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The Initial Position and Postural Attitudes of Driver Occupants

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The Initial Position and Postural Attitudes of Driver Occupants. Anthropometry

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ABSTRACT
This report contains a description of all anthropometric measurements of 102 subjects measured in an investigation of driver posture and comfort while operating a 1995 mid-sized vehicle and sitting in a seat buck. The investigation measured twelve anthropometric dimensions with the subject in standing and seated positions as appropriate. The data are divided into baby boomer and pre-baby boomer samples by sex. Subjects were selected to represent the general U. S. population according to age and sex. The dimensions are reported for the total sample as well as the 40 subjects that participated in the driver comfort sutdy. All results were compared to the U. S. Army survey reported by Gordon et al (1989) and lie within ratios of .95 to 1.043 of the Army results.

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Preface and Acknowledgments

This is the second of a series of reports to Delphi Interior and Lighting Systems that describe the results of an investigation into seating comfort. This investigation is one of the most ambitious undertaken to investigate the driver posture and comfort. A multi-variable sampling strategy was employed to obtain subjects from the Lansing, Michigan metropolitan area that represented the general US population in body size, age, and sex. The results are presented in this report as a series of tables that compares the total sample and the driving sample with the US ARMY survey of 1989.

We would like to express our thanks to Alicia Vertiz, MD at Delphi Interior and Lighting Systems for understanding the need to pursue this study to improve seat design. We obtained our list of subjects from R. L. Polk and pursued a sampling strategy whose results in terms of body size are outlined in the report that follows.

In addition to the personnel at Delphi Interior and Lighting Systems, we would like to acknowledge the support of Provost Lou Anna Simon, Michigan State University and Douglas Wood, Dean of the College of Osteopathic Medicine. The Department of Biomechanics, College of Osteopathic Medicine also contributed to the support of this research.

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THE INITIAL POSITION AND POSTURAL ATTITUDES OF VEHICLE OCCUPANTS

ANTHROPOMETRY

I. Introduction

This research investigated subjects sitting in five postures with different amounts of spinal curvature in the low back and the position of the pelvis in a seat buck. The purpose of this investigation was to develop a model of the spinal column relative to pelvic position in a seated driving position of the vehicle operator. Thus, measurements of these subjects were collected to develop a model of the spinal column for vehicle operators, and test this model with independent measures of spinal curve in a seat buck. A sub-set of these subjects also drove a 1995 mid-size vehicle in a study of vehicle operator comfort.

Subjects in this study of spinal column geometry in sitting positions were selected to represent the general non-institutionalized population of the United States. Consequently, selection of subject participation was based upon age, sex and body size. This report describes the sample of subjects in this investigation in terms of their age, sex and body size dimensions. Comparisons are made to the general US population and a representative sample from a recent anthropometric investigation of US Army personnel.

II. Methods and Materials

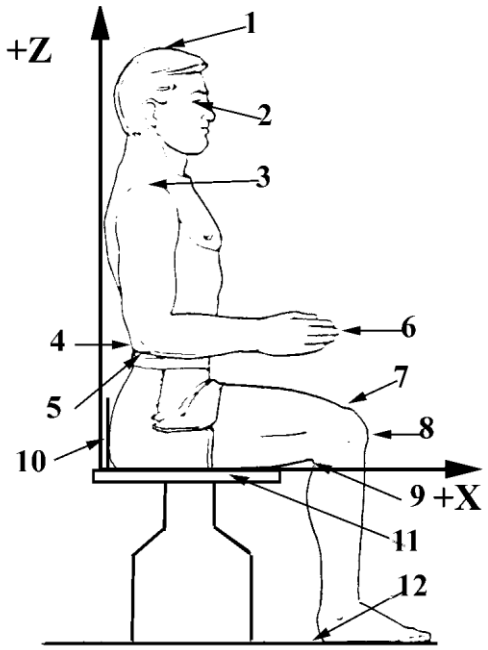
One hundred and two subjects were measured. Their age ranged from 25 to 76 years. Fifty percent of the subjects were born prior to 1945 (i.e., pre baby boomers) and the remainder during or after 1945 (i.e. baby boomers). There were 52 males and 50 females measured in the total sample. In the drive sample, there were 20 males and 20 females measured (Table 1). The subjects were selected on the basis of whether they were above or below (A & B columns in Table 1) the average stature of the US Army [1].

	MALE				FEMALE			
Sample	TOTAL		DRIVE		TOTAL		DRIVE	
Height	A	B	A	B	A	B	A	B
Post-1945	13	13	6	4	12	13	5	4
Pre-1945	13	13	4	6	13	12	5	6

Table 1. Distribution of subjects by sex, sample group, height group and age (pre and baby boomer).

All subjects were dressed in biking shorts and tank top. They removed their shoes, but wore their socks. All seated measurements were taken while the subject sat in a standard

position to eliminate differences due to posture. Except for stature and weight all measurement were taken using a Metrocom [2] which determines the 3 dimensional location of desired points. We located the following body landmarks: maximum left deltoid, maximum right deltoid, left anterior superior iliac spine, left anterior superior iliac spine, vertex of head, right ectocanthus (outside corner of the eye), right acromion, bottom of olecranon (elbow), rear of olecranon, dactylion III (tip of middle finger), top of knee, front of knee, popliteal fossa (dorsal junction of the calf and thigh). The following fixed targets were also located: right seatback target, left seatback target, seat platform target and floor target.

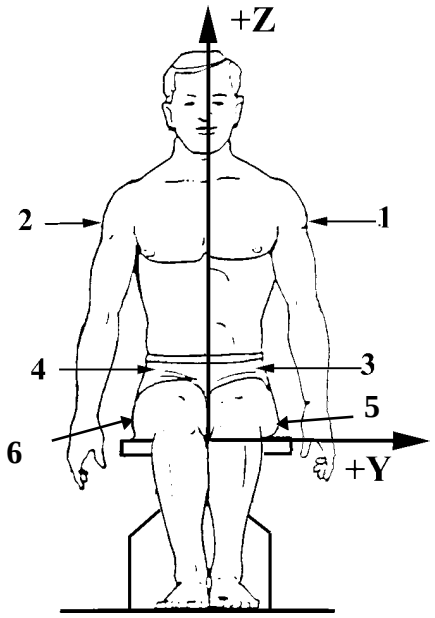


1 - Vertex
2 - Ectocanthus
3 - Rt Acromion
4 - Back of Elbow
5 - Bottom of Elbow
6 - Tip of Finger
7 - Top of Knee
8 - Front of Knee
9 - Popliteal fossa
10 - Seat back
11 - Seat pan

Figure 1. Side view of anthropometric landmarks used for body measurements.

Using components of the three dimensional position vectors for these points we were able to determine the following body measurements:

Sitting Height = $Z_{\text{Vertex}} - Z_{\text{Seat Pan}}$
Eye Height, Sitting = $Z_{\text{Ectocanthus}} - Z_{\text{Seat Pan}}$
Knee Height, Sitting = $Z_{\text{Top of Knee}} - Z_{\text{Floor}}$
Popliteal Height, Sitting = $Z_{\text{Popliteal fossa}} - Z_{\text{Floor}}$
Shoulder-Elbow Length = $Z_{\text{Rt Acromion}} - Z_{\text{Bottom of Elbow}}$
Forearm-Hand Length = $X_{\text{Tip of Finger}} - X_{\text{Back of Elbow}}$
Buttock-Popliteal Length = $X_{\text{Popliteal fossa}} - X_{\text{Seat Back}}$
Shoulder Breadth = $Y_{\text{Lt Deltoid}} - Y_{\text{Rt Deltoid}}$
Hip Breadth = $Y_{\text{Lt Hip}} - Y_{\text{Rt Hip}}$
Bispinous Breadth = $Y_{\text{LASIS}} - Y_{\text{RASIS}}$



1 - Left deltoid
2 - Right deltoid
3 - Left anterior superior iliac spine (LASIS)
4 - Right anterior superior iliac spine (RASIS)
5 - Left Hip

Figure 2. Front view of anthropometric landmarks used for body measurements.

To determine statistically significant differences at the 0.05 level of significance, a two tailed T test was used. A significant difference between the sexes was denoted by "*", while "†" denoted a significant difference between generations within the sexes.

III. Results

A. Stature is measured with an anthropometer from the floor to the top of the head (i.e. vertex) while the subject stands as erect as possible. We selected subjects with a wide range of heights in order to accurately represent the general population. The total female sample is .999 of the US ARMY and the males are 1.001 of US ARMY stature.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***162.8 (8.0)**	**143.2**	**181.4**	***162.4 (7.1)**	**162.9 (6.4)**
	Baby Boomer	162.3 (8.2)			162.8 (7.2)	
	Pre Baby Boomer	163.3 (8.0)			162.1 (7.4)	
Male		***175.7 (6.6)**	**161.5**	**190.3**	***174.1 (6.1)**	**175.6 (6.7)**
	Baby Boomer	175.5 (6.0)			175.6 (6.2)	
	Pre Baby Boomer	176.0 (7.3)			172.7 (5.9)	

Table 2. Stature by sex, sample, and pre- and baby boomer compared to US ARMY.

B. Weight was measured with the subject in the driving uniform previously described. The total female sample weighs 1.011 of the US ARMY and the male weight is .986.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***60.72 (9.72)**	**34.70**	**90.60**	***60.06 (7.24)**	**62.01(8.35)**
	Baby Boomer	†57.04 (8.60)			59.19 (6.92)	
	Pre Baby Boomer	†64.40 (9.52)			60.77 (7.75)	
Male		***77.43 (7.97)**	**62.20**	**95.90**	***72.65 (7.22)**	**78.49 (11.10)**
	Baby Boomer	75.85 (7.61)			†71.67 (7.48)	
	Pre Baby Boomer	79.00 (8.15)			†73.63 (7.20)	

Table 3. Weight by sex, sample, and pre- and baby boomer compared to US ARMY.

C. Sitting Height was defined as the distance from the sitting surface to the top of the head while the subject sat erect with the head in the Frankfort plane. The thighs were parallel to the floor and the knees were at 90 degrees with feet flat on the floor. The total female sample is .992 of the US ARMY sitting height and the males are .989.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***84.5 (3.5)**	**77.6**	**91.9**	***84.1 (3.4)**	**85.2(3.5)**
	Baby Boomer	85.0 (3.8)			85.6 (3.5)	
	Pre Baby Boomer	83.9 (3.1)			91.0 (3.5)	
Male		***90.4 (3.3)**	**83.1**	**98.2**	***89.5 (2.9)**	**91.4 (3.6)**
	Baby Boomer	91.2 (2.9)			†82.9 (2.9)	
	Pre Baby Boomer	89.5 (3.5)			†87.9 (2.7)	

Table 4. Sitting height by sex, sample, and pre- and baby boomer compared to US ARMY.

D. Eye Height, Sitting was defined as the vertical distance from the seat pan to the eye while the subject sat erect with head in the Frankfort plane, elbows and knees at 90 degrees, and

forearms and thighs parallel to the floor. The total female sample is .989 of the US ARMY in sitting eye height and the males are .980.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***73.1 (3.3)**	**66.6**	**80.0**	***72.6 (3.4)**	**73.9 (3.3)**
	Baby Boomer	73.6 (3.5)			74.1 (3.3)	
	Pre Baby Boomer	72.5 (3.1)			78.5 (3.3)	
Male		***77.6 (3.5)**	**65.9**	**84.0**	***77.0 (2.9)**	**79.2 (3.4)**
	Baby Boomer	†78.6 (2.9)			†71.4 (3.2)	
	Pre Baby Boomer	†76.7 (3.9)			†75.6 (2.6)	

Table 5. Sitting eye height by sex, sample, pre- and baby boomer compared to US ARMY.

E. Knee Height, Sitting was defined as the vertical distance from the floor to the top of the knee while the subject sat erect with knees at 90 degrees, thighs parallel to the floor. The total female sample is .969 of the US ARMY knee height and the males are .979.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***49.9 (3.3)**	**41.6**	**55.4**	***49.9 (3.0)**	**51.5 (2.6)**
	Baby Boomer	49.4 (3.1)			49.7 (3.0)	
	Pre Baby Boomer	50.5 (3.4)			54.4 (3.0)	
Male		***54.7 (3.0)**	**49.7**	**61.6**	***54.2 (2.8)**	**55.9 (2.8)**
	Baby Boomer	54.1 (2.9)			50.0 (3.0)	
	Pre Baby Boomer	55.3 (3.0)			54.0 (2.7)	

Table 6. Knee height by sex, sample, pre and baby boomer compared to US ARMY.

F. Popliteal Height was defined as the vertical distance from floor to the popliteal fossa while the subject sat erect with knees at 90 degrees, thighs parallel to the floor. The total female sample is 1.015 of the US ARMY popliteal height and the males are 1.002.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***39.5 (2.7)**	**34.1**	**44.2**	***39.6 (2.7)**	**38.9 (2.4)**
	Baby Boomer	39.4 (2.5)			40.0 (2.4)	
	Pre Baby Boomer	39.5 (2.9)			44.2 (2.4)	
Male		***43.8 (2.7)**	**38.3**	**49.9**	***43.7 (2.5)**	**43.4 (2.5)**
	Baby Boomer	43.6 (2.6)			39.3 (3.0)	
	Pre Baby Boomer	43.9 (2.8)			43.3 (2.3)	

Table 7. Popliteal height by sex, sample, pre and baby boomer compared to US ARMY.

G. Shoulder - Elbow Length was defined as the vertical distance from the bottom of the right elbow to the acromion while the subject sat erect with right arm hanging at the side, elbow flexed at 90 degrees and palms facing inward. The total female sample is .997 of the US ARMY shoulder-elbow length and the males are 1.013.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***34.2 (2.1)**	**28.9**	**38.0**	***34.3 (1.6)**	**33.6 (1.7)**
	Baby Boomer	33.8 (2.1)			34.3 (1.7)	
	Pre Baby Boomer	34.6 (1.9)			36.7 (1.7)	
Male		***37.4 (2.1)**	**33.9**	**42.3**	***37.1 (1.9)**	**36.9 (1.8)**
	Baby Boomer	†36.7 (1.6)			34.3 (1.5)	
	Pre Baby Boomer	†38.1 (2.2)			37.5 (2.2)	

Table 8. Shoulder-elbow length by sex, sample, pre- and baby boomer compared to US ARMY.

H. Forearm - Hand Length was defined as the horizontal distance between the back of the elbow to the tip of the middle finger while the subject sat erect with the elbows at 90 degrees and the forearms parallel to floor with palms facing inward. The total female sample is .980 of the US ARMY forearm-hand length and the males are .992.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***43.4 (2.2)**	**36.3**	**48.5**	***43.5 (1.9)**	**44.3 (2.3)**
	Baby Boomer	43.2 (2.3)			43.7 (1.9)	
	Pre Baby Boomer	43.6 (2.2)			47.4 (1.9)	
Male		***48.0 (1.9)**	**43.4**	**52.9**	***47.7 (1.8)**	**48.4 (2.3)**
	Baby Boomer	47.5 (1.6)			43.3 (1.8)	
	Pre Baby Boomer	48.5 (2.2)			47.9 (1.7)	

Table 9. Forearm-hand length by sex, sample group, pre- and baby boomer compared to US ARMY.

I. Buttock - Popliteal length was defined as the horizontal distance between the seatback target to the popliteal fossa while the subject sat erect and against the seat back with the knee at 90 degrees and the thigh parallel to the floor. The total female sample is .987 of the US ARMY buttock-popliteal length and the males are .988.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***47.6 (3.0)**	**39.1**	**55.0**	**48.2 (2.7)**	**48.2 (2.7)**
	Baby Boomer	47.3 (3.1)			49.0 (2.1)	
	Pre Baby Boomer	47.9 (3.0)			47.9 (2.1)	
Male		***49.5 (2.5)**	**44.8**	**55.2**	**49.2 (2.0)**	**50.1 (2.7)**
	Baby Boomer	48.7 (2.2)			49.1 (2.3)	
	Pre Baby Boomer	50.2 (2.6)			48.7 (2.4)	

Table 10. Buttock-popliteal length by sex, sample, group, pre- and baby boomer compared to US ARMY.

J. Shoulder Breadth was defined as the horizontal distance between the left and right deltoid landmarks while the subject stood with arms hanging to the sides. The total female sample is .963 of the US ARMY shoulder breadth and the males are .955.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***41.7 (2.6)**	**36.3**	**47.0**	**41.9 (2.6)**	**43.3 (2.3)**
	Baby Boomer	40.9 (2.8)			44.1 (3.1)	
	Pre Baby Boomer	42.4 (2.3)			42.0 (3.1)	
Male		***47.0 (2.0)**	**43.1**	**53.6**	**45.9 (1.5)**	**49.2 (2.6)**
	Baby Boomer	47.4 (2.0)			45.7 (1.7)	
	Pre Baby Boomer	46.7 (1.9)			43.9 (2.9)	

Table 11. Shoulder breadth by sex, sample group, pre- and baby boomer compared to US ARMY.

K. Hip Breadth was defined as the widest horizontal distance between the lateral points of the hips while subject sat erect with knees at 90 degrees, feet shoulder width apart. The total female sample is 1.013 of the US ARMY hip breadth and the males are 1.043.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		**39.0 (3.1)**	**30.6**	**44.7**	***39.9 (2.4)**	**38.5 (2.7)**
	Baby Boomer	38.9 (3.8)			38.8 (3.6)	
	Pre Baby Boomer	39.2 (2.4)			39.2 (3.6)	
Male		**38.3 (2.4)**	**31.1**	**44.7**	***37.7 (3.1)**	**36.7 (2.5)**
	Baby Boomer	†37.3 (2.1)			38.6 (2.9)	
	Pre Baby Boomer	†39.2 (2.3)			38.8 (2.9)	

Table 12. Hip breadth by sex, sample group, pre- and baby boomer compared to US ARMY.

L. Bispinous Breadth was defined as the horizontal distance between the right and left anterior superior iliac spine landmarks while the subject was standing. The total female sample is 1.036 of the US ARMY bispinous breadth and the males are 1.030.

Sex	Age Group	TOTAL			Drive Sample	US ARMY
		Average (SD)	Minimum	Maximum	Average (SD)	Average (SD)
Female		***22.8 (2.1)**	**16.9**	**27.8**	**23.2 (1.9)**	**22.0 (2.1)**
	Baby Boomer	22.4 (2.4)			23.3 (1.8)	
	Pre Baby Boomer	23.1 (1.8)			23.3 (1.8)	
Male		**23.8 (1.8)**	**19.4**	**29.8**	**23.9 (2.1)**	**23.1 (2.0)**
	Baby Boomer	†23.2 (1.7)			24.3 (2.5)	
	Pre Baby Boomer	†24.3 (1.9)			23.5 (2.0)	

Table 13. Bispinous breadth by sex, sample group, pre- and baby boomer compared to US ARMY.

IV. Discussion

Anthropometric dimensions are traditionally measured with a beam caliper. In the US Army survey [1], a beam caliper was used for these dimensions. This investigation utilized a 3d electro-goniometer to measure the position of landmarks on the body in three-dimensional space [2]. This procedure has been rarely used because it is difficult to obtain comparable distances between landmarks when measuring points on the body rather than measuring the distance with the beam caliper. With the exception of shoulder breadth, the comparison between the results of the total sample and the US Army sample are remarkably similar. The average ratios of total sample to US ARMY results are .996 (female) and .997 (male). A complete comparative study of the two methods, however, is still needed.

Statistically different results between men and women in the total sample are observed in the following dimensions: weight, sitting height, sitting eye height, knee height, popliteal height, shoulder-elbow length, forearm-hand length, buttock-popliteal length, shoulder breadth and bispinous breadth. Only hip breadth was not significantly different between the sexes, and it is the only dimension in which females were larger than males.

Statistically different results between the generations (i.e. pre- and baby boomers) were observed in the males for the following dimensions: sitting eye height, knee height, shoulder-elbow length, hip breadth and bispinous breadth. For the total sample of fifty-two males, however, the baby boomers were larger than the pre-baby boomer sample in only sitting eye height. This difference in sitting eye height is reversed in the drive subjects where the pre-baby boomers were larger than the baby boomers. These differences are contrary to the observed changes in the population due to the secular trend. They are present in our sample due to sampling error arising from how we selected subjects for participation. As reported in a previous report [3], we used self-reported heights and weights to pre-select our subjects for participation. In general, we found that males tend to over-estimate their height and females tend to under-estimate their weight when asked to report their height and weight. As a result, we accepted subjects into the study who did not fit our criteria of being above average height, for example. In addition, we had some exceptionally tall pre-baby boomer males in the sample.

Statistically different results between the generations (i.e. pre- and baby boomers) were observed in the females for the following dimensions: weight, sitting height, and sitting eye height. Similar to the males, the pre-baby boomers were larger in all dimensions than the baby boomers.

In conclusion, the sample measured for this investigation appears to represent the general population (if we use the US Army as representative of that population). The difference between the average of the ERL and Army samples is minimal. Thus, we conclude that the sample and the data in the subsequent reports on driving posture, contact areas, pelvis location, etc. are representative of the 50th percentile male and female in the US population.

V. List of References

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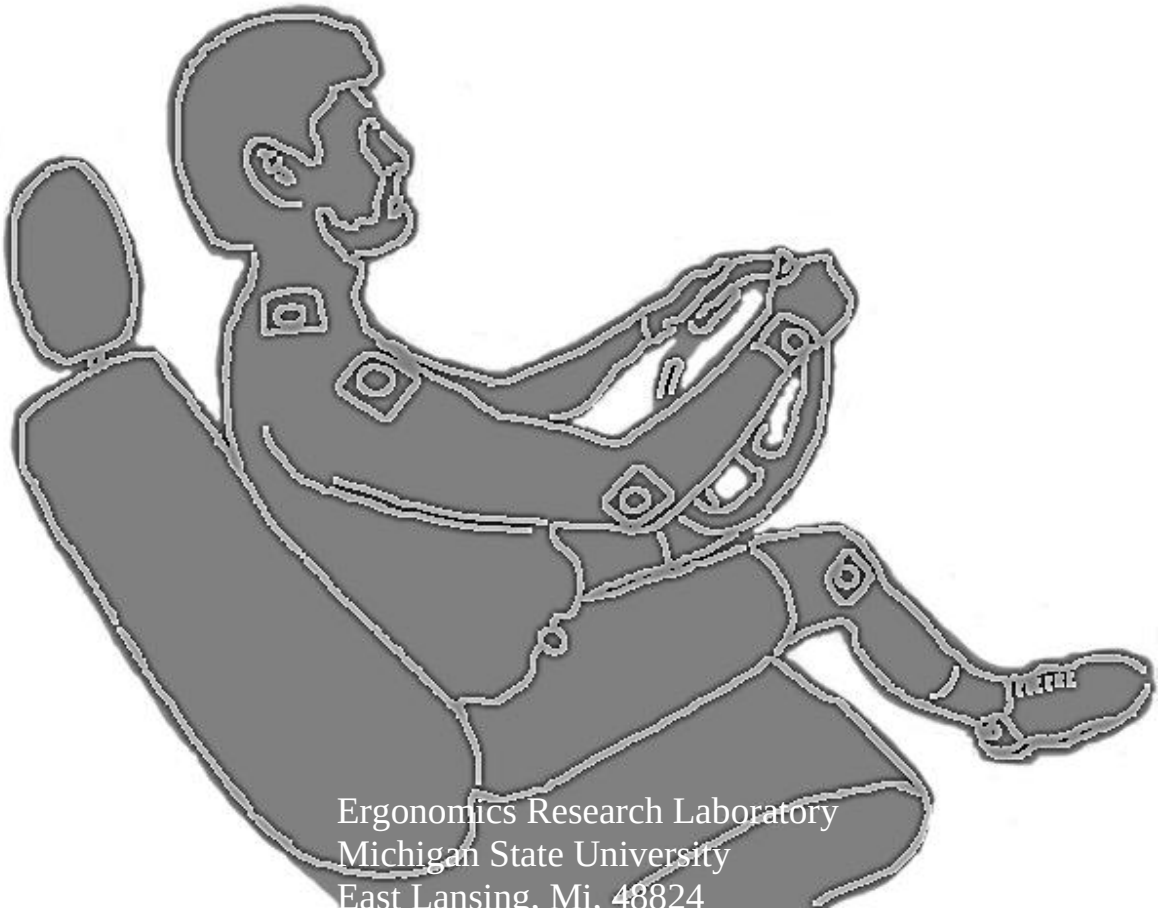

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