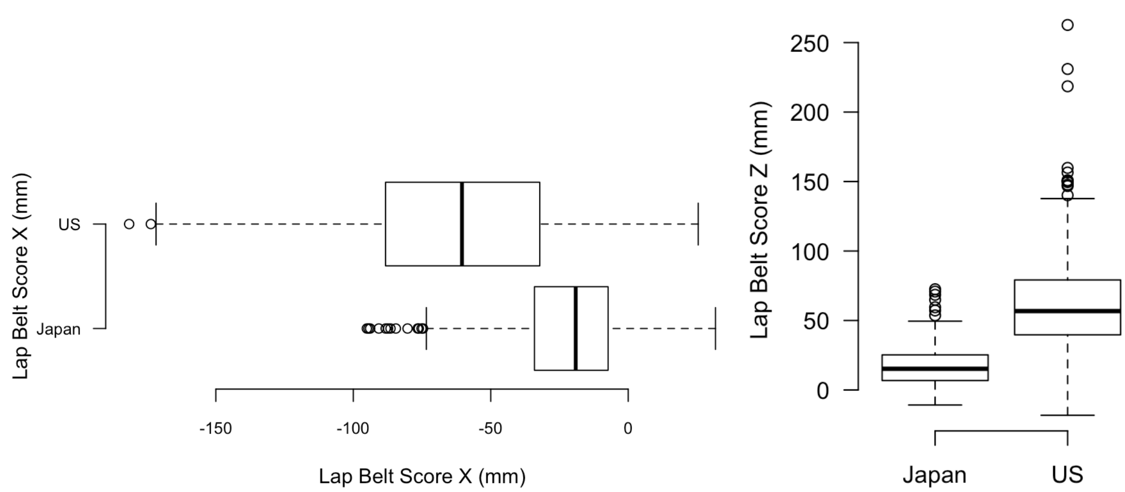


Figure 24. Comparison of fore-aft (X) and vertical (Z) lap belt scores for US and Japanese drivers.

The differences between studies appear to be driven primarily by differences in the distribution of BMI. Figure 25 shows the lap belt scores (X and Z) by BMI, demonstrating that the belt fit scores for Japanese drivers lie within the range of US drivers with similar BMI. With the pooled data, the horizontal and vertical belt fit scores were found to be strongly affected by BMI, as shown in Figure 25, but the effects of other variables were either not significant or did not influence the R^2_{adj} value by more than 0.01.

Lap Belt Score X (mm) = 110 – 6.12 BMI, RMSE = 23.0, $R^2_{adj} = 0.66$
Lap Belt Score Z (mm) = -86 + 5.04 BMI, RMSE = 22.9, $R^2_{adj} = 0.59$

After accounting for BMI, the lap belt scores were 7 mm further rearward (closer to the pelvis) and 16 mm lower for the Japanese drivers. In both cases, these values are less than the residual standard deviation from the regressions (RMSE).

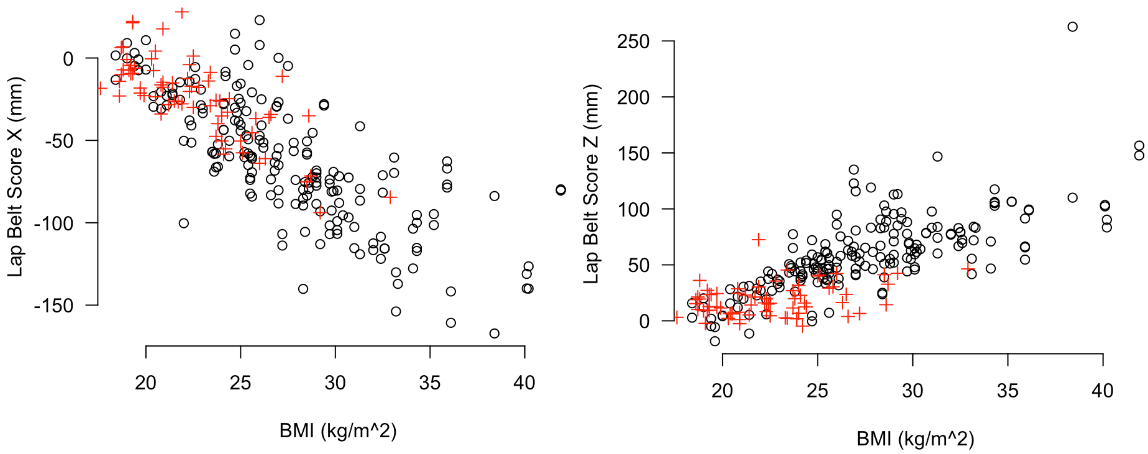


Figure 25. Relationships between lap belt scores and BMI in belt condition DB1 for US (o) and Japanese (+) drivers.

Shoulder belt scores were significantly affected by the D-ring location and stature, with smaller statures showing larger effects. Figure 26 shows the effects of these factors.

Shoulder Belt Score (mm) = -687 + 27.2 DringYZAngle + 0.553 Stature – 0.0216 Stature*DringYZAngle, RMSE = 22.9, $R^2_{adj} = 0.57$

After accounting for these factors, shoulder belt scores were not significantly different between study populations.

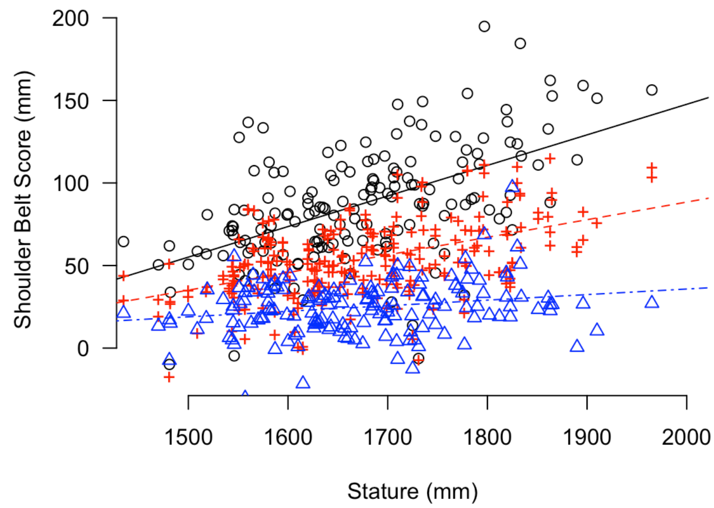


Figure 26. Effect of stature on shoulder belt score for DringYZAngles of 17 (black), 21 (red), and 24 (blue) degrees.

Body Shape

The body shape regression models were exercised for different combinations of anthropometric variables and nationality to quantify differences in body shape. Table 10 shows the mean values of primary body measures for the US and Japanese populations (Fryar et al. 2016, ISO 7250-2). For purposes of this analysis, the target age was set to 48 years, the mean of the pooled study population.

Table 10
Reference Mean Anthropometric Values for the US and Japanese Populations

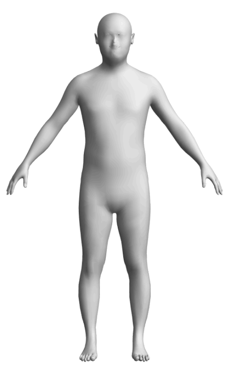
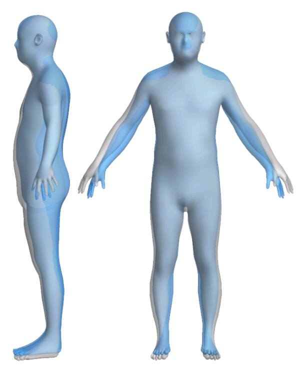
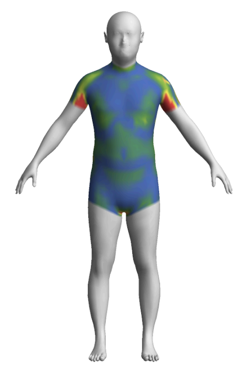
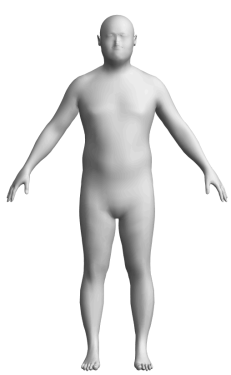
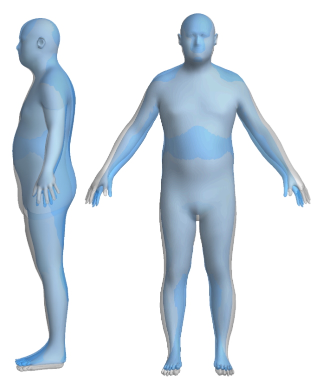
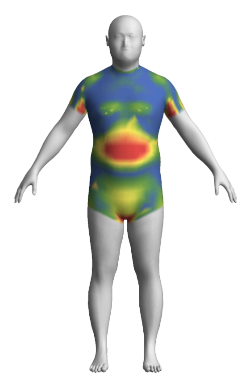
Variable	US		Japan	
	Male	Female	Male	Female
Stature	1757	1618	1708	1570
Body Weight	88.8	76.4	69.1	51.9
BMI*	28.7	29.2	23.7	21.1
SH/S†	0.52	0.52	0.54	0.54

* Computed from mean stature and body weight; actual mean BMI is somewhat different.
† Values from current studies were used

A primary advantage of the body shape modeling methodology is that the effects of nationality can be isolated from the effects of overall body characteristics. To illustrate this, Table 11 shows male figures generated for the US and Japanese mean target values from Table 10. Table 12 shows a similar comparison for women. A "Japanese" figure is generated for comparison using the US values and a "US" figure is generated using the US values. In general, the surface forms are very similar across nationalities after accounting for stature, body weight, sitting height, and age. A quantitative comparison of the body shapes was created by computing the distance from each node in one mesh to the surface defined by the other mesh. These discrepancies are shown in Tables 11 and 12 as color gradients. The largest discrepancies are noted in the torso, where the US predictions have greater abdomen depth (and chest depth for women). However, discrepancies in torso breadth, including at the hips and shoulders, are generally less than 10 mm.

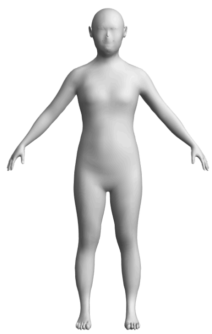
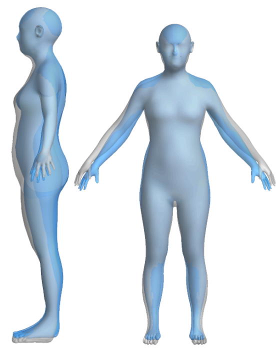
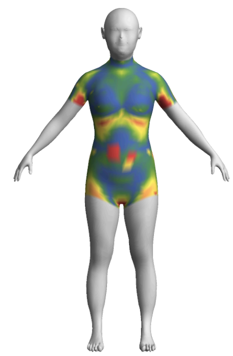
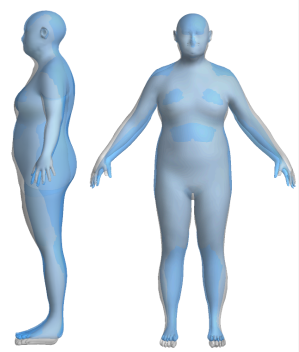
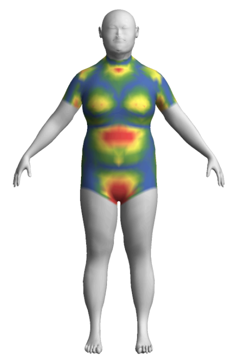
Tables 13 and 14 show a similar comparison for the automotive seated posture. The differences in the arm location reflect differences in the average posture used when scanning and are not indicative of nationality differences. As with the standing data, the largest discrepancies are in the anterior torso for both men and women. (The discrepancies in the upper arms are due to posture differences between studies.) Figure 27 shows larger side-view images of the four male and female overlays

Table 11
Comparison of Standing Body Shape Predictions for Mean US and Mean Japanese Reference Values: Stature, Body Weight, and Sitting Height at Age 48 Years: **MALE**

Target Dimensions	Nationality Specified in Model		Overlay	Discrepancy*
	Japanese	US		
Japanese Male				
US Male				

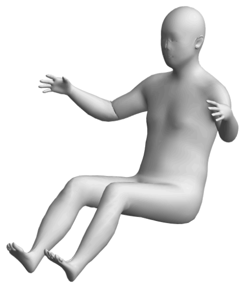
* Blue = 0 mm; Red >= 15 mm

Table 12
Comparison of Standing Body Shape Predictions for Mean US and Mean Japanese Reference Values: Stature, Body Weight, and Sitting Height at Age 48 Years: **FEMALE**

Target Dimensions	Specified Nationality		Overlay	Discrepancy*
	Japanese	US		
Japanese Female				
US Female				

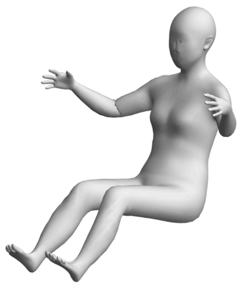
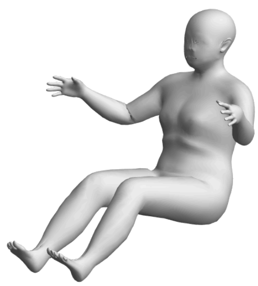
* Blue = 0 mm; Red >= 15 mm

Table 13
Comparison of Seated Body Shape Predictions for Mean US and Mean Japanese Reference Values: Stature, Body Weight, and Sitting Height at Age 48 Years: **MALE**

Target Dimensions	Specified Nationality		Overlay	Discrepancy*
	Japanese	US		
Japanese Male				
US Male				

* Blue = 0 mm; Red >= 15 mm

Table 14
Comparison of Seated Body Shape Predictions for Mean US and Mean Japanese Reference Values: Stature, Body Weight, and Sitting Height at Age 48 Years: **FEMALE**

Target Dimensions	Specified Nationality		Overlay	Discrepancy*
	Japanese	US		
Japanese Female				
US Female				

* Blue = 0 mm; Red >= 15 mm

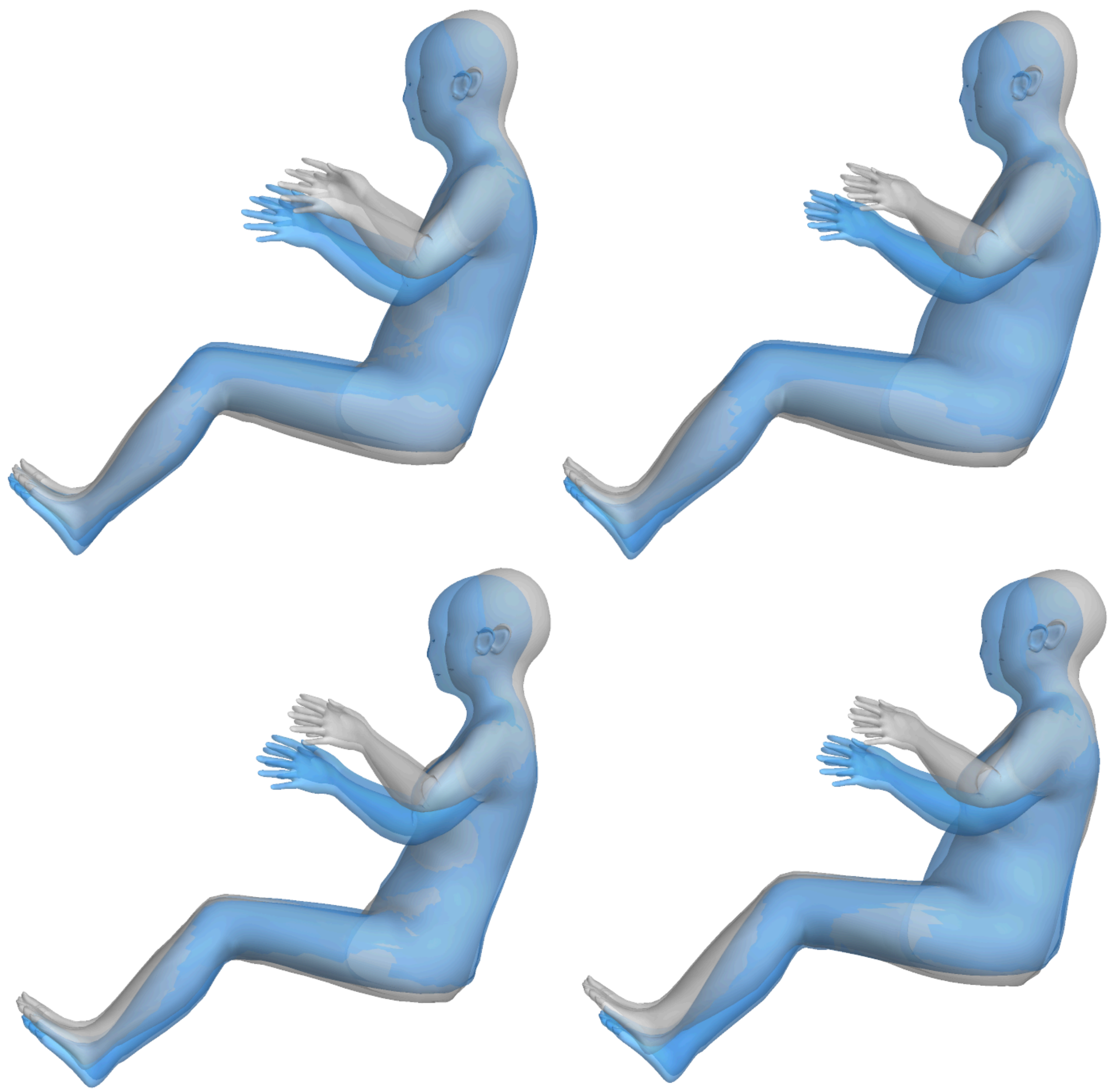


Figure 27. Side-view overlay of automotive postures for men (top) and women (bottom) with mean Japanese anthropometric targets (left) and mean US anthropometric targets (right). Predictions for Japanese nationality are shown in gray, US nationality in blue. Upper extremity posture differences are due to differences in test protocol

DISCUSSION

Overview

This study is the first to conduct a robust comparison of driving postures, body shape, and belt fit between US and Japanese drivers. The populations of the two studies differed substantially with respect to the distributions of several anthropometric variables, notably BMI and the ratio of sitting height to stature. The age distribution was also broader and skewed toward older drivers in the US sample.

The substantial differences in the body dimensions of the populations were not unexpected, because the Japanese population is on average thinner and shorter than the US population. The most substantial limitation of the Japanese sample is the lack of men and women older than 60 years of age. The analyses of posture and belt fit in the US sample (Reed et al. 2013, Park et al. 2016) showed statistically significant but relatively small effects of age. In the current pooled analysis, age was not an important factor, and age was in effect confounded with nationality. Indeed, the mean age of the US sample, which was deliberately skewed toward older drivers, was greater than the oldest driver in the Japanese study population. Nonetheless, the study populations exhibited substantial overlap in all variables of interest.

By design, the study participants were experienced drivers in Japan and had been in the US less than 3 years. Relatively recent arrivals were recruited to address the possibility that adaptation to US driving conditions would change driving postures or belt donning procedures. Nonetheless, if such adaptation exists and happens very quickly, the Japanese participants may have behaved more like US drivers. Testing drivers in Japan would address this issue, but obtaining comparable results in both Japan and the US would be very challenging. As the analysis indicates, differences between the populations are fairly subtle, after accounting for body size. Small differences in experimental methods could easily swamp these effects. For example, as noted above, it's possible that the choice of starting positions for the seat coupled with differences on population stature, could account for the small difference in mean seat position after accounting for body size.

Posture and Belt Fit Measures

On average, the Japanese drivers sat slightly rearward and slightly more reclined than the US drivers, after accounting for body size. A choice in how the test conditions were presented may have produced some of this difference. In previous research, we have found that the initial positions of vehicle components bias driver adjustments. For example, if the seat is started in a full-rear position, the average seat position selected by a population of drivers will be rearward of the mean seat position that would be obtained if the seat were initially placed at the middle of the adjustment range. In the US study, the starting seat positions for men and women were set to the mean expected seat positions based on Reed et al. (2000), using median statures for adult men and women in the US population. We used the same starting positions in the study with the Japanese population. However, on average the Japanese men and women were shorter in stature than their US counterparts, which means that the seat positions for that population would have been biased rearward. We cannot reliably estimate how much of an effect starting the seat at a more representative position would have, but we anticipate that it would reduce the observed difference between the populations.

The Japanese study population sat with a more reclined posture than the US study population, using the side-view angle of the vector from the mean hip location to the eye as a measure of recline. However, the seat back angles were not significantly different between studies, indicating that the difference in recline was due to body shape within the seat. The examination of body segment angles showed more-reclined torso angles, consistent with the overall recline difference. Interestingly, the eye height above the hips and the seat H-point was not significantly different between studies, after accounting for body size, in spite of the larger recline within the seat. However, this finding should be viewed with caution because of the substantial differences between studies in factors that are associated with recline. For example, greater age is associated with less torso recline. The regression analysis may have underestimated the age effect due to the large number of younger subjects added from the Japanese population. A larger age effect would have reduced the nationality effect on eye location. Likewise, SH/S is the strongest predictor of torso recline, with larger values associated with greater recline. If this effect were underestimated, the adjustment for the larger values in the Japanese study may have been insufficient to fully account for the differences between population in SH/S.

Some previous analyses have found interesting differences between male and female postures (Park et al. 2016), but those effects are small compared to the effects of other variables of interest, such as stature and BMI. In the current analyses, with the pooled data set, gender was not an important predictor and hence was not included in any of the models. The lack of significant gender effects was due in part to the fact that combining the populations resulted in greater overlap between the male and female populations on anthropometric variables.

The lack of influence of the ratio of sitting height to stature (SH/S) on seat position was unexpected. This difference in body proportions is one of the most apparent anthropometric differences between populations of Asian and European descent, although substantial overlap is observed. Individuals with higher SH/S have shorter lower extremities than those with lower SH/S of the same stature. With shorter lower extremities, a more-forward seat position might be expected. However, the data did not support that hypothesis. Indeed, the seat position of the Japanese drivers was on average somewhat rearward of US drivers with the same body dimensions. SH/S is not a significant predictor of fore-aft seat position in the US sample, which has a wide range, suggesting that leg length is not an important factor affecting seat position after accounting for overall stature. Analyses of lower extremity segment angles and seat cushion angle (adjusted by the drivers) found no significant differences between study populations after accounting for other variables. This finding would be consistent with a larger fore-aft offset between the sitter's hips and the seat H-point, but only a small difference between the study populations was found.

The belt fit findings highlight the critical effects of BMI, or more specifically abdominal adiposity, on lap belt placement. The offset between the pelvis and the lap belt for the Japanese study population was markedly smaller, on average, than for the US population. The analysis suggests that this is due primarily to the low BMI among the Japanese drivers, rather than anything related to nationality. Previous analyses of belt fit (Reed et al. 2013, Park et al. 2016a) have shown an effect of age after accounting for BMI, but the effect was not important in the pooled population.

Body Shape Models

The body shape models are the first to provide a rigorous comparison of the body shapes of Japanese and US adults. The model demonstrates that body shapes are similar after accounting for gender, stature, body weight, erect sitting height, and age. The observed discrepancies are likely due in part to the differences in the age and gender distribution of the populations. That is, the Japanese study population was much younger than the US study population, and the effects of BMI on body shape are known to differ with age. That is, at the same BMI, older individuals on average have more torso mass, with most of the additional mass in the abdomen. The modeling approach used for the current analysis fit separate age and BMI effects for each nationality and gender, but because of the restriction of range for both variables in the Japanese population, these effects are likely to be underestimated for that population. An alternative model that fits the BMI and age effects for the combined population might produce more accurate predictions for Japanese individuals who are older and have higher BMI. Similarly, the relatively small number of Japanese women included in the sample means that the effects of anthropometric variables and age are likely to be underestimated with the current model formulation.

Model Evaluation

The nature of the regression analysis can lead to an inappropriate emphasis on statistical significance. For example, whether age has a “significant” effect on a variable of interest is unimportant, because with a large enough sample a “significant” effect would almost certainly be found for any variable. A more appropriate question is how large the effect is, particularly in relation to the other variables. In the current analysis, we have presented estimates of the effect of nationality after accounting for body size, vehicle layout, and driver age. Because the distribution of body size and age in Japan is different from the US, the distribution of driver posture and position, as well as belt fit, will be different as well. The regression models presented in this report provide a means of estimating those distributions. Importantly, all three of the major anthropometric predictors (stature, BMI, and SH/S) differed substantially between the study populations. Hence, any estimates of those effects will be correlated with the difference between studies. The analysis methodology attempted to address that through a pooled analysis, but the adjustments provided by the pooled analysis may not have completely eliminated the effects of this bias.

One basic question that could be asked is the extent to which this study demonstrated the “validity” of the US-based models for predicting postures, belt fit, and body shape for Japanese drivers. The study does not directly bear on “validity”, but rather quantifies the extent to which the populations differ after taking into account important variables other than nationality. The study demonstrated only small differences in posture and belt fit attributable to nationality, where “small” is judged relative to the residual variance not accounted for by the models without nationality (generally less than half of the residual variance), and also with respect to the overall variance — 5% or less for all posture variables other than Eye X, for which nationality accounted for was 10% of variance.

Strong assessments of validity would require comparison of the model predictions to data from a new study, preferably one conducted in multiple vehicles with large driver samples. Instead, the current work serves to bound the precision of model predictions in relation to important factor effects, such as those due to vehicle layout or overall driver body size. Whether the documented precision is acceptable would depend on the application. (Note that the Japanese driver model, which is based on a relatively homogeneous sample, would not work well for a US population. On the other hand, the results show that a US driver model, because it is from a more diverse sample, would work reasonably well for a Japanese driver population, except that the age effect could not be robustly compared between study populations.)

An important consideration is that the anthropometric corrections applied to isolate the nationality effects are dependent on the sample and the choices in model construction. For example, the body shape model includes all interactions between anthropometry and nationality. This has the effect of essentially eliminating the BMI and age effects for the Japanese predictions, because those variables (particularly BMI) had restricted range in the Japanese sample. An alternative model that did not include those interactions would show smaller discrepancies when predicting using the median US values for stature & BMI, because the BMI effect would take into account the BMI effects in the US sample.

Whether these differences are important depend on the application. For most applications in traffic safety, the minor differences attributable to nationality after accounting for body dimensions and age are probably of minimal importance because nationality accounts for only a small fraction of the variance in posture, belt fit, and body shape.

Limitations and Future Work

This study is limited by the use of a static vehicle mockup. Previous studies have found good correlation between laboratory and in-vehicle data (Reed et al. 2002), but have also found differences across vehicles in the accuracy of predictions of seat position and eye locations (Manary et al. 1998). The drivers were also seated in each condition for less than five minutes; postures over long periods of time could be different (Manary et al. 1998). The participants wore minimal clothing to facilitate posture measurement. Bulky clothing would be expected to change the relationship between the sitter and the seat and alter belt fit.

This study provides evidence that statistical models of posture and belt fit developed using US or Japanese populations could be applied to either population with good accuracy and precision, provided that the models take into account body dimensions, particularly stature and BMI. Importantly, no meaningful differences were observed in the effects of seat height or steering wheel position on driver posture between the two study populations.

These results emphasize the value of gathering data from different national populations using the same methodologies to evaluate hypotheses about driving posture and component location preferences. As noted above, the reasonable hypothesis that the difference in the mean sitting height to stature ratio would result in Japanese drivers sitting further forward as a function of stature was not supported by this analysis. With that in mind, careful experimentation should be conducted to examine other hypotheses regarding national differences in driving posture that have been proposed.

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APPENDIX A

Participant Self-Reporting Demography Form

Current age _______________ years

Gender (Circle one): Male Female

Country of primary citizenship ____________________________

Total number of years lived in country of primary citizenship_________________

Are you a licensed driver in your country of primary citizenship? (Circle one) **Yes** **No**

Excluding the U.S. or your country of primary citizenship, have you live in another country for longer than 12 months? (Circle one) **Yes** **No**

If yes,

Where?___________________

Did you drive while living there? (Circle one) **Yes** **No**

Vehicle driven most often in country of primary citizenship:

Make_____________ Model_______________ Year_______________

Transmission type (circle one): Manual/with clutch Automatic/no clutch

Total number of months lived in the U.S. __________________________

Have you lived in the U.S. previously or visited for longer than 12 months? **Yes** **No**

If yes,

Did you drive? **Yes** **No**

Vehicle driven most often in U.S.:

Make________________ Model_______________ Year_______________

Transmission type (circle one): Manual/with clutch Automatic/no clutch

Driving Related Questions

1. In the past 3 months, how many times did you drive in a typical week?
   - ☐ I don't drive
   - ☐ Less than once
   - ☐ Once
   - ☐ Twice
   - ☐ Three or more

2. In the past year, how many crashes, if any, have you been involved in as a driver?
   __________________ (0, 1, 2, 3, 4+)

3. In the past 12 months how many times have you been given a ticket, not counting parking tickets?
   __________________ (0, 1, 2, 3, 4+)

4. How often do you use seat belts when you drive as a driver in a car?
   - ☐ Always
   - ☐ Nearly always
   - ☐ Sometimes
   - ☐ Seldom
   - ☐ Never
   - ☐ Don't know

5. How often do you use seat belts when you ride as a passenger in the front seat of a car?
   - ☐ Always
   - ☐ Nearly always
   - ☐ Sometimes
   - ☐ Seldom
   - ☐ Never
   - ☐ Don't know

6. How often do you use seat belts when you ride as a passenger in the rear seat of a car?
   - ☐ Always
   - ☐ Nearly always
   - ☐ Sometimes
   - ☐ Seldom
   - ☐ Never
   - ☐ Don't know

Demographic Related Questions

Which demographic group do you usually select on questionnaires?

❑	❑	❑	❑	❑	❑	❑
White	Black	Hispanic	Asian	Native Hawaiian/ Pacif Islander	Amer. Indian/ Alask Native	Other

Your Population Subgroup: (please mark all that apply)

❑ White, not of Hispanic Origin

❑ Black, not of Hispanic Origin

❑ Hispanic (please mark all that apply)

- ❑ Mexican ❑ Latin American: _______________________
- ❑ Puerto Rican ❑ Other Hispanic: _______________________
- ❑ Cuban

❑ Asian or Pacific Islander (please mark all that apply)

- ❑ Chinese ❑ Japanese ❑ Korean
- ❑ Vietnamese ❑ Filipino ❑ Samoan
- ❑ Guamanian/Chamorro ❑ Melanesian ❑ Micronesian
- ❑ Polynesian ❑ Other Pacific Islander: __________________
- ❑ Other Asian: ____

❑ Native American (please mark all that apply)

- ❑ Eskimo ❑ Aleut ❑ U.S./Canadian Tribe(s): ________________

❑ Other (please mark all that apply)

- ❑ East / Asian Indian ❑ Arab or Middle Eastern
- ❑ Caribbean Islander ❑ Other: _____________________________

Appendix B
Detailed Anthropometric Data

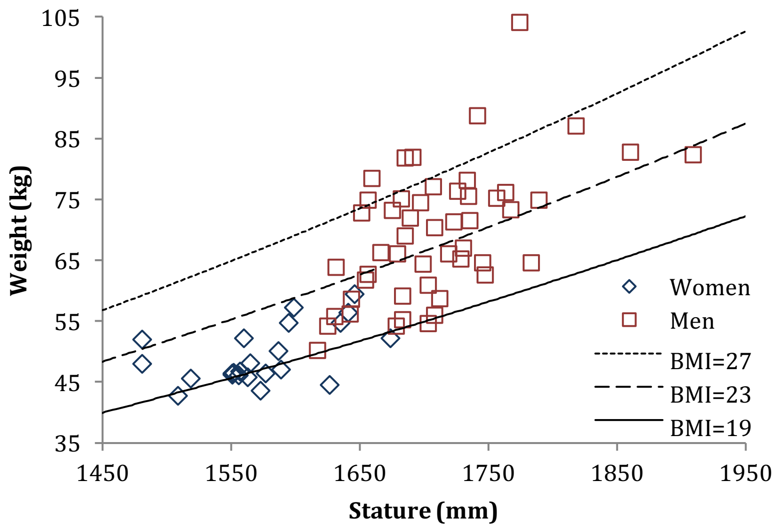

Figure B1. Weight versus stature for all participants

Table B1
Anthropometry of Female Participants

Measurement*	Min.	Max.	Mean	SD	Percentiles 5th	25th	50th	75th	95th
Age (yr)	21	51	33	7	27	29	31	36	48
Stature With Shoes	1493	1692	1590	50	1506	1561	1591	1619	1662
Stature Without Shoes	1481	1674	1573	50	1484	1552	1565	1597	1646
Weight (kg)	42.7	59.5	49.2	5	43.7	46.2	47.0	52.2	57.2
BMI (kg/m^2)	16.8	23.7	19.9	2	17.7	18.7	19.3	21.2	22.3
Erect Sitting Height	817	906	860	26	821	839	863	880	898
Eye Height (Sitting)	714	797	756	26	717	727	759	780	790
Acromial Height (Sitting)	514	615	574	26	540	560	567	594	610
Knee Height (Sitting)	426	510	466	22	439	452	464	478	505
Head Height	110	143	123	9	111	115	123	128	136
Head Length	165	194	182	7	172	176	184	187	191
Head Breadth	141	176	160	9	150	153	161	165	174
Shoulder-Elbow Length	299	357	329	16	303	320	332	341	353
Elbow-Hand Length	382	462	419	20	392	404	416	434	449
Hip Breadth (Sitting)	325	395	358	20	330	343	354	373	389
Buttock-Knee Length (Sitting)	496	580	538	22	503	524	532	555	571
Buttock-Popliteal Length (Sitting)	405	489	444	20	424	428	441	456	484
Biacromial Breadth	316	370	344	15	321	334	345	357	364
Shoulder Breadth	369	545	417	34	387	399	411	427	451
Chest Depth (Scapula)	155	257	215	27	165	206	221	231	249
Chest Depth (Spine)	132	217	173	23	146	157	168	186	214
Bispinous Breadth	190	232	212	13	193	202	212	222	231
Chest Circumference	765	926	826	39	775	800	824	845	900
Waist Circumference	560	810	703	58	630	672	693	739	805
Hip Circumference	830	975	902	40	848	874	888	935	964
Upper Thigh Circumference	433	593	515	41	437	492	520	542	564

*mm unless noted

Table B2
Anthropometry of Male Participants

Measurement*	Min.	Max.	Mean	SD	Percentiles 5th	25th	50th	75th	95th
Age (yr)	21	55	36	8	25	30	34	41	50
Stature With Shoes	1630	1929	1731	59	1649	1697	1721	1767	1829
Stature Without Shoes	1618	1910	1711	58	1631	1677	1704	1736	1806
Weight (kg)	50.1	104.0	69.2	11	54.3	61.8	69.6	75.3	85.0
BMI (kg/m^2)	18.8	33.0	23.7	3	19.3	21.3	23.6	25.7	28.7
Erect Sitting Height	865	1017	923	32	884	901	918	943	979
Eye Height (Sitting)	756	887	813	34	768	784	815	834	872
Acromial Height (Sitting)	549	690	613	32	557	597	613	640	651
Knee Height (Sitting)	436	590	508	27	466	494	510	518	551
Head Height	111	167	127	10	114	120	125	133	141
Head Length	179	203	192	6	180	189	193	196	200
Head Breadth	146	177	164	6	154	159	164	169	173
Shoulder-Elbow Length	323	410	358	18	334	344	357	369	386
Elbow-Hand Length	411	519	457	20	430	444	455	467	489
Hip Breadth (Sitting)	323	616	368	44	325	345	358	384	411
Buttock-Knee Length (Sitting)	481	663	585	28	544	574	587	599	627
Buttock-Popliteal Length (Sitting)	424	627	479	33	443	455	479	495	530
Biacromial Breadth	341	447	392	24	349	377	392	410	427
Shoulder Breadth	419	538	470	25	432	453	469	485	515
Chest Depth (Scapula)	171	291	224	29	183	203	217	244	279
Chest Depth (Spine)	147	279	201	28	167	181	195	215	254
Bispinous Breadth	194	283	226	16	208	214	224	233	257
Chest Circumference	797	1125	948	68	847	897	949	985	1059
Waist Circumference	674	1082	834	90	713	764	824	884	1008
Hip Circumference	842	1099	953	58	862	908	961	1001	1039
Upper Thigh Circumference	463	687	557	52	466	523	559	588	630

*mm unless noted

Table B3
Comparison of Women in US and Current Study

Measurement*	Study	Mean	SD	Percentiles				
				5th	25th	50th	75th	95th
Stature	*Current*	*1573*	*50*	*1484*	*1552*	*1565*	*1597*	*1646*
	US	1604	69	1491	1559	1600	1643	1725
Weight (kg)	*Current*	*49*	*5*	*44*	*46*	*47*	*52*	*57*
	US	70	16	49	61	67	80	101
BMI (kg/m^2)	*Current*	*20*	*2*	*18*	*19*	*19*	*21*	*22*
	US	27	6	20	24	26	30	36
Erect Sitting Height	*Current*	*860*	*26*	*821*	*839*	*863*	*880*	*898*
	US	846	43	774	816	847	879	908

Table B4
Comparison of Men in US and Current Study

Measurement*	Study	Mean	SD	Percentiles				
				5th	25th	50th	75th	95th
Stature	*Current*	*1711*	*58*	*1631*	*1677*	*1704*	*1736*	*1806*
	US	1750	84	1609	1690	1755	1819	1866
Weight (kg)	*Current*	*69*	*11*	*54*	*62*	*70*	*75*	*85*
	US	85	17	59	74	86	96	113
BMI (kg/m^2)	*Current*	*24*	*3*	*19*	*21*	*24*	*26*	*29*
	US	28	5	20	25	28	31	35
Erect Sitting Height	*Current*	*923*	*32*	*884*	*901*	*918*	*943*	*979*
	US	906	46	834	875	914	940	974