UMTRI-87-29

Gdom
91866

ERGONOMIC INVESTIGATION OF ARMREST LOCATIONS IN G-, H-, AND S-BODY VEHICLES USING A COMPUTER-CONTROLLED UNIVERSAL SEATING BUCK

Lawrence W. Schneider

Final Report to:

Interior Trim Engineering
Chrysler Corporation
Detroit, Michigan
48288

July 15, 1987

UMTRI The University of Michigan Transportation Research Institute

ERGONOMIC INVESTIGATION OF ARMREST LOCATIONS

FOR G-, H-, AND S-BODY VEHICLES

USING A COMPUTER-CONTROLLED UNIVERSAL SEATING BUCK

FINAL REPORT

Submitted to:

Interior Trim Engineering
Chrysler Corporation
Detroit, Michigan
48288

July 15, 1987

Technical Report Documentation Page

1. Report No. UMTRI-87-29	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Ergonomic Investigation of Armrest Locations in G-, H-, and S-Body Vehicles Using a Computer-Controlled Universal Seating Buck		5. Report Date
		6. Performing Organization Code
		8. Performing Organization Report No. UMTRI-87-29
7. Author(s) Lawrence W. Schneider		
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109		10. Work Unit No. 389038
		11. Contract or Grant No. #2000513
12. Sponsoring Agency Name and Address Interior Trim Engineering Chrysler Corporation Detroit, Michigan 48288		13. Type of Report and Period Covered Final Report Sept. 1, 1985-June 30, 1987
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A computer-controlled universal seating buck was designed and constructed to allow simulation of G-, H-, and S-body seating packages and push-button adjustment of locations for primary vehicle controls and armrests. This facility was used to study the preferred and acceptable locations of door and center armrests for one hundred drivers ranging in stature from 5th percentile female to 95th percentile male. The data were analyzed to determine the optimal and required locations of armrests in the different seating packages and to determine relationships between preferred armrest heights and locations among drivers of different statures.

17. Key Words vehicle control ergonomics anthropometry driver armrests seating buck	18. Distribution Statement Limited Distribution

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 256	22. Price

ACKNOWLEDGEMENTS

The author would like to acknowledge and thank the many persons who contributed to the success of this research project. In particular, the development of the universal seating buck required the expertise and effort of many talented persons. Much of the early design work and engineering of the seating buck was done by Timothy Carlson, a graduate student in mechanical engineering at the University of Michigan. Additional design assistance was obtained from Ernest Lueder, instrument maker, who also performed all the fabrication of mechanical parts and assembly of the components. Design and engineering of the electronic interface hardware was by Michael Hagan, who also contributed much of the IBM PC assembly-language software for controlling the movement of vehicle components and making the A/D conversions of position data. Fabrication and installation of the electronic components was done by Marvin Dunlap.

The difficult and tedious job of testing one hundred subjects was done by Mary Frankovich, Melinda Rock, and Warren Jocz. In addition, Mary and Melinda made substantial contributions to the data analysis and writing of this report. Special thanks are also due to Carol Sobecki for preparing the text of this report, to Kathleen Richards for the excellent graphic work, and to Jean Brindamour for preparing all the photographs.

Finally, the author would like to thank the many Chrysler staff members who offered their time and assistance throughout the project. These include: Helen Cost, Al Lacroix, Brian Pecheniuk, Duane Miller, and many others.

CONTENTS

LIST OF FIGURES

PAGE

LIST OF FIGURES (continued)

LIST OF TABLES

PAGE

SUMMARY AND CONCLUSIONS

A computer-controlled universal seating buck was designed and constructed to simulate G-, H-, and S-body seating packages in the laboratory and to allow push-button adjustment of locations for primary vehicle controls and armrests. This facility was used to study the preferred and acceptable locations of door and center armrest for one hundred male and female drivers ranging in stature from 5th percentile female to 95th percentile male. The data were analyzed to determine the optimal and required locations of armrests in the different seating packages and to determine relationships between preferred armrest heights and locations among drivers of different statures.

It was found that there was no relationship between driver stature and preferred armrest height for either the door- or console-side armrests, and that many drivers preferred the center armrest lower than the door armrest while very few preferred the door armrest lower than the center armrest. There was a relationship between preferred front/back elbow position and driver stature, whereby the elbows of taller drivers, who tend to sit more rearward, are also positioned further rearward.

In order to determine the optimal door armrest heights in the three vehicles, the locations that maximized the number of subjects who would accept the armrest height were determined. The data from the different subject groups were weighted to represent the driver population by stature. As expected, the optimal armrest heights are higher relative to acceleration heel point (AHP) for vehicles with higher seats. For the door armrest the optimal height above AHP is about 18.7 inches for the G-body vehicle and about 21.6 inches for the S-body vehicle. For the console armrest, the optimal height above AHP is about 17.5 inches for the G-body vehicle and about 20.2 inches for the S-body vehicle.

With respect to design H-point, the optimal armrest heights are highest in the G-body vehicle and lowest in the S-body vehicle. For the G-body the optimal armrest heights are 9.6 inches and 8.4 inches above H-point for the door and console armrests, respectively. In the S-body vehicle, the optimal armrest heights are 7.8 inches and 6.4 inches above H-point for the door and center armrests, respectively. The smallest variance between vehicles in optimal armrest height is for the distance relative to the center of the steering wheel.

In all but one case the optimal armrest heights determined in this study are significantly higher than the heights of door armrests and console surfaces in current vehicles. The only exception is the current height of the seat armrest in the S-body vehicle which is located within a few millimeters of the optimal height determined in this study.

Front-to-back elbow position data were used to determine required and "potentially usable" armrest locations and lengths in the X-direction. Results match closely to locations in current vehicles. The optimal positions for finger grip controls on the door armrest were also measured with the elbow in the preferred location. The results show no relationships to driver stature, and the optimal positions are from 16.3 inches forward of H-point for the S-body vehicle to 18.9 inches forward of H-point for the G-body vehicle.

A pilot study was conducted to determine the repeatability of the position data by having four subjects return on another day to perform the testing a second time. The results of this study indicate good repeatable and consistency of subjects in locating their preferred positions and estimating their acceptable ranges.

I. INTRODUCTION

With increased competition in the automotive marketplace and continuing pressures to make cars smaller as well as safer, improved ergonomic design of the driver workspace has become an important concern of vehicle designers and engineers. One important area of driver ergonomics is with regard to the locations and orientations of primary vehicle controls and related components of driver convenience, such as the driver armrests. In the past, decisions about control and component locations have not been based on experimental data of driver needs and preferences. At best, decisions regarding control locations have been educated guesses by experienced designers and engineers. Too frequently, however, locations of interior components and controls are based on the preference of one or two individuals in the corporation, or are dictated by other physical design constraints.

There is a need to remove the guess work involved in vehicle interior design by establishing a scientific ergonomic data base upon which driver workspace and seating design decisions can be made. Ultimately, such a data base will lead to the establishment of driver workspace design criteria and design parameter values. Such a data base must deal not only with the range of vehicle types and seating packages but also with the range of driver physical characterisitics.

This study was undertaken, as a part of the Chrysler Challenge Fund, to meet this need for ergonomic data by experimentally determining the preferred and acceptable locations of driver components and controls. Since it would be extremely difficult, if not impossible, to conduct such studies in actual vehicles, where the locations of primary controls and other vehicle components must be varied over significant ranges, it was first necessary to design and build a test facility that would allow the collection of the desired data base.

This report describes the "universal" seating buck that was engineered and fabricated and the procedures and results for an initial measurement study in which one hundred subjects were evaluated for preferred armrest positions in three passenger vehicle seating packages, ranging from the sports car or G-body to the minivan or S-body. A subsequent study, with the goal of determining driver preference for the locations of the seat, steering wheel, pedals, and shift knob as well as the armrests, is in progress and will be reported on in a future document.

The rights, welfare, and informed consent of the volunteer subjects who participated in this study were observed under guidelines established by the U.S. Department of Health, Education and Welfare Policy (now Health and Human Services) on Protection of Human Subjects and accomplished under medical research design protocol standards approved by the Committee to Review Grants for Clinical Research and Investigation Involving Human Beings, Medical School, The University of Michigan.

II. METHODS AND PROCEDURES

A. DESCRIPTION OF TEST FACILITY

1. Seating Buck Design Criteria

In order to meet the needs of the research program, several general design criteria were established for the "universal" seating buck. First, the facility had to be capable of representing a range of passenger car package configurations, including the Chrysler G-body (sports car), the H-body (sedan), and the S-body (minivan). Second, in order to test subjects in all three vehicle packages during a single measurement session, the buck had to be easily adjustable from one package configuration to another. A third general requirement was that subjects be able to adjust the positions of primary vehicle controls and armrests easily and without intimidation by the investigator. Finally, in order to facilitate the testing process and minimize errors in data acquisition, it was desired that the measurement and recording of position data be as automated as possible.

2. General Description

Figures 1 and 2 show the completed computer-controlled "universal" seating buck that resulted from these basic design considerations. The base structure is made of 2" x 2" steel tubing with 3/4-inch plywood forming the platforms for seat attachment, subject entry and exit, and the accelerator heel point (AHP) reference surface. Separate structural modules are bolted to the base unit to provide support and position adjustment for the different driver controls and components. Black cloth was used to cover most of the metallic structures and mechanisms to give a more attractive and less distracting appearance to the buck. During testing, a more realistic driving environment is provided by projecting a road scene onto a screen mounted on the buck in front of the subject.

The clutch/brake pedal assembly and the steering-wheel hardware are supported by an aluminum frame structure mounted to the left front area of the base unit. As shown in

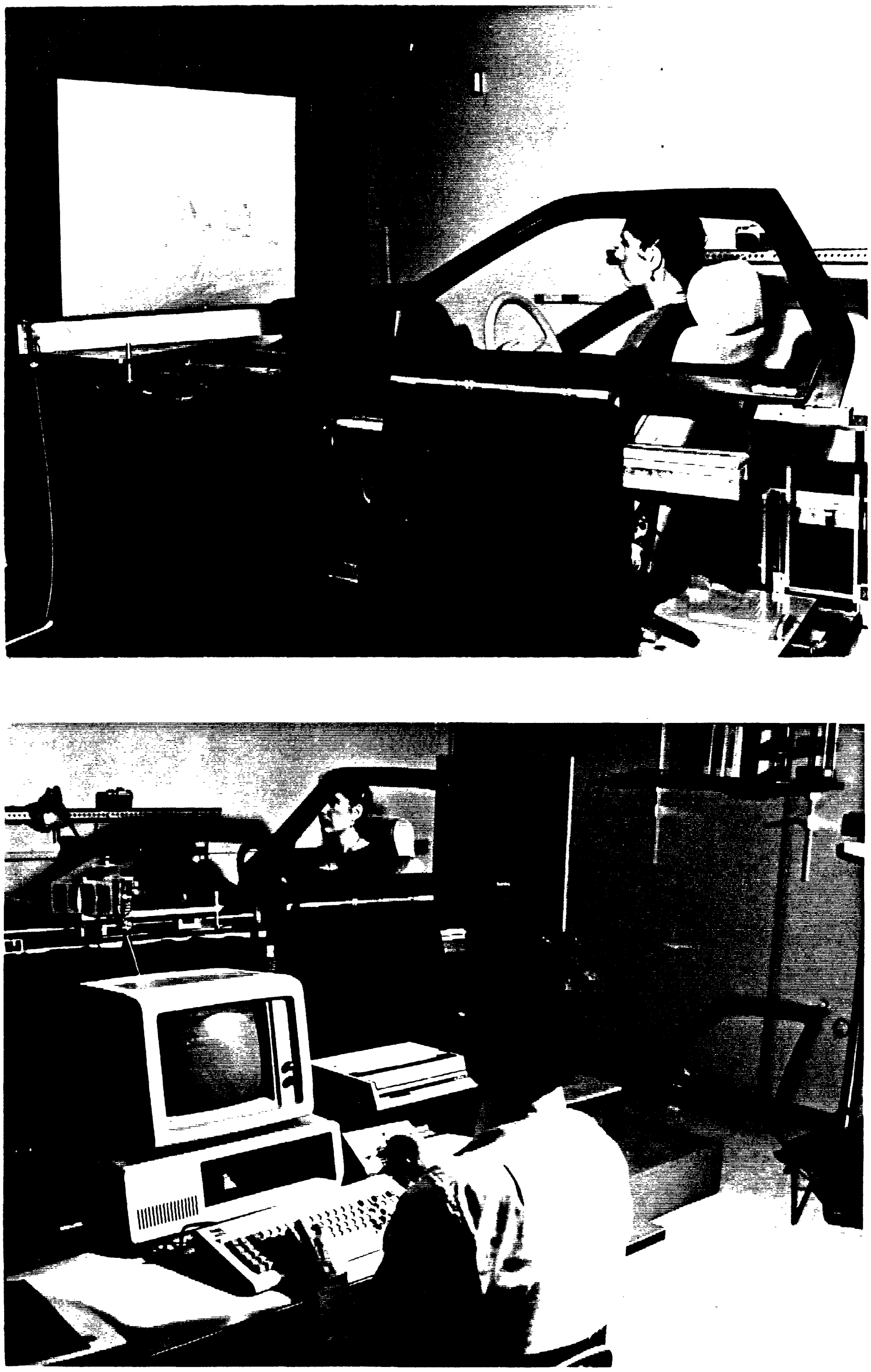


Figure 1. UMTRI computer-controlled "universal" seating buck.

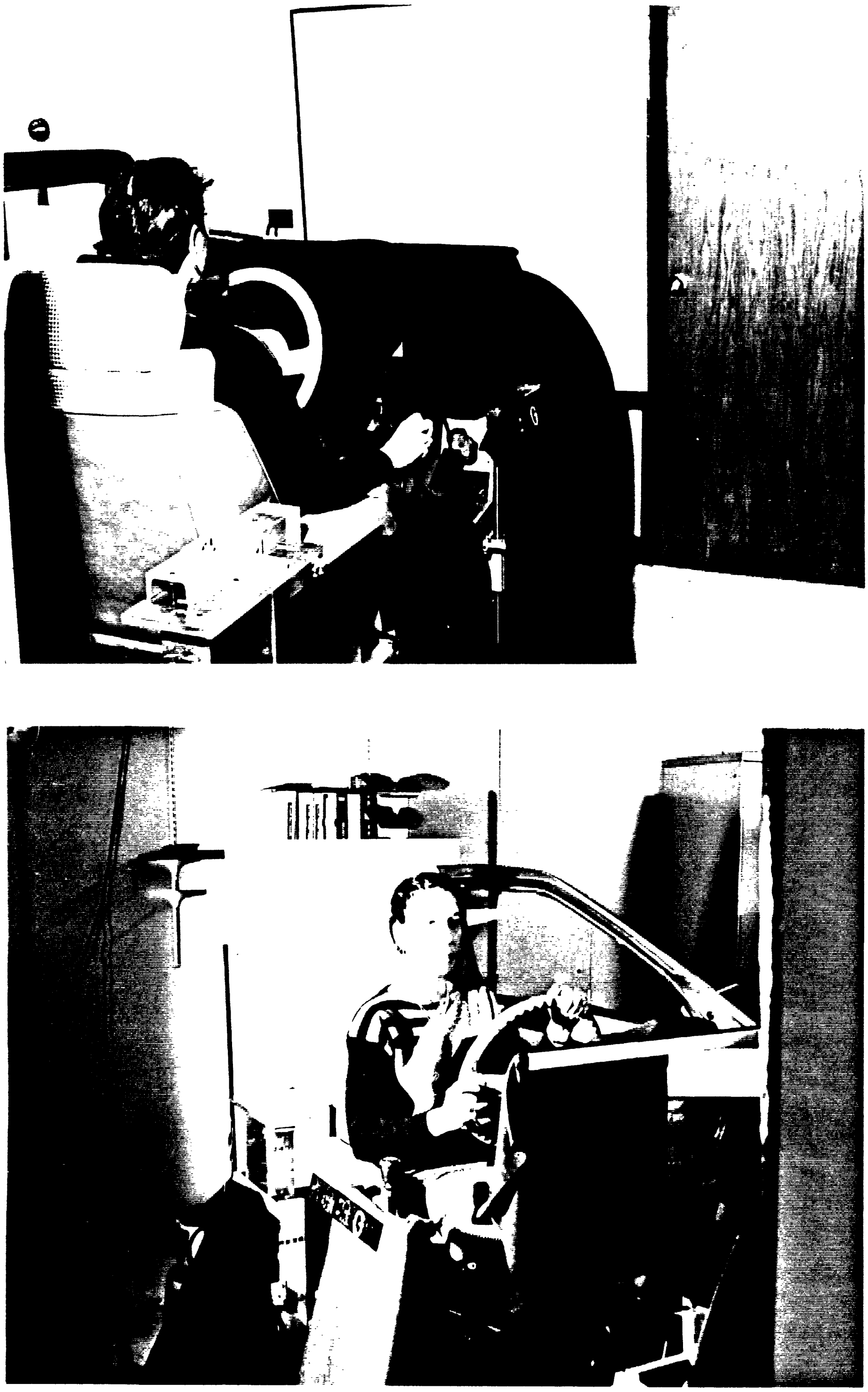


Figure 2. UMTRI "universal" seating buck.

Figure 3, this module also houses the electronic interface hardware and power supplies for component positioning and readout of vehicle component positions. The shift linkage assembly and console armrest positioning modules are located and attached along the right side of the main frame, while the door structure and door armrest unit is attached to the base structure to the left of the vehicle seat. This modular design approach provides for easy system modification in future studies since any of the component modules can be easily removed and replaced or modified.

In addition to providing for manual adjustment of component positions and orientations to simulate the different package configurations, the facility includes the ability to adjust the position of several components by electrically-powered screw-motor actuators. Selection and activation of these devices is by either the hand-held module shown in Figure 4, or by the computer keyboard. With the hand-held unit, the component to be moved is selected by a rotary switch at one end of the plastic cylinder and the direction of motion is controlled by two pushbutton switches on the side of the unit. Keyboard control allows the actuator (i.e., component) selected by the investigator to be moved in small increments using the "PgUp" or "PgDn" keys or by alternating starts and stops using the "up-arrow" or "down-arrow" keys.

Dimensions and coordinates obtained from the G-body, H-body, and S-body package drawings and J826 H-point specifications were used to establish design positions and orientations for the steering column, pedals, seat, and door window frames for the sports car, mid-size sedan, and minivan configurations, respectively. A complete list of the package coordinates and dimensions is presented in Appendix A of this report. The following paragraphs describe the features of this test facility and the manual and automatic adjustments in greater detail.

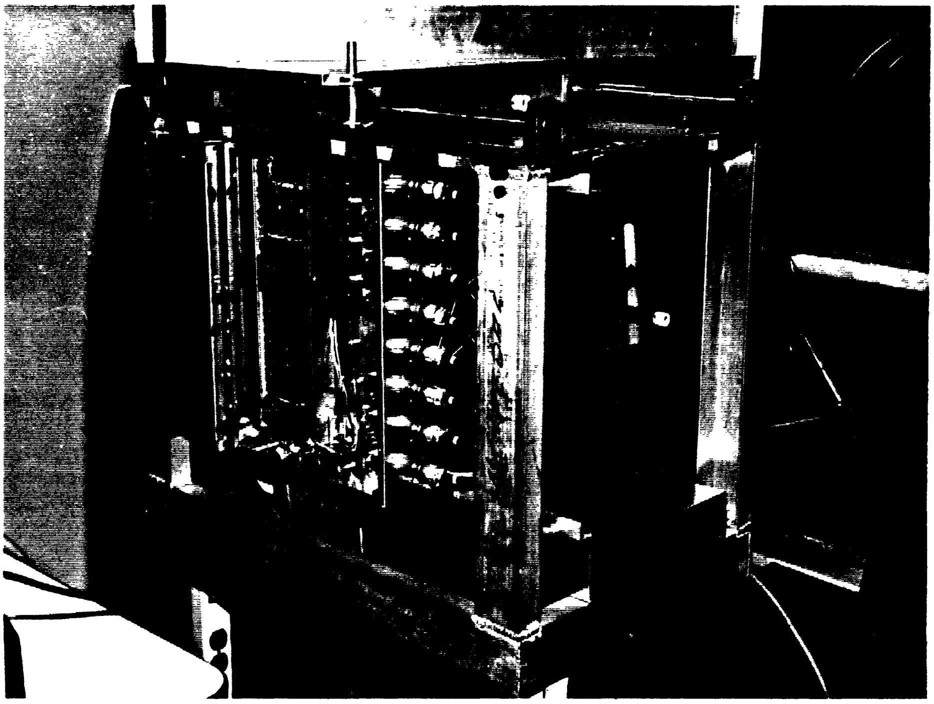


Figure 3. Pedal and steering wheel support structure containing electronic interface hardware.

Figure 4. Hand-held module used by subjects to adjust positions of vehicle components.

3. Vehicle Components

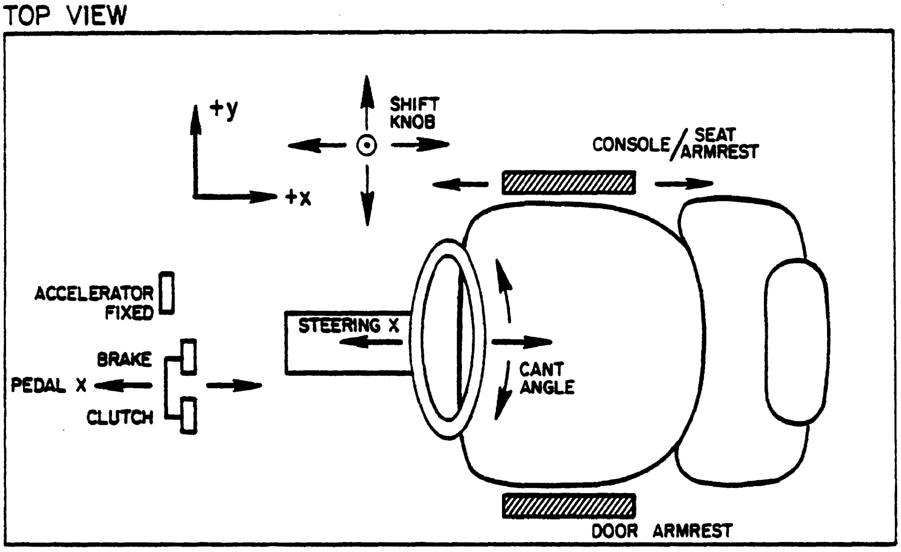
In order to facilitate adjustment from one seating package configuration to another, the same driver control and seat components were used for all three body styles. Thus, the same steering wheel, accelerator pedal, seat/seat track assembly, clutch/brake pedal assembly, and shift knob/linkage mechanisms were used in all three package setups. However, as described below, adjustability in the positions, orientations, and movements (e.g., clutch pedal travel) of these assemblies and components was provided for in order to achieve the different package configurations.

In addition to the primary control components and vehicle seat, the test facility includes a simulated driver door/window frame structure which is different for each body style, a common driver door armrest surface, and a center armrest surface. For the H- and G-body styles, the center armrest surface consists of the plastic console lid used in the H-body vehicle. For the S-body configuation, this is replaced by the seat-mounted pivoting-type armrest from an S-body vehicle.

4. Buck Reference System

The accelerator heel point (AHP) was established as a common, fixed reference point on the buck for all three seating packages. As illustrated in Figure 5, the X axis is positive toward the rear, the Z axis is positive up, and the Y axis is positive toward the right. The origin of the buck coordinate system can be considered to lie at the intersection of an X-Z plane (i.e., front to back vertical plane) at the seat centerline with a line in the Y-direction (i.e., side to side) passing through the AHP. The X and Z coordinates of the AHP for each of the vehicle package drawings (see Tables 1, 2 and 3 of Appendix A) can be used with measurement distances from the AHP along the three axes to convert control/component locations in buck coordinates to locations in vehicle coordinates. Calibration of the

TOP VIEW



SIDE VIEW

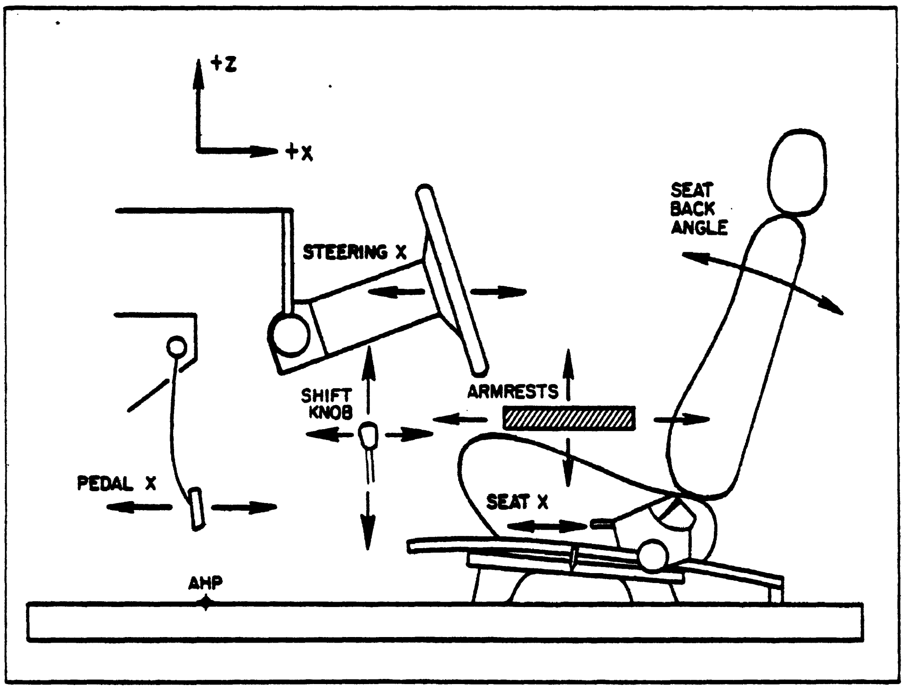


Figure 5. Schematic drawing of seating buck illustrating buck and vehicle coordinate axes and vehicle components that can be positioned by subjects.

measurement systems and validiation of component locations in buck coordinates was achieved by measuring orthogonally from established reference surfaces using a standard anthropometer fitted with bubble levels. Vertical distances were measured from either the AHP surface or seat-base platform surface, lateral distances were measured from the right edge of the seat-base platform, while longitudinal measurements were taken from a vertical reference surface located behind the seat. The locations of these surfaces relative to key vehicle landmarks such as the AHP and seat centerline are also given in the tables of Appendix A.

5. Seat and Seat Track

The seat used for all three package configurations is Chrylsers' 1986 Enthusiast high-performance seat with manual seat track mechanism and seat back angle adjuster. The inflatable bags for thigh and lumbar support were kept deflated during all calibration and testing. The seat track was anchored to a 3/4-inch-thick plywood board by means of four aluminum spacers and fitted with measuring scales for manual readout of seat detent and seat back angle. In order not to limit a subject's desired seat position by available seat travel in production seats, the track length was extended at each end to allow several detents of seat travel beyond that normally provided. This extended seat track has a total of 21 detents with detent spacings of approximately 21 mm (.83 inches), for a total seat travel range of about 420 mm (16.5 inches). As shown in Figure 6, the seat track is inclined upward toward the front of the buck and is slightly curved so that the seat tilts backward approximately 1/2 degree for every detent moved rearward over the normal seat track operating range.

The SAE J826 H-point machine was used to determine the spacer heights needed to properly position the seat mounting board so that the design H-point specifications for the

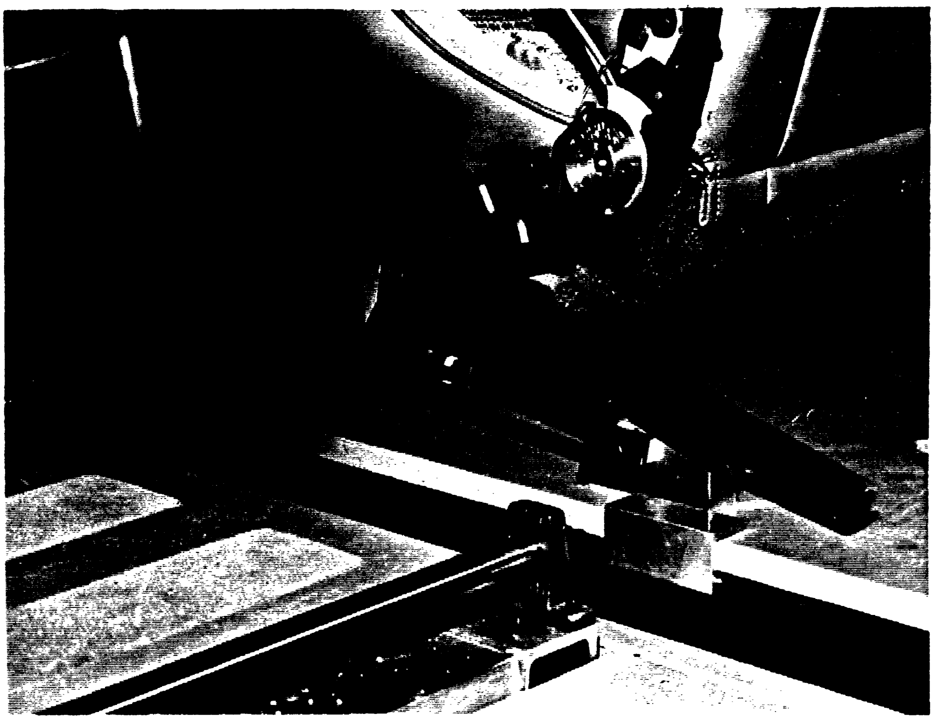


Figure 6. Seat with extended track mounted to plywood board via aluminum spacers. Note detent indicator and seatback angle scale.

G-, H-, and S-body vehicles would be achieved. This H-point validation process was also used to determine which detent on the extended seat track corresponded to the design position in each package. Figure 7 shows the H-point machine on the seat during this process. Several trials were conducted at different seat positions and seat back angles in order to determine the design detents. After these initial H-point calibrations, support fixtures and spacers were fabricated to locate and orient the seat and provide for seat adjustment among the different vehicle packages. Upon completion of these fixtures, the H-point machine was used again to verify that the desired specifications had been met. Table 1 compares the results obtained for the two trials. The differences are small and within acceptable tolerances.

Figures 8 and 9 show the seat positioned at the G- and S-body locations respectively. Table 2 provides some basic information on the seat track and travel for the G-, H-, and S-body seat orientations.

6. Power-adjusted Control Locations and Electrical Readout of Position

In its present configuration, the test facility provides for push-button control of eight vehicle component/direction variables by either the hand-held module or by the computer keyboard. In order to quickly and reliably record the positions of power-actuated components selected by subjects, and to enable the computer to position these components at desired locations, high-resolution ten-turn potentiometers and spring-loaded pulley/cable mechanisms were incorporated into the facility to provide electrical signals proportional to component positions. Figure 10 shows the position monitoring system for the steering-wheel-front/back adjustment. The potentiometer is attached to the non-moving structure and the wire cable that winds around and attaches to a pulley on the shaft of the potentiometer is attached to the moving structure to which the steering-wheel assembly is

Figure 7. H-point calibration of seating buck.

Table 1.
Comparison of Final H-Point Calibration Values
with G, H, and S Body Design Specifications

H-Point Measurement	Specification Desired	Measured	Diff
G-BODY: Detent=15, Back Angle=22			
AHP to H-POINT (horiz.)	880	879	1
AHP to H-POINT (vert.)	231	230	1
FOOT ANGLE	65	65	1
ANKLE ANGLE	87	87	0
KNEE ANGLE	128	129	1
HIP ANGLE	98	98	.5
BACK ANGLE	26	26	0
H-BODY: Detent=14, Back Angle=22			
AHP to H-POINT (horiz.)	828	828	0
AHP to H-POINT (vert.)	264	264	0
FOOT ANGLE	59	59	0
ANKLE ANGLE	87	87	0
KNEE ANGLE	119	120	0
HIP ANGLE	94	94	0
BACK ANGLE	24	24.5	.5
S-BODY: Detent=13, Back Angle=20			
AHP to H-POINT (horiz.)	698	700	2
AHP to H-POINT (vert.)	352	345	7
FOOT ANGLE	43	43	0
ANKLE ANGLE	87	87	0
KNEE ANGLE	103.3	103.5	.2
HIP ANGLE	91	91.5	.5
BACK ANGLE	22	24	2

Note: Back angle corresponds to reading on scale attached to seat

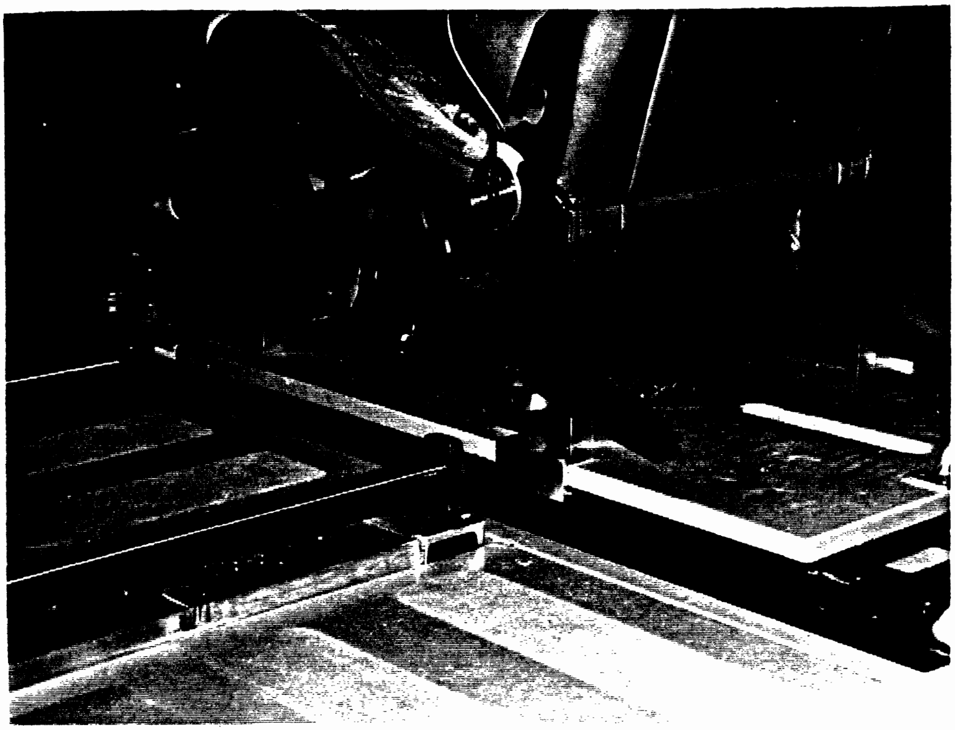


Figure 8. Seat positioned in G-body location.

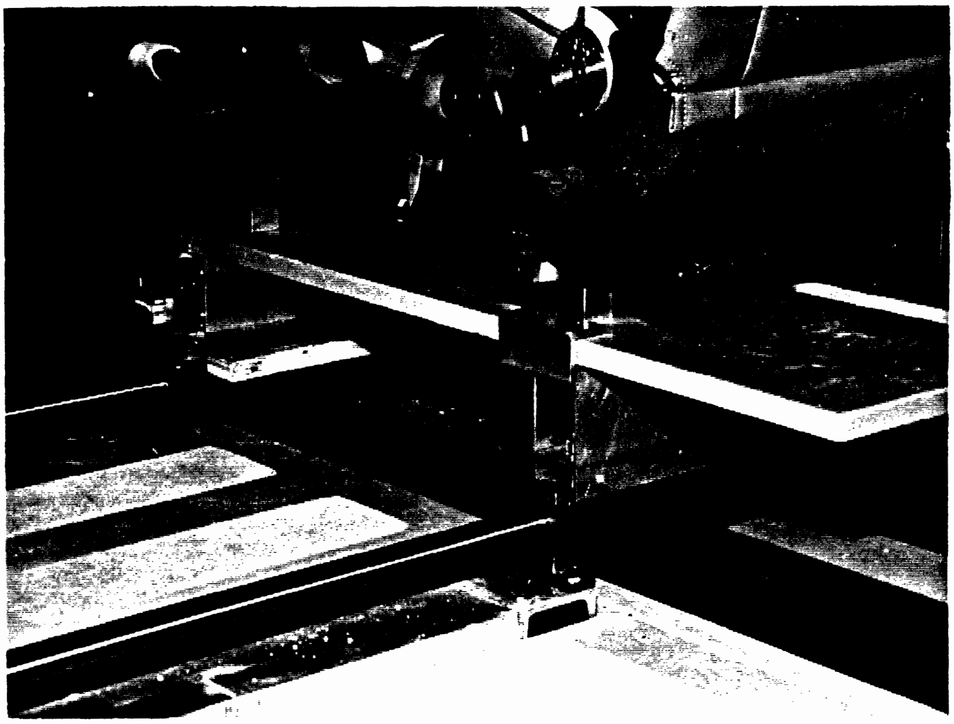


Figure 9. Seat positioned in the S-body location.

Table 2.
Seat Track Characteristics
of Vehicles and Buck

		Vehicle G	Vehicle H	Vehicle S
Vehicle				
# Detents	x:	11	10	10
Design Detent	z:	10	9	8
Design H-point	x:	1430	1405	1334
	z:	286	319	550
Full Rearward H-point	x:	1449	1424	1375
	z:	282	315	542
Full Forward H-point	x:	1245	1236	1192
	z:	318	349	574
Horizontal Seat Travel (mm)		204	188	183
Seat Rise (mm)		36	34	32
Detent Spacing (mm)		20.4	20.9	20.3
Buck				
Detent = Design H-point		15	14	13
Detent Spacing (mm)		21	21	21
Detent = full rear		16	15	15
Detent = full forward		6	6	6

fastened. A coil spring inside the pulley maintains tension on the cable and rewinds it when the steering wheel moves forward on the buck.

The voltage at the wiper arm of each potentiometer is proportional to the location of the steering wheel and is input to the IBM PC computer via one of eight A/D channels. Calibration of each potentiometer unit was achieved by recording A/D values at specified component locations measured in buck coordinates. These data were plotted on graph paper to check the linearity of the relationships and to determine the slope and intercept of each linear calibration equation. The equations were then adjusted by adding an appropriate offset term to give coordinate values in the different vehicle reference systems. Thus, each component/direction calibration equation is of the form:

$$\text{Veh. Coord.} = (AD_x - AD_R) * C_1 + R_1$$

where:

- Veh. Coord. = the component location in the vehicle reference system
- AD_x = the A/D reading at the component location
- AD_R = the A/D reading for that component/direction variable at a fixed point
- C_1 = the slope of the A/D versus measured distance (in mm) for that component/direction variable
- R_1 = the vehicle coordinate corresponding to the fixed point at which AD_R was obtained

7. Steering-Wheel Positioning

Steering-wheel height and steering-column tilt were designed to be manually adjustable to accomodate the differences for the three vehicle types. Figure 11 shows the

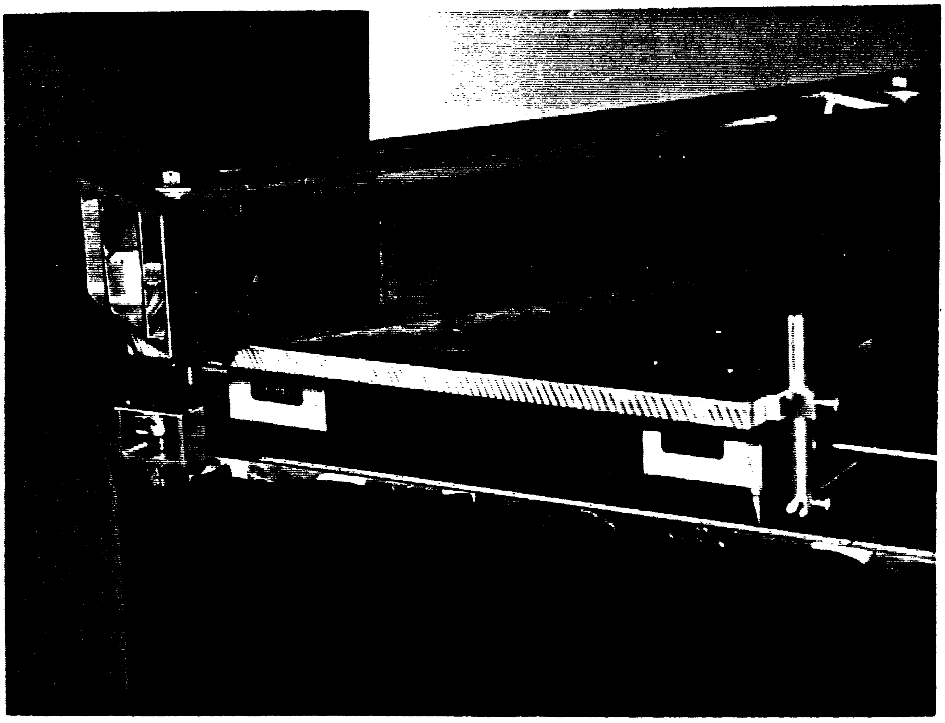


Figure 10. Position sensing unit for steering-wheel front/back location (i.e., X-coordinate).

Figure 11. Steering-wheel angle and height adjustment mechanism.

steering-wheel support and adjustment mechanism that replaces the standard column and allows these desired adjustments. In addition to tilt and height adjustments, the offset or "cant" angle of the steering wheel/column from the X-Z plane is manually adjustable to allow the center of the steering wheel to move about 3" to either side of the seat center line. Steering-wheel-front-to-back adjustment for establishing the steering wheel at design locations as well as for subject adjustments in future studies is by means of the screw-motor actuator.

8. Brake and Clutch Pedal Positioning

As previously indicated, the brake and clutch pedals used in the buck are the same for all three vehicle body styles and are fixed laterally with respect to each other and relative to the accelerator pedal at locations that minimize the position errors (see pedal dimensions in Tables 4, 5, and 6 of Appendix A). There are also differences in the brake-to-clutch pedal offset for the three vehicles in the X-Z plane. In the G- and H- body vehicles the offsets are nearly identical at about 30 mm, measuring between the top centers of the two pedals in the package drawings. In the S-body vehicle this distance is approximately 21 mm on the package drawings. In the seating buck the distance was set between 21 and 30 mm to minimize the error for the different vehicles.

Figure 12 shows the support structure for the clutch and brake pedal unit. Differences in clutch and brake travel for the different vehicles are accomplished by wooden blocks of different heights that clip to the aluminum plate behind the pedal linkage. Realistic clutch pedal force is achieved by attaching the clutch cables to a clutch/transmission assembly mounted just forward of the pedals. Brake pedal force is simulated by means of a block of hard rubber placed between the pedal linkage and the mounting plate. The heights and orientations of the brake/clutch pedal assembly are

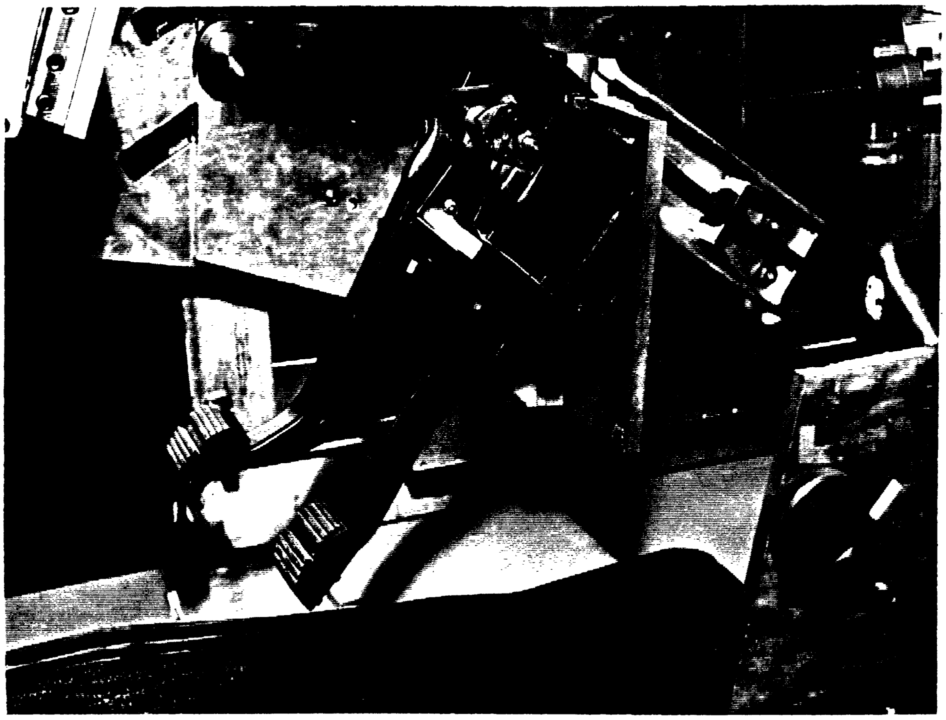


Figure 12. Support structure for brake/clutch pedal assmebly.

Figure 13. Contoured slots in pedal assembly mounting plate for manual adjustment of brake/clutch pedal height and orientation.

different for the three body styles and are achieved by means of a pair of bolts that connect the clutch/brake support structure to the translating mounting plate. As shown in Figure 13, specially contoured slots in the translating plate provide for adjustment and orientation of the pedals to the different vehicle package requirements. Adjustment of the brake/clutch pedal assembly from one configuration to another is achieved by manually sliding the assembly along the slots to one of three sets of detents which correspond to the desired pedal orientations. At each of these detents, a knurled-handled bolt is tightened to lock the pedal assembly in position.

9. Accelerator Pedal Positioning

A single accelerator pedal is located at the same lateral position relative to the seat centerline for all three vehicles. The angle of the accelerator pedal is manually adjustable by the mechanism shown in Figure 14 in order to achieve the desired pedal orientations in the different vehicles. Resistance of the accelerator pedal is accomplished by means of a simple tension spring that hooks the pedal linkage to the mounting plate.

10. Shift Knob Positioning

The same shift linkage unit is used for all three vehicle models and is attached to the support module shown in Figure 15 that allows positioning in the X, Y, and Z directions by means of screw-motor actuators. The shift linkage is connected to a 5-speed manual transmission by the standard cables and the transmission was lubricated and adjusted to provide a smooth and realistic "feel" to shift linkage operation.

11. Armrests and Driver Door/Window

The seating buck includes two armrests and armrest supports -- one for the driver

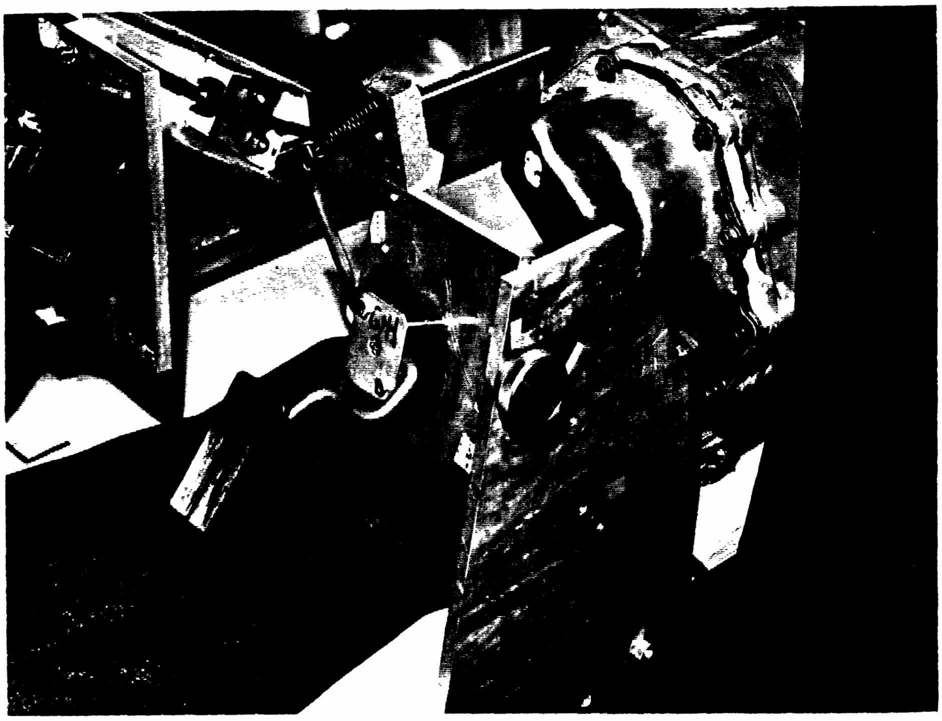


Figure 14. Accelerator pedal support and adjustment module.

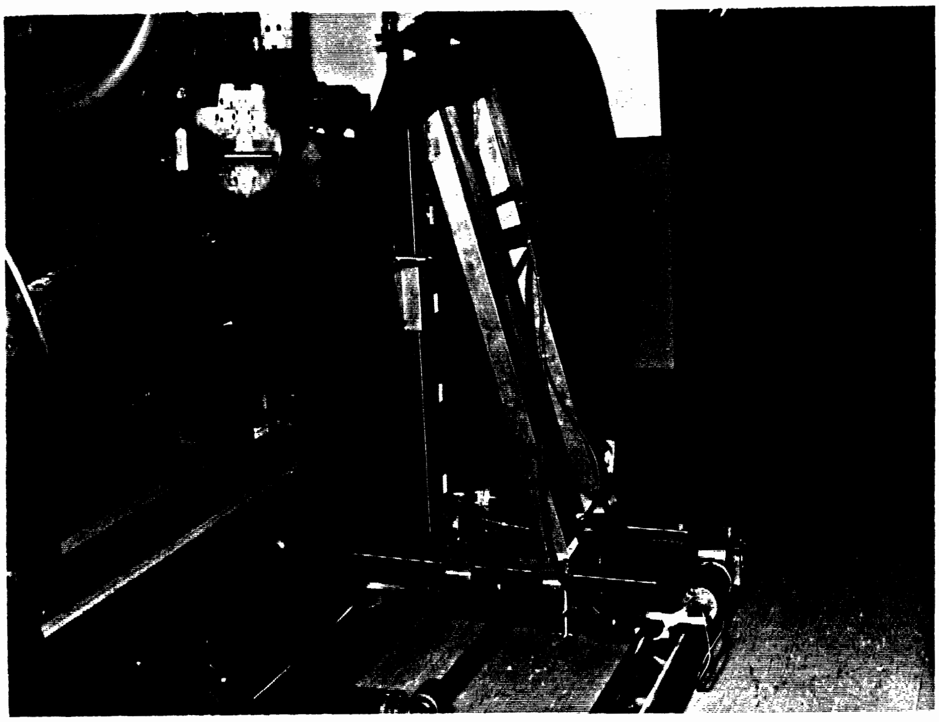


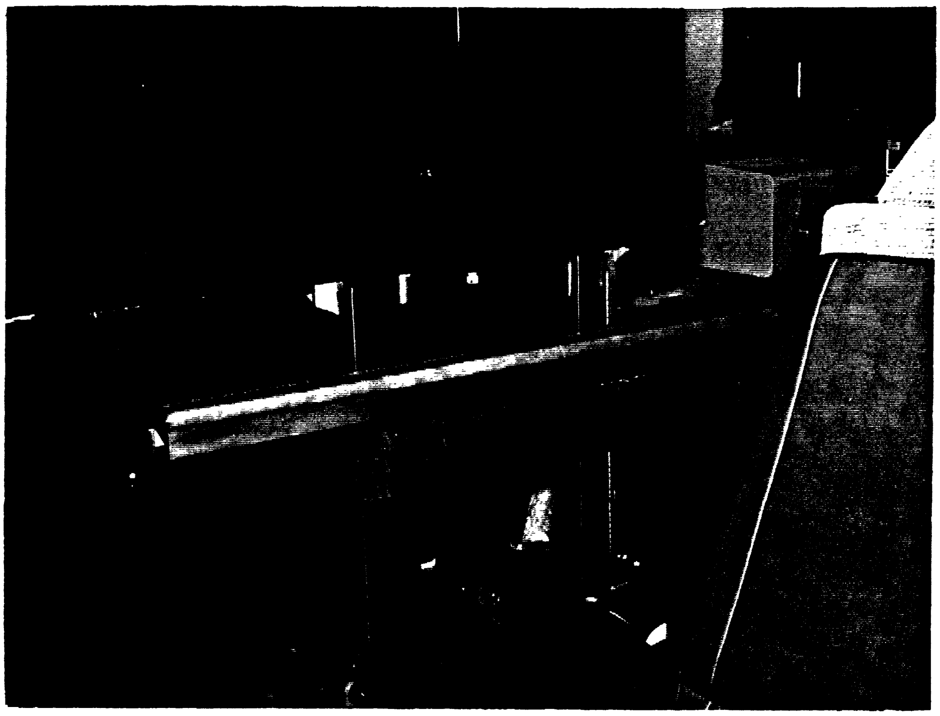
Figure 15. Shift knob/linkage support and adjustment module.

door and one for the center armrest. The driver door armrest consists of a three-inch-wide vinyl-padded surface that runs longitudinally and horizontally along the driver door. Up-and-down positioning of this armrest is by means of a screw-motor actuator located within the pseudo-door structure as shown in Figure 16. A measuring tape was attached to the top surface of the vinyl armrest to provide for measurement of elbow position in the X direction (i.e., front to back). The door/armrest assembly slides laterally on linear bearings and shafts to provide for manual adjustment of door and armrest lateral positions relative to the seat centerline and to enable easy ingress and egress for the subject. Driver-door window frame units were fabricated from G-, H-, and S-body vehicle doors and can be manually attached and removed from the door armrest support structure during a test session.

The center or console armrest attaches to a cantilevered aluminum arm fixed to a support structure located to the right of the seating buck as shown in Figures 17 and 18. The armrest moves up and down and front and back by means of screw-motor actuators and can be manually adjusted in the lateral direction to accomodate the different lateral positions of the center armrest with respect to the seat centerline. As previously mentioned, a standard center console cover is used as the armrest surface for the G- and H-body vehicles, while a soft, seat-mounted armrest from a minivan is attached to the unit for S-body testing.

B. SELECTION AND RECRUITMENT OF SUBJECTS

Two sampling strategies were considered for this study. In one, 100 subjects would be selected with the goal of matching the distribution of U.S. adult population for stature, gender, age, and weight characteristics. In the second, equal numbers of subjects would be selected within specific stature ranges from the 5th percentile female to the 95th percentile male, while weight and age would be allowed to vary over normal ranges in each stature/gender group. The first approach would produce results that could be easily



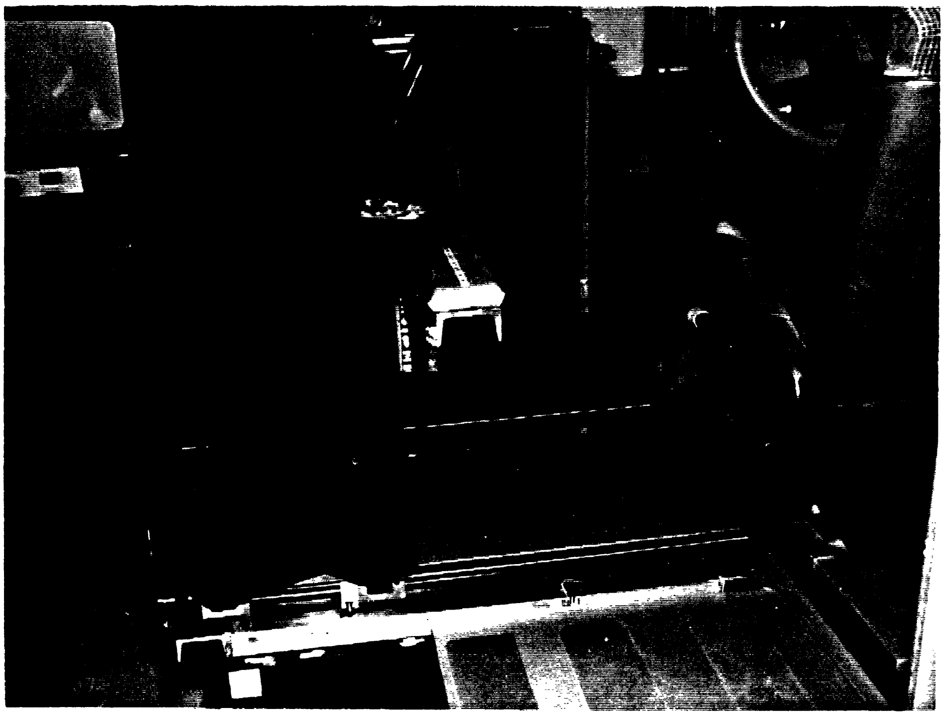


Figure 16. Driver door module and adjustable armrest.

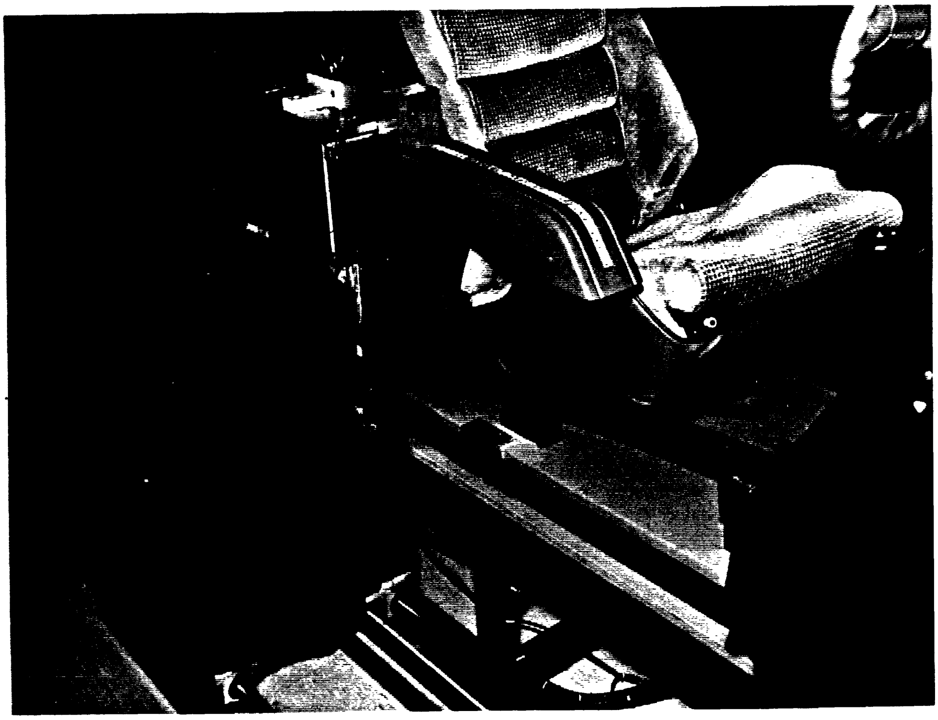


Figure 17. Center armrest support and adjustment module with H- and G-body console cover in place.

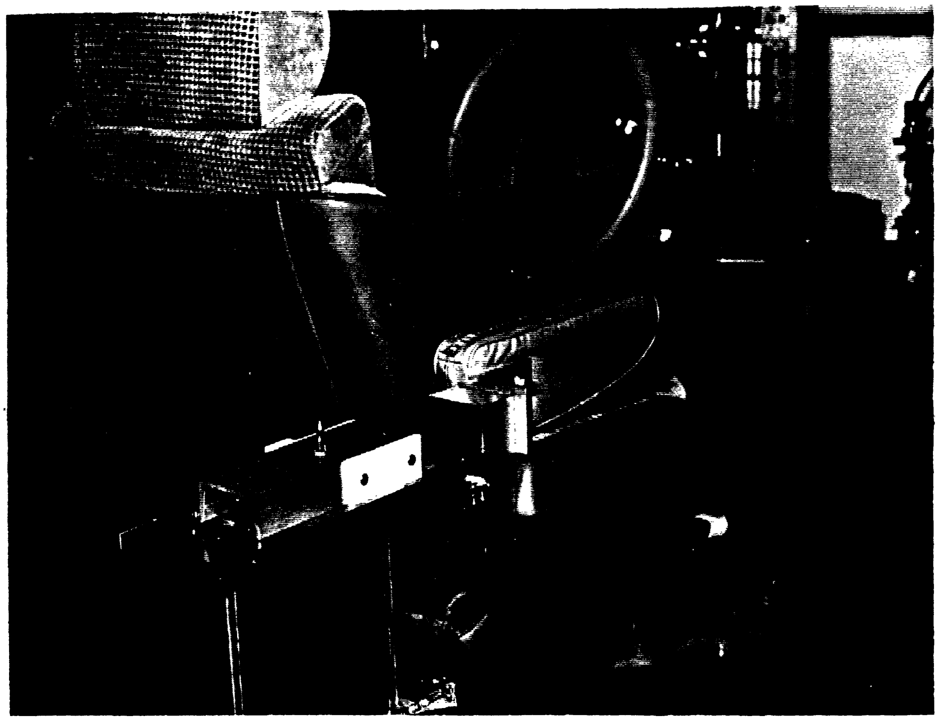


Figure 18. S-body seat armrest unit in place on center armrest support structure.

interpreted for population percentile information, but data obtained for subjects at the population extremes (i.e., small and large persons) would be highly sensitive to the one or two subjects chosen to represent these segments of the population. In addition, the first sampling strategy does not allow for the effects of variability in body proportions for a given stature (i.e., long torso, short legs versus long legs, short torso) or for variability in preferred positions due to non-anthropometric factors (e.g., driving habit, type of vehicle).

In contrast, the second sampling strategy uses equal numbers of subjects for all stature segments of the population and thereby provides data on measurement variability within specific stature groups. Population percentile values can still be determined by weighting the data from subjects in different groups. For these reasons, the second approach was chosen for this study.

Ten subject groups were defined around the 10th, 25th, 50th, 75th, and 90th percentile values of stature for males and females based on the 1971-74 Health and Nutrition Examination Survey or HANES data (Abraham et al., 1979). In each group, ten subjects were recruited for a total sample size of 100. Table 3 shows selected percentile values of stature for U.S. population males and females, while Table 4 shows the stature ranges for the subject groups defined in this study. For example, for the 10th percentile female group, the stature ranged from the 5th to the 15th percentile with corresponding stature values of 151.1 cm (59.5 in.) and 154.9 cm (61.0 in.). As indicated, values for the 15th, 40th, 60th, and 85th stature percentiles were not directly available from HANES reports and were therefore estimated using the mean values and standard deviations of population stature data for males and females, along with the assumption that stature values are normally distributed for the male and female segments of the population.

Within each group, subject weight and age were allowed to vary over a "normal" range. An attempt was made to obtain subjects over the full age range from 18 to 74 years

Table 3.
Percentile Values for Stature for U.S. Males and Females

Percentile	Males in.	Males cm.	Females in.	Females cm.
5	64.4	163.6	59.5	151.1
10	65.5	166.4	60.5	152.4
* 15	66.1	167.9	61.0	154.9
25	67.1	170.4	62.0	157.5
* 40	68.3	173.5	63.0	160.0
50	69.0	175.3	63.7	161.8
* 60	69.7	177.0	64.2	163.1
75	70.8	179.8	65.3	165.9
* 85	71.9	182.6	66.2	168.1
90	72.6	184.4	66.8	169.7
95	73.6	186.9	67.8	172.2
Mean	69.0	175.3	63.6	161.5
S.D.	2.8	7.1	2.5	6.4

* percentile calculated from mean and standard deviation using normal distribution table.

e.g. 60th%ile = x + .2533*(s.d.)
85th%ile = x + 1.036*(s.d.)

Table 4.
Subject Group Definitions by Stature

Gp #	Name	Mean %ile	%ile RANGE	Stature Range (in.)	Mean Stature (in.)
FEMALES					
1	Short	10th	5 - 15	59.5-61.0	60.25
2	Medium-Short	25th	15 - 40	61.0-62.8	61.90
3	Medium	50th	40 - 60	62.8-64.5	63.65
4	Medium-Tall	75th	60 - 85	64.5-66.2	65.35
5	Tall	90th	85 - 95	66.2-67.8	67.00
MALES					
6	Short	10th	5 - 15	64.4-66.1	65.25
7	Medium-Short	25th	15 - 40	66.1-68.0	66.90
8	Medium	50th	40 - 60	68.0-69.9	68.95
9	Medium-Tall	75th	60 - 85	69.9-71.9	70.90
10	Tall	90th	85 - 95	71.9-73.6	72.75

and not to use extremely obese individuals. Subjects were also required to have recent experience driving a 4- or 5-speed manual transmission vehicle.

While the seating buck was being designed and constructed, subjects were recruited through advertisements in local newspapers and postings in public places. In addition, subjects who had been involved in previous studies at UMTRI were contacted for participation. Those persons who responded to the advertisements were screened in a phone interview for basic qualifications and informed of the purpose of the study. Interested volunteers were then scheduled for a brief measurement session during which their stature was verified and a standard health questionnaire and subject consent form were filled out.

If a potential subject met the study criteria and qualified for one of the stature/gender groups for which subjects were needed, additional anthropometric measurements were taken to obtain a more complete physical description of the subject and to obtain body size measurements that might correlate with preferred seat and armrest locations. Table 5 shows a list of these measurements. The subject was then informed that he/she would be contacted by phone to schedule a time for testing in the seating buck.

C. MEASUREMENT PROCEDURES AND PROTOCOL

1. Pretest Preparation

Upon completion of the seating buck and the IBM XT interface hardware, recruited subjects were scheduled for a test session. Table 6 summarizes the steps involved in preparing for and testing each subject. Volunteers were scheduled approximately one week in advance and were told that a questionnaire (see Appendix H) regarding how and when they used armrests in their own vehicle would be sent to them by mail. Because of a concern that drivers may not be consciously aware of their use of armrests, subjects were instructed to read the questionnaire when it arrived and to consider the questions and issues

Table 5.
List of Anthropometric Measurements
(without shoes/with clothes)

1. Stature
2. Stature (with shoes)
3. Sitting Height
4. Eye Height (sitting)
5. Shoulder Height (sitting)
6. Knee Height (sitting)
7. Shoulder Breadth
8. Shoulder-Elbow Length
9. Elbow-Hand Length
10. Maximum Arm Reach
11. Grasping Arm Reach
12. Hip Breadth
13. Buttock-Knee Length

Table 6.
Summary of Armrest Study Test Protocol

Prior to Subject Arrival

1. Run "ARMNEW" program. Determine initial vehicle seating package. Enter anthropometric data.

2. Configure buck to represent desired seating package.

After Subject Arrival

3. Explain purpose of tests, familiarize subject with facility, and collect armrest questionnaire.

4. Collect PREFERRED SEAT TRACK and BACK ANGLE data.

5. Move door structure into correct lateral position.

6. Collect PREFERRED ARMREST LOCATION data.

7. Collect PREFERRED ELBOW AND FINGER POSITION data.

8. Collect left ELBOW front/back ACCEPTABLE RANGE data.

9. Collect ARMREST HEIGHT ACCEPTABLE RANGE data.

10. Take right-side PHOTOGRAPH of subject in relaxed driving posture with hand on steering wheel and elbows on armrests located at preferred positions.

11. Collect SEATED ANTHROPOMETRIC measurements.

12. Instruct subject to leave buck while components are repositioned for next vehicle package.

13. Repeat steps 4 through 12 for two more seating packages.

it raised as they drove their vehicle over the next few days. They were then to write down their responses and bring the completed questionnaire to their test session. This not only helped to get more accurate and meaningful information in the armrest survey, but it made the subjects more conscious of their use of armrests prior to their test session.

Before a subject arrived, the anthropometric measurements taken in a previous session were entered into the computer and saved in a file on the XT hard disk. The seating buck was manually configured to one of the three package designs (G-, H-, or S-Body) that was randomly selected by the computer. Upon arrival, the subject was reinformed that the goal of the study was to obtain information about preferred locations of door and console armrests in three types of passenger cars. The basic features and operation of the seating buck were explained and the subject was instructed that he should verbalize any thoughts and impressions experienced during the testing process. These comments were hand recorded by the investigator during testing and subsequently added to the subject's data file.

Prior to instructing the subject to sit in the seat, the buck was configured by computer-generated commands to the desired initial conditions. The steering wheel, pedals, and shift knob were positioned at the design locations and orientations while the console armrest was moved back and to the lowest possible height and the door armrest was also placed at a minimum height. The seat was manually positioned at a detent toward the back of the travel range (detent 16 or greater) so that it was further back than the subject would prefer and the seat-back angle was set to the most upright position corresponding to a scale reading of 20 degrees. During the SAE J826 H-point calibration, the design seat-back angles were determined to be inclined back from this position. Therefore, scale readings were subsequently converted to "back-angle-re-H-point" values according to the H-point calibrations for the different vehicles.

2. <u>Preferred Armrest Locations</u>

With the buck set to the above conditions, the subject was instructed to step onto the platform and to sit in the vehicle seat. The slide projector was turned on to project a road scene on the screen and the subject was instructed to adjust the seat fore/aft position and seat-back angle to positions that he judged to be most comfortable for driving. Subjects were encouraged to search for their preferred seat locations and to try several detent and back-angle positions before making a decision. When a subject had selected his/her preferred seat conditions, the detent number and back angle were read from the scales attached to the side of the seat and entered into the computer via the keyboard. The door structure was then moved into the lateral position for the vehicle body style being represented.

At this time the subject was instructed to place his hands on the steering wheel in the way he would normally drive. Recognizing that drivers may use different hand positions at different times and under different driving conditions, the subjects were encouraged to select hand positions for the kind of driving in which they would be most likely to use the vehicle armrests (generally highway driving). They were then given the hand control module and instructed to dial in and adjust the door armrest height, the console armrest height, and the console fore/aft position to locations that were most comfortable for their use. Figure 19 shows the investigator in the seating buck operating the hand-control module. The subjects were encouraged to search for a position, to simulate vehicle steering, and to alternately adjust the three armrest position variables since they might be interrelated (e.g., preferred door armrest height may be influenced by preferred console armrest height). For the G- and H-body vehicle mockups, the subject was also instructed to consider operation of the shift knob when adjusting the console armrest. When the subject was satisfied with the locations, the investigator key-stroked the computer to record the A/D values corresponding

Figure 19. Investigator using hand control module.

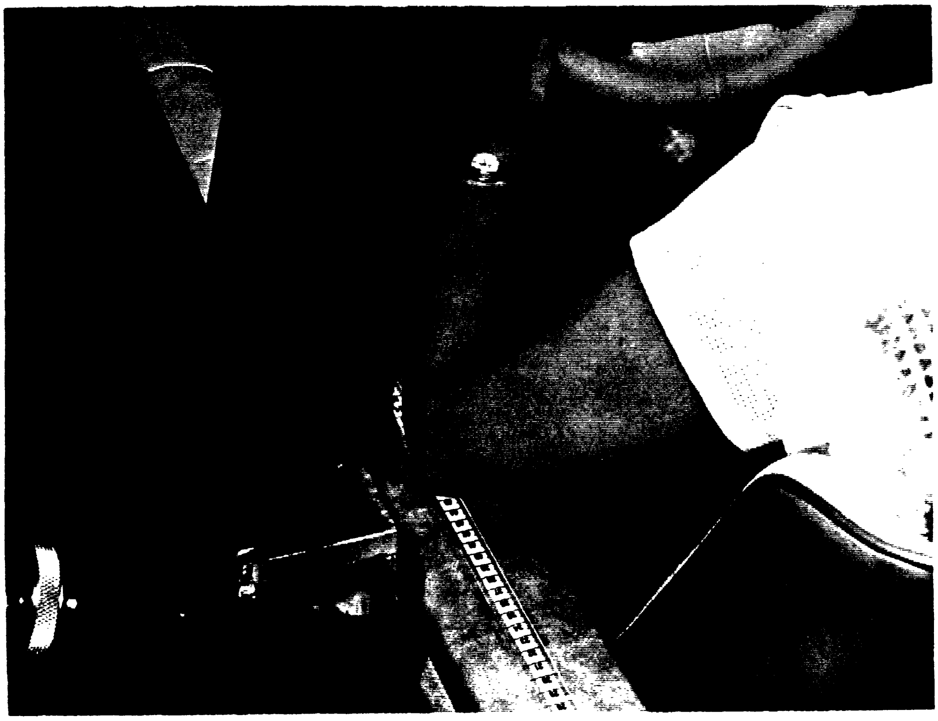


Figure 20. Measurement of subject back-of-elbow position.

to potentiometer voltage readings of the armrest positions.

Upon completion of the preferred armrest locations, the hand-held control module was taken from the subject and he/she was instructed to position his/her elbows on the armrests in the most comfortable front/back locations on the two armrests. The preferred fore/aft back-of-elbow locations were then read from tape measures attached to the armrests as illustrated in Figure 20 and were typed into the computer. The subject was then instructed to keep his/her left elbow in this preferred position and to pinch a sliding metal bracket near the front of the door armrest between the thumb and fingers. The location of this bracket was read from the tape as a measure of the preferred location for finger-tip controls as illustrated in Figure 21.

3. Acceptable Limits of Armrest Locations

In addition to information on preferred heights and front/back locations of the armrests, it was desired to determine locations that describe each person's acceptable range. That is, we wanted to determine armrest heights that would be usable even though they may not be optimal, and elbow locations that defined the maximum required armrest length.

Acceptable height ranges for the armrests were determined with the investigator controlling armrest height from the computer keyboard. The subject was instructed to keep his elbows on the armrests while they were moved. Beginning with the door armrest in the subject's preferred position, the armrest was moved up until the subject indicated that it was definitely out of a usable range. The armrest was then moved down in increments of approximately 5 mm until the subject indicated that the height was usable (i.e. acceptable). The computer automatically recorded the A/D value for this position and calculated the corresponding vehicle coordinate value. The armrest was then returned to the subject's preferred position from which it was brought down to search for a lower limit in a similar

Figure 21. Measurement of subject finger grip position.

manner. The same procedure was repeated for the console armrest. While performing these tests for acceptable armrest heights, subjects were allowed to move their hands to different positions on the steering wheel to accommodate the position of the armrest.

Rearward and forward acceptable limits for the left (i.e., door-side) elbow position were measured to obtain information that would define a maximum length for the door armrest and its location in vehicle coordinates. With the left elbow in the preferred front/back location, each subject was instructed to move his elbow back as far as he could reasonably place it, while still being comfortable. This position was read from the tape measure and entered into the computer. The subject was then instructed to slide his elbow as far forward as he could reasonably rest his elbow and again the back-of-elbow location was read and entered into the computer.

4. <u>Additional Measurements</u>

After the limits of the acceptable ranges had been determined, a right-side photograph of the subject in a relaxed driving posture was taken to provide a qualitative record of the subject with preferred armrest locations. Finally, three anthropometric measurements were taken while the subject was in the vehicle seat. With the subject in a relaxed driving posture with both hands on the steering wheel and eyes looking straight ahead, seated height, top-of-shoulder height, and top-of-shoulder front/back location were measured and entered into the computer. When these were completed (approximately 20 minutes into testing), the subject was instructed to step out of the buck for a short rest while manual and computer-controlled adjustments to the buck were made in order to configure it to the next vehicle body-style. At the end of the test session, subjects were informed that they would be contacted at a future date for testing in the second phase of the study (i.e., the study of primary control positions).

D. DATA PROCESSING AND ANALYSIS

All component and subject position data collected by A/D conversion or manually entered into the computer were converted to vehicle coordinates and stored in a file on diskette. Four seperate files were used to save the data for each subject -- one for the anthropometric data, and one each for data from of the G-, H-, and S-body vehicles. The data for all subjects were later combined into one file on the Michigan Terminal System (MTS) with the data for each subject occupying one line or record. A statisical analysis package called MIDAS was used along with other computer programs to display and interpret the results.

A first step in the analysis of the data was to "clean" or edit the data of "outliers." This was accomplished by visual examination of histograms and scatter plots generated for each measurement or set of two related variables. Identified outliers or questionable data points were traced back to the subject's file and decisions as to the validity of these data points were made. In some cases the correct value could be determined, such as when an error in the entry of an anthropometric measurement value was found. In others, it was necessary to delete the data point. Data for two of the 100 subjects were entirely deleted from the test sample. A subject from Group 4 was deleted because she had several "bad" data points, and one from Group 9 was deleted after it was learned that he was required by his physician to position his legs in an unnatural way while driving.

When the data set was judged to be "clean", further analysis and interpretation was begun. New variables were created from the baseline variables for which data had been collected. For example, a variable for the range of door armrest heights was created by subtracting the variable for the lower armrest height limit from that of the upper armrest height limit. Results were displayed in graphical and tabular form by individual subject and by subject group (i.e., means and standard deviations) to examine for relationships within groups, between groups, and between preferred component locations and other subject and vehicle parameters. Where relationships could be visually observed, linear regressions were computed for the variables involved and scatter plots were generated.

The armrest and elbow preferred-location and acceptable-range data for the individual subjects were used to determine optimal armrest heights and required armrest lengths for each of the vehicles. Assuming that in a production vehicle the armrest will be located at a fixed height, and that there is no relationship between preferred armrest height and preferred elbow front/back locations (which was found to be the case in this study), the optimal armrest height was defined as the Z-coordinate that would accommodate the largest percent of the population. This location, which is based on the acceptable-range data, would also hopefully maximize the number of persons whose preferred armrest height would be accomodated.

For the front-to-back locations and lengths of the armrests, the minimum and maximum values of back-of-elbow preferred locations and acceptable limits (left side only) for the total population of subjects were simply used to define minimum (using preferred elbow position) and maximum (using acceptable limits) armrest lengths, respectively, and their corresponding locations in vehicle coordinates.

Figure 22 shows the manner in which the acceptable-range data were used to determine the coordinate value that minimized the number of persons in the population that would not accept a particular armrest height. A computer program was written to count the number of subjects whose acceptable range for a particular measurement variable spanned discrete coordinate values along the axis of interest. The program begins with a coordinate value that is less than the lowest acceptable limit for all subjects and examines the subject data at ten-millimeter increments until a coordinate value greater than the maximum acceptable limit is examined. Since the distribution of stature in the subject population is

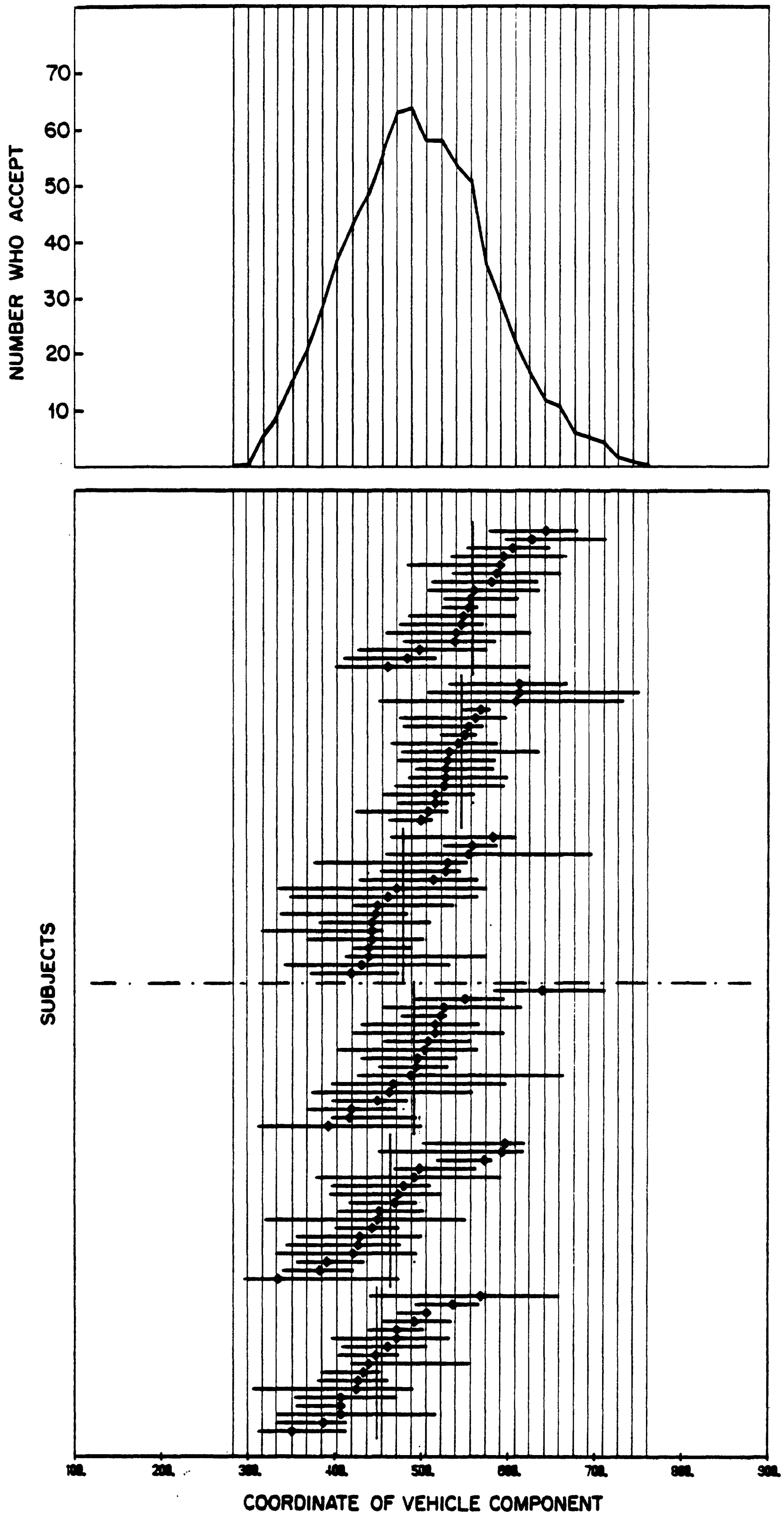


Figure 22. Procedure for counting the number of subjects who would accept a vehicle component at discrete coordinates.

Table 7.
Weighting Factors Used to Describe Results for the U.S. Adult Population with Subject Population Data

Group #	Sample Size	% of U.S. Represented	Weighting Factor
1	10	7.5	.75
2	10	12.5	1.25
3	10	10.0	1.00
4	9	12.5	1.38
5	10	7.5	.75
6	10	7.5	.75
7	10	12.5	1.25
8	10	10.0	1.00
9	9	12.5	1.38
10	10	7.5	.75

not representative of the distribution of stature in the U.S. population (i.e., the driver population), different weighting factors were applied to the "count" in each subject group. Table 7 shows the weighting factors used.

As an example, subjects in group 1 were considered to represent 15 percent of the U.S. female population (i.e., 0 to 15th percentile in stature) or 7.5 percent of the U.S. adult population (assuming equal numbers of males and females). Subjects in group 2, on the other hand, were considered to represent 12.5 percent of the U.S. population. Since each of these groups contain ten subjects, the count from each subject in group 1 was given a weighting factor of .75 = 7.5/10 (i.e., each subject represents .75 percentile) and the count from each subject in group 2 was given a weighting factor of 1.25 = 12.5/10 (each subject represents 1.25 percentile of the U.S. population).

After counting the number of subjects whose acceptable range spanned the coordinate value, and weighting and summing these counts, the totals were converted to describe the percent of the driving population who would not accept the control or component at each coordinate location. These "percent-not-acceptable" values were then plotted versus the appropriate coordinate axis as shown by the solid line of Figure 23.

In addition to using the acceptable-range data to determine the component location with greatest acceptance (i.e., minimum percent not acceptable), the computer program also counted the number of subjects whose preferred location fell inside a one-inch-wide window as it moved along the coordinate axis in increments of ten millimeters. These data were also weighted and converted as described above to obtain the percent of the population who would not prefer the component at the location defined by the center of the one-inch window plus and minus 1/2 inch. These results were plotted along with the "percent-not-acceptable" curve as illustrated by the dashed line in Figure 23.

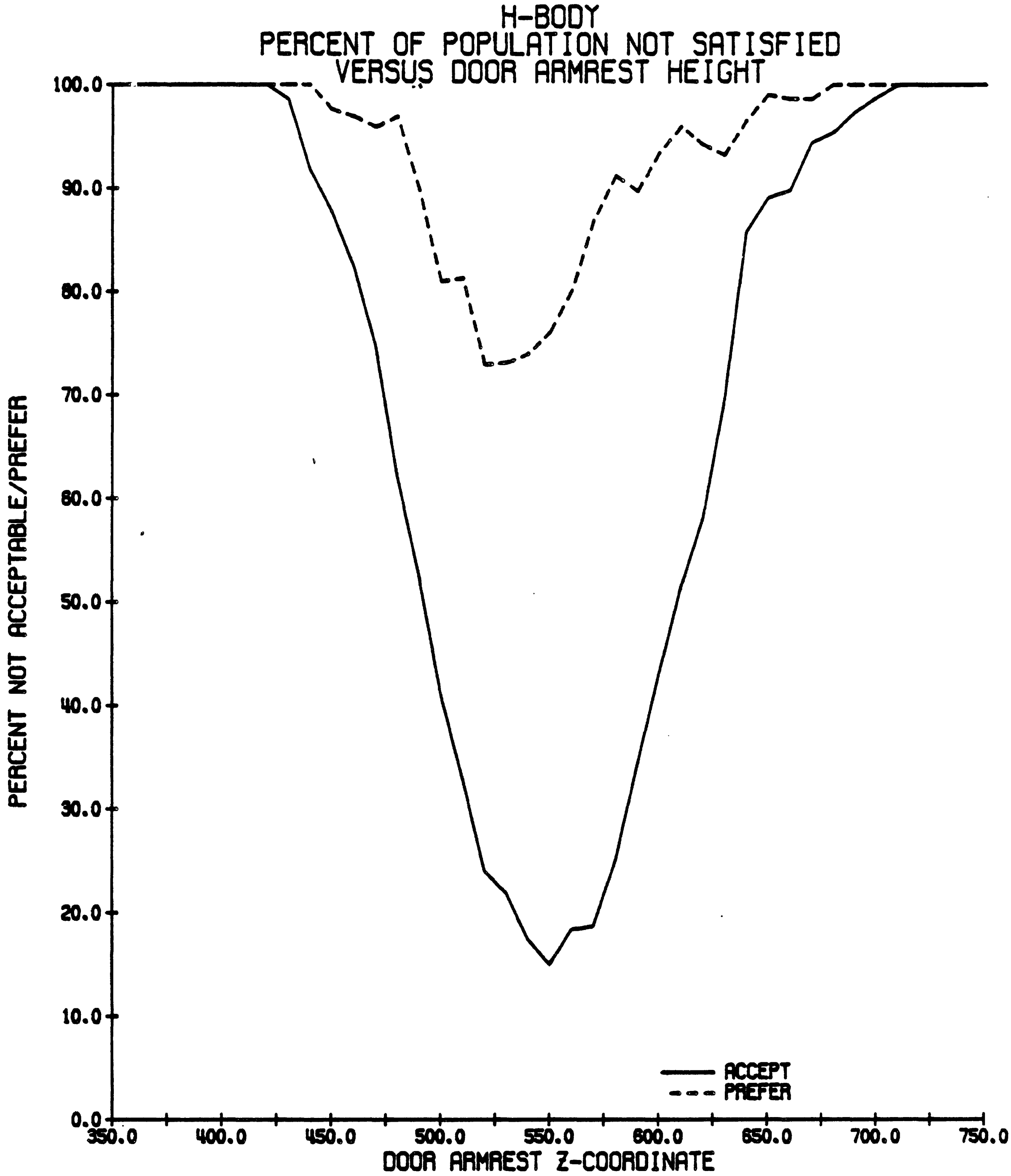


Figure 23. Percent of population who would not accept (solid line) and percent of population who would not prefer (dashed line) door armrest height at specific vehicle coordinates of G-body vehicle.

III. RESULTS

It isn't possible within the time frame and scope of the present study to perform all the data analyses or investigate all the relationships between dependent and independent variables that one might eventually want to examine. The following sections summarize some the anthropometric and test results, examine these results for obvious trends and relationships, and interpret the armrest position information with regard to improved armrest locations and vehicle factors that seem to have a primary influence on armrest location. Further analyses of the raw data can be performed as needed with regard to specific questions and problems that may arise.

The descriptions of the results that follow have been divided into several subsections. Subsection A briefly describes the anthropometric characteristics of the ten subject groups, subsection B presents the results of preferred seat locations and seat-back angles for the three seating configurations, and subsection C presents the seated anthropometry results. Subsection D describes the results for preferred and acceptable locations of armrests, subsection E presents the interpretation of these armrest position results in terms of optimal and required armrest locations in the vehicles, and, in subsection F, some additional relationships between optimal armrest height and locations of vehicle components and package dimensions are given. Subsection G briefly describes the results of a repeatability mini-study in which four subjects were retested for preferred armrest locations. Finally, subsections H and I summarize the survey questionnaire results and subject comments made during testing.

Because of the large number of graphs and plots used to present and describe the study results, these have been placed, for the most part, in the appendices at the end of the report with appropriate references in the text that follows. In addition, Appendix B contains the qualitative side-view photographs of each subject in each seating package with the armrests positioned at the subject's preferred locations.

A. SUBJECT ANTHROPOMETRY AND AGE

Table C-1 in Appendix C summarizes the mean values of the standard anthropometric measurements and age for the ten subject groups, while Figures C-1 through C-5 illustrate and compare the frequency distributions of stature, weight, sitting height, buttock knee length, and age for the different groups. It will be noted that, while the subject statures in each group occupy (by definition) distinct and separate ranges for males or females, the other anthropometric measures show considerable overlap among groups. In other words, for persons of the same stature, the distributions of body dimensions have considerable variation that result in overlapping of these measurements among stature groups. It will also be noted that female groups 4 and 5 correspond closely by height to male groups 6 and 7.

B. PREFERRED SEAT POSITIONS AND SEAT BACK ANGLES

Table D-1 summarizes the preferred-seat-position results for the ten subject groups in the three vehicle seating packages. Results are expressed both in terms of seat detent on the extended seat track and in terms of the vehicle X-coordinate location of the translated design H-point. The first three plots in Appendix D show the distributions of selected seat positions of all subjects in the ten subject groups, where the data for each subject are plotted at a different vertical level and where the groups have been ordered from small females (group 1) at the bottom and tall males (group 10) at the top of each chart. Within each group, the seat position data have been ordered from the most forward seat position (i.e., lowest detent) at the bottom to the most rearward seat position at the top. A short vertical line within the boundaries of each group indicates the group mean seat position and arrows along the bottom scale indicate the first, last, and design detent positions in the actual vehicles.

From these results, the expected relationship between preferred seat position and driver stature, whereby taller drivers tend to sit further rearward, is clearly evident in each vehicle. However, while there is a relationship between stature and preferred seat position in each case, there is also considerable overlap in the distributions of selected seat positions for the different groups to the extent that some short females (group 1) selected the same seat position as some tall females (group 5) and some short males (group 6) selected the same seat position as some tall males (group 10). The ranges of preferred seat positions within the different groups are shown in Table D-1.

It is also noted from the figures in Appendix D that, in each seat configuration, only one subject (a small female) chose to sit further forward than would be allowed by the seat track in the production vehicle. Inspection of the individual subject data revealed that this was the same subject in each case -- a subject who was not the shortest by either stature or leg length. For the G-body, no subjects selected a seat position further rearward than would be allowed in the production vehicle, but in the H- and S-body setups, six and four subjects in the mid and tall male groups, respectively, chose to sit further back than the production seat track would allow.

The last three figures in Appendix D show scatter plots of preferred seat position (measured by the x-coordinate of the translated vehicle H-point) versus stature for the three vehicle seats, and show the least-squares linear regressions for the relationships. Figure 24 compares the group mean preferred seat positions relative to vehicle accelerator heel point (AHP) for the three vehicles. As expected, the horizontal distance between preferred seat position and AHP is inversely related to the vertical distance from AHP to H-point.

Table D-2 presents the group statistics for preferred seat-back angle for the three vehicles, where the angles given are in terms of the angles measured during in the H-point calibrations. As indicated, there is no relationship between the mean preferred angle and group mean stature for any seating package, and there are relatively small differences between the mean seat-back angles of all subjects for the three vehicles. As expected, the overall mean seat-back angle for the G-body vehicle is the largest, but the observation that the mean seat-back angle for the S-body vehicle is larger than for the H-body vehicle is unexpected.

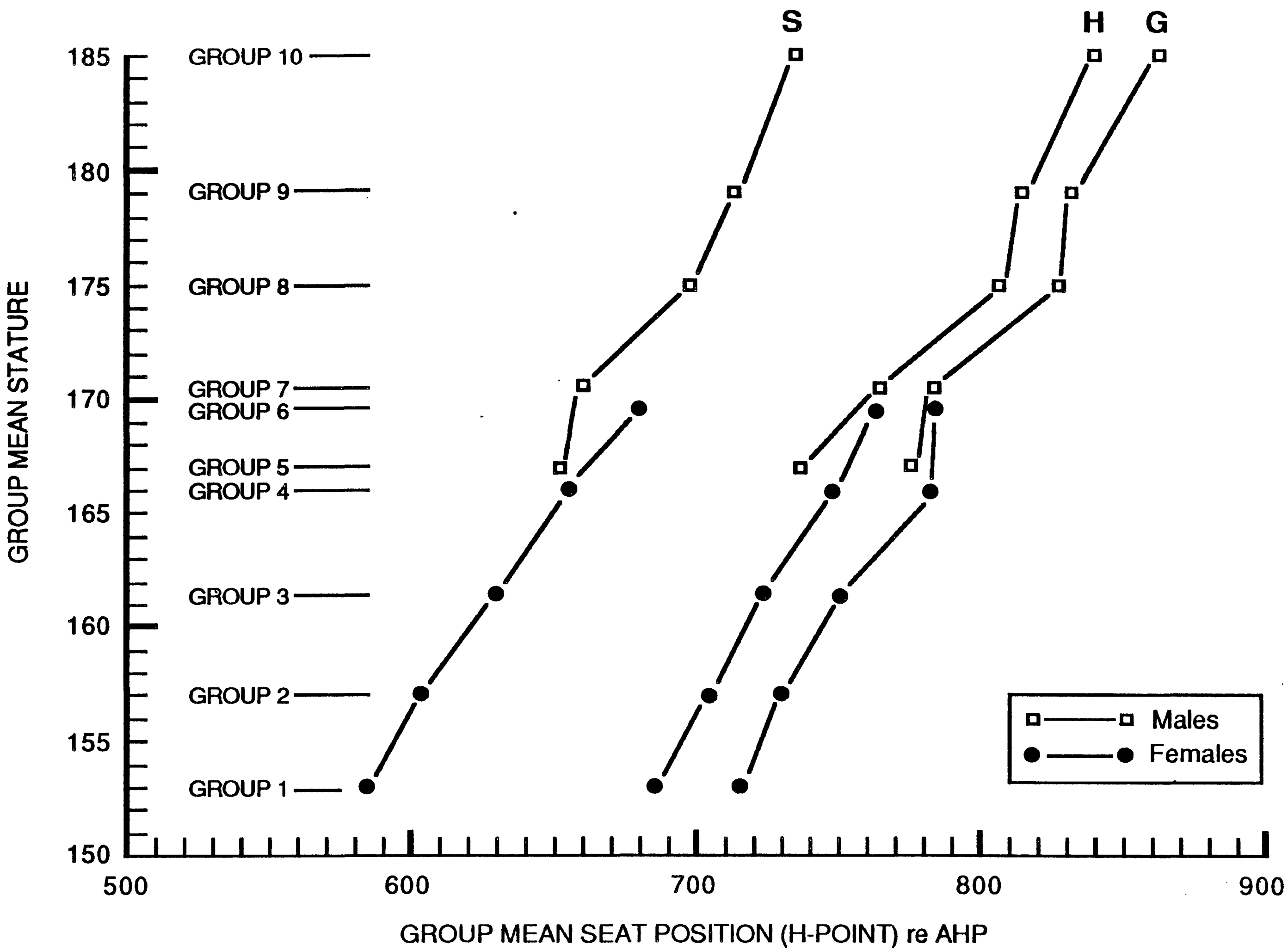


Figure 24. Comparison of Group Mean Preferred Seat positions re AHP for G-, H-, and S-body vehicles.

C. SEATED MEASUREMENTS

Table 8 gives the group-mean values, standard deviations, and sample sizes for top-of-head Z-coordinate, top-of-shoulder X-coordinate, and top-of-shoulder Z-coordinate while Figure 25 presents these results graphically. All values are given in terms of vehicle coordinates. As expected, heights tend to increase and the position of the shoulder tends to move rearward with increasing stature.

Tables 9 and 10 present the mean-coordinate values in terms of distances from the AHP and the design H-point for each each vehicle type. As expected from differences in seat heights, the top-of-head and top-of-shoulder distances from AHP are the largest for the S-body and the smallest for the G-body. Conversely, the horizontal distances of the shoulder from AHP are the largest for the G-body and the smallest for the S-body. In Table 10, where the distances are given relative to the Seating Reference Point (SgRP), it is seen that the height values are very similar for all vehicles. The horizontal distances of the shoulder from SgRP are quite similar for the G- and H-body vehicles but are somewhat greater for the S-body vehicle, perhaps indicating that the design H-point in this vehicle does not represent the same percentile seating position as it does in the G- and H-body vehicles.

Figures 26 and 27 compare the left and right hand positions on the steering wheel used by subjects during the testing for preferred armrest positions, while Table 11 gives the mean hand positions by subject group and for all subjects. As expected, most of the left hand positions are between 7 and 9 o'clock and most of the right hand positions are between 3 and 5 o'clock on the steering wheel with the overall mean hand positions being at about 4 and 9 o'clock for the right and left hands, respectively.

Table 8
Seated Anthropometric Measurements in Vehicle Coordinates (mm)

Group	N	Top-of-Head Z-Coordinate mean	(s.d.)	Top-of-Shoulder X-Coordinate mean	(s.d.)	Top-of-Shoulder Z-Coordinate mean	(s.d.)
G-BODY:							
1	10	978	(24)	1415	(35)	732	(20)
2	10	1003	(19)	1442	(30)	732	(26)
3	10	1019	(27)	1451	(22)	749	(24)
4	9	1006	(27)	1498	(26)	745	(26)
5	10	1034	(23)	1501	(34)	756	(18)
6	10	1039	(27)	1478	(54)	758	(30)
7	10	1048	(20)	1484	(43)	764	(14)
8	10	1034	(36)	1572	(62)	759	(28)
9	9	1071	(35)	1552	(31)	778	(29)
10	10	1078	(37)	1590	(46)	777	(32)
H-BODY:							
1	10	1030	(20)	1407	(37)	763	(22)
2	10	1033	(20)	1427	(48)	762	(29)
3	10	1053	(30)	1436	(29)	784	(26)
4	9	1048	(37)	1478	(26)	781	(30)
5	10	1068	(18)	1508	(44)	786	(16)
6	10	1072	(24)	1459	(38)	790	(27)
7	10	1083	(22)	1469	(41)	801	(12)
8	10	1072	(36)	1559	(43)	791	(26)
9	9	1109	(29)	1538	(40)	813	(26)
10	10	1115	(36)	1586	(45)	814	(33)
S-BODY:							
1	10	1244	(27)	1375	(41)	976	(24)
2	10	1252	(17)	1393	(33)	979	(27)
3	10	1265	(29	1413	(32)	997	(27)
4	9	1267	(29)	1447	(26)	999	(24)
5	10	1283	(20)	1481	(54)	1002	(20)
6	10	1284	(19)	1450	(42)	1000	(28)
7	10	1294	(19)	1441	(31)	1009	(11)
8	10	1298	(32)	1515	(38)	1016	(23)
9	9	1322	(25)	1508	(38)	1015	(42)
10	10	1325	(29)	1551	(54)	1023	(30)

Table 9
Seated Anthropometric Measurements
relative to AHP

Group #	Top-of-Head Z-Distance			Top-of-Shoulder X-Distance			Top-of-Shoulder Z-Distance		
	G	H	S	G	H	S	G	H	S
1	923	975	1045	865	830	739	677	708	777
2	948	978	1053	892	850	757	677	707	780
3	964	998	1066	901	859	777	694	729	798
4	951	993	1068	948	901	811	690	726	800
5	979	1013	1084	951	931	845	701	731	803
6	984	1017	1085	928	882	814	703	735	801
7	993	1028	1095	934	892	805	709	746	810
8	979	1017	1099	1022	982	879	704	736	817
9	1016	1054	1123	1002	961	872	723	758	816
10	1023	1060	1126	1040	1009	915	722	759	824

Table 10
Seated Anthropometric Measurements
relative to design H-point

Group #	Top-of-Head Z-Distance			Top-of-Shoulder X-Distance			Top-of-Shoulder Z-Distance		
	G	H	S	G	H	S	G	H	S
1	692	711	694	-15	2	41	446	444	426
2	717	714	702	12	22	59	446	443	429
3	733	734	715	21	31	79	463	465	447
4	720	729	717	68	73	113	459	462	449
5	748	749	733	71	103	147	470	467	452
6	753	753	734	48	54	116	472	471	450
7	762	764	744	54	64	107	478	482	459
8	748	753	748	142	154	181	473	472	466
9	785	790	772	122	133	174	492	494	465
10	792	796	775	160	181	217	491	495	473

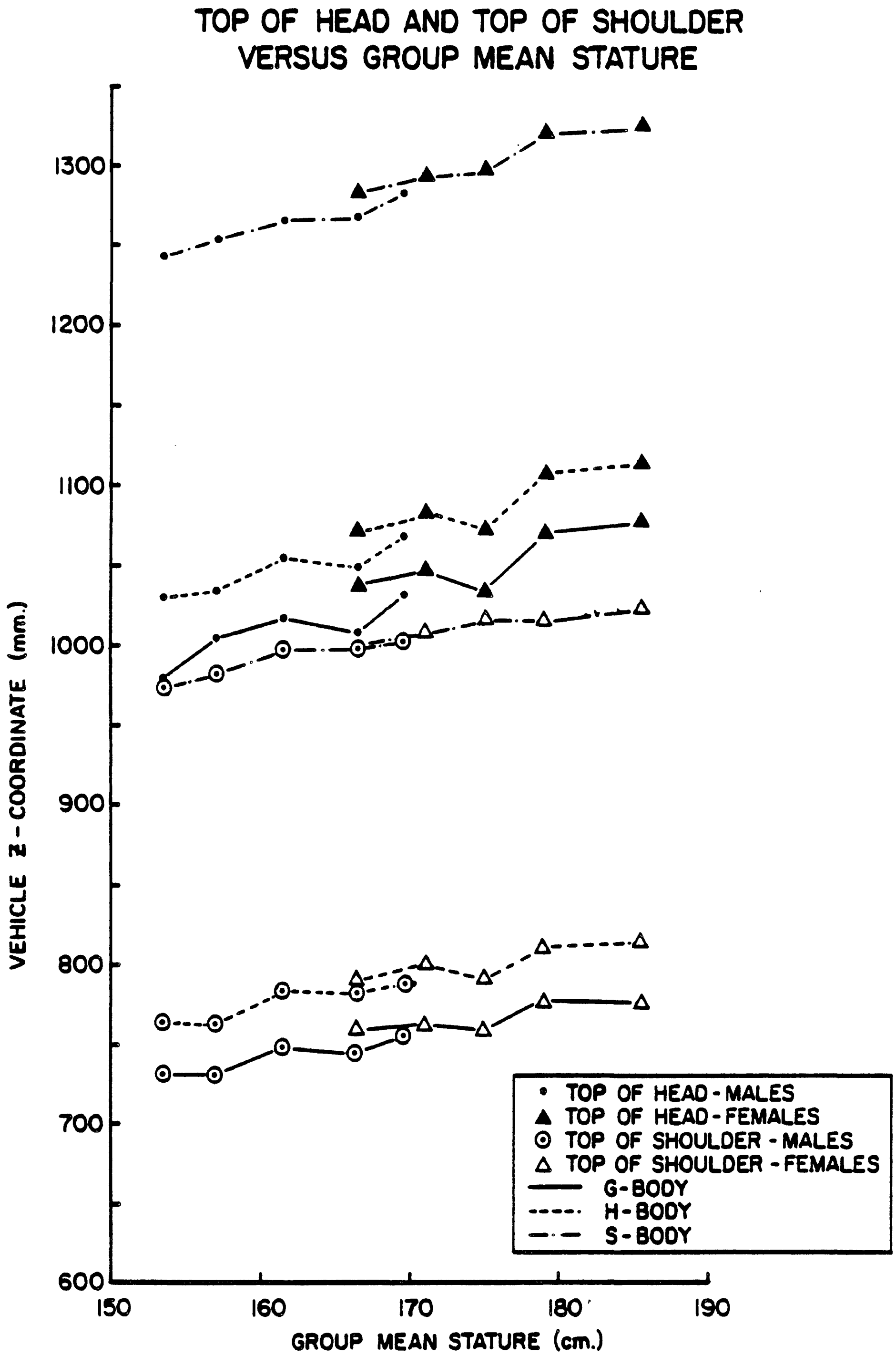


Figure 25. Top-of-head and top-of-shoulder coordinates versus group mean stature.

HAND POSITION ON WHEEL (O'CLOCK)

G-BODY

```
 1.0    0 +
 2.0    0 +
 3.0    0 +
 4.0    0 +
 5.0    0 +
 6.0    0 +
 7.0   12 +XXXXXXXXXXXX
 8.0   17 +XXXXXXXXXXXXXXXXX
 9.0   53 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.0   15 +XXXXXXXXXXXXXXX
11.0    1 +X
12.0    0 +
```

H-BODY

```
 1.0    0 +
 2.0    0 +
 3.0    0 +
 4.0    0 +
 5.0    0 +
 6.0    0 +
 7.0   14 +XXXXXXXXXXXXXX
 8.0   16 +XXXXXXXXXXXXXXXX
 9.0   47 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.0   21 +XXXXXXXXXXXXXXXXXXXXX
11.0    0 +
12.0    0 +
```

S-BODY

```
 1.0    0 +
 2.0    0 +
 3.0    0 +
 4.0    0 +
 5.0    0 +
 6.0    0 +
 7.0   19 +XXXXXXXXXXXXXXXXXXX
 8.0   21 +XXXXXXXXXXXXXXXXXXXXX
 9.0   52 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
10.0    6 +XXXXXX
11.0    0 +
12.0    0 +
```

Figure 26. Frequency histograms for left-hand positions on steering wheel.

HAND POSITIONS ON WHEEL (O'CLOCK)

G-BODY

```
 1.0    0 +
 2.0    5 +XXXXX
 3.0   39 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 4.0   31 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 5.0   21 +XXXXXXXXXXXXXXXXXXXXX
 6.0    0 +
 7.0    0 +
 8.0    0 +
 9.0    0 +
10.0    0 +
11.0    0 +
12.0    0 +
```

H-BODY

```
 1.0    1 +X
 2.0    7 +XXXXXXX
 3.0   32 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 4.0   28 +XXXXXXXXXXXXXXXXXXXXXXXXXXXX
 5.0   30 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 6.0    0 +
 7.0    0 +
 8.0    0 +
 9.0    0 +
10.0    0 +
11.0    0 +
12.0    0 +
```

S-BODY

```
 1.0    0 +
 2.0    3 +XXX
 3.0   32 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 4.0   25 +XXXXXXXXXXXXXXXXXXXXXXXXX
 5.0   35 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 6.0    0 +
 7.0    0 +
 8.0    0 +
 9.0    0 +
10.0    0 +
11.0    0 +
12.0    0 +
```

Figure 27. Frequency histograms for right-hand positions on steering wheel.

Table 11
Left and Right Hand Positions on Steering Wheel

		Mean Hand Position (o'clock)					
		G		H		S	
Group #	N	Left	Right	Left	Right	Left	Right
1	10	8.6	3.7	9.1	4.2	8.3	4.3
2	10	8.6	3.7	9.1	3.5	8.9	3.5
3	10	8.9	3.6	8.8	3.5	8.9	3.7
4	9	8.8	3.9	8.3	4.1	8.2	4.4
5	10	8.8	3.3	8.6	4.5	8.2	3.8
6	10	8.7	3.4	8.6	3.4	8.4	3.8
7	10	8.9	3.7	9.2	3.5	8.7	3.4
8	10	8.8	3.5	8.6	3.6	8.3	3.6
9	9	8.9	3.6	8.8	3.6	8.3	3.6
10	10	8.6	4.0	8.5	4.2	8.2	4.3
All Subjects	98	8.8	3.6	8.8	3.8	8.5	3.8

D. PREFERRED AND ACCEPTABLE ARMREST POSITIONS

The figures of Appendix E present the armrest-and elbow-position data for individual subjects for the three body styles. In each plot the data are grouped by subject group with the small females (group 1) at the bottom and the tall males (group 10) at the top. Within each group, the preferred locations (indicated by diamond symbols) have been ordered , with the data for each subject in the group occupying a different vertical level. If acceptable range data were collected for a particular variable, the range is indicated by a horizontal line through the diamond symbol. The mean-preferred position for each group is indicated by the short vertical line within the group boundaries.

Tables F-1 through F-3 of Appendix F summarize the armrest-and elbow-position results giving the mean and standard deviation for each measurement variable (preferred location and acceptable limit where applicable) by subject group. These group results are more clearly visualized in the figures of Appendix F which graphically display the results by subject group ordered vertically by the mean statures of the groups. In these plots, the group mean of the preferred locations are indicated by the "*" symbols. In some plots the means of preferred locations plus and minus one standard deviation are indicated by horizontal lines through these symbols. For those measurements where acceptable limit data were collected, such as door and console armrest height and left-elbow fore/aft position, an additional plot is included where the "*" symbols indicate the group means of the preferred locations and the horizontal lines indicate the group means of the acceptable limits.

From these results, the following general observations can be made:

1. There is no apparent or consistent relationship between preferred armrest height and subject stature for any of the vehicles. If any relationship exists at all, there may be a slight tendency for taller subjects to prefer a slightly higher console armrest.

2. There are relationships between preferred elbow position and stature for both the door armrest and the console armrest. Taller subjects tend to place their elbows further rearward than shorter subjects.

3. While there are relationships between elbow position and subject stature, there is also significant overlap between preferred elbow positions for subject groups of different stature. There is, in fact, overlap in the range of preferred elbow positions between subjects in the tallest group (group 10) and subjects in the shortest group (group 1) for two of the three vehicles.

4. While taller persons tend to position their elbows further rearward, the preferred locations of the finger grip demonstrate no relationships with subject stature.

5. The preferred locations for the front edge of the center console show no relationship with subject size.

E. OPTIMAL AND REQUIRED ARMREST POSITIONS

Using the procedures described previously, an attempt was made to determine optimal locations for door and center armrest heights, optimal locations for door finger tip switches, and required lengths and front/back positions of armrests. The figures in Appendix G show the plots of acceptable range (solid lines) and preferred location loss functions for the different armrest/elbow measurement variables for the three vehicles. In each case the horizontal scale gives the coordinate values in vehicle reference coordinates and the vertical scale is the percent of the U.S. population (i.e., weighted subject data) that would not accept or prefer the armrest or finger switch at that location (plus and minus 1/2 inch for preferred).

1. Armrest Heights

As noted in the previous section, there was no relationship between preferred armrest height and driver stature in any of the vehicles and therefore no indications that the armrest height should be changing with the front/back position of the armrest. Given this, one would like to find a single coordinate value for each armrest/vehicle situation that would satisfy all subjects (i.e., all of the population) and also maximize the number of persons who would have their preferred height accommodated. Upon inspection of the plots for armrest height in appendix G, it is seen that, in no case, were 100% of the subjects satisfied with a single armrest height. At best, approximately 85 % of the population can be satisfied, based upon the data from this study. However, given the subjective nature of the test results, it may very well be that one would in fact obtain an acceptable response from all subjects with the armrest located at or near those positions that minimize the number of subjects who would not accept.

In any case, using these plots of "percent of population who would not accept", the optimal armrest height was chosen to be the Z-coordinate value at which a minimum percent of the population would not accept. In some cases, the actual peak (i.e., minimum) of the curve is skewed or off-center from the general shape of the loss function curve. In these situations, this skewness was assumed to be due to small sample size rather that to be real, and the coordinate for minimum-percent loss was determined by taking the coordinate of midpoint of the loss-function curve at a wider part array from the peak where the curve is more symmetric.

In addition to these optimal positions, the acceptable-loss-function curves were used to determine those coordinate values that bracket regions of defined percentages of the population who would not accept the armrest within those height ranges. As illustrated in Figure 28, horizontal lines were constructed on the plots at 20%, 30%, 50%, and 70% who would not accept, and the intercepts of these lines with the acceptable-loss-function curve were determined as the limits of 80%, 70%, 50%, and 30% acceptability, respectively.

Tables 12 and 13 show the results of these analyses for the door and console armrest heights in each of the vehicles. Also included in these tables are the mean values of the preferred armrest height for all subjects. Table 14 compares the optimal armrest heights determined experimentally in this study with the actual armrest heights in the G-, H-, and S-body vehicles. In all but one case (S-body seat or center armrest), the vehicle armrest surface is considerably below the optimal armrest height.

It is also interesting to note from these results that the optimal door armrest height is significantly higher that the optimal center armrest height in all vehicles. Figure 29 shows frequency histograms of the height differences between door and center armrests for the three vehicles from which it is seen that, while a large number of subjects positioned the two armrests at approximately equal heights, a large number of subjects positioned the door armrest higher than the console armrest and almost no subjects positioned the console armrest higher than the door armrest. One possible explanation is that many subjects tended

Table 12
Results for Door Armrest Height
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	521	542	746
Maximum Acceptable	530	549	749
% Accept	85	85	90
Range for 80 % Acceptable	515-551	533-572	727-777
Range for 70 % Acceptable	485-564	513-585	719-782
Range for 50 % Acceptable	463-594	491-607	698-789
Range for 30 % Acceptable	439-623	474-629	684-817
Length of 80% Acceptable	36	39	50
Length of 70% Acceptable	79	72	63
Length of 50% Acceptable	131	116	91
Length of 30% Acceptable	184	156	133

Note: All dimensions in millimeters

Table 13
Results for Console Armrest Height
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	479	498	698
Maximum Acceptable	500	510	712
% Accept	82	85	80
Range for 80 % Acceptable	489-504	504-522	698-708
Range for 70 % Acceptable	466-519	486-543	686-734
Range for 50 % Acceptable	444-546	465-564	670-753
Range for 30 % Acceptable	424-559	444-579	651-775
Length of 80% Acceptable	15	18	10
Length of 70% Acceptable	53	57	48
Length of 50% Acceptable	102	99	83
Length of 30% Acceptable	135	135	124

Note: All dimensions in millimeters

Table 14
Optimal versus Actual Armrest Heights
(vehicle coordinates)

	DOOR			CONSOLE		
	OPTIMAL*	ACTUAL+	DIFF.	OPTIMAL*	ACTUAL+	DIFF.
G-Body	530	480	50	500	405	95
H-Body	549	507	42	510	477	33
S-Body	749	715	34	715	710	5

* Maximum acceptable
\+ At x-coordinate of design H-point

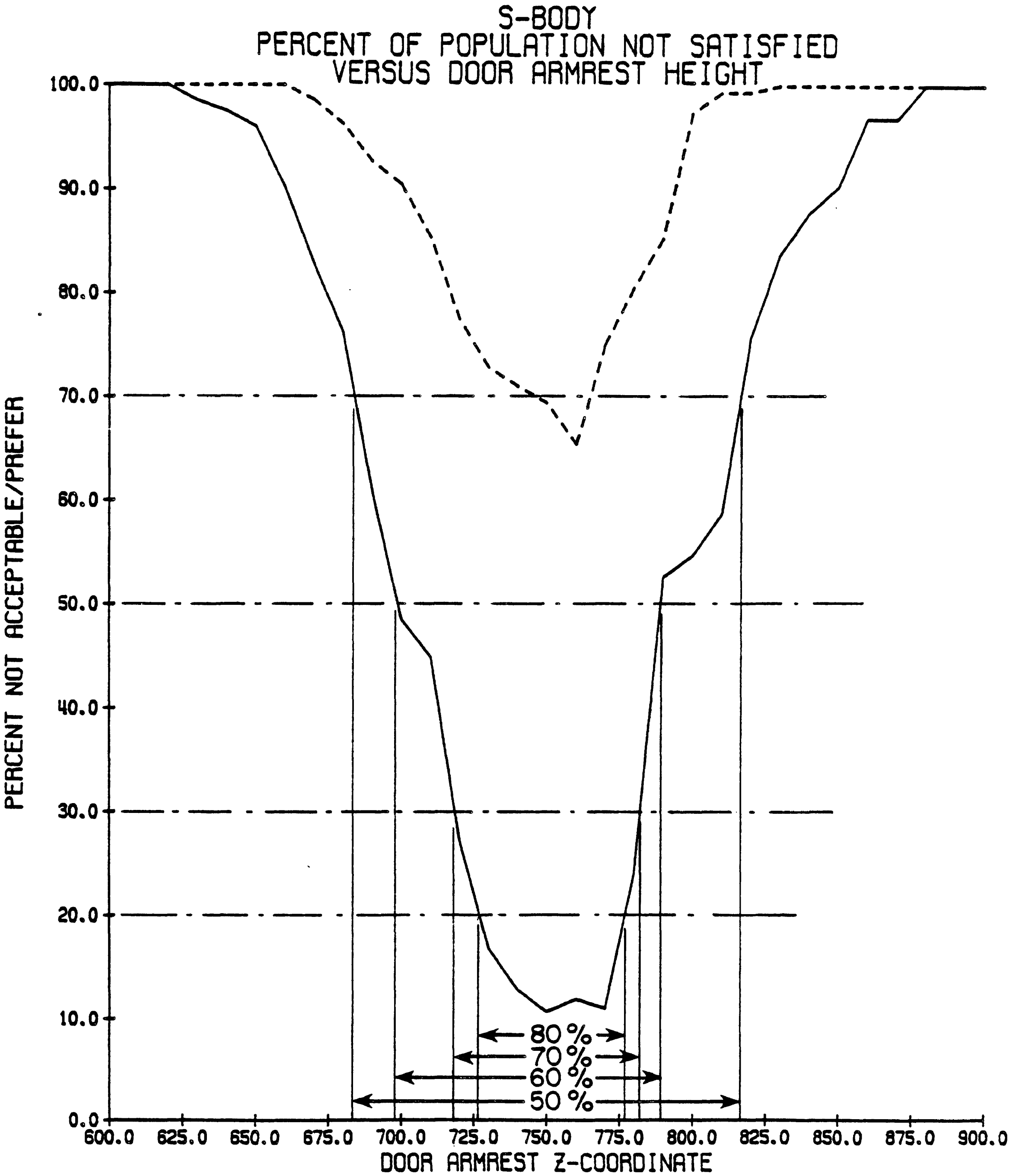


Figure 28. Determining percent acceptability ranges from loss function.

DIFFERENCE IN ARMREST HEIGHTS (mm.)

```
-150.    0 +
-125.    1 +X
-100.    0 +
 -75.    0 +
 -50.    2 +XX
 -25.    7 +XXXXXXX
   0.   21 +XXXXXXXXXXXXXXXXXXXXX
  25.   16 +XXXXXXXXXXXXXXXX              G-BODY
  50.   18 +XXXXXXXXXXXXXXXXXX
  75.   14 +XXXXXXXXXXXXXX
 100.    8 +XXXXXXXX
 125.    9 +XXXXXXXXX
 150.    1 +X
 175.    1 +X
 200.    0 +

-150.    0 +
-125.    0 +
-100.    0 +
 -75.    0 +
 -50.    3 +XXX
 -25.   10 +XXXXXXXXXX
   0.   24 +XXXXXXXXXXXXXXXXXXXXXXXX
  25.   22 +XXXXXXXXXXXXXXXXXXXXXX        H-BODY
  50.   11 +XXXXXXXXXXX
  75.   11 +XXXXXXXXXXX
 100.    8 +XXXXXXXX
 125.    6 +XXXXXX
 150.    2 +XX
 175.    1 +X
 200.    0 +

-150.    0 +
-125.    0 +
-100.    0 +
 -75.    0 +
 -50.    1 +X
 -25.   11 +XXXXXXXXXXX
   0.   23 +XXXXXXXXXXXXXXXXXXXXXXX
  25.   22 +XXXXXXXXXXXXXXXXXXXXXX        S-BODY
  50.   20 +XXXXXXXXXXXXXXXXXXXX
  75.    7 +XXXXXXX
 100.    3 +XXX
 125.    6 +XXXXXX
 150.    4 +XXXX
 175.    0 +
 200.    0 +
```

Figure 29. Frequency histograms for the difference between door and console armrest heights. Values plotted are door minus console differences.

to adjust the center armrest lower in order to operate the shift knob. However, for the S-body, the differences between left and right armrests were also observed even though subjects were instructed not to consider the shift knob when adjusting the seat armrest height since it was too low to be reasonably compatible with a useful armrest position.

2. Elbow Locations

Tables 15 and 16 summarize the results for front/back elbow locations which define the required X-coordinates of armrests. For the left elbow, both preferred and "potentially-usable" location data were obtained by having each subject slide his/her elbow forward and backward from the preferred location. For the right elbow, preferred locations only were measured. Since it is not required to position the armrest at only one coordinate location as with armrest height (at least for a given X-coordinate), interpretation of the elbow position results is somewhat different from armrest height. While the tables indicate the location that would satisfy the largest percentage of the population and the percent that would be satisfied at this location, the more useful information is the range of X-coordinates required to meet the population needs.

To determine these ranges, one could interpret the data in several ways as indicated in Table 15 for the door armrest. Perhaps the most meaningful indication of required armrest length and the position of this length is the range of preferred elbow locations for all subjects tested. The coordinates for these ranges are given in the vehicle reference systems for each of the vehicles, along with the required armrest lengths of 288, 348, and 299 millimeters for the G-, H-, and S-body vehicles, respectively. Also shown in Table 15 for the door armrest are the ranges of positions required to satisfy all the "potentially-usable" (i.e. acceptable limits) armrest positions, to cover the range of group-mean-preferred locations, and to cover the range of group mean "potentially-usable limits".

Table 15
Results for Left Elbow Position
(Vehicle Coordinates)

	G	H	S
Maximum Acceptable	1400	1394	1360
% Accept	79	71	69
Range of Acceptable Limits	1141-1638	1171-1627	1150-1607
Length for Acceptable Limits	497	456	457
Range for Group Mean Acceptable Limits	1295-1528	1278-1541	1252-1478
Length for Group Mean Acceptable Limits	233	263	226
Mean Preferred	1384	1377	1338
Range of Preferred	1253-1541	1181-1529	1210-1509
Length for Preferred Range	288	348	299
Range of Group Mean Preferred	1337-1453	1328-1433	1286-1407
Length for Group Mean Preferred Range	116	105	121

Note: All dimensions in millimeters

Table 16
Results for Preferred Locations of Right Elbow
(Vehicle Coordinates, all subjects)

	G	H	S
Mean Preferred Position	1427	1412	1373
Range of Preferred Positions	1286-1612	1244-1595	1240-1579
Length of Preferred Range	326	351	339

Note: All dimensions in millimeters

In Table 16, the results for the center armrest (i.e., the right elbow) are given, but only include ranges and lengths for preferred locations of all subjects and the range of group mean preferred locations since "potentially-usable" position data were not collected for the right elbow. It is interesting to compare the differences in mean preferred positions for the left and right elbows in Tables 15 and 16. The mean-preferred elbow locations as well as the front and back limits of the preferred ranges tend to be further forward for the left elbow in all cases. This may again be due to the need to operate the shift lever with the right hand.

3. Locations for Finger-tip Controls

As with the armrest height, one would like to find a location that is acceptable to everyone and that maximizes the number of persons whose preferred location is reasonably accommodated. While acceptable range data for the finger-tip position were not directly collected, it has been assumed that the ranges of acceptable elbow locations forward and rearward of preferred elbow positions would also apply to the preferred finger position data. Therefore, the differences between left-elbow preferred locations and left elbow front and back acceptable limits were calculated and added or subtracted from the preferred finger location data to determine acceptable limits for finger controls.

Table 17 describes the interpretation of these preferred-and acceptable-range finger position results with regard to the optimal locations of finger-tip controls located on the door armrest. For each vehicle, the X-coordinates corresponding to the overall preferred mean position as well as the position at which a minimum number of people would not accept are given. For the latter, the percents of the population which would be satisfied by these locations are indicated. It is seen that the coordinate values for these two measures of optimal finger-tip control locations are generally quite close, the greatest difference being

Table 17
Results for Left Hand Finger Grip Position
(Vehicle Coordinates)

	G	H	S
Maximum Acceptable	950	959	919
% Accept	85	73	77
Range for 80% Acceptable	934-958	--	--
Range for 70% Acceptable	921-988	935-970	910-942
Range for 50% Acceptable	897-1033	894-1026	860-988
Range for 30% Acceptable	868-1067	864-1057	831-1021
Length of 80% Acceptable	24	--	--
Length of 70% Acceptable	67	35	32
Length of 50% Acceptable	136	132	128
Length of 30% Acceptable	199	193	190
Mean of Preferred	947	939	902
Range of Preferred Means	907-975	892-972	866-929

Note: All dimensions in milimeters

Table 18
Results for Preferred Locations of Front edge of Center Armrest
(Vehicle Coordinates, all subjects)

	G	H	S
Mean Preferred Position	1250	1250	1177
Range of Preferred Positions	1143-1383	1150-1360	1066-1297
Length of Preferred Range	240	210	231
Mean distance from shift 3/4 Neutral	188	176	109

Note: All dimensions in millimeters

20 mm in the H-body. Also shown in this table are ranges of X-coordinate values that bracket the 80, 70, 50, and 30% population acceptability locations.

4. Front Edge of Center armrest

For the G- and H-body vehicles, where it may be desired to use the center armrest while operating the shift knob, the preferred location of the front of this armrest was considered of possible importance. Thus, subjects were asked to adjust the front/back location of the center armrests as well as the armrest heights. (This was also done for the S-body, but since this armrest travels with the seat and is not considered to be a reasonable resting surface when using the shift knob in its current location, the results are probably not as meaningful.) During the tests, the coordinate values of the front edge of the H-body console lid (used for both G- and H-body vehicles) were recorded but, for purposes of analysis, a distance of 70 mm was added to these coordinate values to approximate the position of the most foward usable point on the center armrest. For the S-body armrest, the position of the front edge was measured and recorded directly.

Table 18 summarizes results which are are based upon preferred location data only, and presents the overall mean values, the ranges of a preferred positions, and the ranges of preferred group means. In addition, the distances of the overall mean positions with respect to the shift knob 3/4 neutral positions (measuring to the top center of the shift knob) are also given for the three vehicles.

F. OPTIMAL ARMREST HEIGHT RE H-POINT, AHP, AND STEERING WHEEL

Tables 19 and 20 and Figures 30 through 33 present the maximum acceptable armrest height values for the three seating packages relative to various vehicle reference points. The overall difference between door and center armrest height previously noted, wherein the center armrest is lower than the door armrest, is immediately apparent from these plots. In Figure 30, the optimal armrest height relative to AHP is seen to follow the expected pattern of being highest for the S-body with the highest seat and lowest for the G-body with the lowest seat. However, in Figure 31 it is somewhat unexpectedly observed that the optimal armrest height relative to design H-point (SgRP) varies inversely with the seat height for both the door and center armrests. For the door armrest, the optimal height is from 7.8 to 9.6 inches above the design H-point while for the center armrest, the optimal height is from 6.4 to 8.4 inches above H-point.

In Figure 32 the optimal armrest heights are plotted relative to the center of the steering wheel while in Figure 33 the optimal heights are plotted relative to the lower rim. For the door armrest, it is seen that the optimal height is nearly the same for all vehicles and lies from 5 to 6 inches below the center of the wheel. For the console armrest, the optimal height is from 6 to 7.5 inches below the center of the wheel. With respect to the lower rim, the optimal door armrest height shows slightly greater variation across vehicles than for the center of the wheel, being about even with the rim for the S-body and just greater than one inch above the rim for the G-body. The optimal center armrest height goes from about even with the rim for the G-body to about 1.5 inches below the rim for the S-body.

While there are distinct differences between center and door armrest heights and also differences for the different vehicle types, these results suggest that the location of the steering wheel has a significant effect on the optimal height of the armrest and that the criteria for locating the armrest height in a vehicle should be based more on steering wheel height rather than on seat height (i.e. H-point). The use of a tilt steering wheel would obviously allow drivers to adapt to armrests at different heights if they are willing to position the steering wheel at the required heights and angles.

Table 19

Optimal Door Armrest Height
relative to Vehicle Landmarks

	Distance - mm (in.)		
	G-body	H-body	S-body
re H-point	244 (9.6)	230 (9.0)	199 (7.8)
re AHP	475 (18.7)	494 (19.4)	550 (21.6)
re Steering wheel center	-131 (-5.2)	-147 (-5.7)	-155 (-6.1)
re Lower steering wheel rim	33 (1.3)	13 (.5)	- 8 (-.3)

Table 20

Optimal Console Armrest Height
relative to Vehicle Landmarks

	Distance - mm (in.)		
	G-Body	H-Body	S-Body
re H-point	214 (8.4)	191 (7.5)	162 (6.4)
re AHP	445 (17.5)	455 (17.9)	513 (20.2)
re Steering wheel center	-161 (-6.3)	-186 (-7.3)	-192 (-7.6)
re Lower steering wheel rim	3 (.1)	- 26 (-1.0)	- 45 (-1.8)

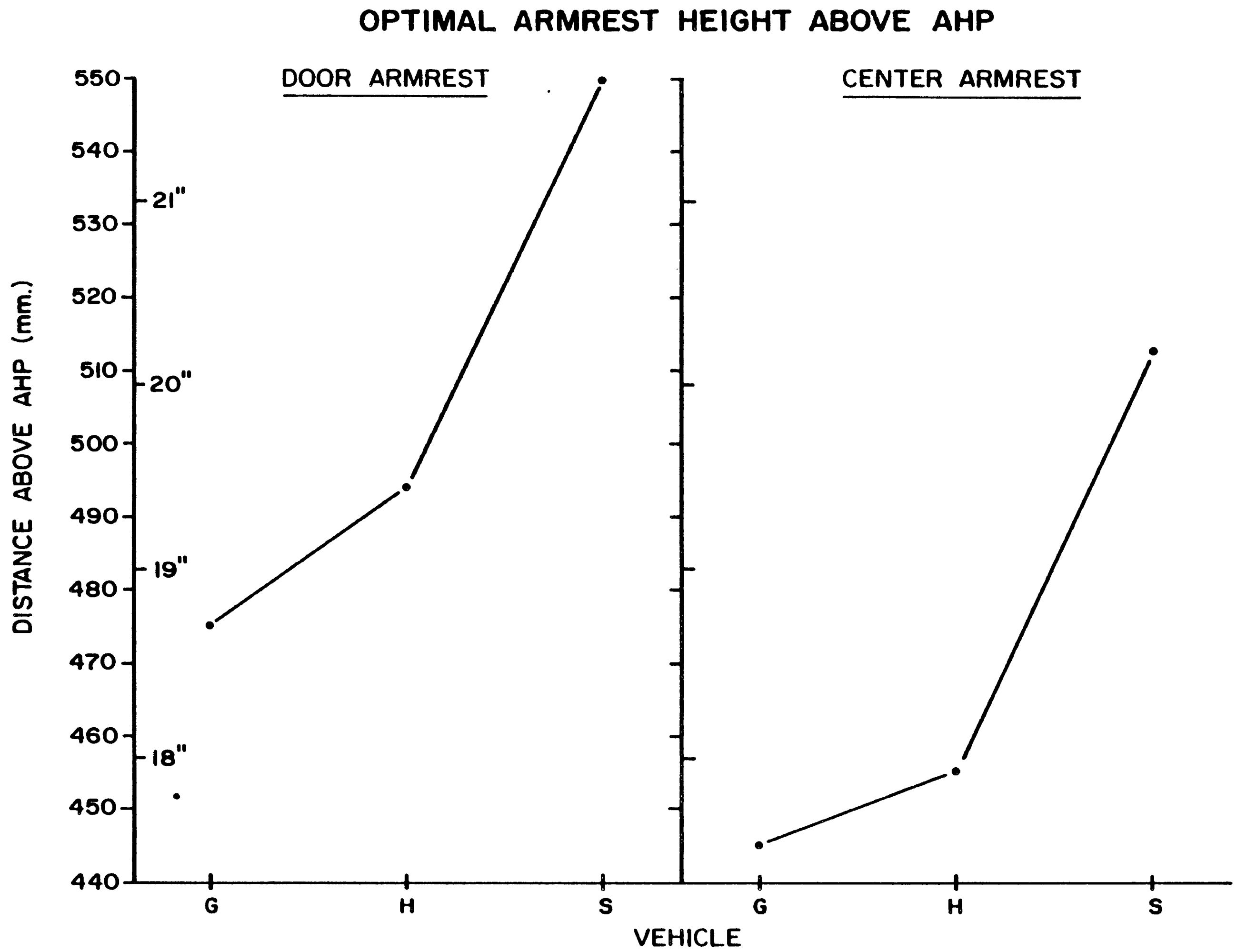


Figure 30. Optimal armrest height above AHP.

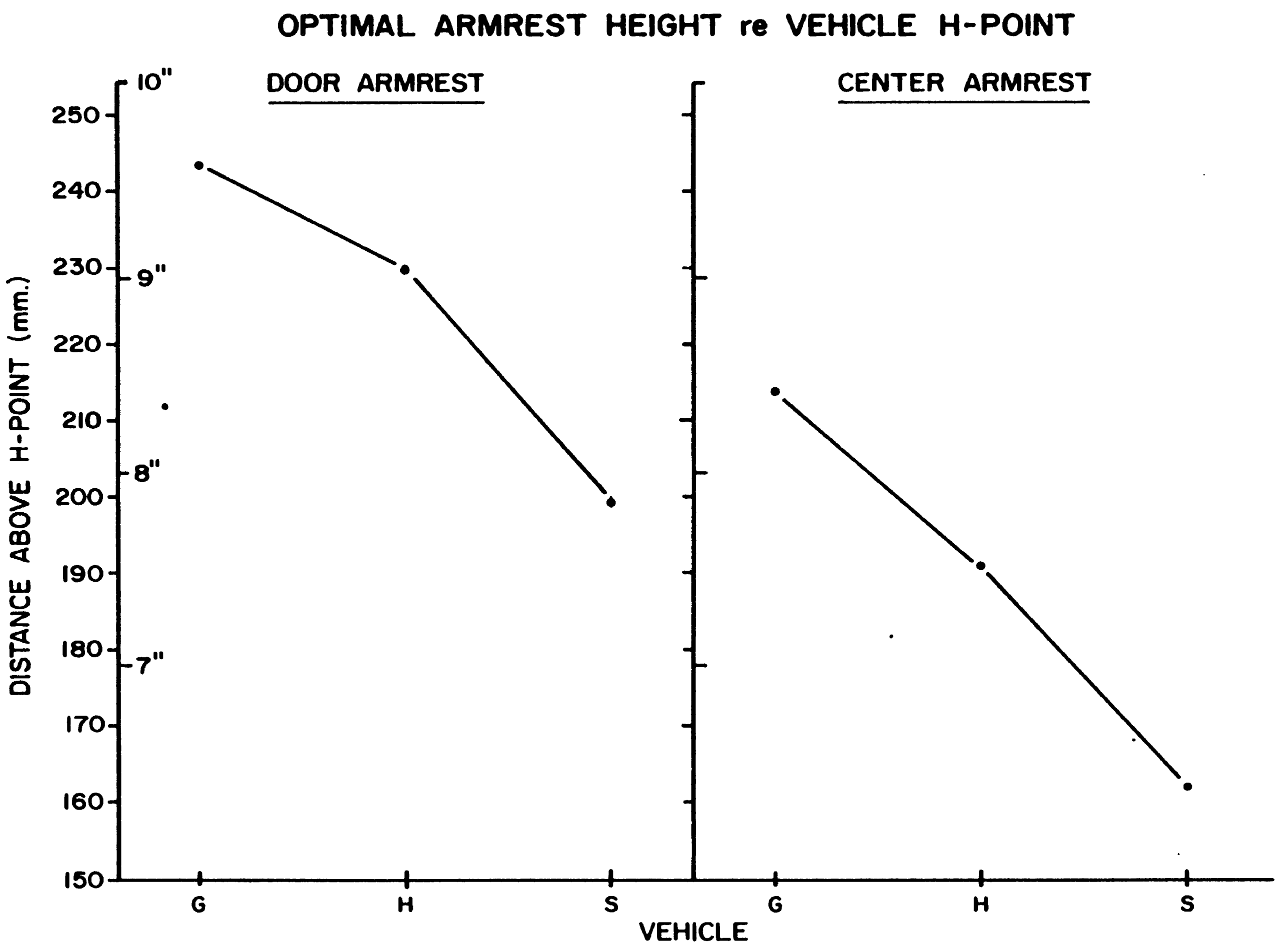


Figure 31. Optimal armrest height re Vehicle H-point.

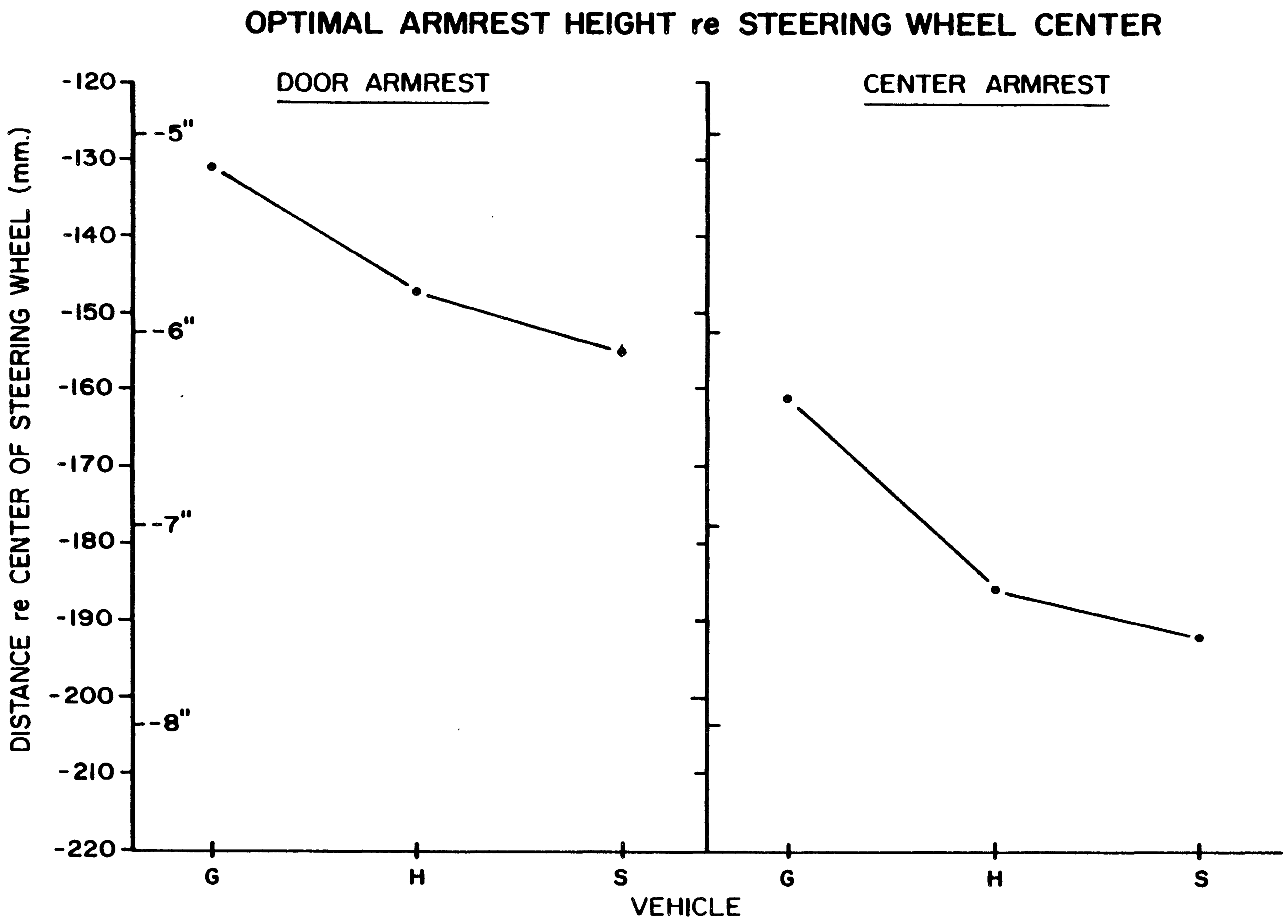


Figure 32. Optimal armrest height re Steering Wheel Center.

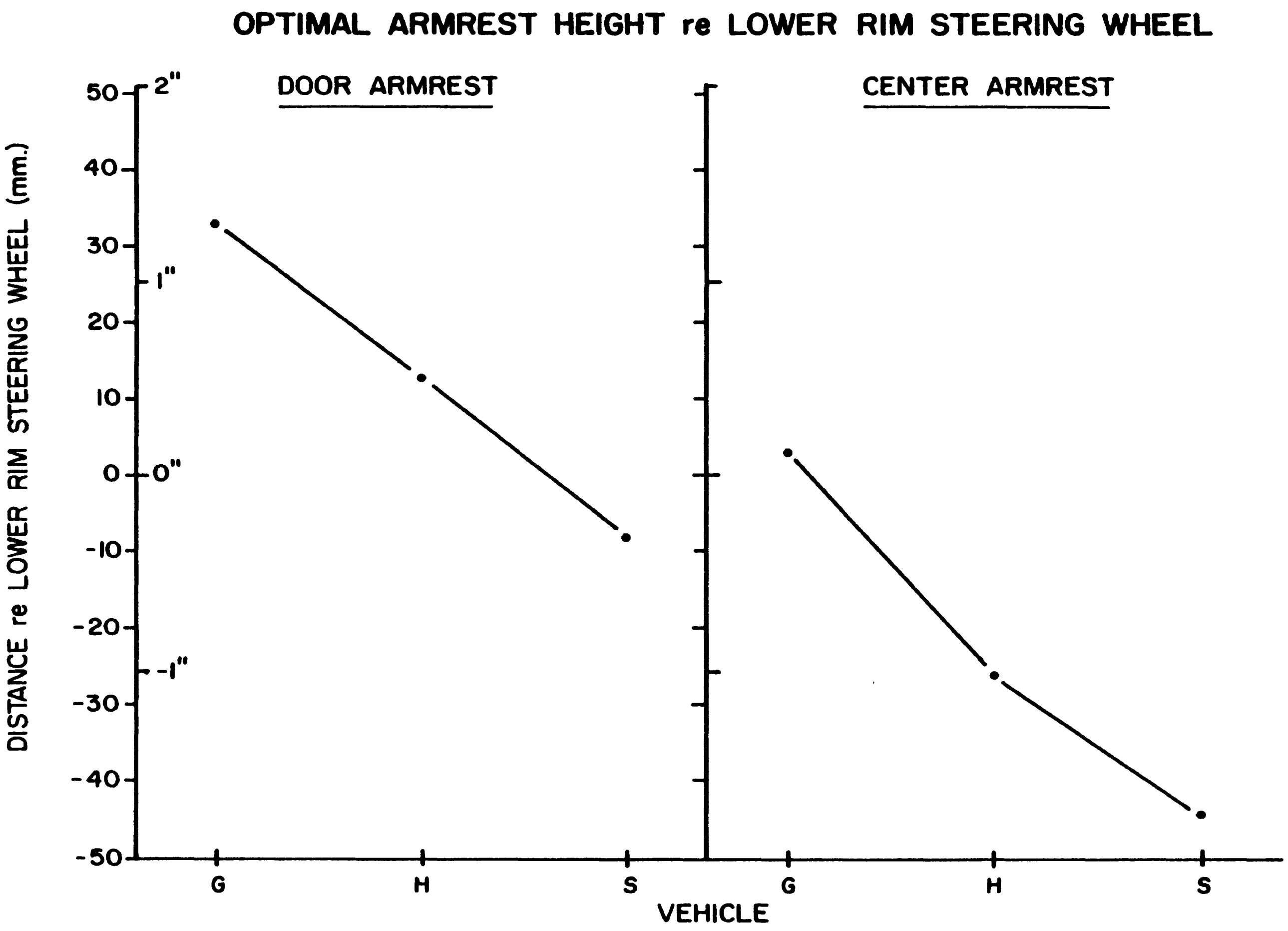


Figure 33. Optimal armrest height re Lower Rim of Steering Wheel.

G. REPEATABILITY OF POSITION DATA

In any study such as this, where a laboratory vehicle mock-up is used to determine design parameters for driver needs and preferences, two questions are of concern. One is with regard to how good the static laboratory data represent the real-world of dynamic driving (i.e., how meaningul are the results). The second is with regard to the ability of the subject to make reasonable and consistent decisions about control and component locations.

The first question can best be answered by implementing the results of laboratory studies in studies with actual vehicles. For example, one could take the optimal armrest height results from this study and road-test a subset of the subjects in actual vehicles in which the armrests have been adjusted to these positions. To answer the second question, one can repeat the testing on some subjects on different days and compare the results from the two separate sessions. This was done for four subjects in the present study to give a qualitative indication of the repeatability of the test results.

Figures 34 through 38 show comparisons of the armrest height results for these four subjects in the three vehicle types. In each graph, both the preferred positions, indicated by boxes, and the acceptable limits, indicated by vertical bars, are plotted. The initial test data are plotted using solid boxes and bars and the retest results are plotted using open boxes and dashed bars.

As an example of the repeatability for different subjects in the same vehicle, Figure 34 shows the results for the H-body vehicle. In general, the preferred location on the retest is within 20 millimeters (i.e., about 3/4 inch) of the initial preferred position, although it is interesting that in all but one case, the preferred retest height is higher than the preferred initial test height. It is also noted that the acceptable ranges selected by these four subjects are in good agreement from initial to retest data.

In Figures 35 through 38 the data are plotted separately for each of these subjects for the three vehicle types. Again, there is excellent agreement between preferred heights in the initial and retest data, the only exception being the preferred door armrest height for subject #10701 in the G-body, where the retest preferred height was significantly greater than the initial height. It will also be noted from these plots that preferred heights on retesting are both lower and higher than the initial preferred heights. The acceptable ranges for the retest are also generally in good agreement with the initial data in both range and location, although there appears to be a tendency for the retest range to be smaller than the initial test range with the exception of subject #20211. In general, these data indicate that the results obtained in this study are repeatable and, in that sense, provide meaningful indications of preferred and acceptable armrest locations.

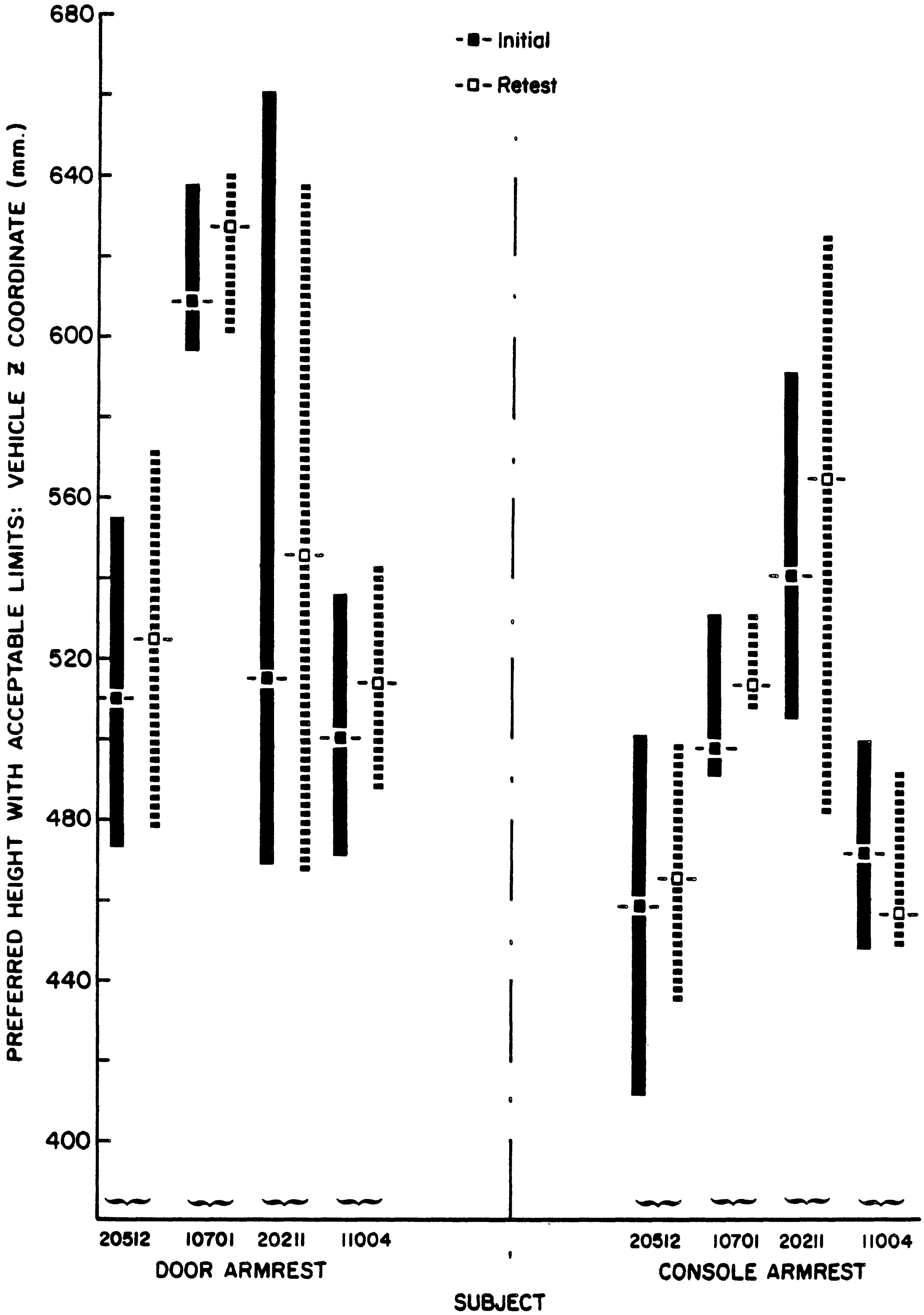


Figure 34. Initial and retest armrest height data for four subjects in H-body.

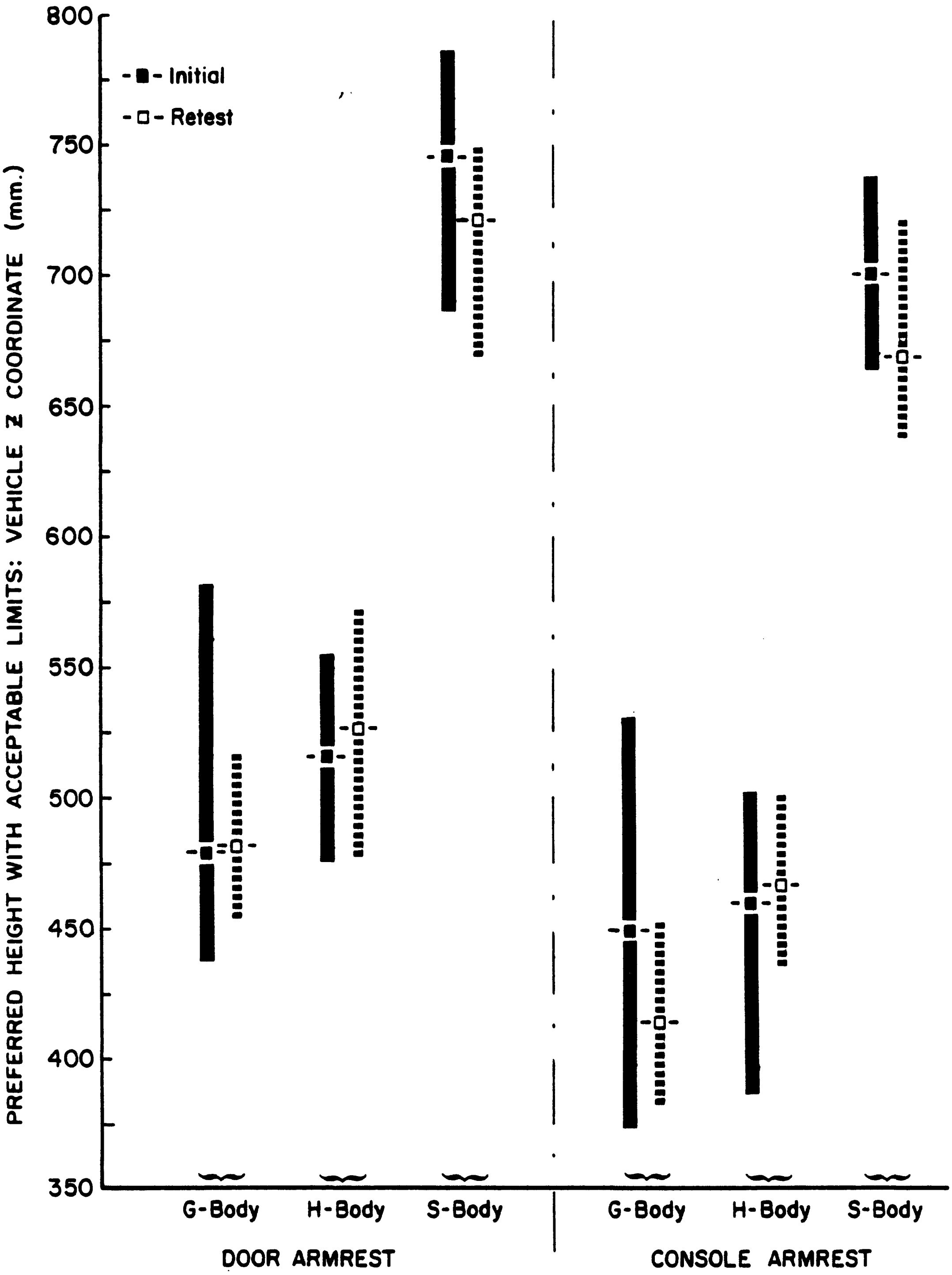


Figure 35. Initial and retest armrest height data for Subject #20512.

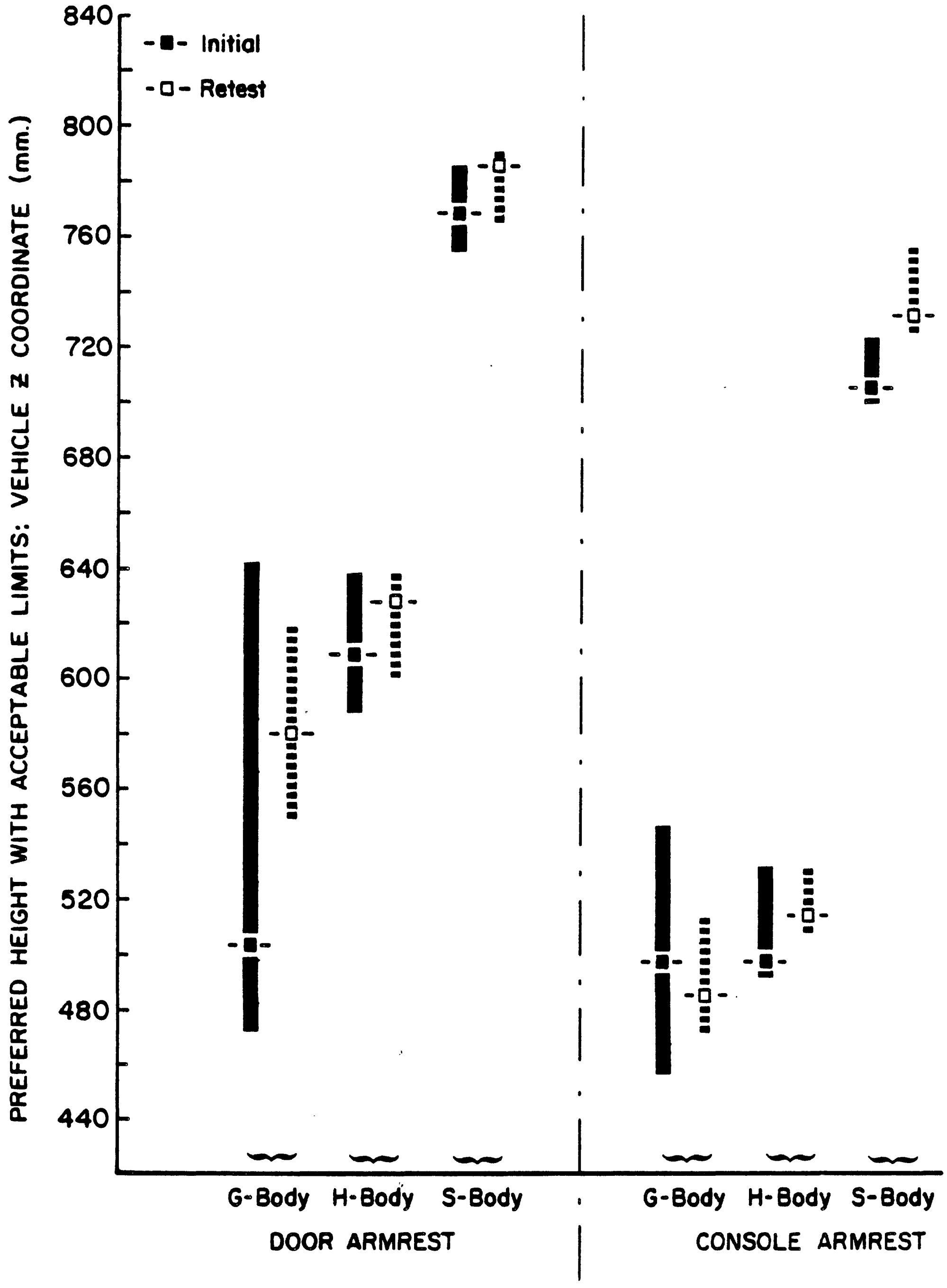


Figure 36. Initial and retest armrest height data for Subject #10701.

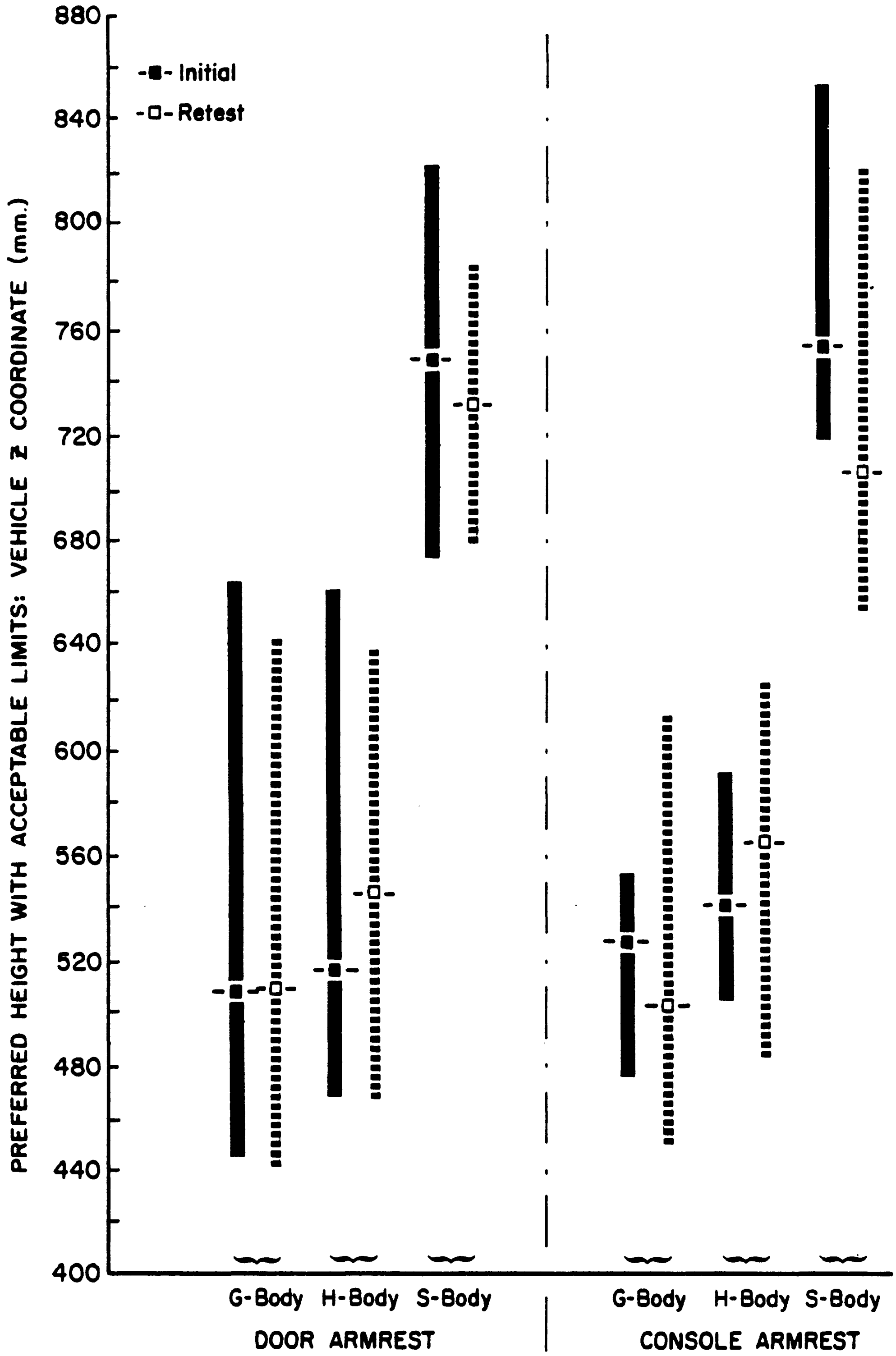


Figure 37. Initial and retest armrest height data for Subject #20211.

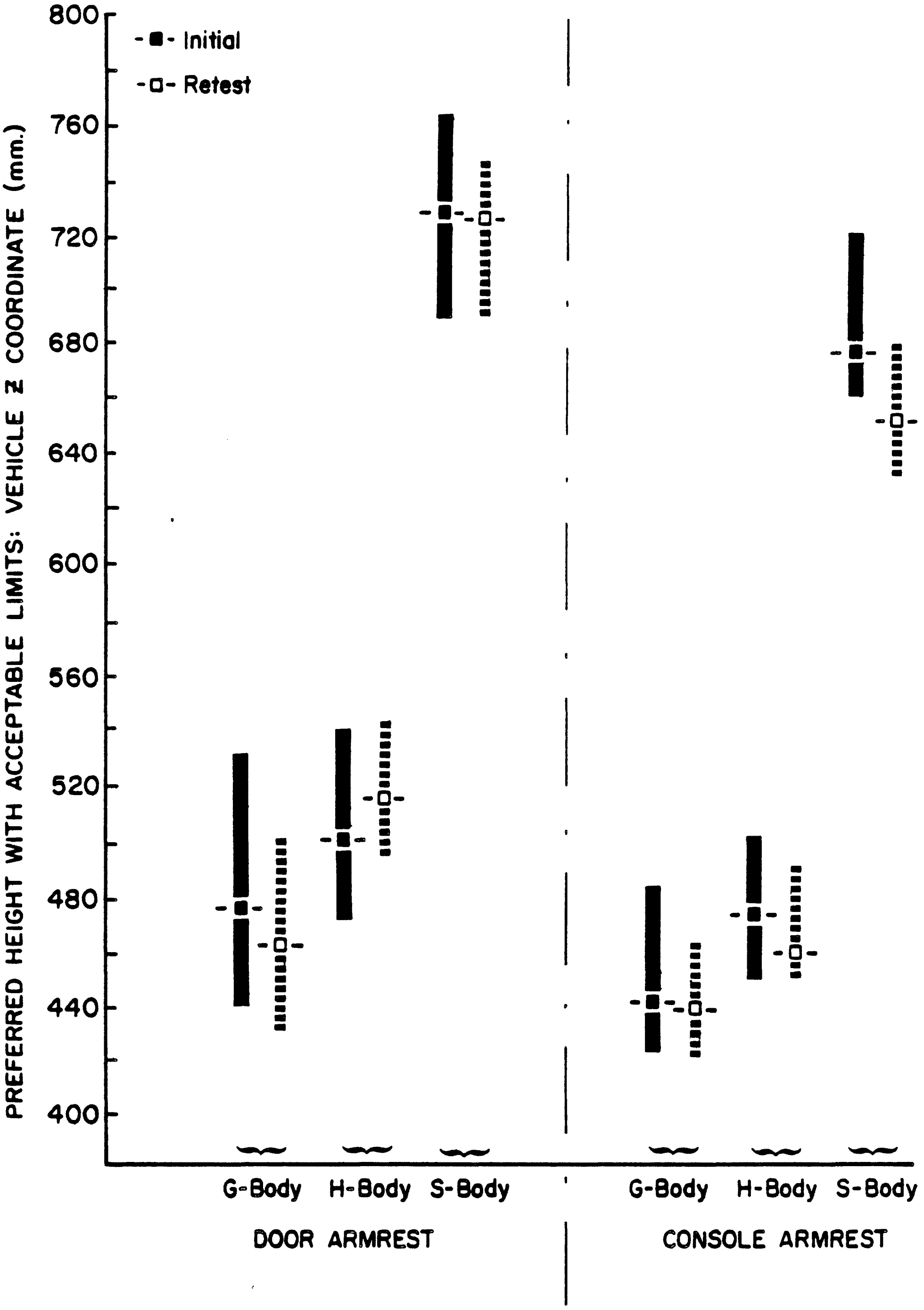


Figure 38. Initial and retest armrest height data for Subject #11004.

H. QUESTIONNAIRE RESULTS

Appendix H shows the questionnaire that was completed by the test subjects before their scheduled sessions and presents a summary of the subject responses in tabular form. Part A of the questionnaire dealt with information on the subject's primary vehicle at the time study. This included the make, year, and model, the body style (2 or 4 door), and the transmission (4 or 5 speed). The make and model of the subjects' vehicles are tabulated by subject group in part A of the results.

Part B of the questionnaire dealt with the door armrest. Subjects were first asked to indicate on a scale of 1 to 5 (1 being never and 5 being most of the time), how often they used this armrest in their vehicle. Responses were fairly evenly distributed with a mean response of 2.7. They were then asked to indicate on a similar scale how important the door armrest was to them (1 being not at all, 5 being very). Again responses were distributed across the scale but were more heavily weighted to the armrest being not very important, with a mean rating of 2.5. As might be expected with regard to the driving conditions under which the door armrest might be used, the greatest number of subjects indicated highway driving, but 25% of the subjects indicated they would use the door armrest under all conditions. In addition to the conditions that were listed, subjects were given the option of listing any other conditions under which they might use the door armrest. Some of the responses given include: using the armrest to open or close the door, and using it to aid in getting in and out of the car.

Subjects who seldom or never use their door armrest were asked to answer the next question regarding why they don't use it. They were given the choice of two possible reasons that might explain why they do not use the door armrest -- because they can't steer comfortably or because they don't feel comfortable with their left arm at rest. Fifty seven subjects indicated non-use of the door armrest because they were unable to steer comfortably using it. They were also given a list of adjectives that might describe why they can't use their armrest and were instructed to check all that apply. While a large number of subjects did not respond, the predominant answers of those who did were: too low, too far away, and too small. Again, they were given the opportunity to either explain that they use something other than the armrest on which to rest their arm or to give any other reason that might explain why they don't use the armrest. Some suggestions given for the former include a purse, a pillow, their lap or leg, and, most commonly, the window sill. One reason suggested for the latter was the inability to rest the left arm because it was needed for steering while the right hand was shifting.

Many people use the window sill as a place to rest their left arm while driving, and the next question was an attempt to get an estimate of just how common this is. It was decided to make a distinction between using the window sill as an armrest in the summer and in the winter since the latter would constitute doing so with the window closed. Subjects were asked to estimate the amount of time spent driving with the arm at rest on the window sill by answering the question regarding how often they do so on a scale of 1 to 5 (1 being never and 5 being most of the time). The responses were distributed across the scale but weighted toward the low end (less often used), especially in winter driving but also in summer driving.

Part C of the questionnaire dealt with the console armrest. It was decided to first ask the subject whether or not their vehicle had a console armrest, since many do not. If their vehicle did not have an armrest they were asked the question of whether or not they thought they would use a console if their vehicle did have one. They were then instructed to skip to Part D of the questionnaire. Seventy two of the subjects indicated that their car did not have a center armrest, and 44 of these said they would use one if they had it. If their vehicle did have a console armrest they were to answer the rest of the questions in Part C.

The first question covered the type of console armrest in the subject's vehicle. It included the position (whether attached to the seat or the floor) and whether it was stationary, flipped up/down, or moved fore/aft, and the material it was made of, whether soft or hard. The majority of subjects who answered this question had a soft armrest attached to the seat.

The next four questions were the same as those asked about the door armrest dealing with how often it is used, how important it is, driving conditions under which it is used, and reasons for not using it. Again, for the question regarding reasons for not using the console armrest and for driving conditions under which the armrest is used, subjects were given the opportunity to enter their own ideas. Responses similar to those for the door armrest were given, although the sample size was quite small.

Part D included general questions about the subject's driving habits in his/her own vehicle. The first two questions dealt with the positioning of the subjects' hands on the steering wheel and whether they usually steer with one hand or two. Sixty-nine subjects indicated that they usually use two hands and 29 subjects said one hand. They were also asked to label left and right hand positions on three circles representing steering wheels, the first circle being for the most frequent hand position and the last one for the least frequent. Some subjects commented here that the hand position depended on the configuration of the spokes of the wheel. For the left hand, 91 subjects indicated a hand position and the mean position was between 9 and 10 o'clock. For the right hand, 77 subjects indicated a hand position, for which the mean location was between 2 and 3 o'clock. Both of these positions are above the 3 and 9 o'clock positions while the mean positions in the testing were below the 3 and 9 o'clock position, indicating, as one might expect, that drivers tend to position their hands lower on the wheel when using the armrest.

The last two questions in Part D concerned the general use of armrests. The first asked whether or not the subject tended to use one armrest more than the other, and if so, which one. Fifty two subjects said they used the door armrest more, and eight subjects said they used the console more. The last question asked whether the subject tended to lean one way or another in order to use an armrest. While most subjects said they don't lean, of those who said they did, the majority said they leaned to the left. This does not, however, support the finding of this study that many subjects tend to prefer the console or right armrest lower than the door or left armrest.

Finally, Part E of the questionnaire was a comments section. Subjects were asked to write any additional comments and thoughts they might have concerning the door and console armrests in vehicles. The last table in Appendix H presents some of the more interesting and enlightening comments written by the subjects.

I. SUBJECT COMMENTS

As previously indicated, subjects were encouraged to express their thoughts as they attempted to position the seat or armrests at their preferred "or acceptable-limit" locations during testing. The table in Appendix I provides a brief summary of some of the typical comments. The subjects were not asked specific questions (except in one case which will be explained below) and therefore the count of subjects for each comment does not imply that other subjects did not experience the phenomenon in question. Thus, one cannot use these numbers as a measure of the percent of subjects or population who have a particular difficulty or concern. Rather, they indicate that these were issues that some subjects experienced and the count may be taken as a rough measure of the magnitude of the problem.

The one case in which subjects were asked a specific question was when the upward travel of the door armrest reached its maximum limit. When this occured, subjects were asked if they would accept the armrest any higher. If so, they were also asked to estimate how much higher they would tolerate it. In the G- and H-body situations this occurence was minimal. In the S-body, however, 72 subjects reached the upper limit of the buck and 44 said they felt they could use it higher. An estimate of how much higher was made in each case. From the results, it has been observed that there is a high correlation between the console upper range and the door armrest upper range both for subjects who estimated an upper limit and for those who didn't. This would seem to indicate that the estimates made were good approximations.

In locating the preferred seat position, 36 subjects commented that they felt too close to the steering wheel if the seat was positioned to enable reaching the pedals and fully depressing the clutch. A few subjects suggested that a tilt steering wheel might alleviate this problem. Eleven subjects commented that they would like to be able to position the seat back more vertically.

A frequent comment was that the subject did not use either or both armrest in their own vehicle. Nine subjects said they don't use either armrest; eleven said they never use (or don't have) the console armrest; and nineteen subjects said that they would not use both armrests while driving.

With respect to the console armrest, the common problem in the G-body was that the armrest was laterally too far from the seat. Forty-six subjects made this comment. In the S-body, twenty-two subjects commented that the shift knob was too low.

J. REFERENCE

Abraham, S.; Johnson, C.L.; and Najjar, F. (1979a) Weight and height of adults 18-74 years of age. Vital and Health Statistics, Series 11, Number 211.

APPENDIX A

VEHICLE AND BUCK COORDINATES AND DIMENSIONS

Table A-1.
Vehicle and Buck Coordinates
Used in Design of G-Body Seating Package

COMPONENT/STRUCTURE	Vehicle coordinates (mm) X	Y*	Z
ACCELERATOR HEEL POINT (AHP)	550	--	55
SGRP (H-POINT)	1430	--	286
TOP CENTER STEERING WHEEL	1067	--	661
TOP CENTER BRAKE PAD	527	65	240
TOP CENTER CLUTCH PAD	523	-70	253
TOP CENTER ACCEL. PAD	461	212	240
TOP CENTER SHIFT KNOB 3/4 NEUTRAL	1061	364	525
WINDOW SILL	--	-427	712
WINDOW FRONT AT SILL	743	--	--
WINDOW BACK AT SILL	1985	--	--
WINDOW AT TOP CENTER	--	-224	1039
INSIDE DOOR SURFACE	--	-361	--
TOP CENTER OF DOOR ARMREST @ SGRP **	--	-338	480
FRONT EDGE OF DOOR ARMREST	1000	-338	544
BACK EDGE OF DOOR ARMREST	1800	-338	465
TOP CENTER OF CONSOLE ARMREST	--	357	405
FRONT EDGE OF CONSOLE ARMREST	1305	357	410
BACK EDGE OF CONSOLE ARMREST	1600	357	390
BACK REFERENCE PLANE	2231	--	--
RIGHT EDGE OF PLATFORM	--	303	--
SEAT BASE PLATFORM	--	--	-55

* Note: Y axis is positive toward right with origin at seat C/L
Back reference plane is 1681 mm from AHP
Seat base platform is 110 mm below AHP

** At approximate center of inclined width

Table A-2.
Vehicle and Buck Coordinates
Used in Design of H-Body Seating Package

COMPONENT/STRUCTURE	Vehicle coordinates (mm) X	Y*	Z
ACCELERATOR HEEL POINT (AHP)	577	--	55
SGRP (H-POINT)	1405	--	319
TOP CENTER STEERING WHEEL	1052	--	696
TOP CENTER BRAKE PAD	527	52	240
TOP CENTER CLUTCH PAD	554	-78	254
TOP CENTER ACCEL. PAD	466	198	242
TOP CENTER SHIFT KNOB 3/4 NEUTRAL	1074	350	527
WINDOW SILL	--	-414	722
WINDOW FRONT AT SILL	867	--	--
WINDOW BACK AT SILL	1619	--	--
WINDOW AT TOP CENTER	--	-220	1110
INSIDE DOOR SURFACE	--	-375	--
TOP CENTER OF DOOR ARMREST @ SGRP	--	-344	507
FRONT EDGE OF DOOR ARMREST	1150	-344	507
BACK EDGE OF DOOR ARMREST	1500	-344	507
TOP CENTER OF CONSOLE ARMREST	--	340	477
FRONT EDGE OF CONSOLE ARMREST	1289	340	477
BACK EDGE OF CONSOLE ARMREST	1609	340	477
BACK REFERENCE PLANE	2258	--	--
RIGHT EDGE OF PLATFORM	--	303	--
SEAT BASE PLATFORM	--	--	-55

* Note: Y axis is positive toward right with origin at seat C/L
Back Reference Plane is 1681 mm from AHP
Seat base platform is 110 mm below AHP

Table A-3.
Vehicle and Buck Coordinates
Used in Design of S-Body Seating Package

COMPONENT/STRUCTURE	Vehicle coordinates (mm) X	Y*	Z
ACCELERATOR HEEL POINT (AHP)	636	--	199
SGRP (H-POINT)	1334	--	550
TOP CENTER STEERING WHEEL	977	--	904
TOP CENTER BRAKE PAD	545	72	366
TOP CENTER CLUTCH PAD	560	-65	381
TOP CENTER ACCEL. PAD	489	217	334
TOP CENTER SHIFT KNOB 3/4 NEUTRAL	1067	390	560
WINDOW SILL	--	-406	873
WINDOW FRONT AT SILL	641	--	--
WINDOW BACK AT SILL	1486	--	--
WINDOW AT TOP CENTER	--	278	1326
INSIDE DOOR SURFACE	--	-335	--
TOP CENTER OF DOOR ARMREST @ SGRP	--	-306	715
FRONT EDGE OF DOOR ARMREST	1045	-306	715
BACK EDGE OF DOOR ARMREST	1390	-306	715
TOP CENTER OF SEAT ARMREST	--	278	710
FRONT EDGE OF SEAT ARMREST @ DESIGN	1232	278	728
BACK EDGE OF SEAT ARMREST @ DESIGN	1572	278	705
BACK REFERENCE PLANE	2317	--	--
RIGHT EDGE OF PLATFORM	--	303	--
SEAT BASE PLATFORM	--	--	88

* Note: Y axis is positive toward right with origin at seat C/L
Back reference plane is 1681 mm from AHP
Seat base platform is 110 mm below AHP
AHP - Back Reference Plane = 1681 mm

Table A-4.
G-BODY Package Dimensions
Desired versus Actual

MEASUREMENT (DIRECTION)	VEHICLE	BUCK	DIFF.
STEERING WHEEL:			
STEERING WHEEL ANGLE	23	23	0
BACK PLANE TO STEERING WHEEL CENTER (X)	1164	1163	-1
AHP TO STEERING WHEEL CENTER (Z)	606	605	-1
PEDALS:			
BACK PLANE TO BRAKE PEDAL PAD (X)	1704	1707	+3
BACK PLANE TO ACCEL. PEDAL PAD (X)	1770	1763	-7
BACK PLANE TO CLUTCH PEDAL PAD (X)	1678	1682	+4
AHP TO ACCEL. PEDAL CNTR (Z)	185	204	+19
AHP TO BRAKE PEDAL CNTR (Z)	185	184	-1
AHP TO CLUTCH PEDAL CNTR (Z)	198	184	-14
RIGHT SIDE PLATFORM TO ACCEL. PED CNTR (Y)	91	90	-1
RIGHT SIDE PLATFORM TO CLUTCH PEDAL CNTR (Y)	373	380	-7
RIGHT SIDE PLATFORM TO BRAKE PEDAL CNTR (Y)	238	240	+2
CNTR BRAKE TO CNTR CLUTCH (Y)	135	140	+5
CNTR BRAKE TO CENTER ACCEL. PAD (Y)	147	150	+3
ANGLE BACK ACCEL PEDAL re Horiz.	59	61	+2
ANGLE BACK BRAKE PEDAL re Horiz.	64	58	-6
ANGLE BACK CLUTCH PEDAL re Horiz.	55	56	+1
DOOR/WINDOW:			
RIGHT SIDE PLATFORM TO INSIDE DOOR (Y)	664	664	0
RIGHT SIDE PLATFORM TO DOOR SILL (Y)	731	705	-26
SEAT BASE PLATFORM TO SILL (Z)	765	767	+2
BACK PLANE TO FRONT OF WINDOW (X)	1488	1488	0
BACK PLANE TO BACK OF WINDOW (X)	246	237	-9
RIGHT SIDE OF PLATFORM TO WINDOW TOP (inside)	527	524	-3
SEATBASE TO TOP OF WINDOW (Z)	1094	1094	0
DOOR SILL TO TOP OF WINDOW (Y)	203	195	-8
SHIFT KNOB:			
RIGHT SIDE PLATFORM TO SHIFT KNOB (Y)	61	62	+1
SEAT BASE TO TOP SHIFT KNOB (Z)	580	578	-2
BACK PLANE TO SHIFT KNOB (X)	1170	1171	+1
BUCK REFERENCE PLANES:			
AHP TO BACK REFERENCE PLANE (X)	--	1681	
SEAT BASE TO AHP HEIGHT (Z)	--	110	
RIGHT SIDE OF BUCK TO SEAT C/L	--	303	

Table A-5.
H-BODY Package Dimensions
Desired versus Actual

MEASUREMENT (DIRECTION)	DESIRED	ACTUAL	DIFF.
STEERING WHEEL:			
STEERING WHEEL ANGLE	26	27	+1
BACK PLANE TO STEERING WHEEL CENTER (X)	1206	1202	-4
AHP TO STEERING WHEEL CENTER (Z)	641	640	-1
PEDALS:			
BACK PLANE TO BRAKE PEDAL PAD (X)	1731	1727	-4
BACK PLANE TO ACCEL. PEDAL PAD (X)	1793	1790	-3
BACK PLANE TO CLUTCH PEDAL PAD (X)	1705	1700	-5
AHP TO ACCEL. PEDAL CNTR (Z)	187	190	+3
AHP TO BRAKE PEDAL CNTR (Z)	185	196	+11
AHP TO CLUTCH PEDAL CNTR (Z)	199	199	0
RIGHT SIDE PLATFORM TO ACCEL. PED CNTR (Y)	105	90	-15
RIGHT SIDE PLATFORM TO CLUTCH PEDAL CNTR (Y)	381	380	-1
RIGHT SIDE PLATFORM TO BRAKE PEDAL CNTR (Y)	251	240	-11
CNTR BRAKE TO CNTR CLUTCH (Y)	130	140	+10
CNTR BRAKE TO CENTER ACCEL. PAD (Y)	146	150	+4
ANGLE BACK ACCEL PEDAL re Horiz.	59	58	-1
ANGLE BACK BRAKE PEDAL re Horiz.	61	61	0
ANGLE BACK CLUTCH PEDAL re Horiz.	55	55	0
DOOR/WINDOW:			
RIGHT SIDE PLATFORM TO INSIDE DOOR (Y)	678	678	0
RIGHT SIDE PLATFORM TO DOOR SILL (Y)	723	692	-31
SEAT BASE PLATFORM TO SILL (Z)	777	771	-6
BACK PLANE TO FRONT OF WINDOW (X)	1391	1386	-5
BACK PLANE TO BACK OF WINDOW (X)	639	635	-4
RIGHT SIDE OF PLATFORM TO WINDOW TOP (inside)	523	514	-9
SEATBASE TO TOP OF WINDOW (Z)	1165	1150	-15
DOOR SILL TO TOP OF WINDOW (Y)	194	188	-6
SHIFT KNOB:			
RIGHT SIDE PLATFORM TO SHIFT KNOB (Y)	47	47	0
SEAT BASE TO TOP SHIFT KNOB (Z)	582	583	+1
BACK PLANE TO SHIFT KNOB (X)	1184	1191	+7
BUCK REFERENCE PLANES:			
AHP TO BACK REFERENCE PLANE (X)	--	1681	
SEAT BASE TO AHP HEIGHT (Z)	--	110	
RIGHT SIDE OF BUCK TO SEAT C/L	--	303	

Table A-6.
S-BODY Seating Package Dimensions
Desired versus Actual

MEASUREMENT (DIRECTION)	DESIRED	ACTUAL	DIFF.
STEERING WHEEL:			
STEERING WHEEL ANGLE	35	35	0
BACK PLANE TO STEERING WHEEL CENTER (X)	1340	1336	-4
AHP TO STEERING WHEEL CENTER (Z)	706	704	-2
PEDALS:			
BACK PLANE TO BRAKE PEDAL PAD (X)	1772	1772	0
BACK PLANE TO ACCEL. PEDAL PAD (X)	1822	1825	+3
BACK PLANE TO CLUTCH PEDAL PAD (X)	1758	1753	-5
AHP TO ACCEL. PEDAL CNTR (Z)	135	136	+1
AHP TO BRAKE PEDAL CNTR (Z)	167	169	+2
AHP TO CLUTCH PEDAL CNTR (Z)	182	178	-4
RIGHT SIDE PLATFORM TO ACCEL. PED CNTR (Y)	86	90	+4
RIGHT SIDE PLATFORM TO CLUTCH PEDAL CNTR (Y)	368	380	+12
RIGHT SIDE PLATFORM TO BRAKE PEDAL CNTR (Y)	231	240	+9
CNTR BRAKE TO CNTR CLUTCH (Y)	137	140	+3
CNTR BRAKE TO CENTER ACCEL. PAD (Y)	145	150	+5
ANGLE BACK ACCEL PEDAL re Horiz.	43	43	0
ANGLE BACK BRAKE PEDAL re Horiz.	48	42	-6
ANGLE BACK CLUTCH PEDAL re Horiz.	34	37	-3
DOOR/WINDOW:			
RIGHT SIDE PLATFORM TO INSIDE DOOR (Y)	646	646	0
RIGHT SIDE PLATFORM TO DOOR SILL (Y)	703	684	-19
SEAT BASE PLATFORM TO SILL (Z)	784	784	0
BACK PLANE TO FRONT OF WINDOW (X)	1676	1672	-4
BACK PLANE TO BACK OF WINDOW (X)	831	827	-4
RIGHT SIDE OF PLATFORM TO WINDOW TOP (inside)	581	577	-4
SEATBASE TO TOP OF WINDOW (Z)	1237	1227	-10
DOOR SILL TO TOP OF WINDOW (Y)	128	130	2
SHIFT KNOB:			
RIGHT SIDE PLATFORM TO SHIFT KNOB (Y)	87	88	1
SEAT BASE TO TOP SHIFT KNOB (Z)	472	474	2
BACK PLANE TO SHIFT KNOB (X)	1250	1250	0
BUCK REFERENCE PLANES:			
AHP TO BACK REFERENCE PLANE (X)	--	1681	
SEAT BASE TO AHP HEIGHT (Z)	--	110	
RIGHT SIDE OF BUCK TO SEAT C/L	--	303	

Table A-7.
G-BODY
H-Point Specifications

DETENT	L-1
AHP TO H-POINT (horiz.)	880
AHP TO H-POINT (vert.)	231
FOOT ANGLE	65
ANKLE ANGLE	87
KNEE ANGLE	128
HIP ANGLE	98
BACK ANGLE	26

Table A-8.
H-BODY
H-Point Specifications

DETENT	L-1
AHP TO H-POINT (horiz.)	828
AHP TO H-POINT (vert.)	264
FOOT ANGLE	59
ANKLE ANGLE	87
KNEE ANGLE	119
HIP ANGLE	94
BACK ANGLE	24

Table A-9.
S-BODY
H-Point Specifications

DETENT	L-1
AHP TO H-POINT (horiz.)	698
AHP TO H-POINT (vert.)	352
FOOT ANGLE	43
ANKLE ANGLE	87
KNEE ANGLE	103.3
HIP ANGLE	91
BACK ANGLE	22

Table A-10.
Armrest Dimensions for G-Body

DOOR ARMREST:

Armrest curves upward toward the front and travels the full length of the door. Armrest also slopes down from the door surface at an angle of approximately 30 degrees.

		mm	in.
Z-coordinate (at design H-point)		480	
Height from AHP (at design H-point)		425	16.7
Height from Design H-point		194	7.6
Front edge of useable armrest:	X	1000	
	Z	544	
Back edge of useable armrest:	X	1800	
	Z	465	
Effective length of armrest		length of door	
Effective width of armrest (sloped)		65	2.5
Seat centerline to edge of armrest		305	12.0
Seat centerline to center of armrest		338	13.3

CONSOLE ARMREST:

Console has slight incline upward toward the front of the vehicle

		mm	in.
Z-coordinate (at design H-point)		405	
Height from AHP (at design H-point)		350	13.8
Height from Design H-point		119	4.7
Front edge of useable armrest:	X	1305	
	Z	410	
Back edge of useable armrest:	X	1600	
	Z	390	
Effective Armrest Length		295	11.6
Effective console width		85	3.3
Seat centerline to edge of console		314	12.4
Seat centerline to center of console		357	14.0

AHP: X = 550, Z = 55 DESIGN H-POINT: X = 1430, Z = 286

Table A-11.
Armrest Dimensions for S-Body

DOOR ARMREST:

Armrest is level and extends approximately 82 mm from door although the padded surface is only about 50 mm wide due to a gap for hand grip. It tapers at the front to about 19 mm over a distance of about 100 mm. The back edge is rounded and tapers sharply.

		mm	in.
Z-coordinate (at design H-point)		715	
Height from AHP (at design H-point)		516	20.3
Height from Design H-point		165	6.5
Front edge of useable armrest:	X	1045	
	Z	715	
Back edge of useable armrest:	X	1390	
	Z	715	
Effective length of armrest		345	13.6
Effective width of armrest		82	3.2
Seat centerline to edge of armrest		265	10.4
Seat centerline to center of armrest		306	12.0

CONSOLE ARMREST:

This armrest is attached to the seat and travels with the seat as it moves along the seat track. It can pivot up and out of the way when not in use.

Z-coordinate (at design H-point)		710	
Height from AHP (at design H-point)		511	20.1
Height from Design H-point		160	6.3
Front edge of useable armrest:	X seat	1232	
	Z in design	728	
Back edge of useable armrest:	X position	1572	
	Z	705	
Effective Armrest Length		340	13.4
Effective console width		50	2.0
Seat centerline to edge of armrest		253	10.0
Seat centerline to center of armrest		278	11.0

AHP: X = 636, Z = 199 DESIGN H-POINT: X = 1334, Z = 55

Table A-12.
Armrest Dimensions for S-Body

DOOR ARMREST:

Armrest is level and extends approximately 82 mm from door although the padded surface is only about 50 mm wide due to a gap for hand grip. It tapers at the front to about 19 mm over a distance of about 100 mm. The back edge is rounded and tapers sharply.

		mm	in.
Z-coordinate (at design H-point)		715	
Height from AHP (at design H-point)		516	20.3
Height from Design H-point		165	6.5
Front edge of useable armrest:	X	1045	
	Z	715	
Back edge of useable armrest:	X	1390	
	Z	715	
Effective length of armrest		345	13.6
Effective width of armrest		82	3.2
Seat centerline to edge of armrest		265	10.4
Seat centerline to center of armrest		306	12.0

CONSOLE ARMREST:

This armrest is attached to the seat and travels with the seat as it moves along the seat track. It can pivot up and out of the way when not in use.

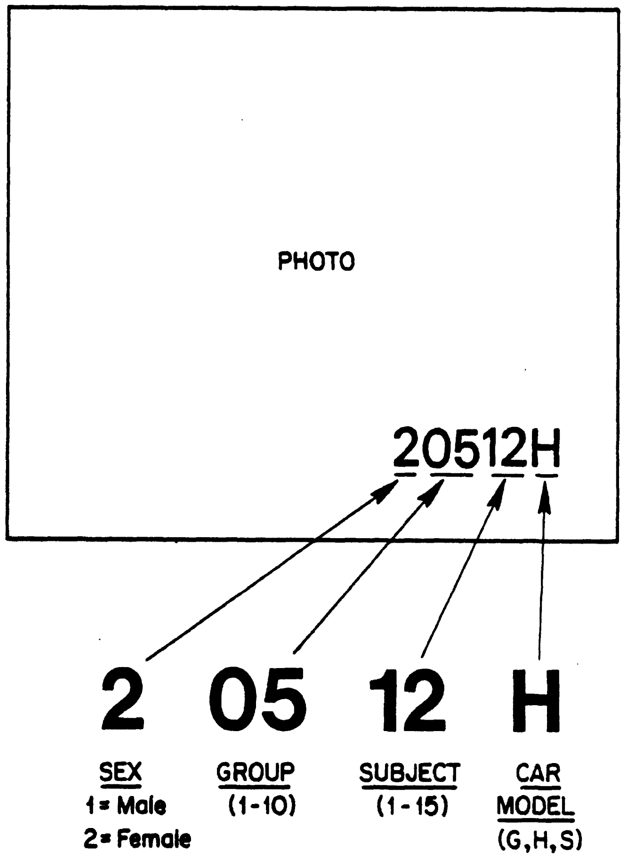
			mm	in.
Z-coordinate (at design H-point)			710	
Height from AHP (at design H-point)			511	20.1
Height from Design H-point			160	6.3
Front edge of useable armrest:	X	seat in design position	1232	
	Z		728	
Back edge of useable armrest:	X		1572	
	Z		705	
Effective Armrest Length			340	13.4
Effective console width			50	2.0
Seat centerline to edge of armrest			253	10.0
Seat centerline to center of armrest			278	11.0

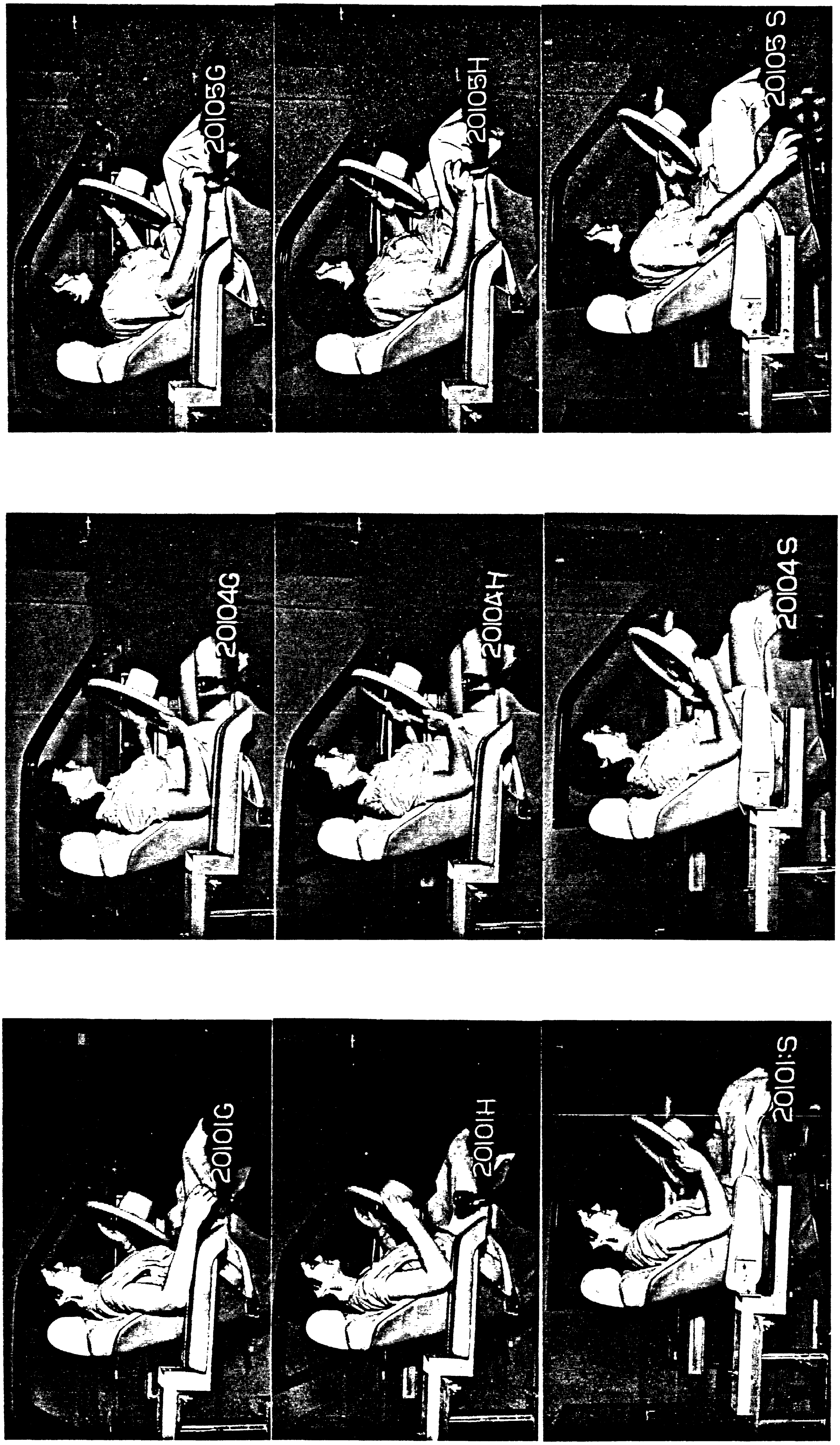
AHP: X = 636, Z = 199   DESIGN H-POINT: X = 1334, Z = 55

APPENDIX B

SIDEVIEW PHOTOGRAPHS OF SUBJECTS IN RELAXED DRIVING POSTURE USING ARMRESTS IN PREFERRED LOCATIONS

Key to Subject Numbers in Photographs




20105G
20105H
20105 S
20104G
20104H
20104 S
20101G
20101H
20101:S


20109G

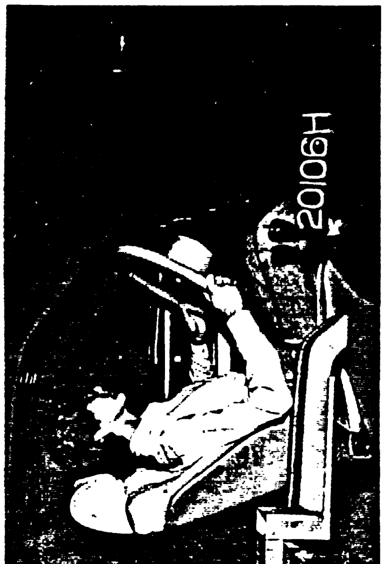
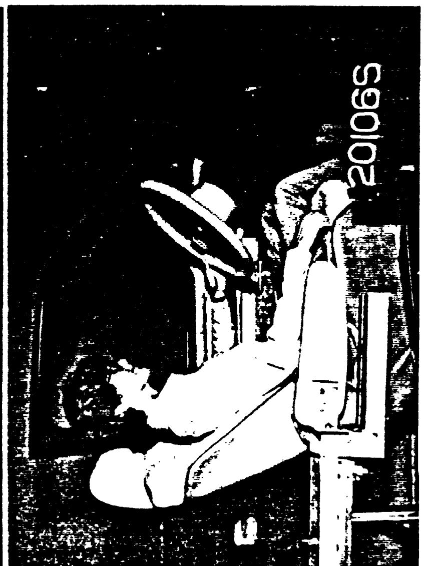
20109H

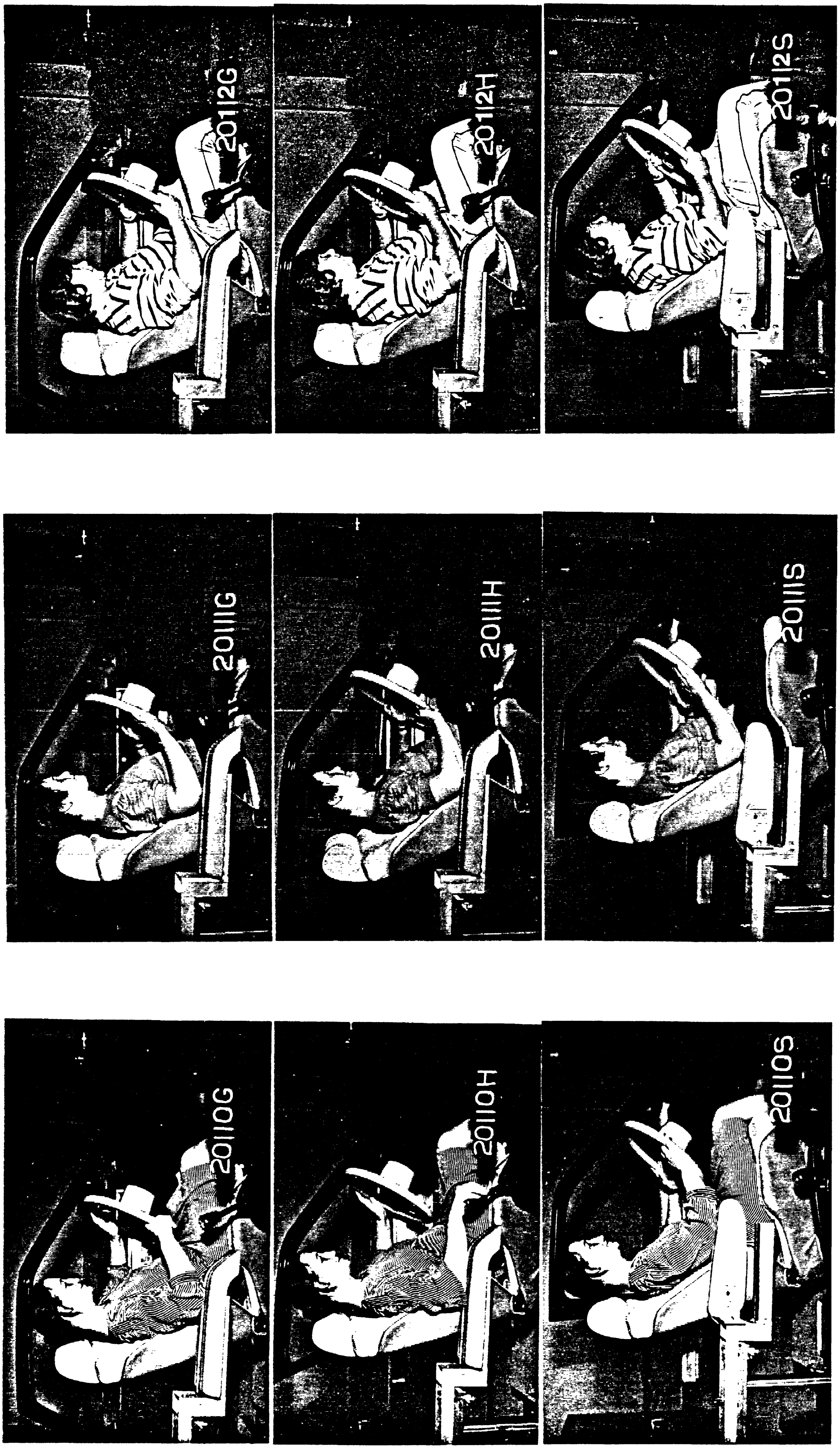
20109S

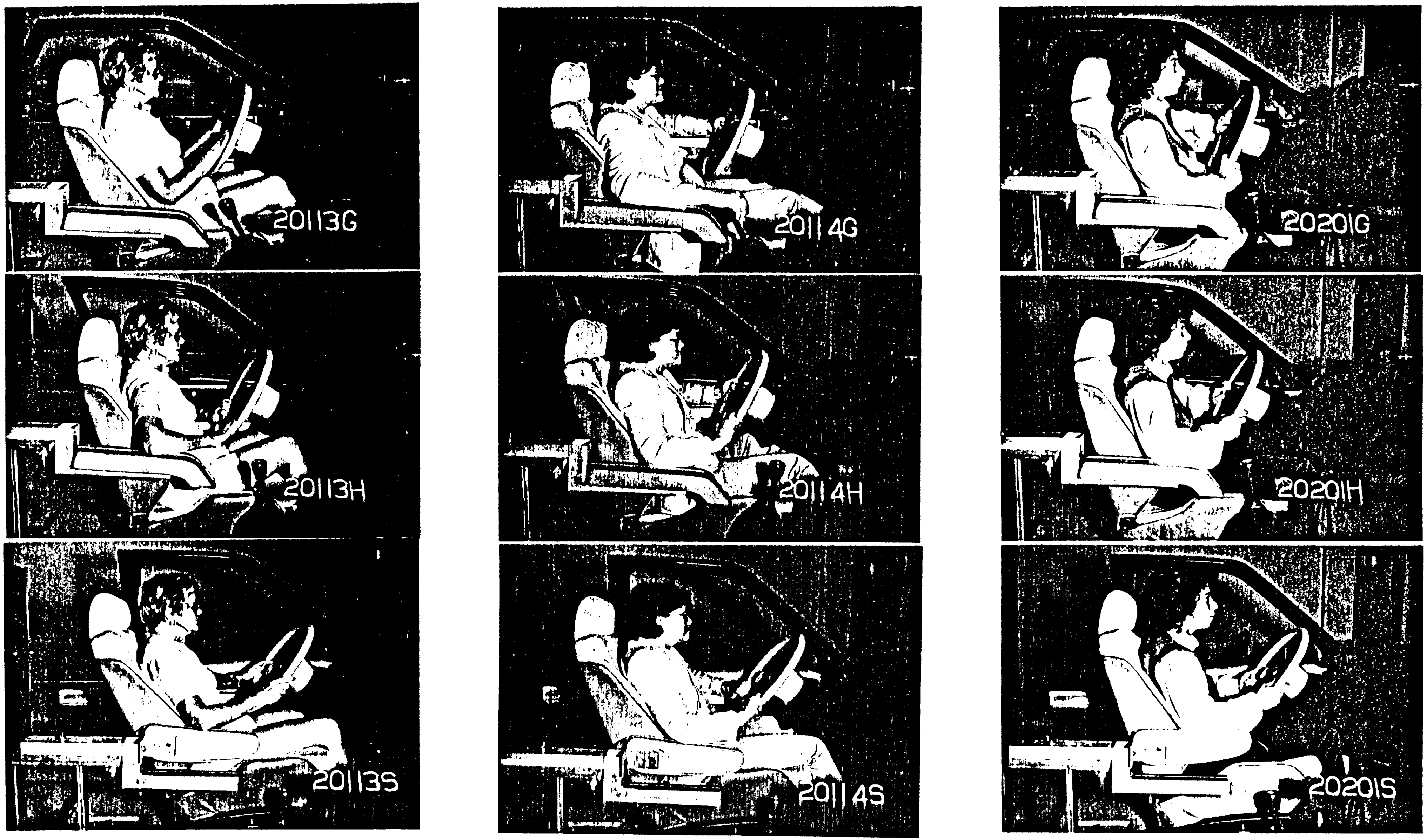
20107G

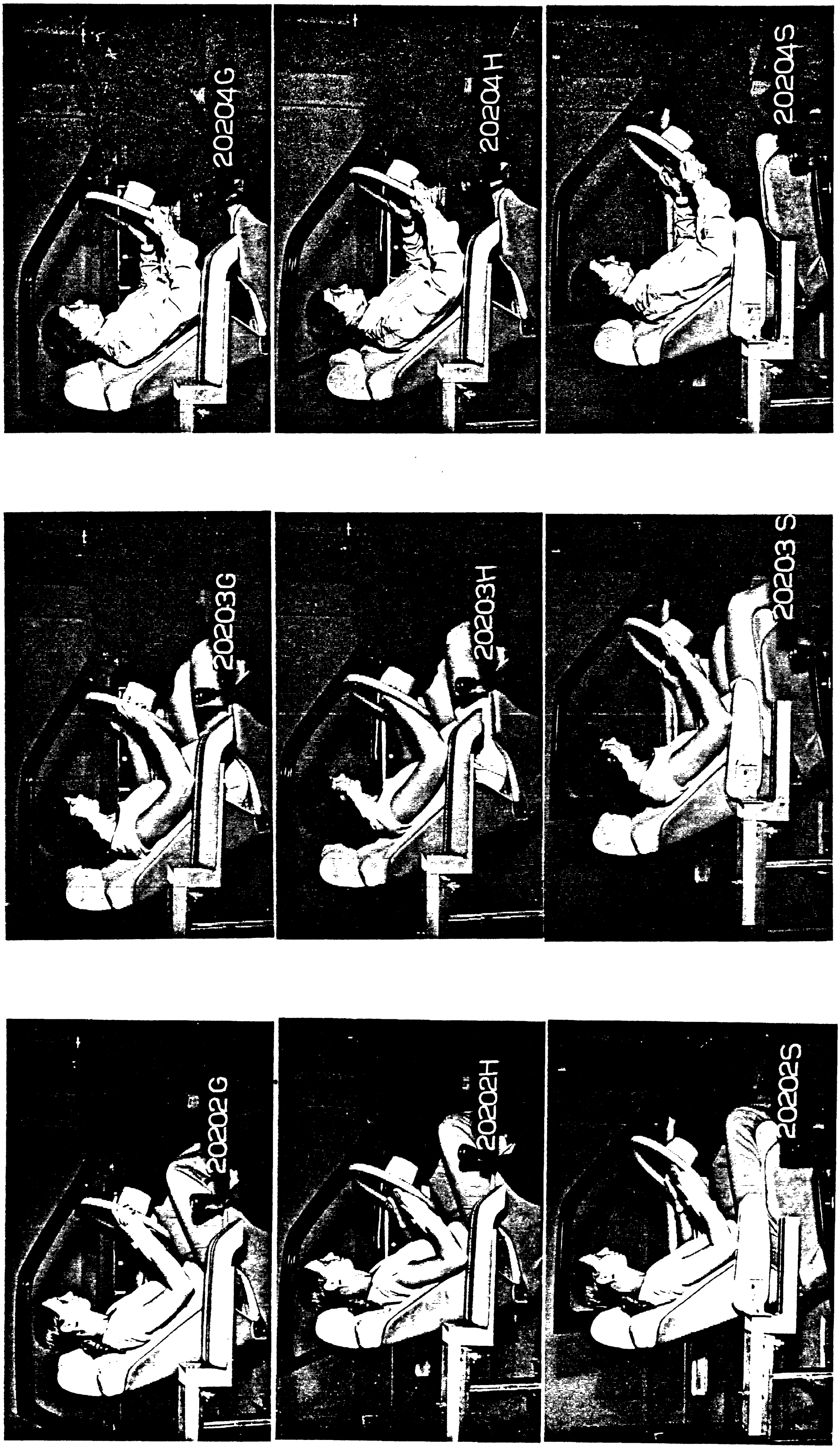
20107H

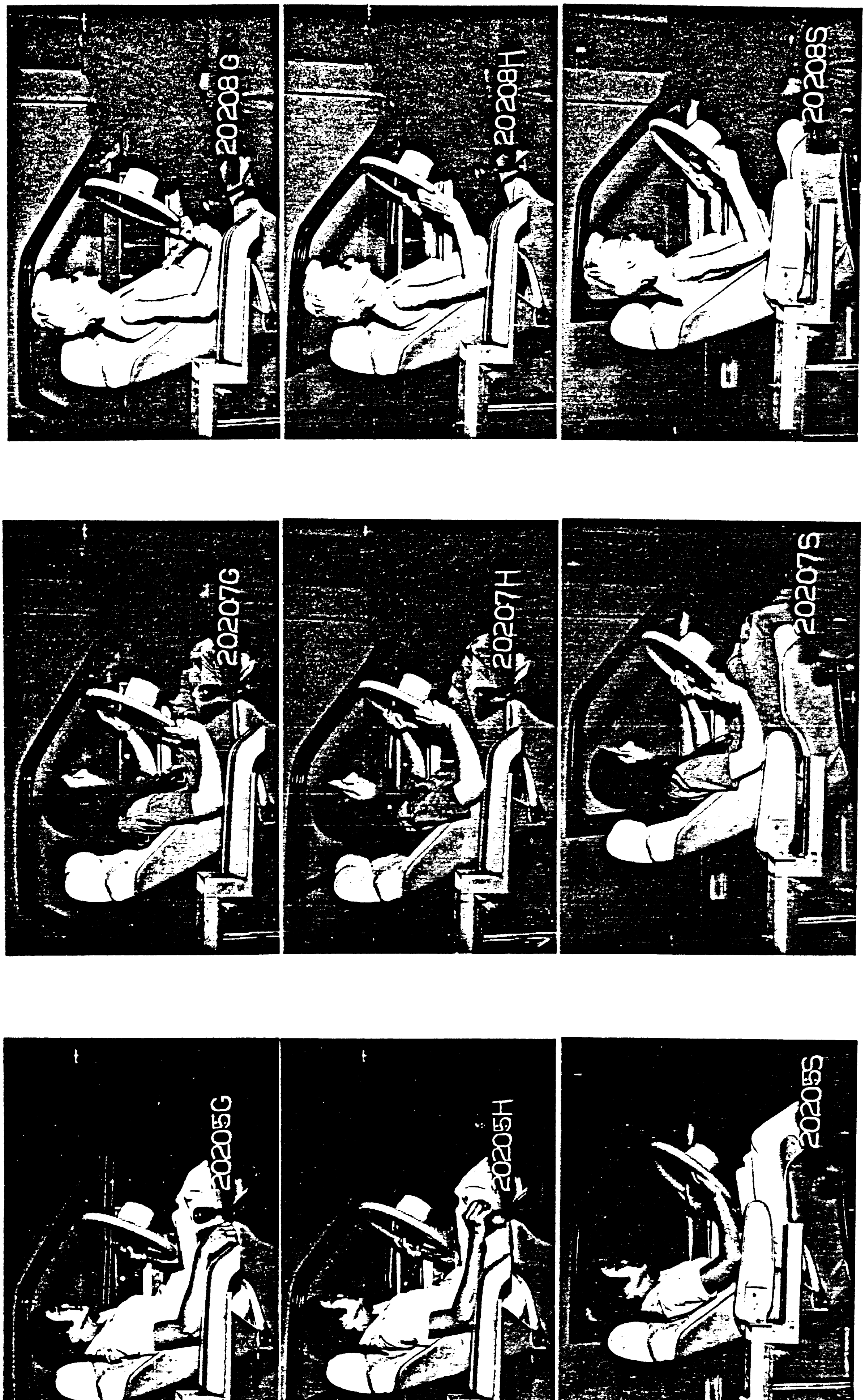
20107S

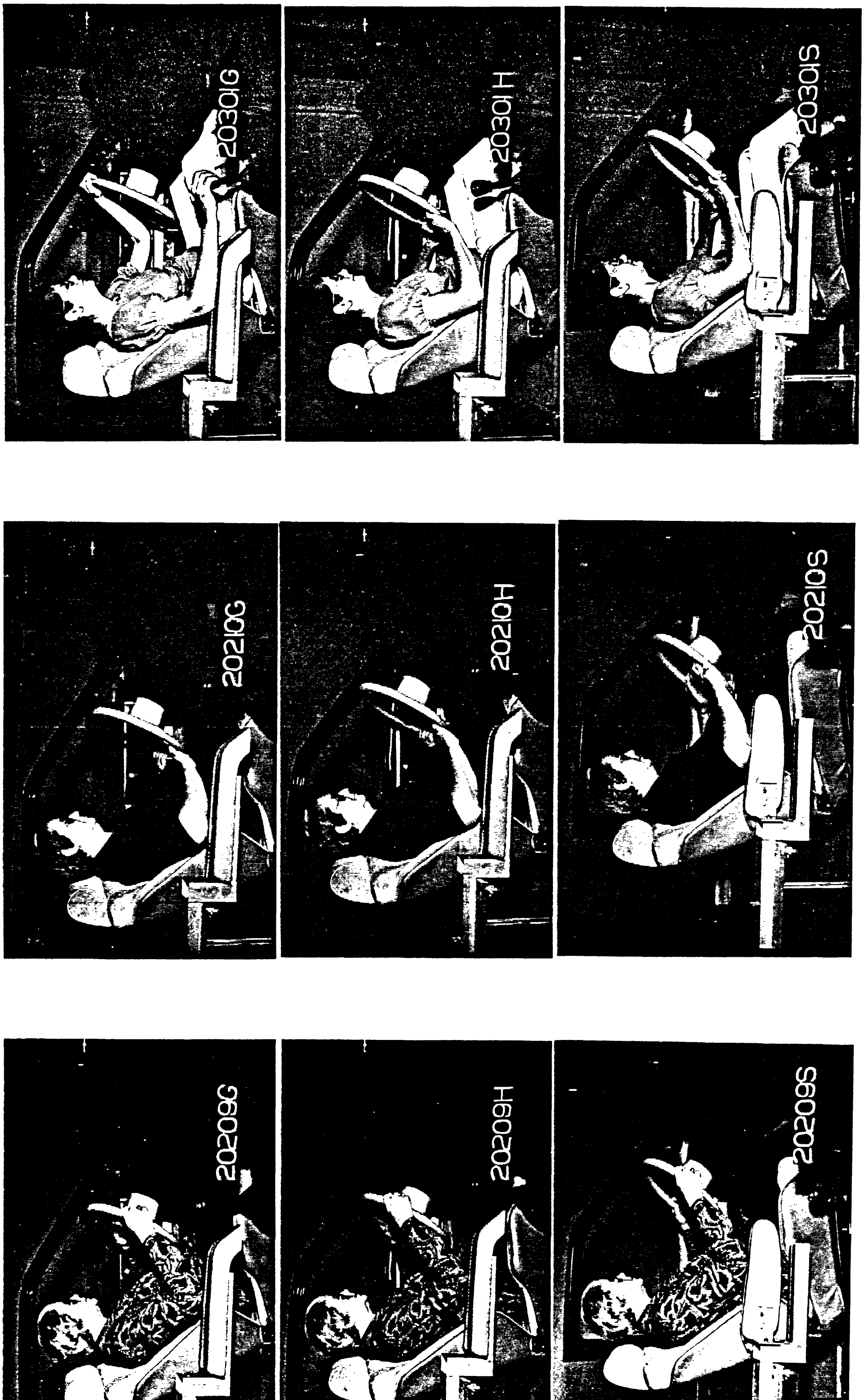
20106G

20106H

20106S

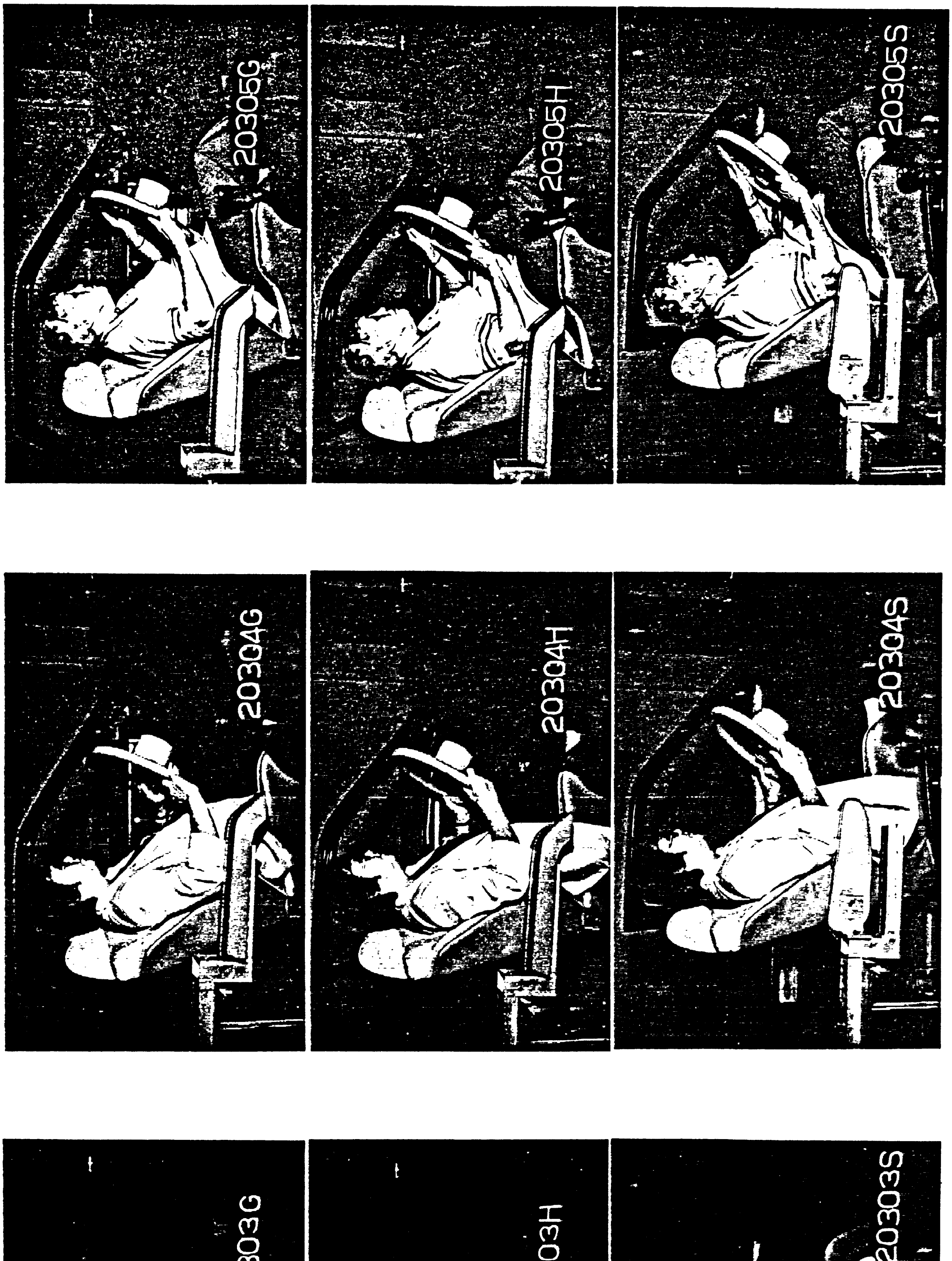

20112G
20112H
20112S
20111G
20111H
20111S
20110G
20110H
20110S

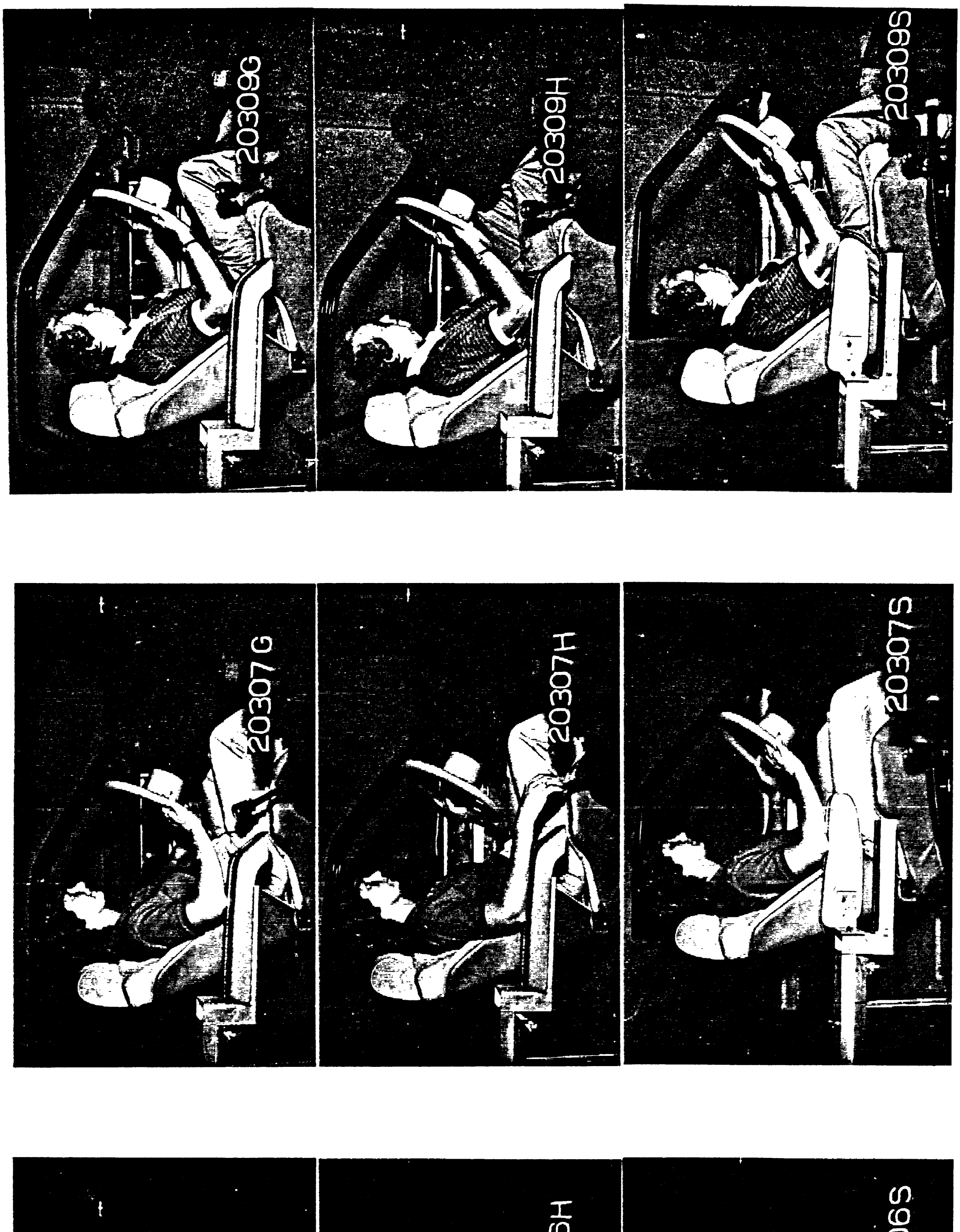

20113G
20113H
20113S
20114G
20114H
20114S
20201G
20201H
20201S

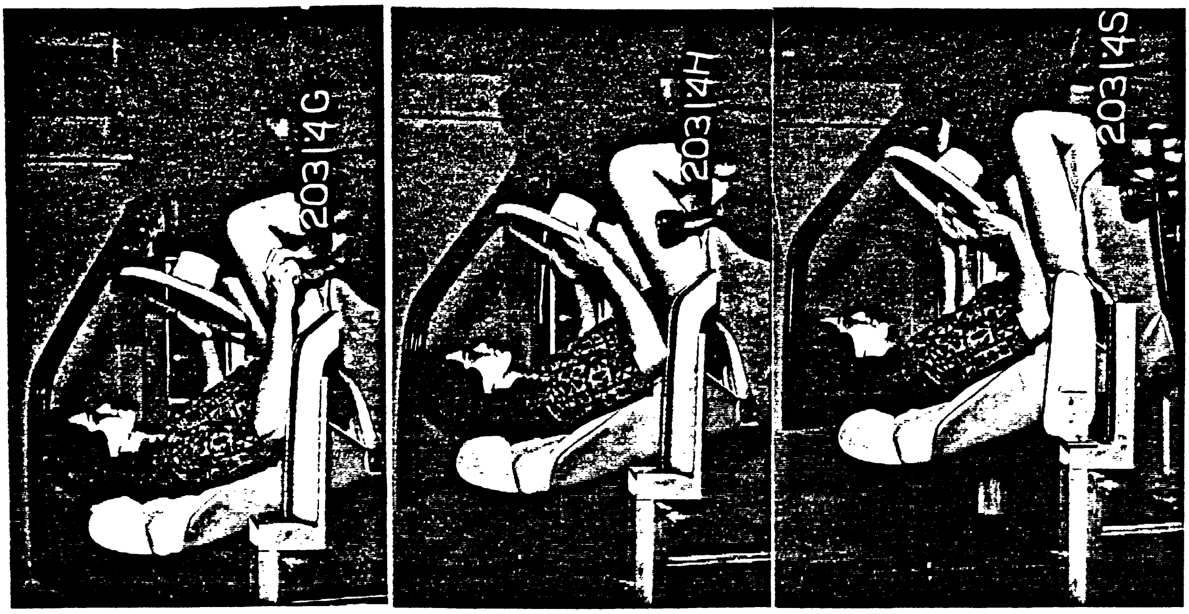

20204G
20204H
20204S
20203G
20203H
20203 S
20202 G
20202H
20202S

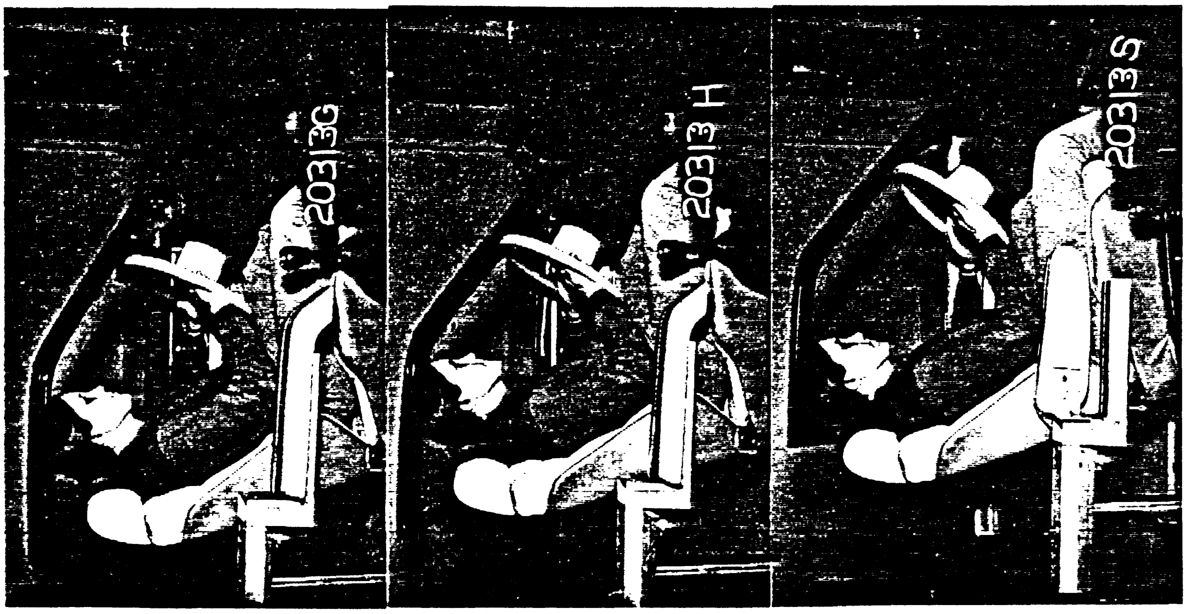

20208 G
20208H
20208S
20207G
20207H
20207S
20205G
20205H
20205S

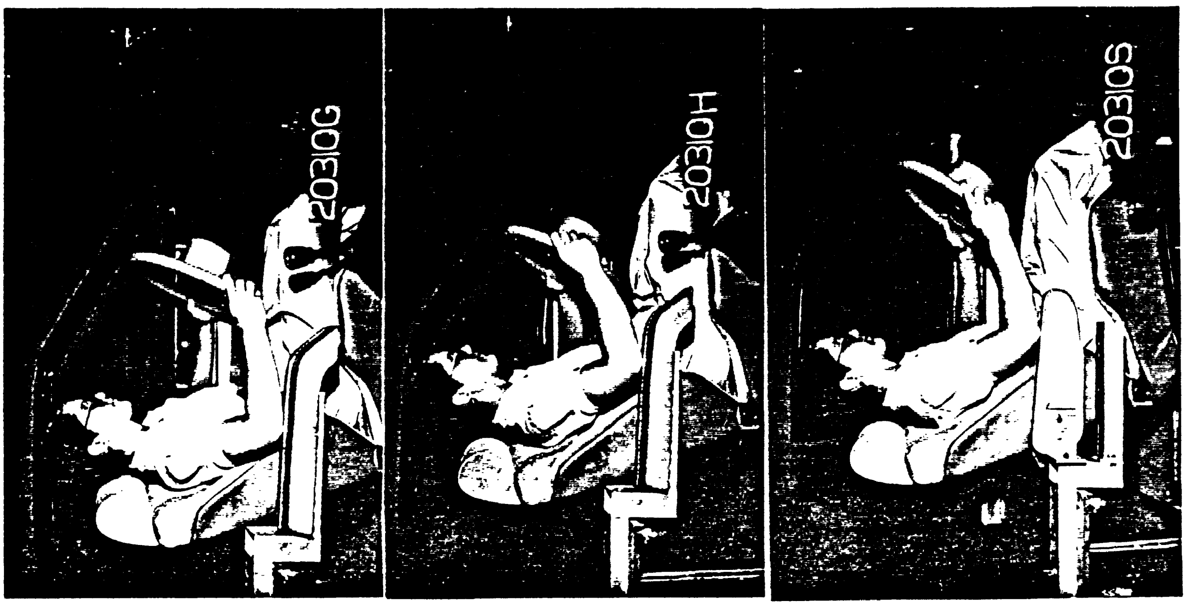

20301G
20301H
20301S
20210G
20210H
20210S
20209G
20209H
20209S

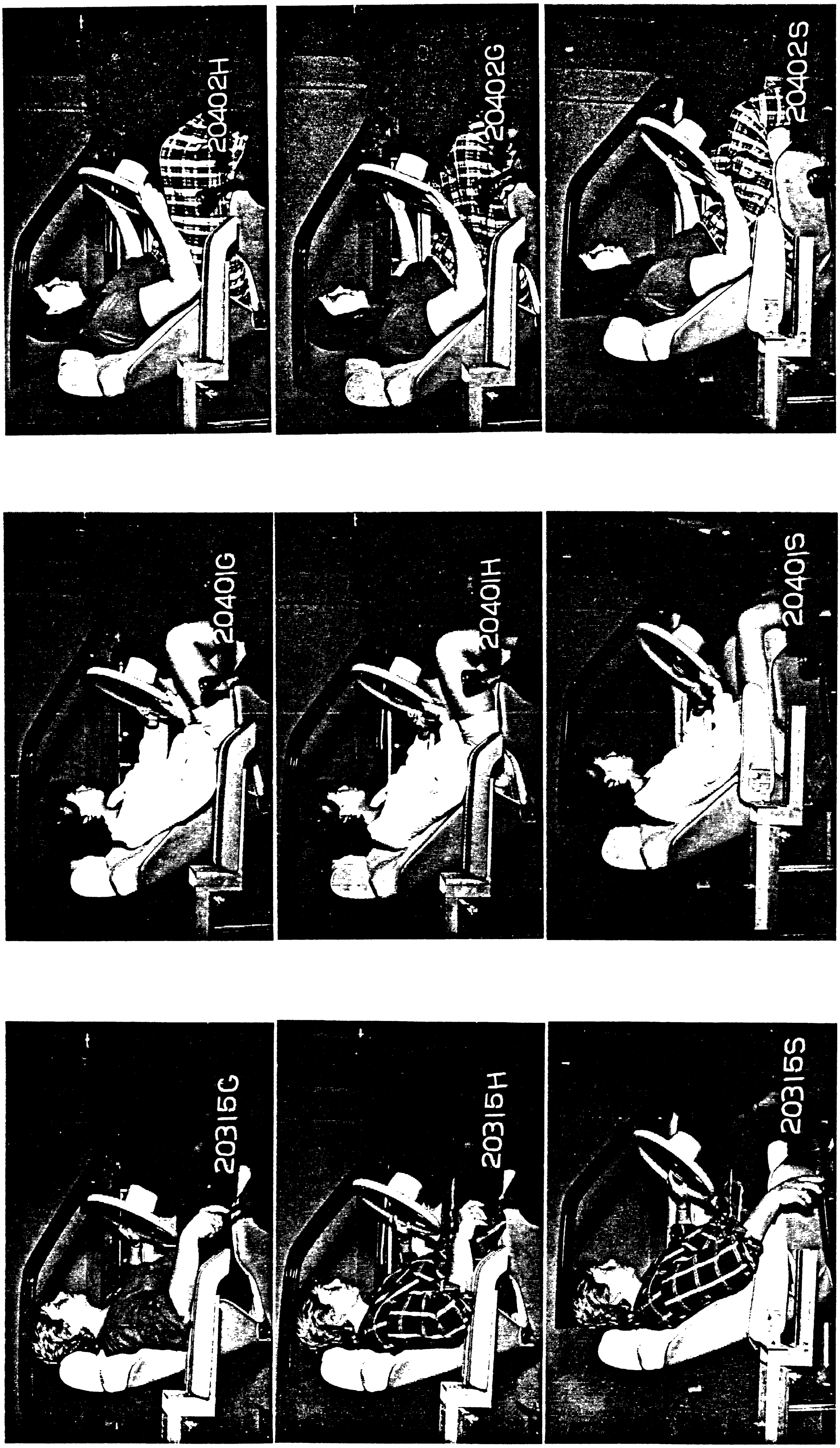

20303G
20303H
20303S
20304G
20304H
20304S
20305G
20305H
20305S

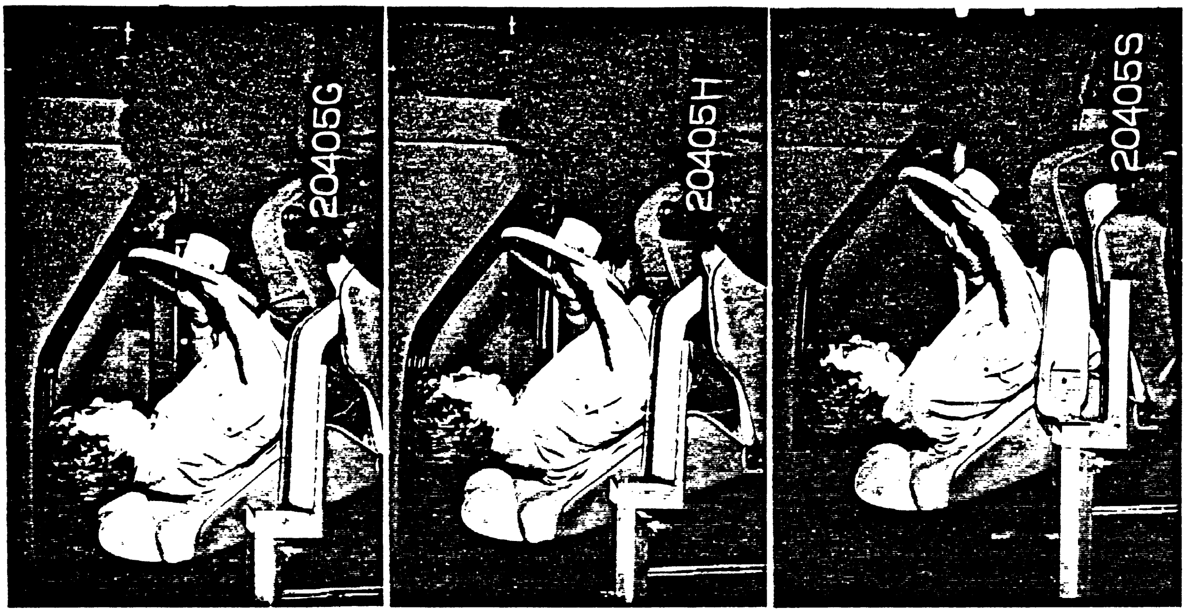

20309G
20309H
20309S
20307G
20307H
20307S
20306G
20306H
20306S

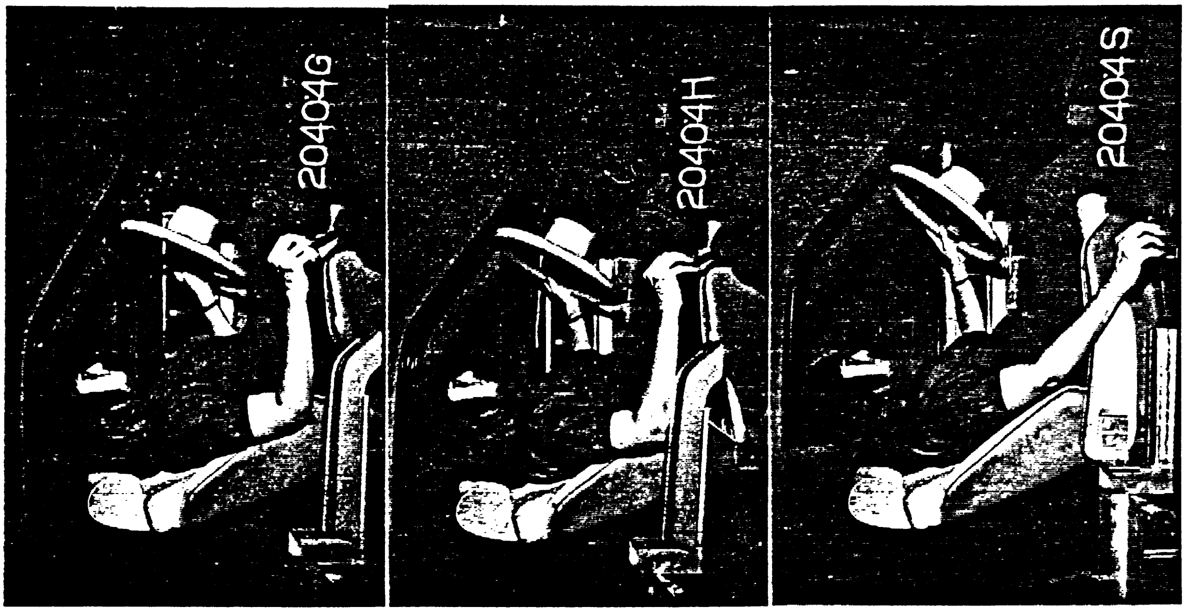

20314G
20314H
20314S

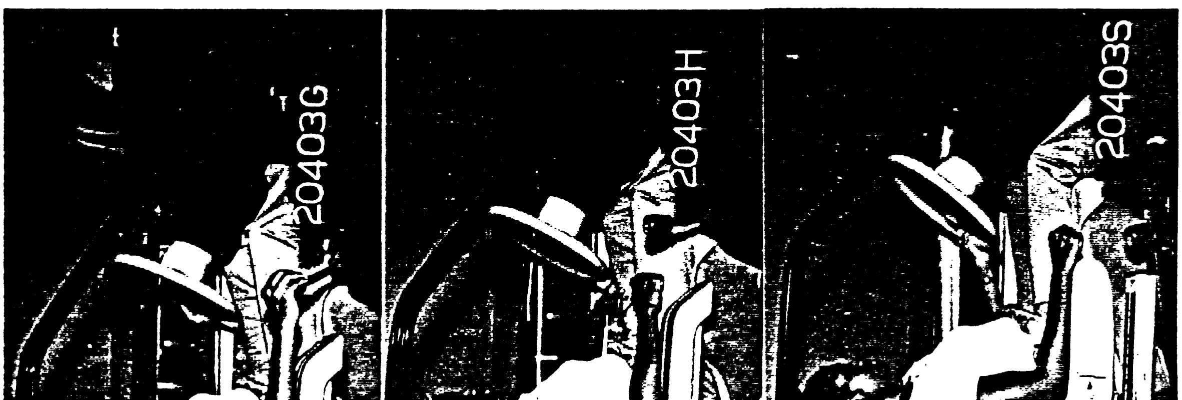

20313G
20313 H
20313 S

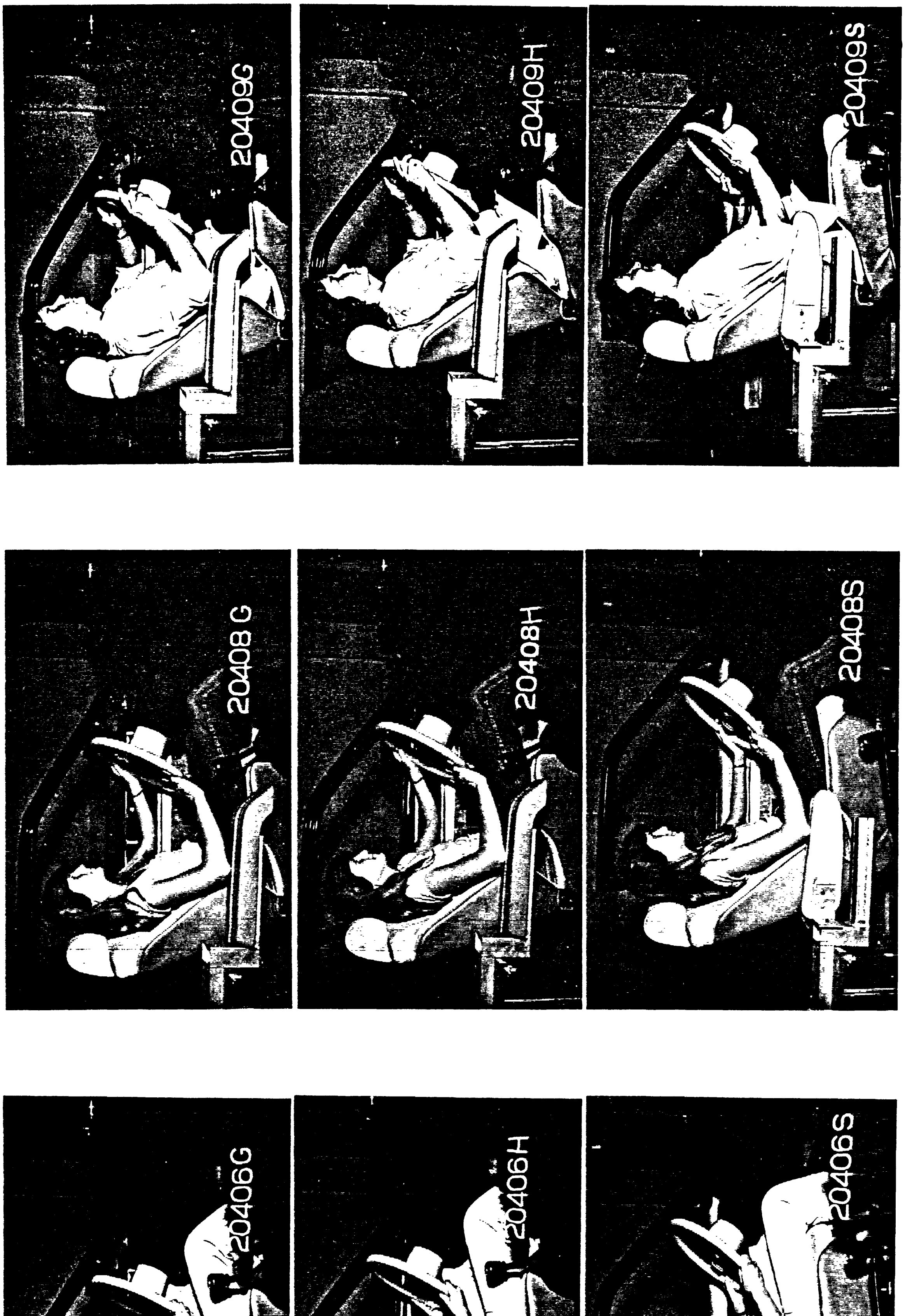

20310G
20310H
20310S

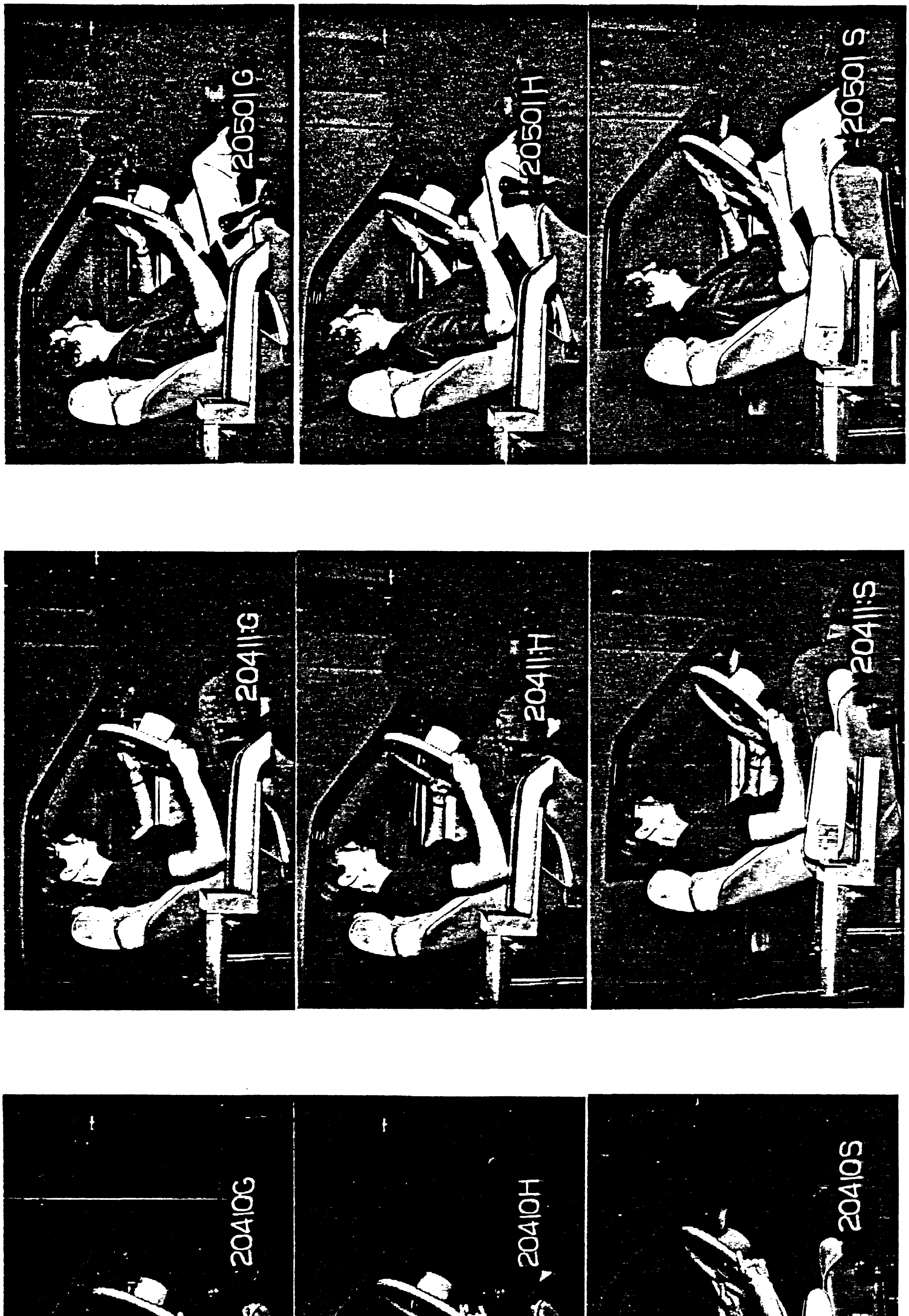

20402H
20402G
20402S
20401G
20401H
20401S
20315G
20315H
20315S

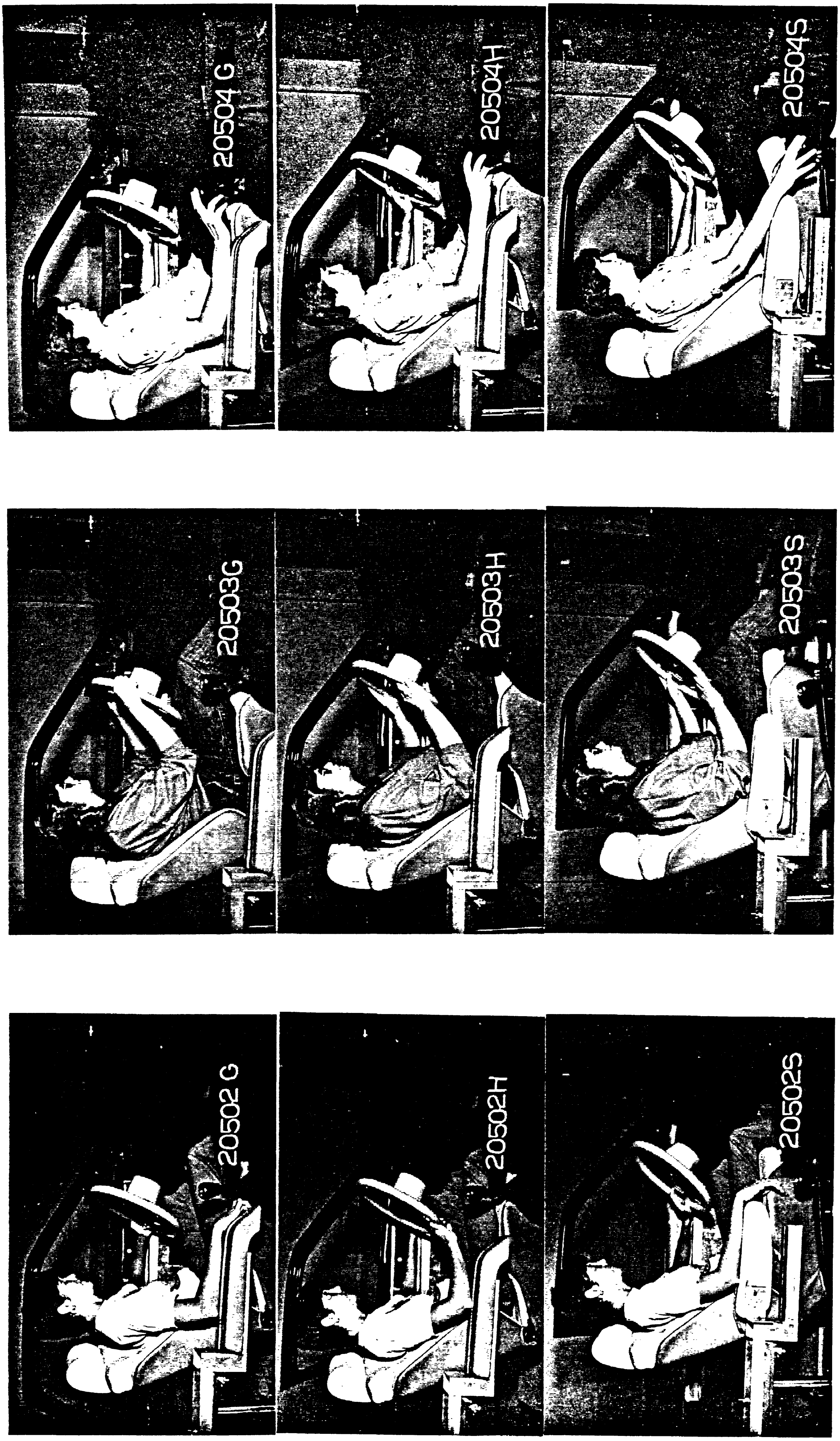

20405G
20405H
20405S

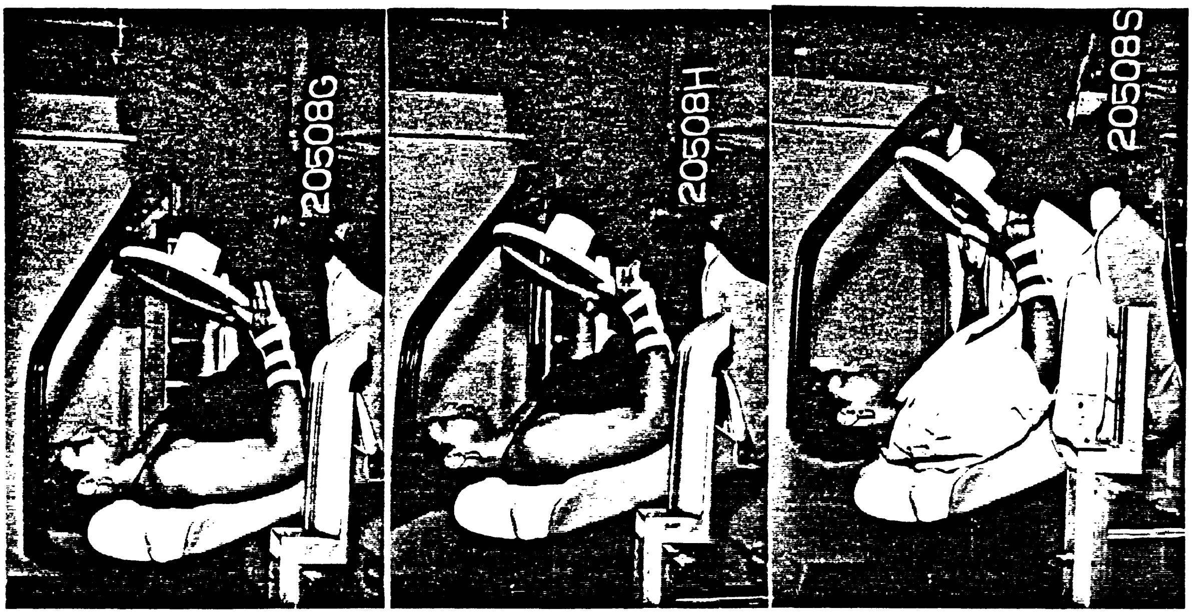

20404G
20404H
20404S

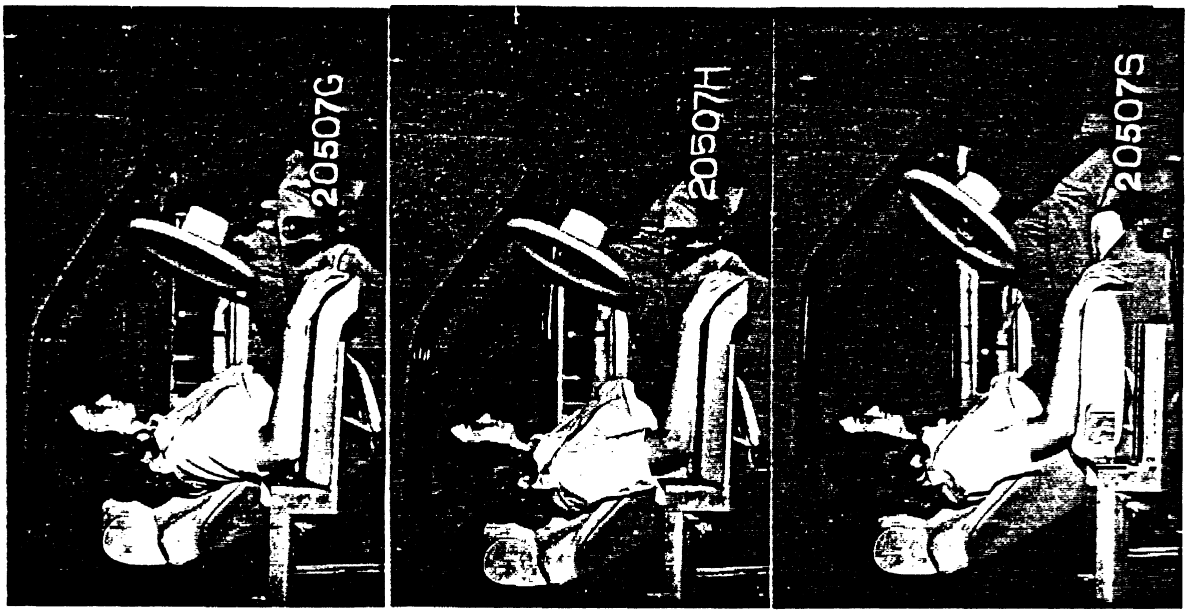

20403G
20403H
20403S

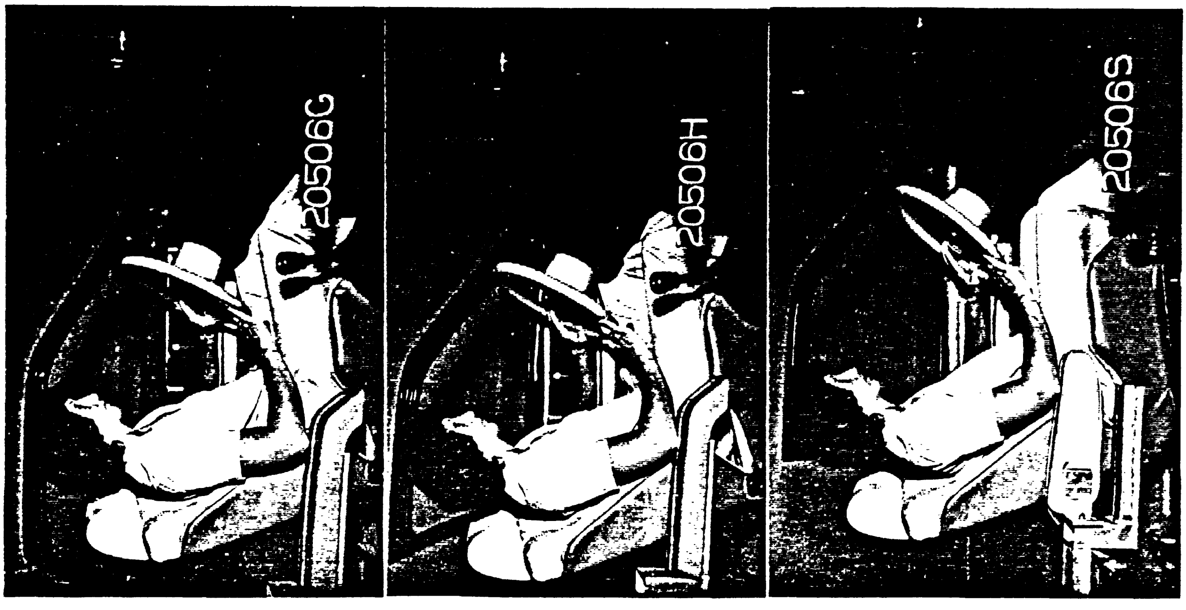

20406G
20406H
20406S
20408 G
20408H
20408S
20409G
20409H
20409S

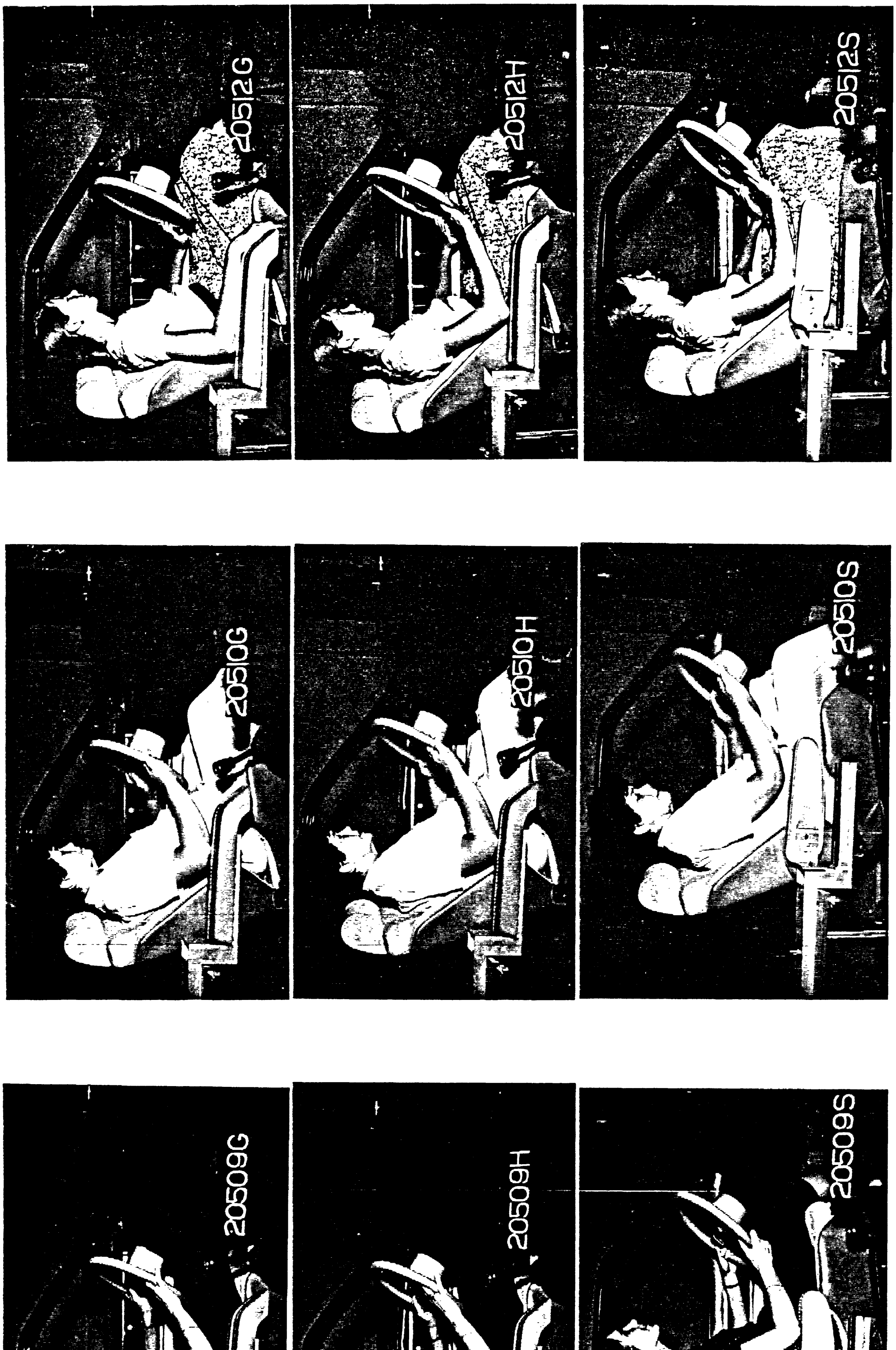

20501G
20501H
20501S
20411G
20411H
20411S
20410G
20410H
20410S

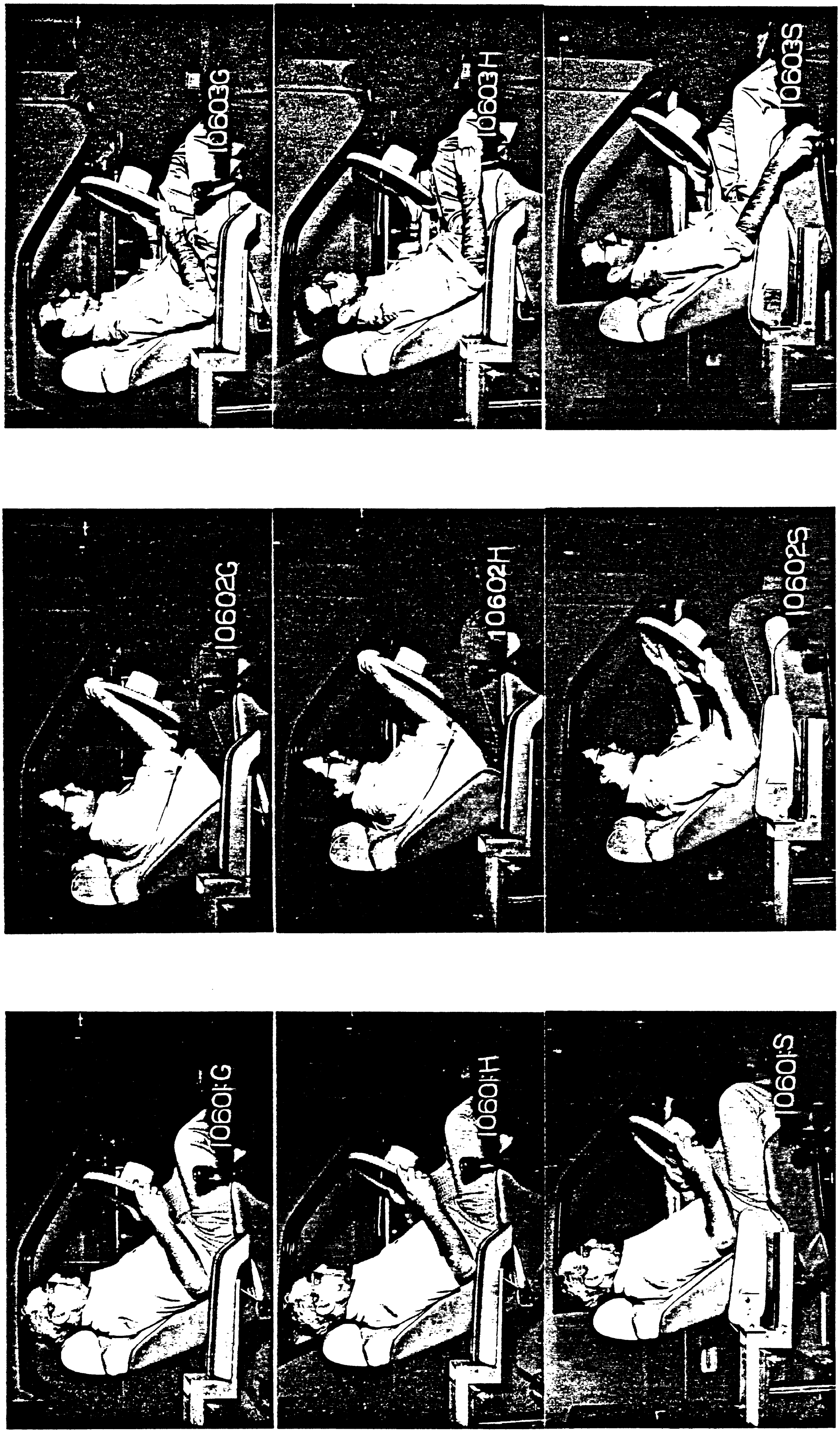

20502 G
20502H
20502S
20503G
20503H
20503S
20504 G
20504H
20504S

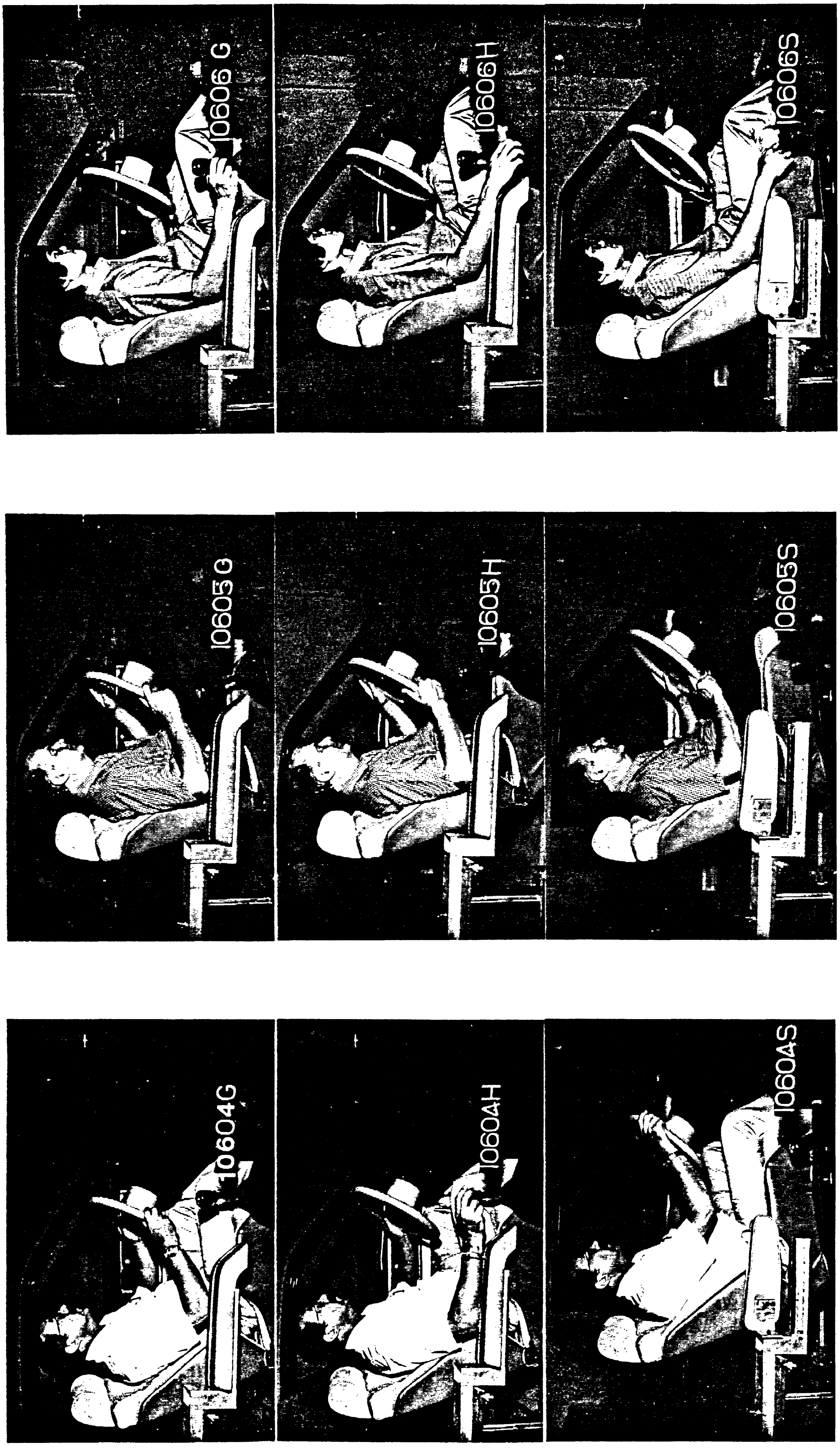

20508G
20508H
20508S

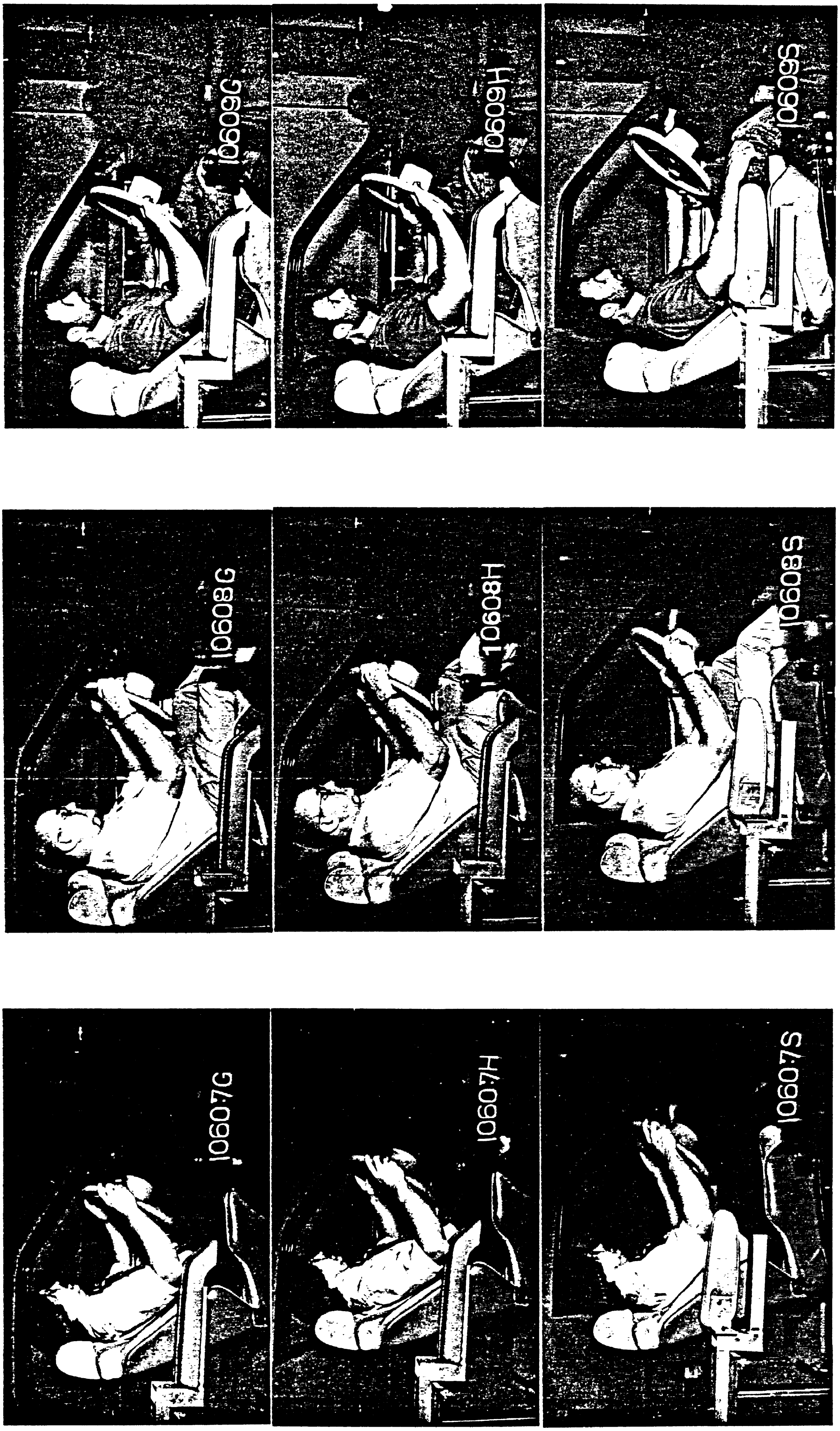

20507G
20507H
20507S

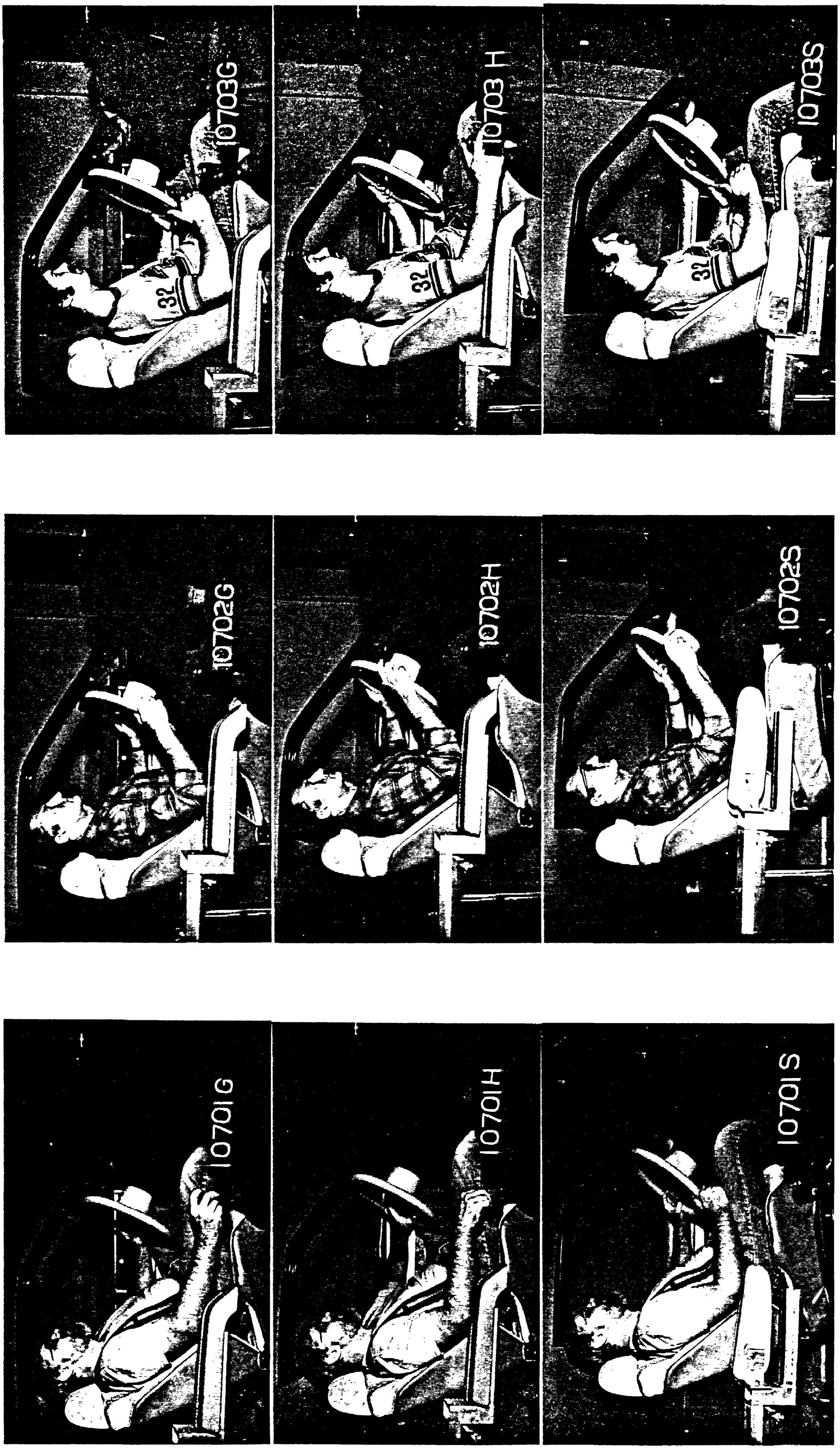

20506G
20506H
20506S

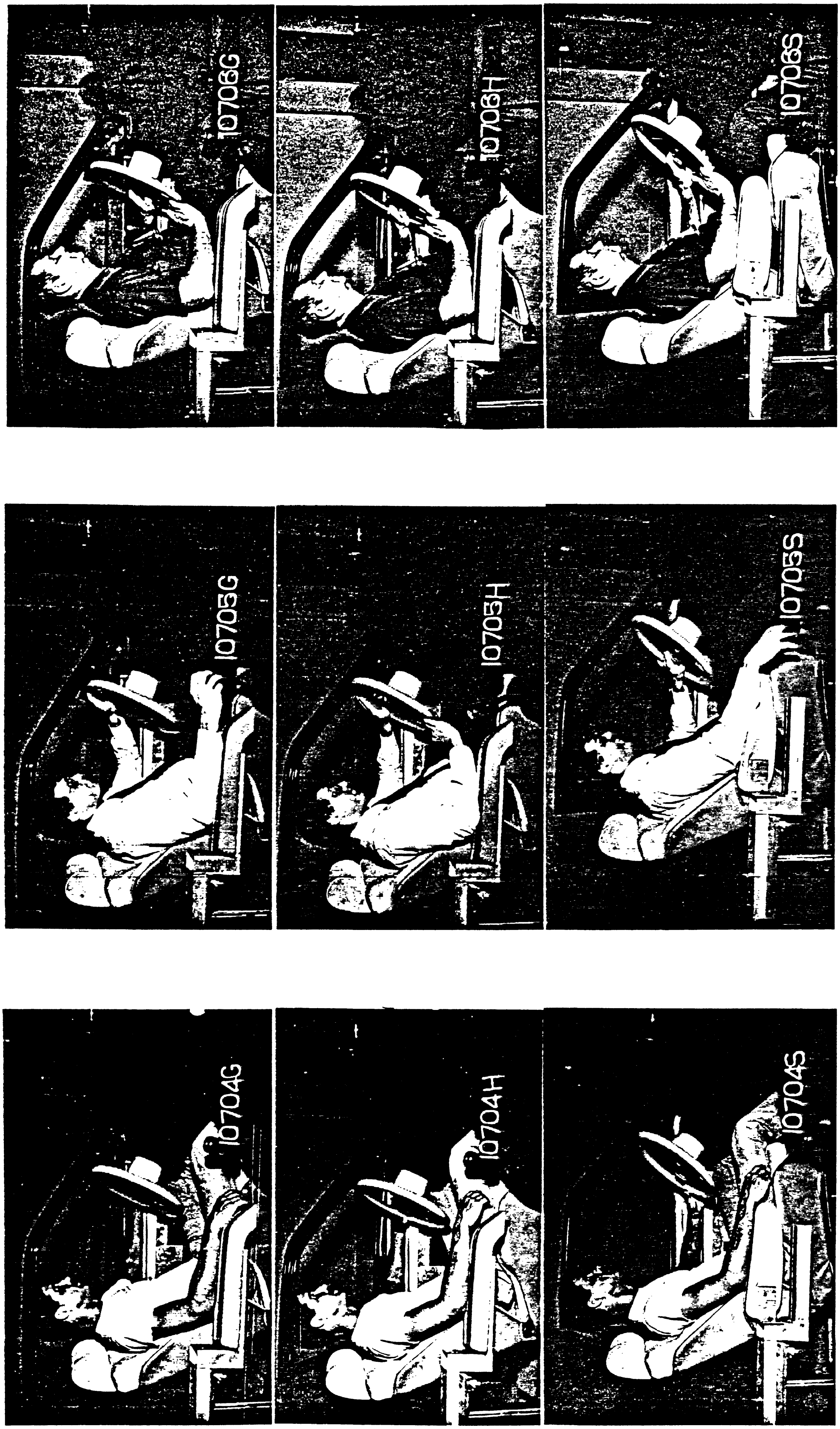

20512G
20512H
20512S
20510G
20510H
20510S
20509G
20509H
20509S

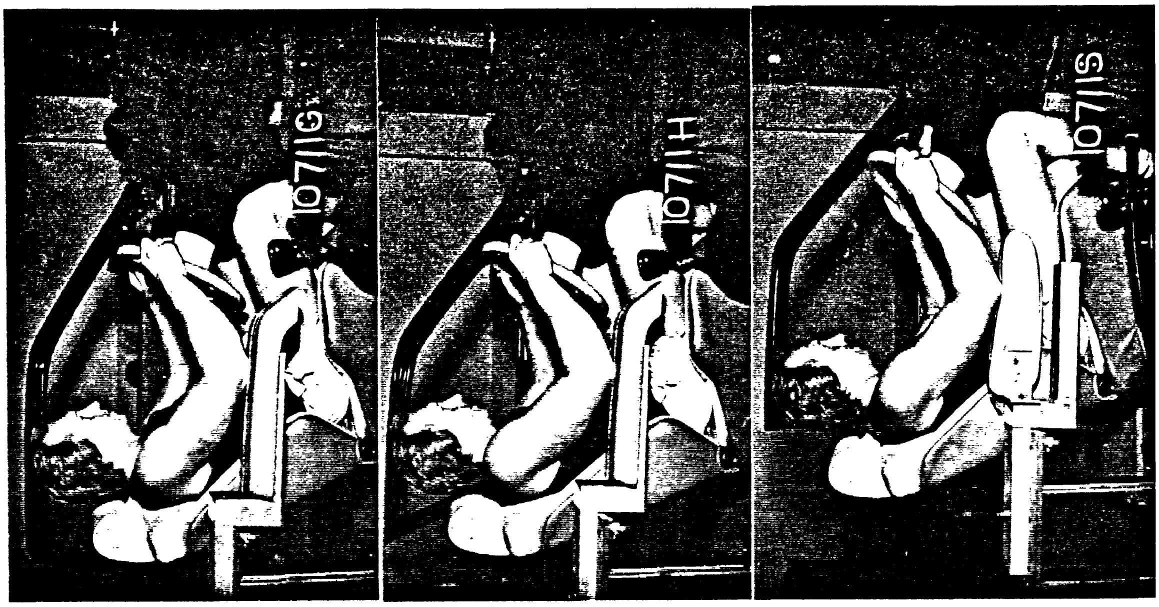

10603G
10603H
10603S
10602G
10602H
10602S
10601G
10601H
10601S

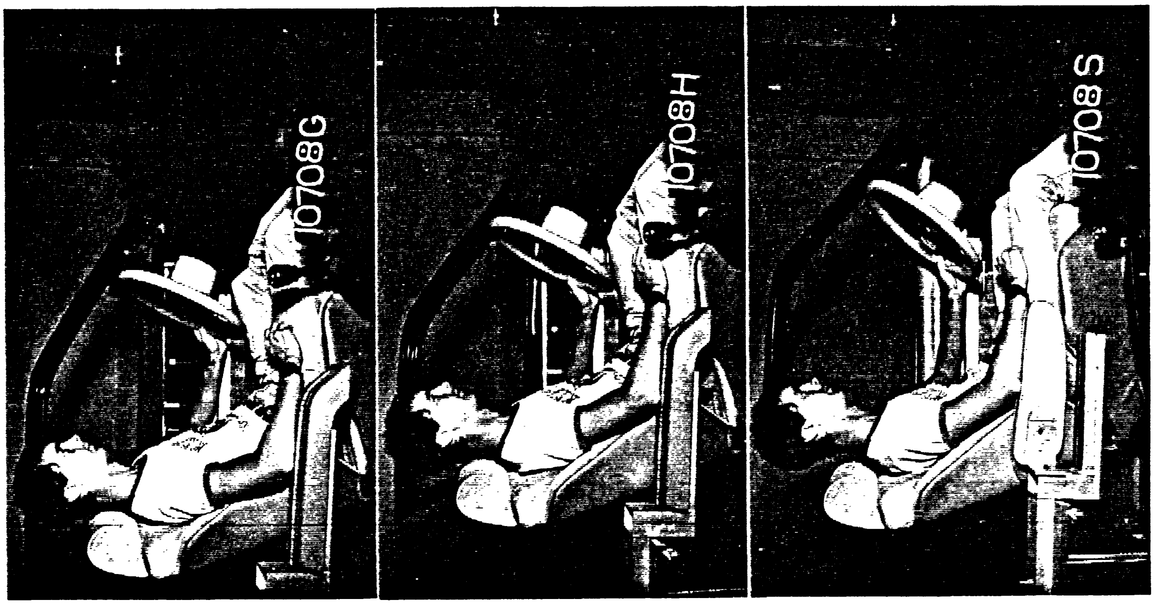

10606 G
10606H
10606S
10605 G
10605H
10605S
10604G
10604H
10604S


10609G
10609H
10609S
10608G
10608H
10608S
10607G
10607H
10607S

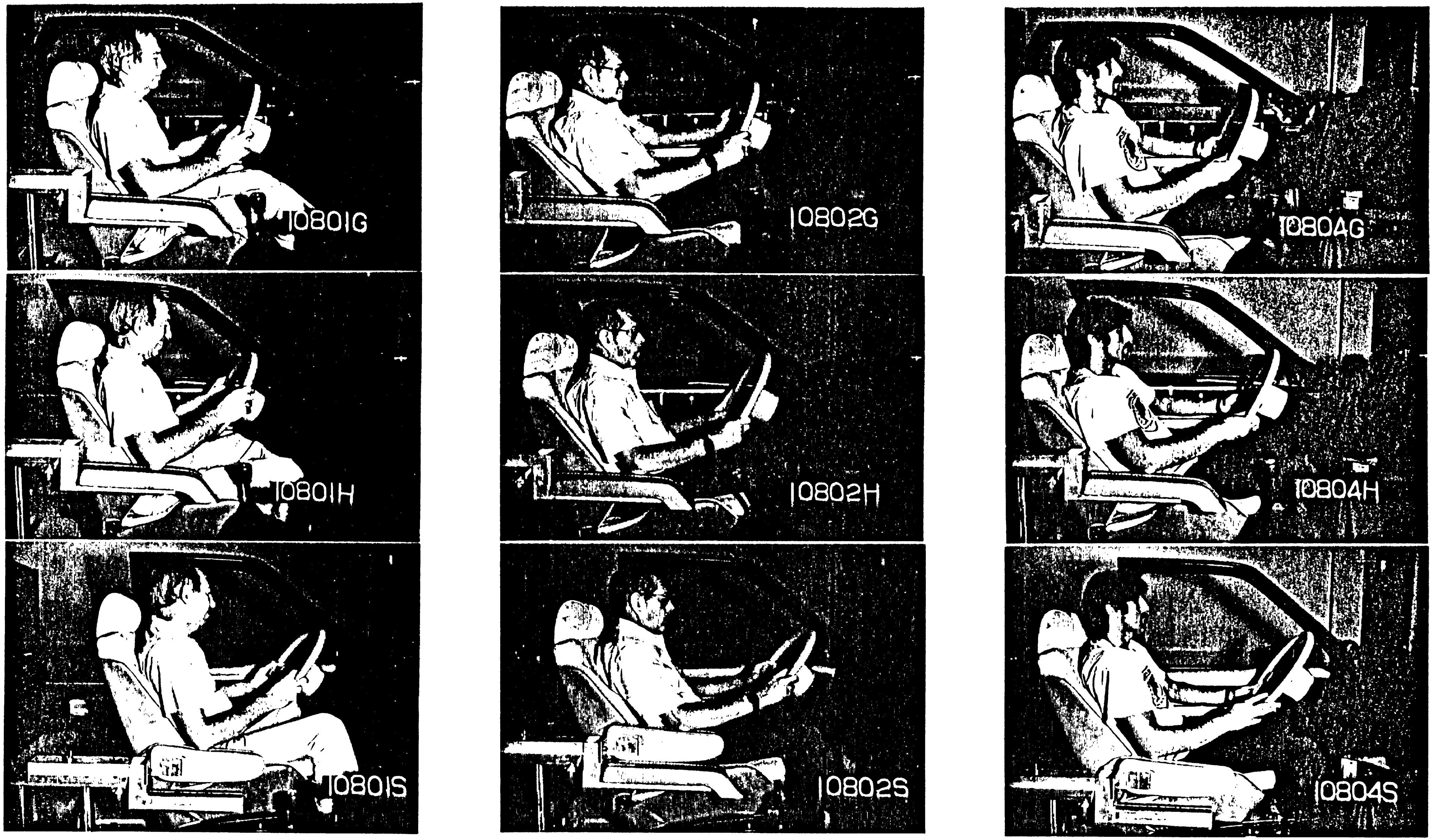

10703G
10703 H
10703S
10702G
10702H
10702S
10701G
10701H
10701S


10706G
10706H
10706S
10705G
10705H
10705S
10704G
10704H
10704S

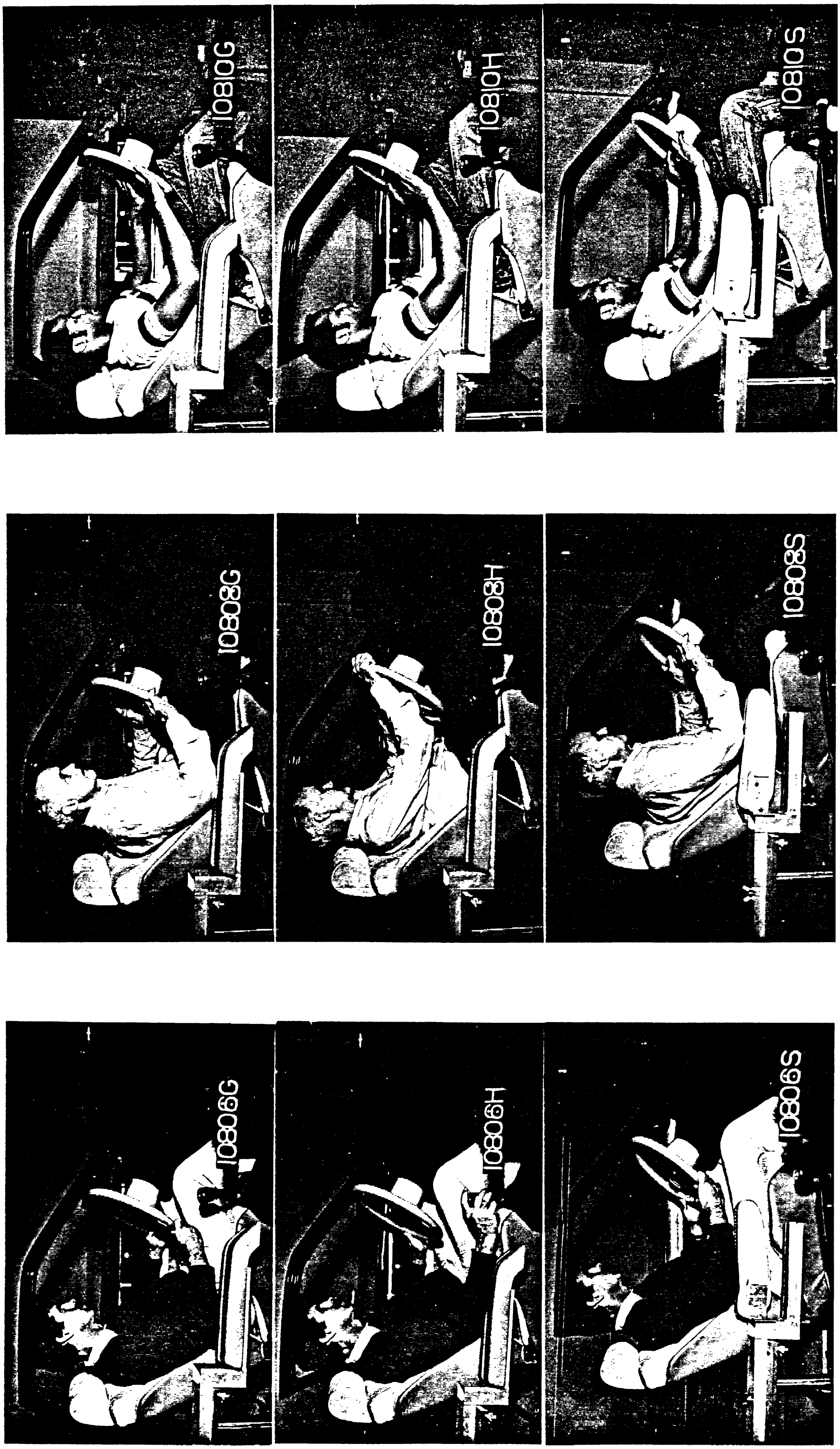

10711G
10711H
10711S

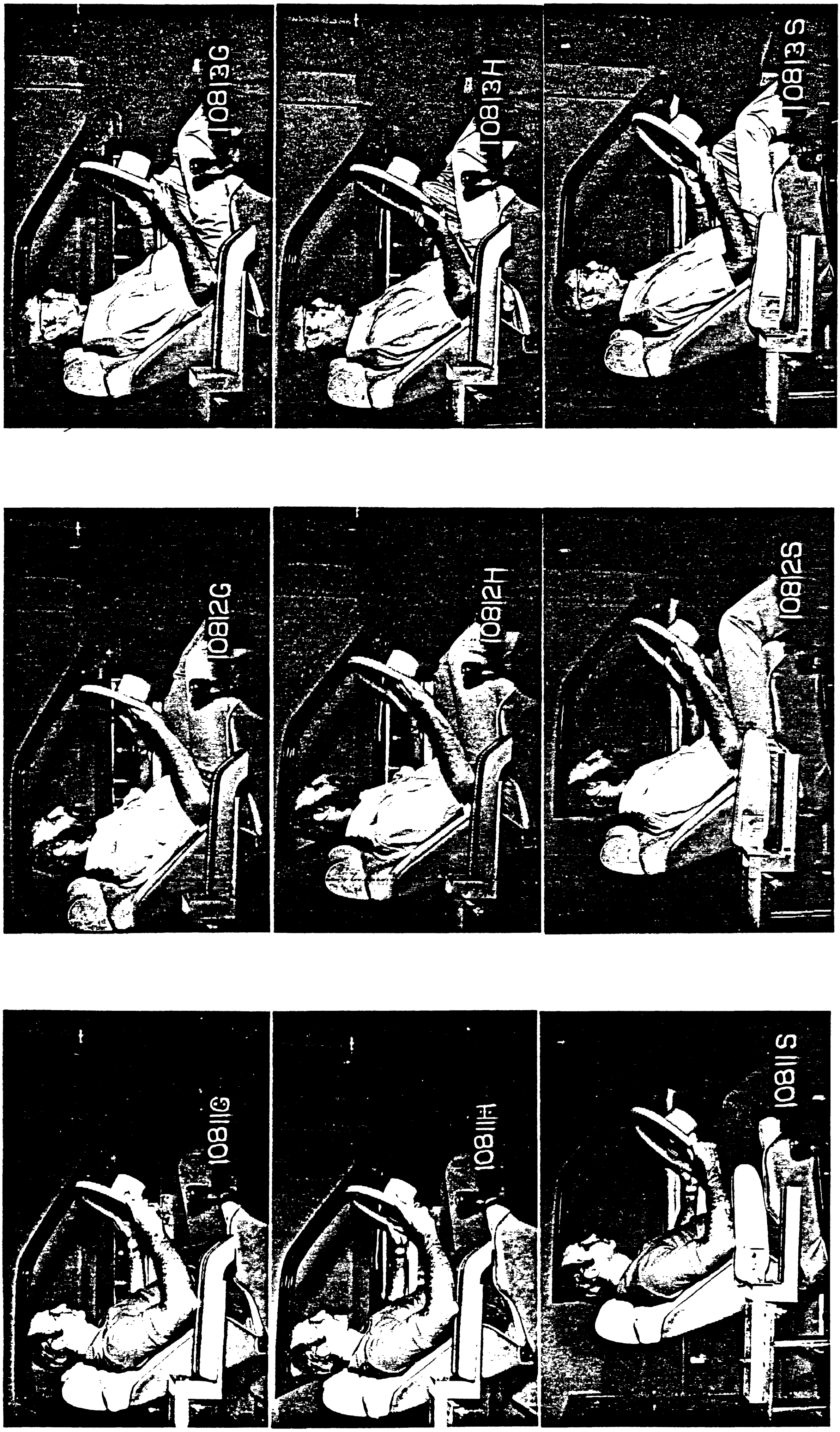

10708G
10708H
10708S

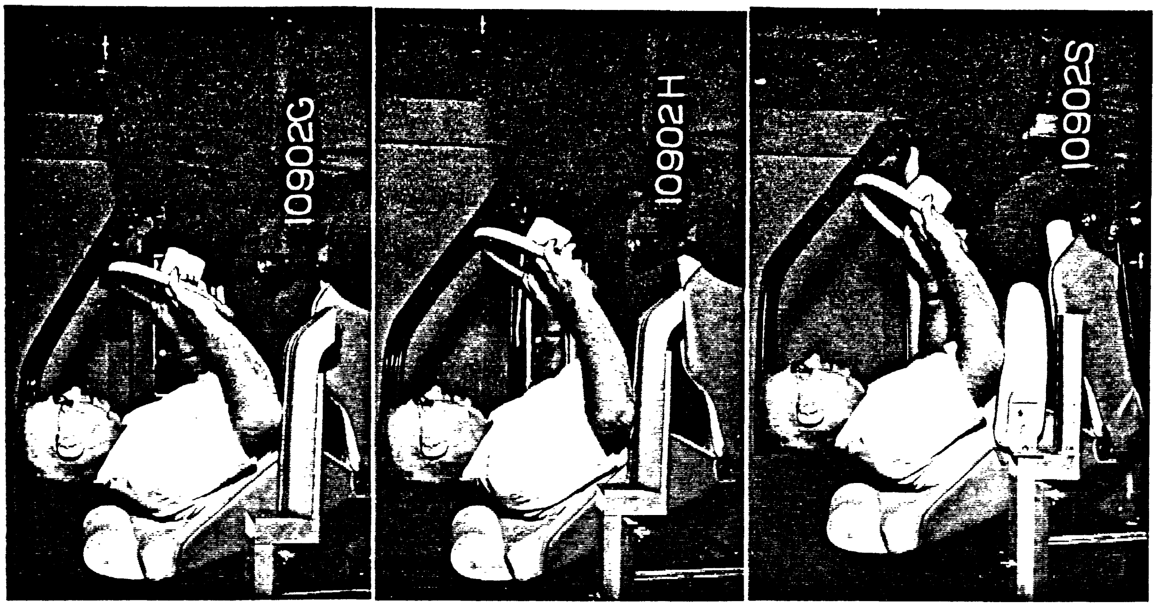

10707G
10707H
10707S

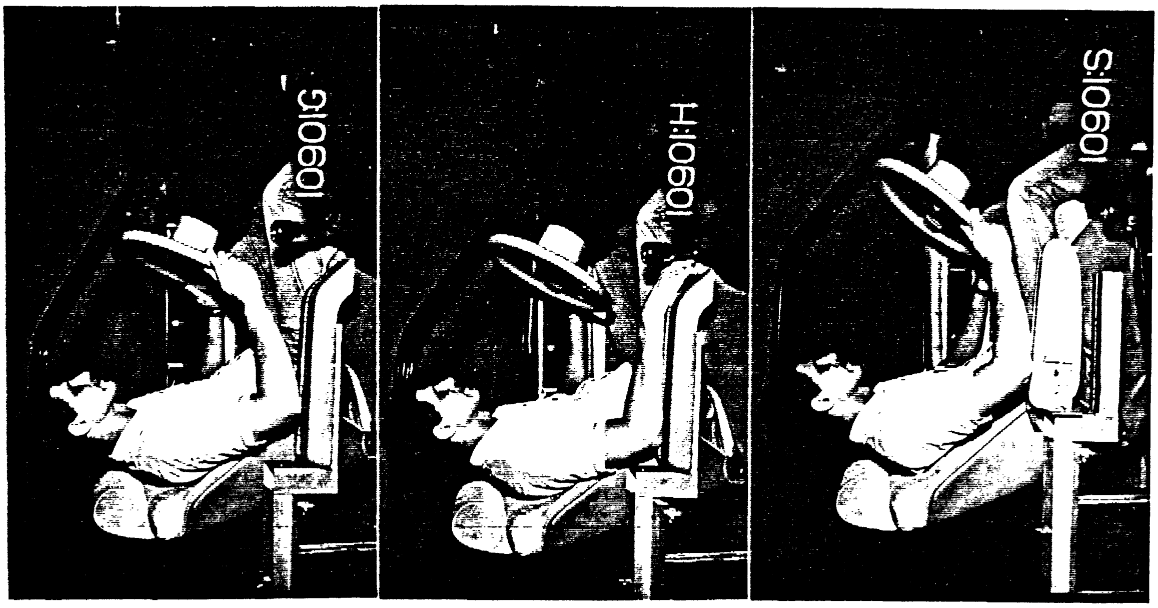


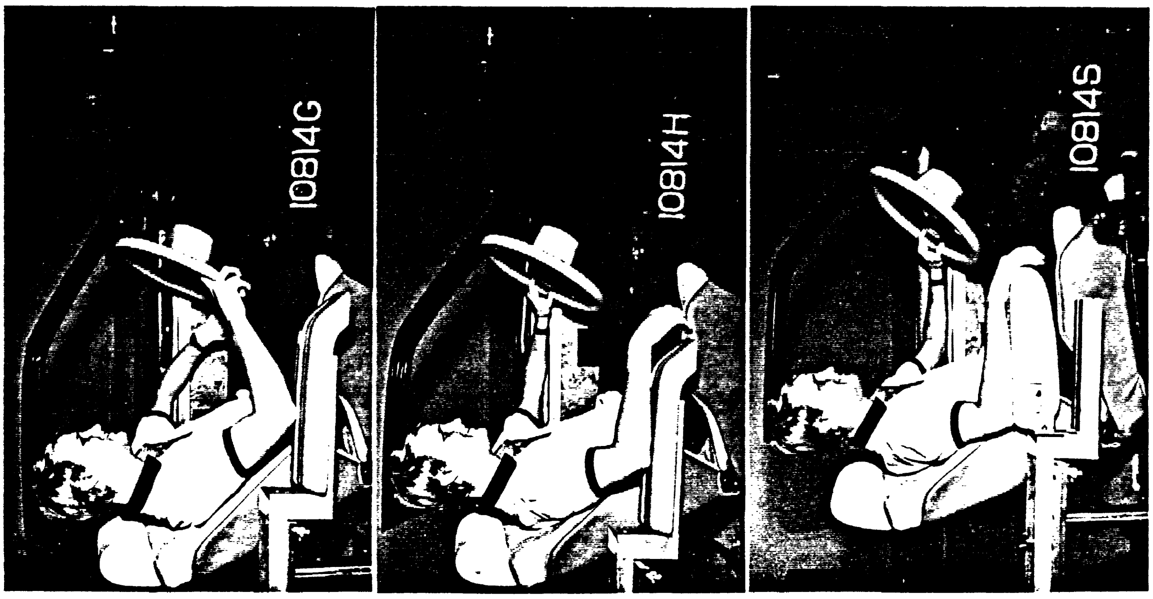
I0801G
I0802G
I0804G
I0801H
I0802H
I0804H
I0801S
I0802S
I0804S

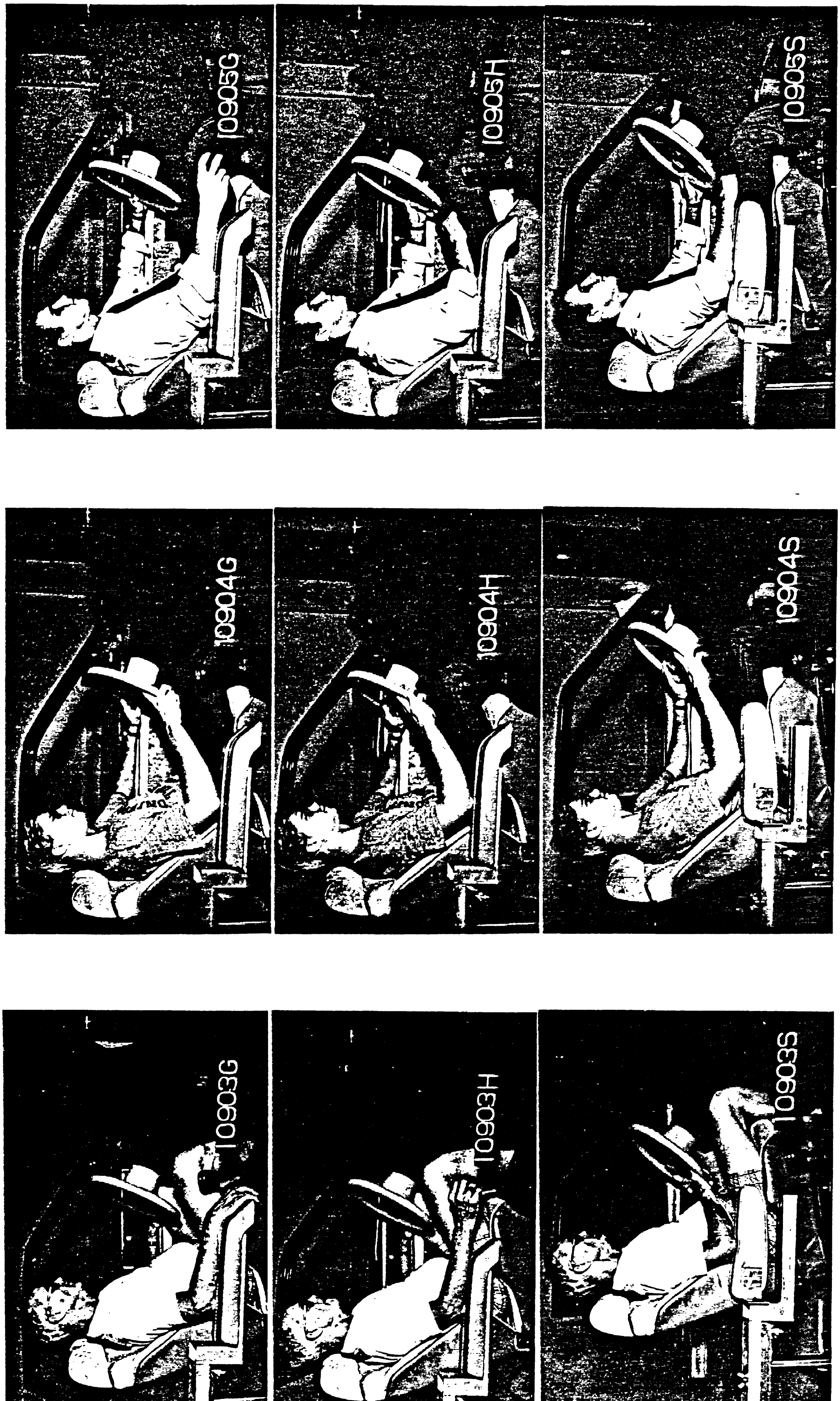

10810G
10810H
10810S
10808G
10808H
10808S
10806G
10806H
10806S

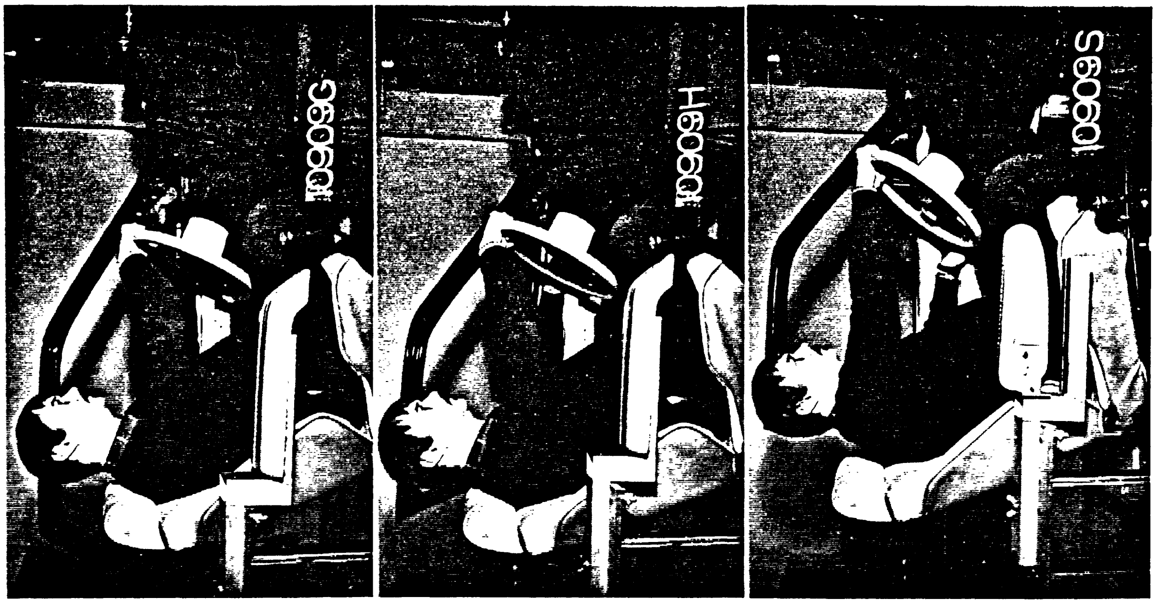

10813G
10813H
10813S
10812G
10812H
10812S
10811G
10811H
10811S

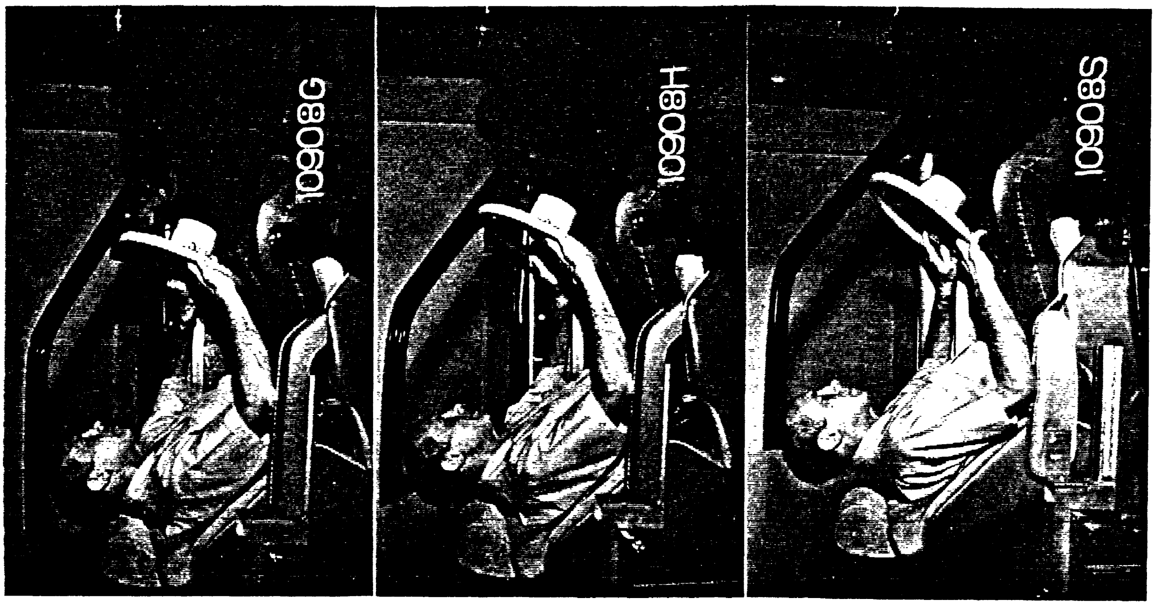

10902G
10902H
10902S

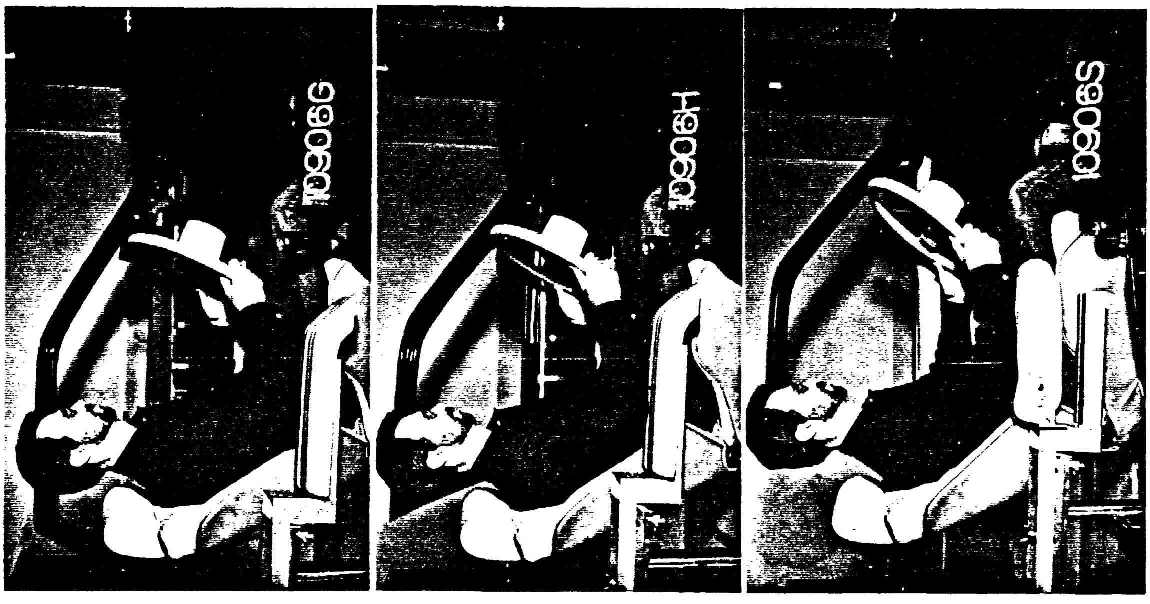

10901G
10901:H
10901:S

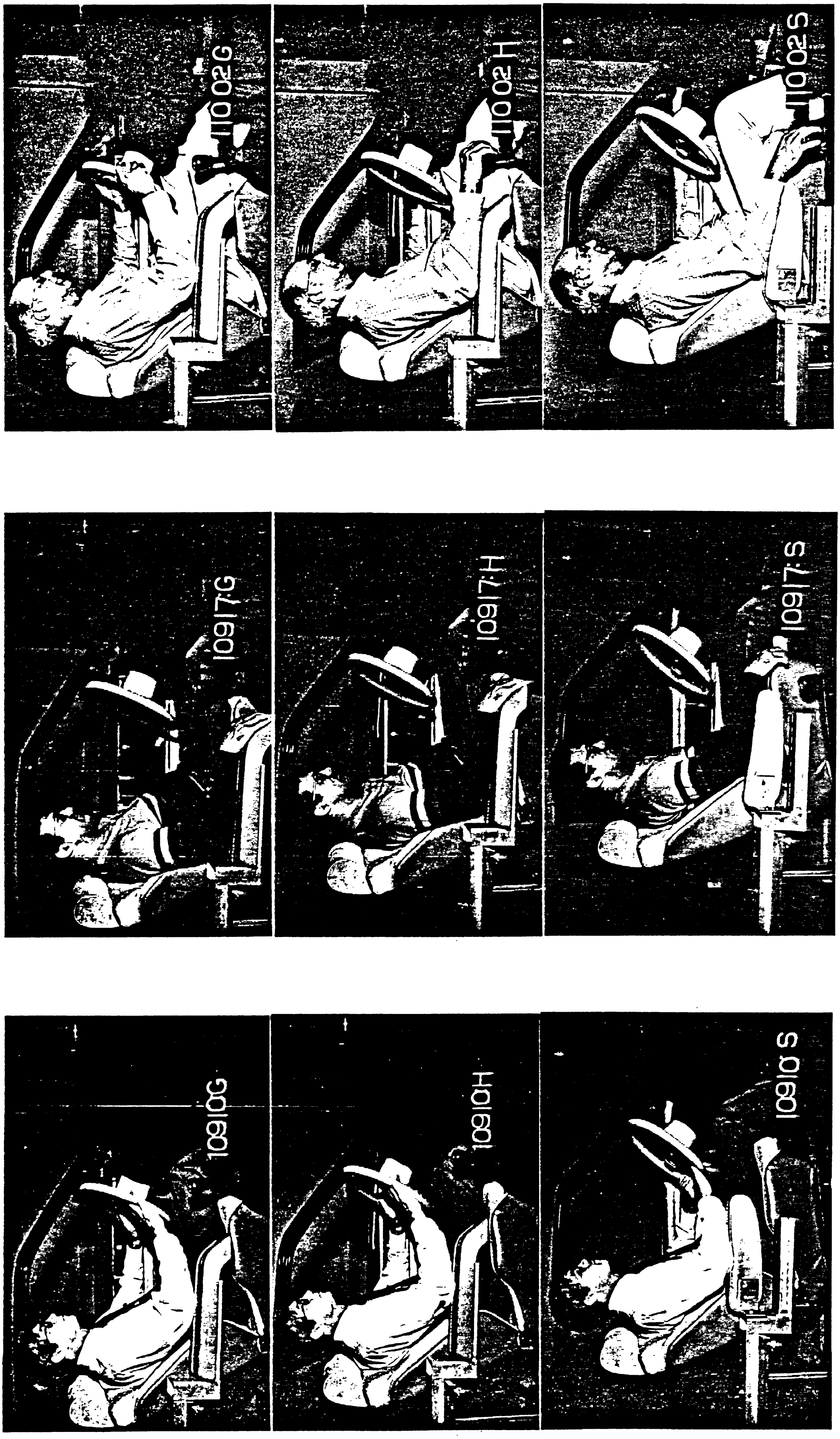

10814G
10814H
10814S

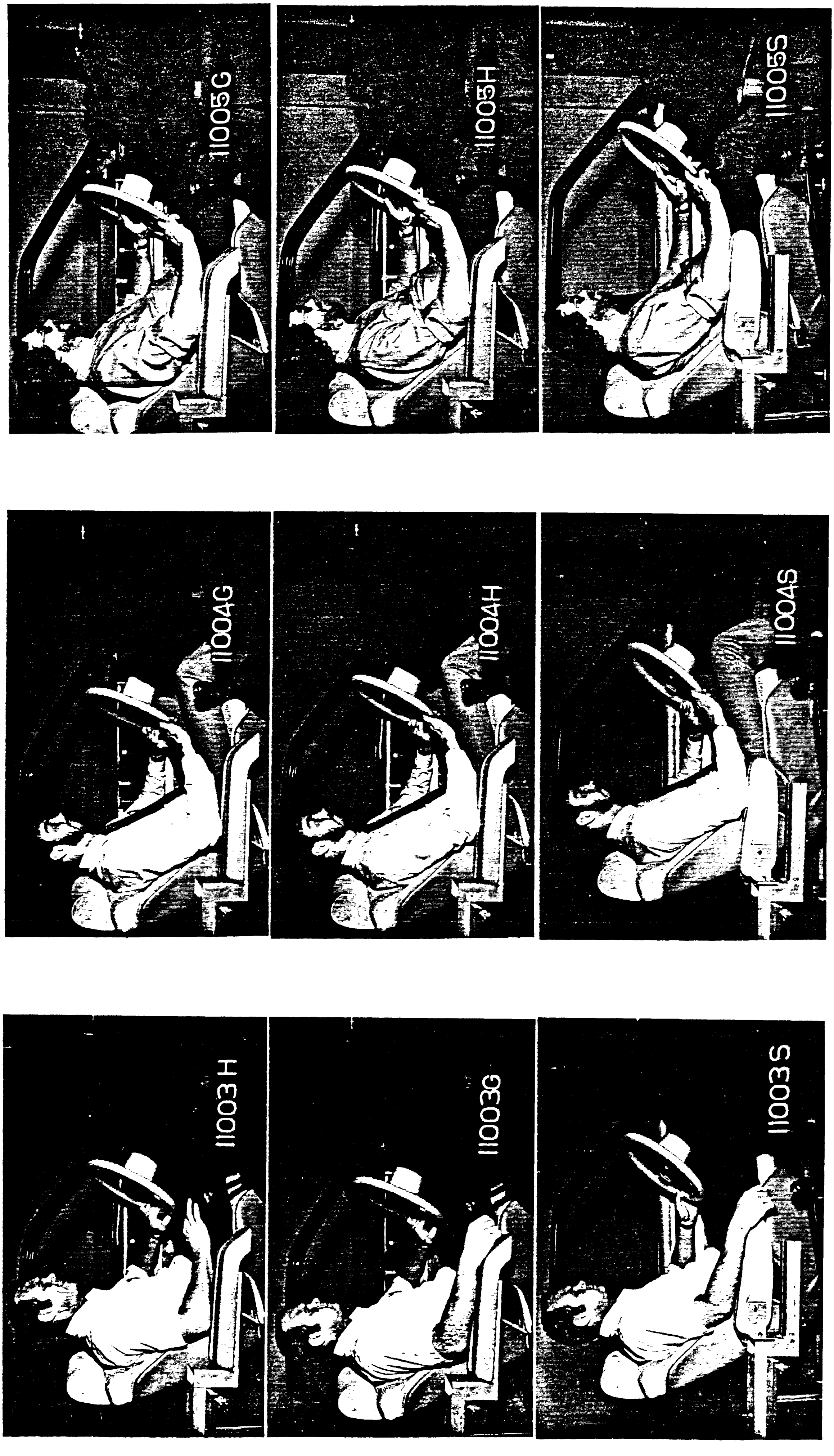

10903G
10903H
10903S
10904G
10904H
10904S
10905G
10905H
10905S

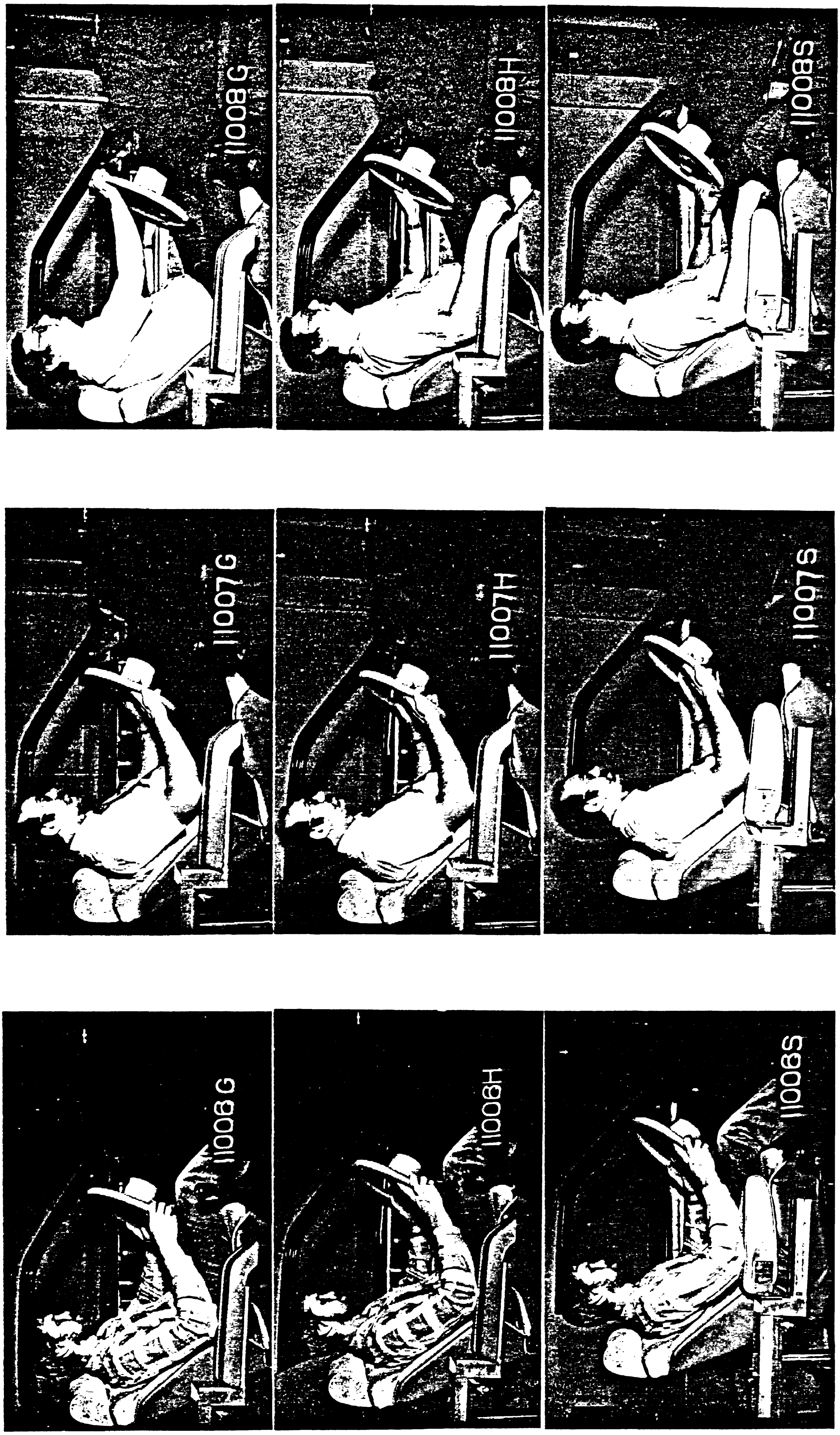

10909G
10909H
10909S

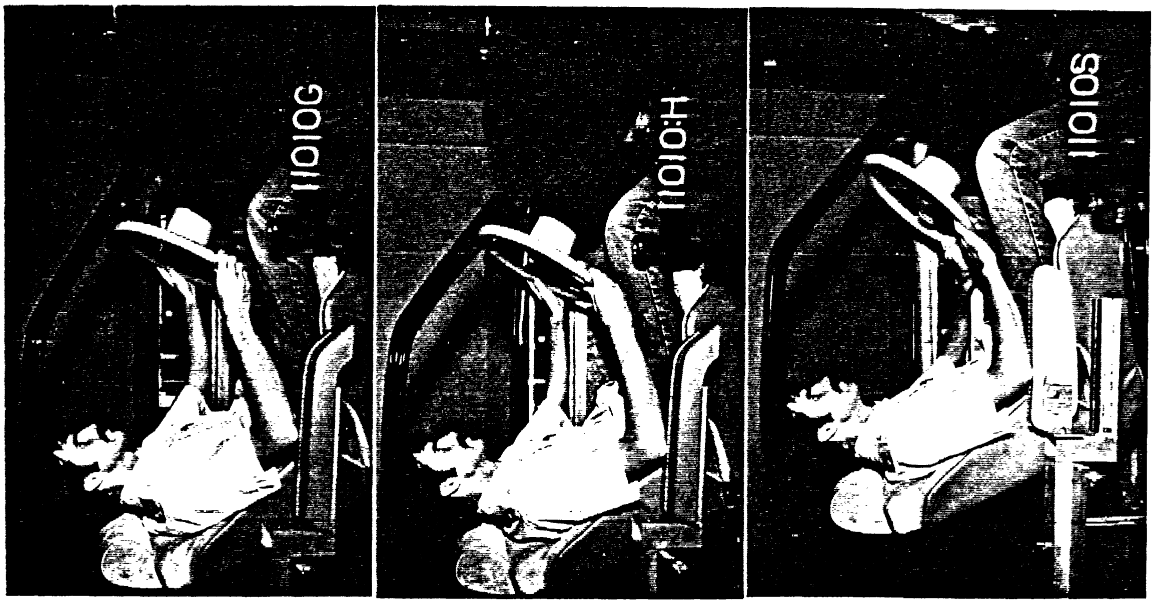

10908G
10908H
10908S

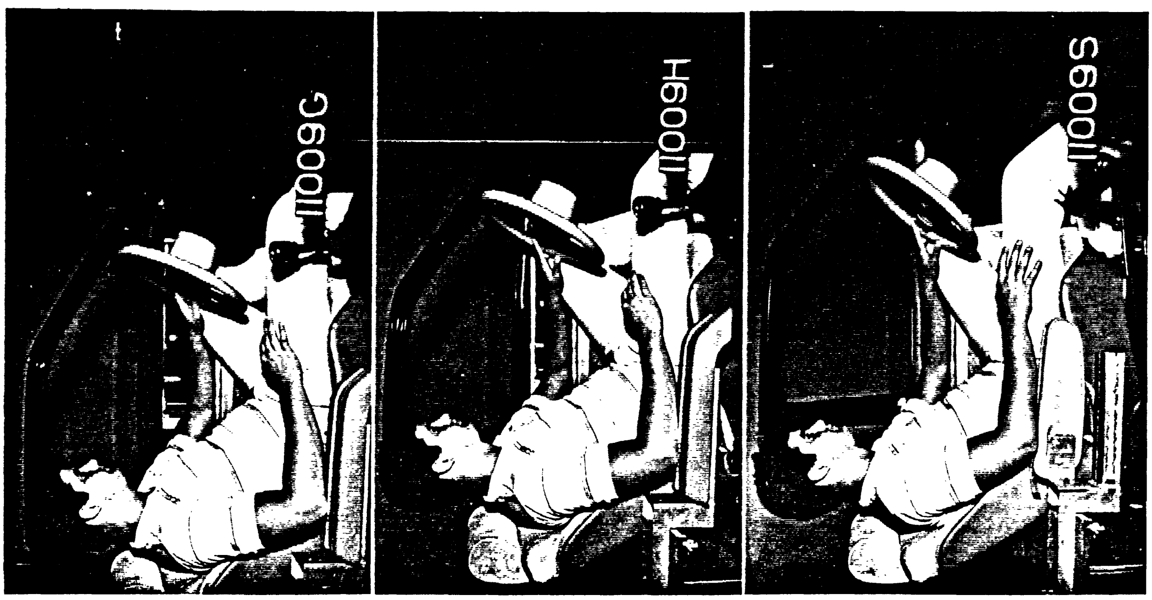

10906G
10906H
10906S


10910G
10910H
10910S
10917G
10917H
10917S
11002G
11002H
11002S


11005G
11005H
11005S
11004G
11004H
11004S
11003 H
11003G
11003S


11008G
11008H
11008S
11007G
11007H
11007S
11006G
11006H
11006S


11010G
11010H
11010S


11009G
11009H
11009S

APPENDIX C

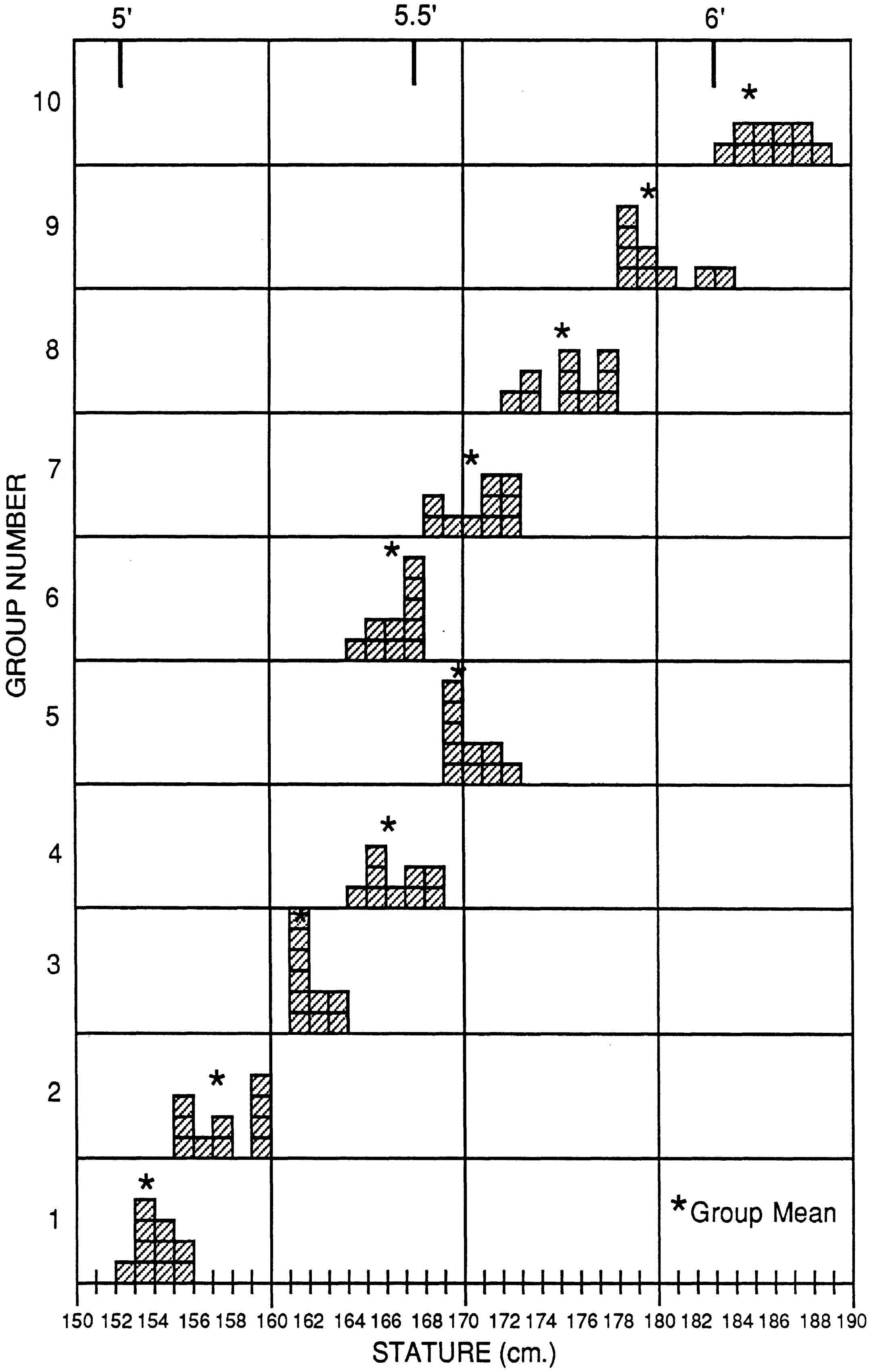
SUBJECT ANTHROPOMETRY

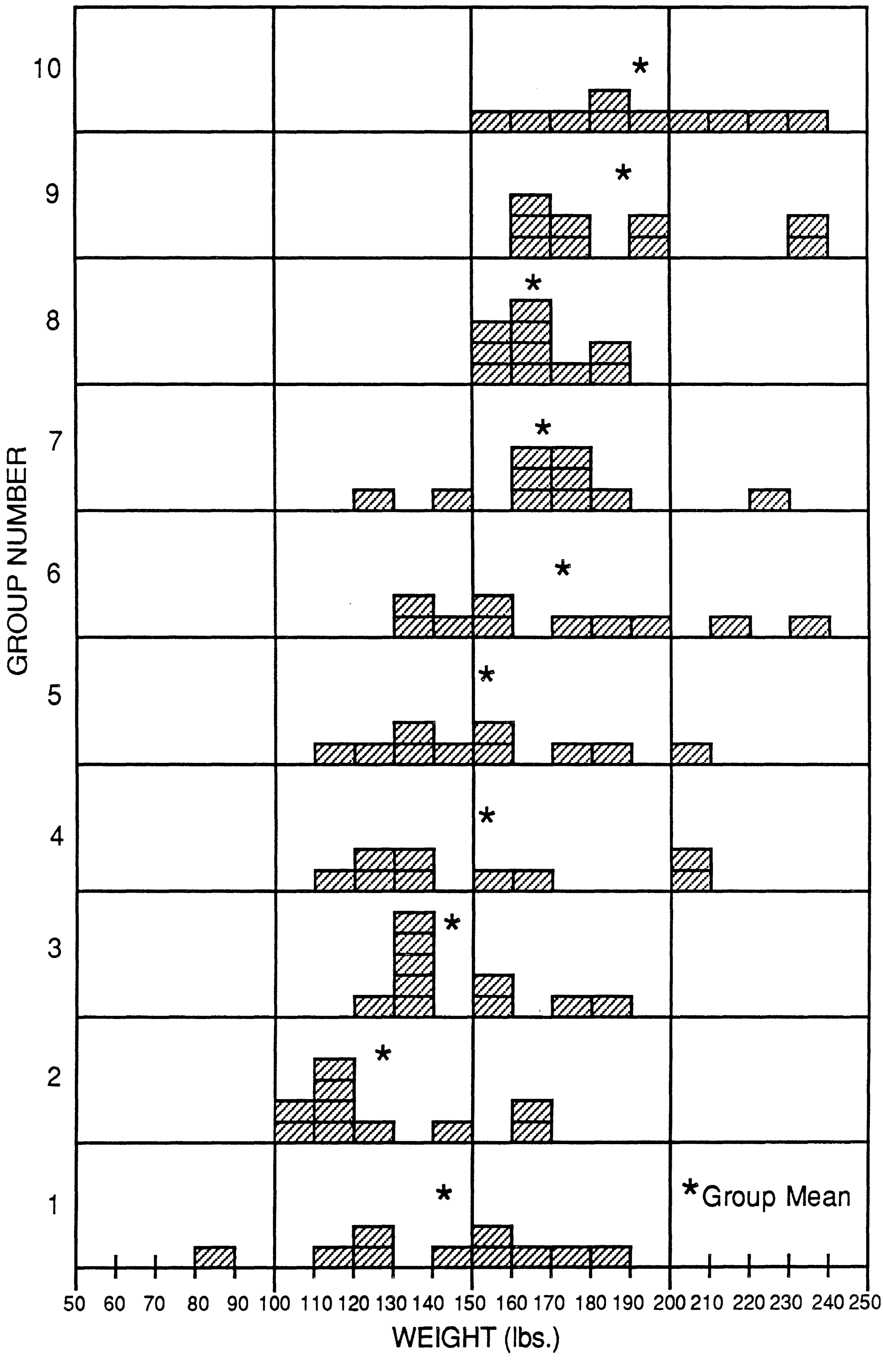
Table C-1

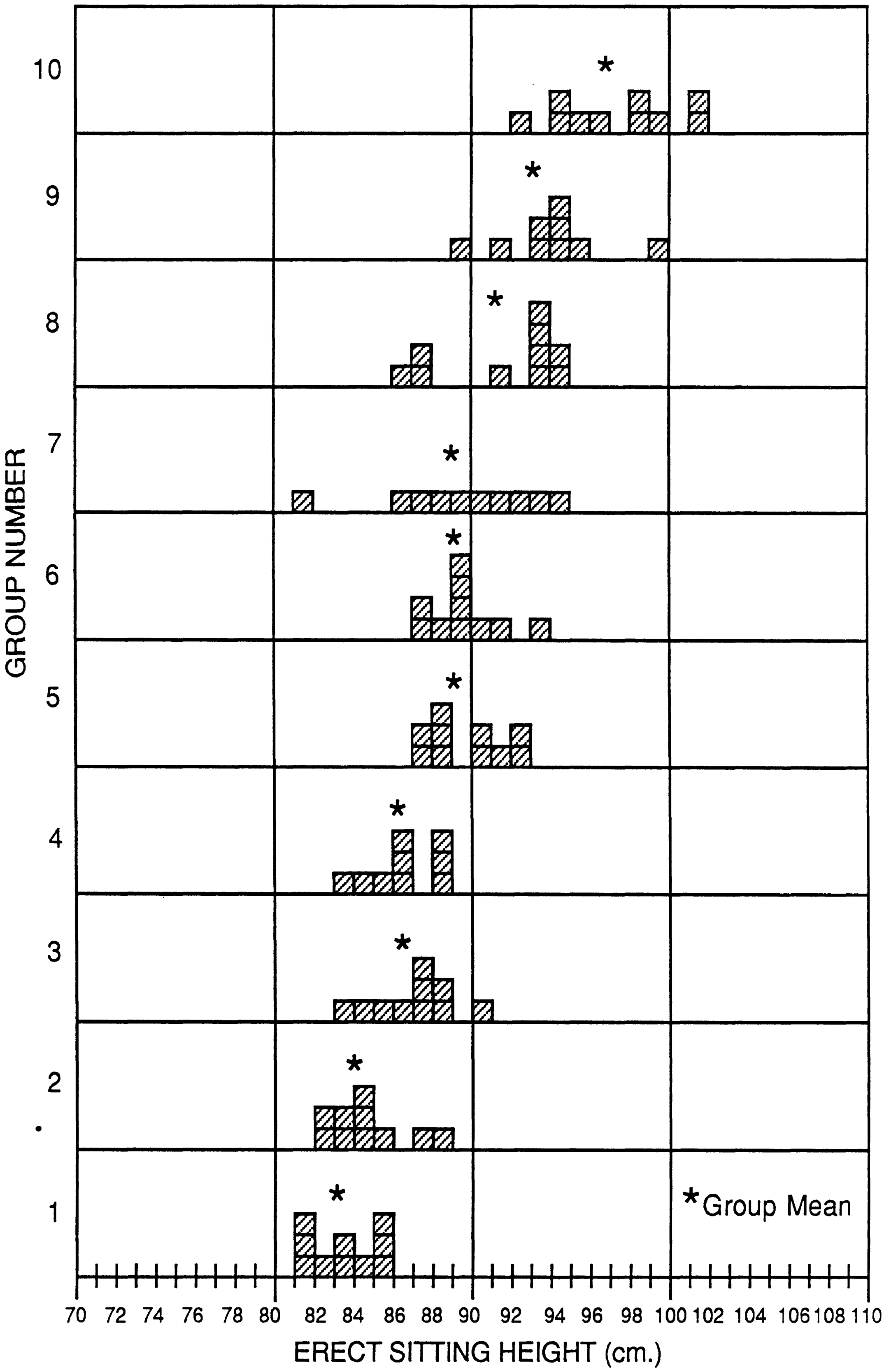
Mean Values of Physical and Anthropometric Measurements by Subject Group

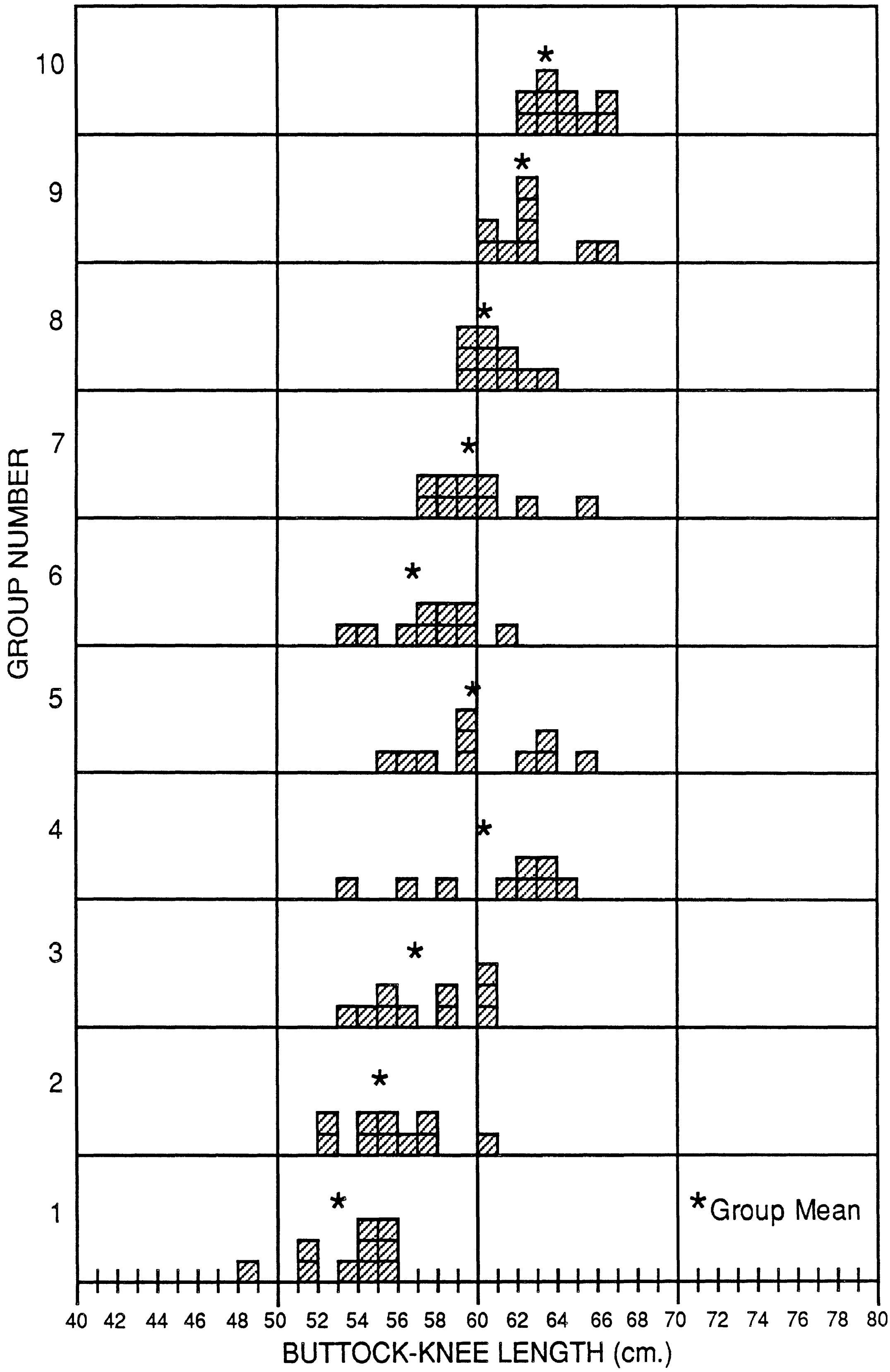
MEASUREMENT	FEMALE GROUPS 1	2	3	4	5
STATURE	153.5	157.0	161.5	166.2	169.7
STATURE (with shoes)	156.9	158.9	163.5	167.8	172.0
WEIGHT (lbs)	142.8	128.5	145.2	152.1	151.3
SITTING HEIGHT	83.1	84.0	86.4	86.1	89.1
EYE HEIGHT	72.7	74.1	75.3	75.7	77.3
SHOULDER HEIGHT	56.2	57.6	57.5	59.3	59.0
KNEE HEIGHT	47.3	49.0	50.1	52.3	52.4
HIP BREADTH	37.5	38.5	39.2	39.4	40.2
BUTTOCK-KNEE LENGTH	53.0	55.2	57.0	60.2	59.7
SHOULDER BREADTH	40.1	40.6	41.1	44.6	41.6
SHOULDER-ELBOW LENGTH	32.0	34.2	33.4	35.9	35.5
ELBOW-HAND LENGTH	41.0	42.0	42.7	44.4	45.5
MAXIMUM ARM REACH	73.8	76.6	76.7	81.0	81.5
GRASPING ARM REACH	65.5	65.1	70.0	69.4	74.3
AGE (years)	42.4	45.7	42.0	37.1	37.5

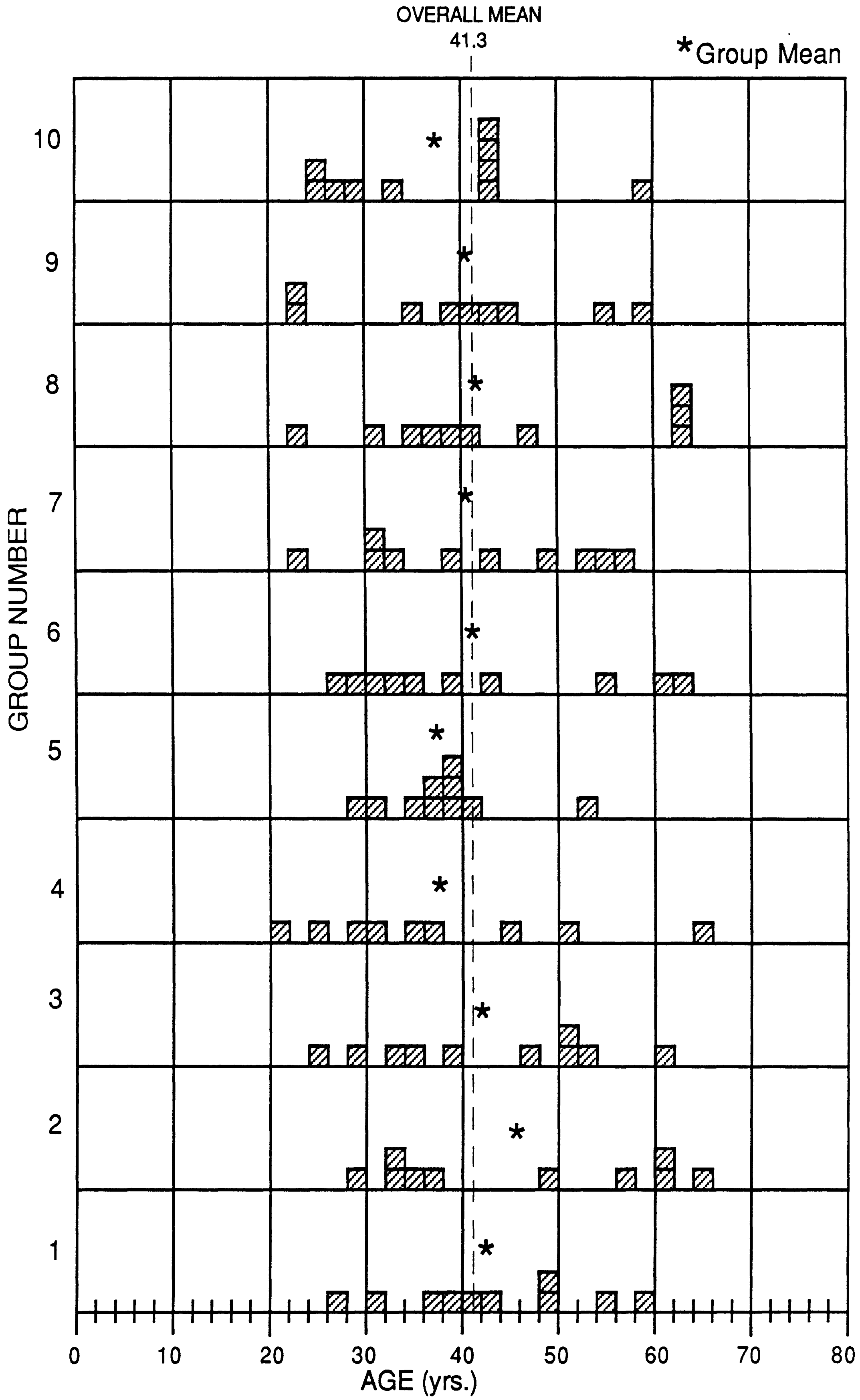
	MALE GROUPS 6	7	8	9	10
STATURE	166.2	170.5	175.0	179.4	185.5
STATURE (with shoes)	168.6	172.9	176.6	181.0	187.1
WEIGHT (lbs)	172.3	169.6	165.7	189.3	193.2
SITTING HEIGHT	89.0	88.9	91.1	93.5	96.6
EYE HEIGHT	76.5	78.4	78.6	82.4	84.5
SHOULDER HEIGHT	60.2	60.8	62.2	64.6	65.6
KNEE HEIGHT	51.1	53.0	54.3	56.3	57.3
HIP BREADTH	37.9	37.4	37.5	39.8	39.3
BUTTOCK-KNEE LENGTH	57.0	59.4	60.2	62.1	63.7
SHOULDER BREADTH	45.5	46.8	45.1	49.7	45.8
SHOULDER-ELBOW LENGTH	35.1	37.7	37.5	39.1	38.7
ELBOW-HAND LENGTH	45.2	46.7	47.2	48.5	50.3
MAXIMUM ARM REACH	82.5	84.7	84.7	86.5	89.1
GRASPING ARM REACH	72.6	73.6	75.0	75.5	80.5
AGE (years)	40.9	40.7	44.1	40.2	36.6


5'
5.5'
6'
GROUP NUMBER
10
9
8
7
6
5
4
3
2
1
*Group Mean
150 152 154 156 158 160 162 164 166 168 170 172 174 176 178 180 182 184 186 188 190
STATURE (cm.)


GROUP NUMBER
10
9
8
7
6
5
4
3
2
1
*Group Mean
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
WEIGHT (lbs.)


10
9
8
7
6
5
4
3
2
1
GROUP NUMBER
*Group Mean
70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110
ERECT SITTING HEIGHT (cm.)


GROUP NUMBER
10
9
8
7
6
5
4
3
2
1
*Group Mean
40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80
BUTTOCK-KNEE LENGTH (cm.)


OVERALL MEAN
41.3
*Group Mean
GROUP NUMBER
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
AGE (yrs.)

APPENDIX D

PREFERRED SEAT POSITION RESULTS

Table D-1

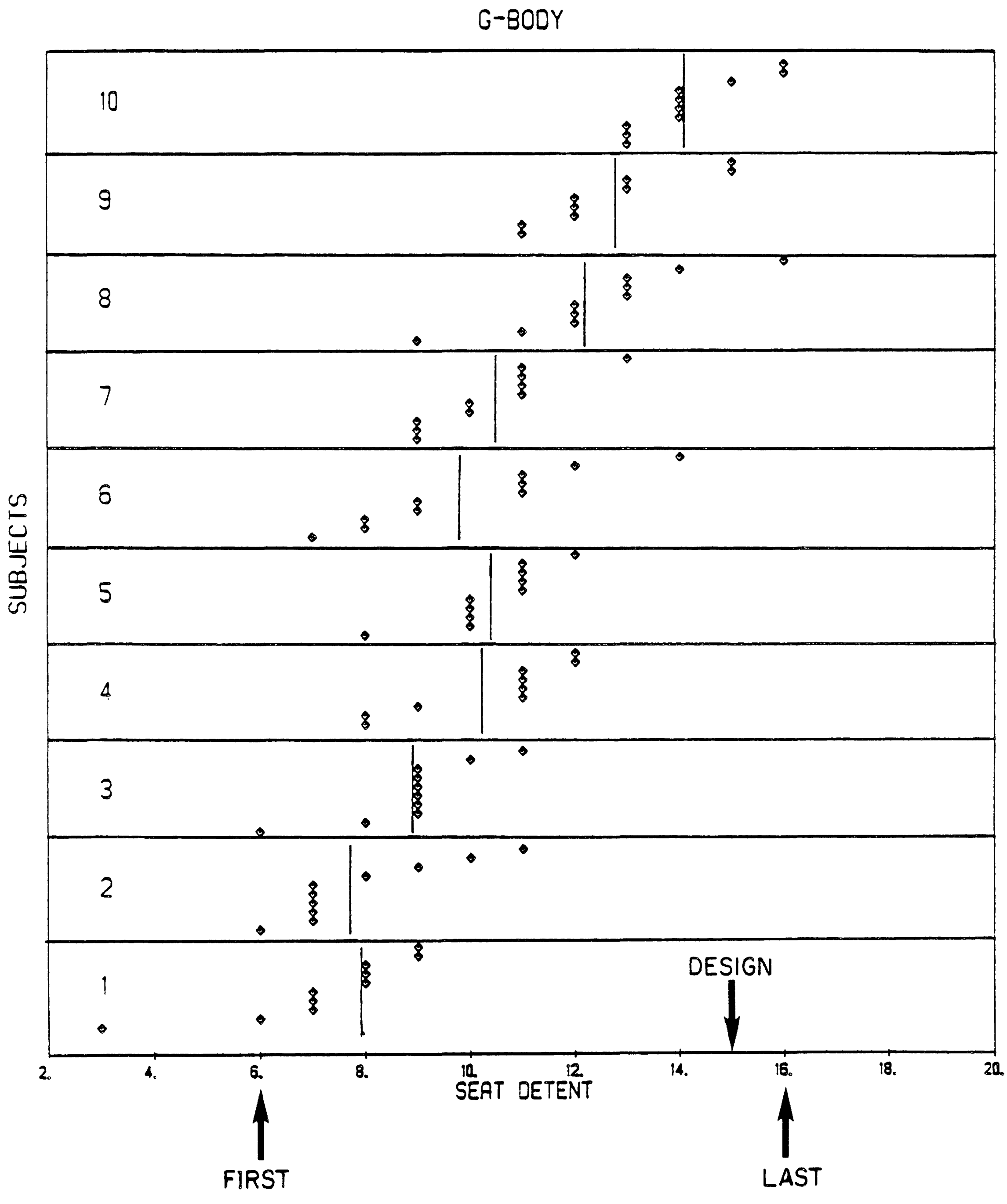
Summary of Preferred Seat Position Results

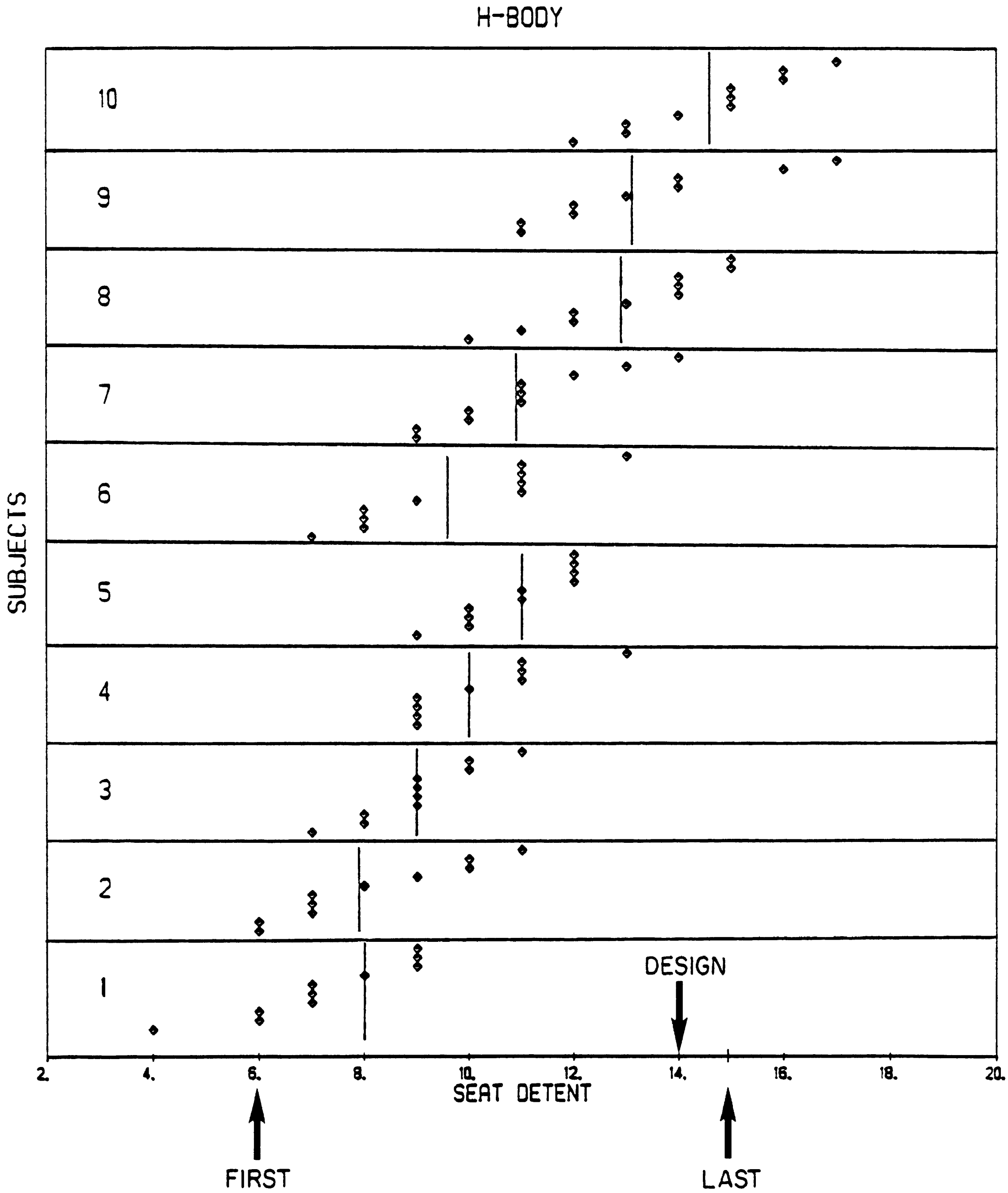
Group	N	Seat Detent mean	Seat Detent range	Seat H-Point (mm) mean	(s.d.)	range
G-BODY:						
1	10	7.2	3 - 9	1266.2	(36.8)	1304 - 1178 = 126
2	10	7.9	6 - 11	1280.9	(33.5)	1346 - 1241 = 105
3	10	8.9	6 - 11	1301.9	(27.0)	1346 - 1241 = 105
4	9	10.3	8 - 12	1332.0	(33.2)	1367 - 1283 = 84
5	10	10.4	8 - 12	1333.4	(22.6)	1367 - 1283 = 84
6	10	10.0	7 - 14	1325.0	(45.4)	1409 - 1262 = 147
7	10	10.4	9 - 13	1333.4	(26.5)	1388 - 1304 = 84
8	10	12.5	9 - 16	1377.5	(38.7)	1451 - 1304 = 147
9	9	12.7	11 - 15	1381.0	(31.5)	1430 - 1346 = 84
10	10	14.2	13 - 16	1413.2	(23.8)	1451 - 1388 = 63
H-BODY:						
1	10	7.2	4 - 9	1262.2	(34.0)	1300 - 1195 = 105
2	10	8.1	6 - 11	1281.1	(37.6)	1342 - 1237 = 105
3	10	9.0	7 - 11	1300.0	(24.3)	1342 - 1258 = 84
4	9	10.2	9 - 13	1325.7	(29.3)	1384 - 1300 = 84
5	10	10.9	9 - 12	1339.9	(23.1)	1363 - 1300 = 63
6	10	9.7	7 - 13	1314.7	(40.9)	1384 - 1258 = 126
7	10	11.0	9 - 14	1342.0	(34.3)	1405 - 1300 = 105
8	10	13.0	10 - 15	1384.0	(35.7)	1426 - 1321 = 105
9	9	13.3	11 - 17	1391.0	(44.6)	1468 - 1342 = 126
10	10	14.6	12 - 17	1417.6	(33.1)	1468 - 1363 = 105
S-BODY:						
1	10	7.6	5 - 10	1220.6	(34.6)	1271 - 1166 = 105
2	10	8.5	7 - 11	1239.5	(24.8)	1292 - 1208 = 84
3	10	9.8	8 - 13	1266.8	(32.5)	1334 - 1229 = 105
4	9	11.0	9 - 13	1292.0	(25.7)	1334 - 1250 = 84
5	10	12.1	10 - 14	1315.1	(33.5)	1355 - 1271 = 84
6	10	10.8	9 - 14	1287.8	(38.1)	1355 - 1250 = 105
7	10	11.2	10 - 13	1296.2	(21.7)	1334 - 1271 = 63
8	10	13.0	11 - 16	1334.0	(35.7)	1397 - 1292 = 105
9	9	13.7	11 - 16	1348.0	(33.2)	1397 - 1292 = 105
10	10	14.7	13 - 18	1369.7	(39.7)	1439 - 1334 = 105

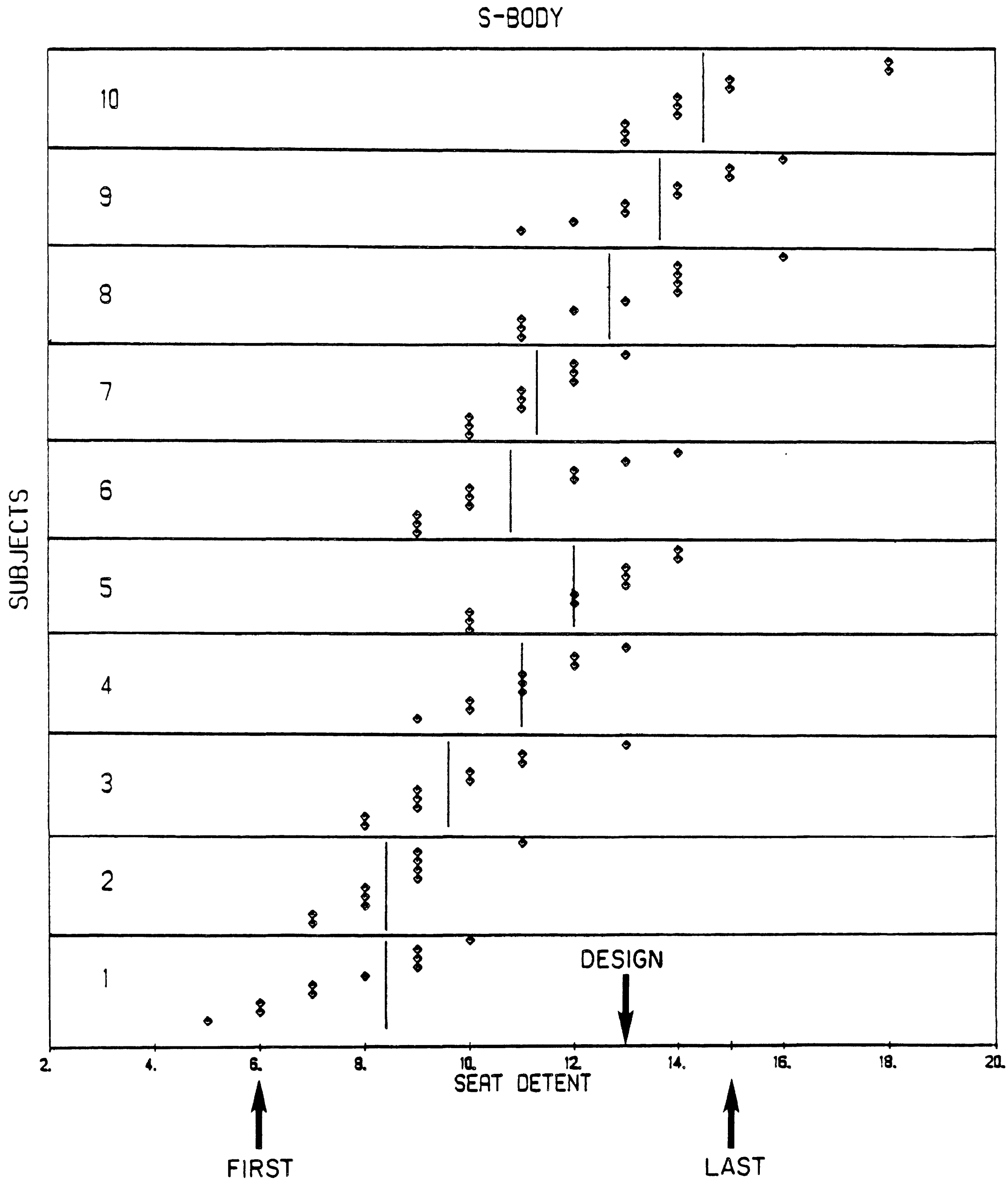
Table D-2

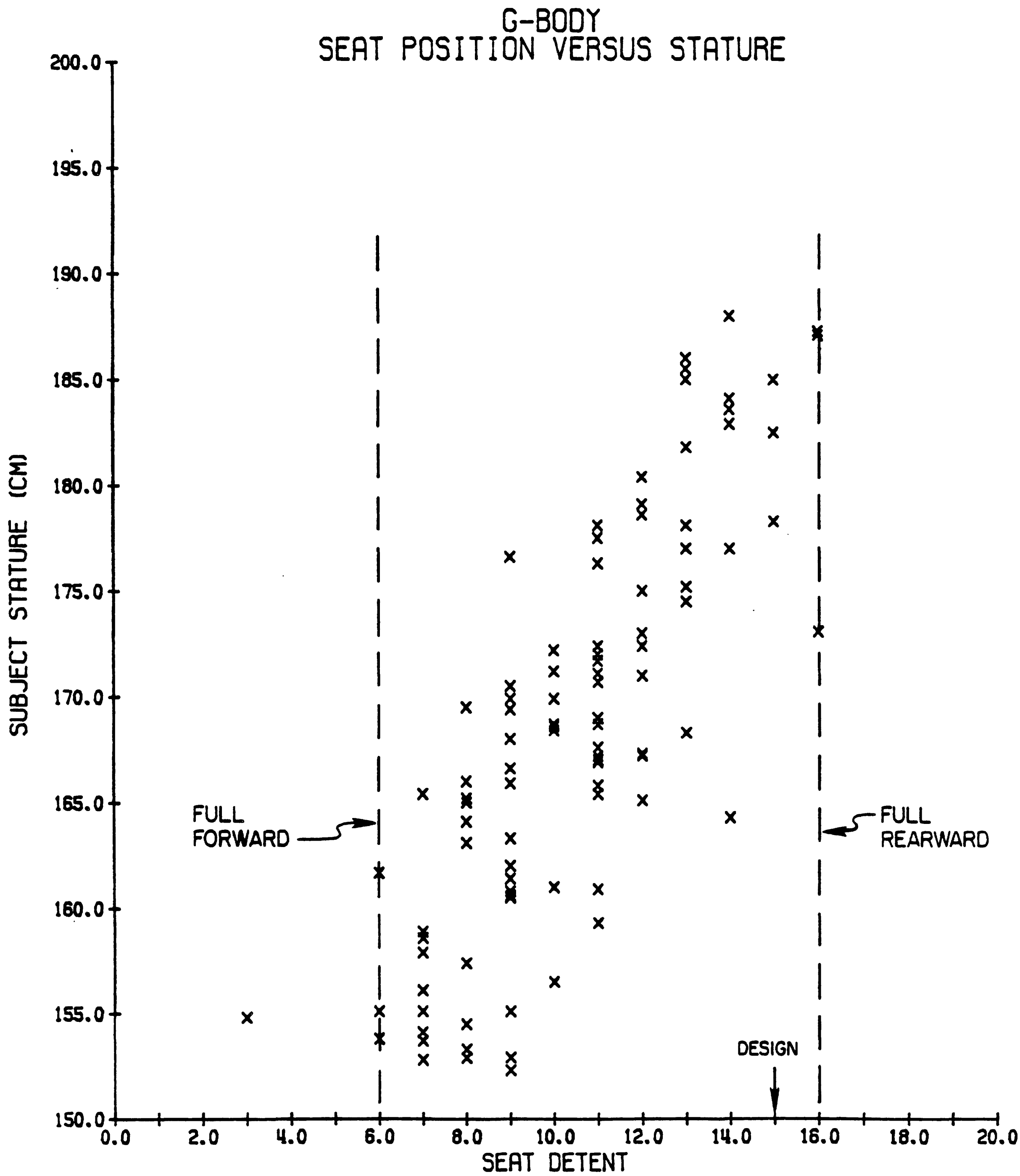
Preferred Seat Back Angle re H-point
Back Angle Calibration

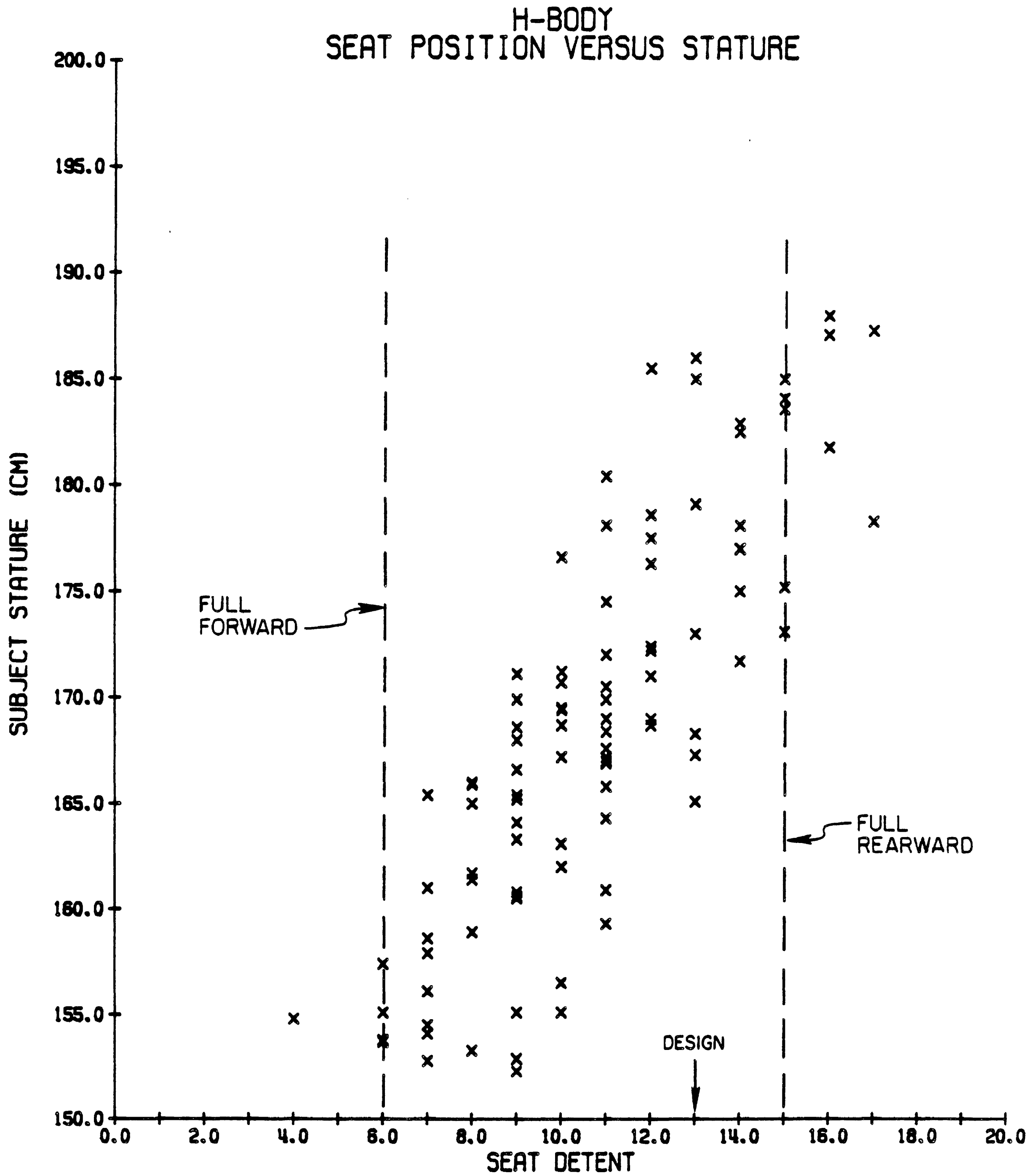
Subject Group	N	G-Body mean	G-Body s.d.	H-Body mean	H-Body s.d.	S-Body mean	S-Body s.d.
1	10	25.5	2.1	24.8	3.0	25.7	3.3
2	10	26.7	3.8	24.8	4.0	24.7	1.6
3	10	25.0	2.2	23.4	2.4	24.0	0.0
4	9	27.0	3.9	24.8	4.7	24.7	1.3
5	10	26.1	2.9	24.8	3.5	25.0	2.2
ALL FEMALES	49	26.1	3.0	24.5	3.5	24.8	1.7
6	10	25.3	2.8	24.5	2.5	24.5	1.6
7	10	25.7	2.2	23.3	2.1	24.8	1.7
8	10	27.9	4.3	25.2	4.4	25.8	2.5
9	9	26.8	3.7	23.9	2.9	25.2	1.9
10	10	26.2	2.9	24.4	2.3	25.4	2.0
ALL MALES	49	26.4	3.2	24.3	2.8	25.1	1.9
ALL SUBJECTS	98	26.2	3.1	24.4	3.2	25.0	1.8

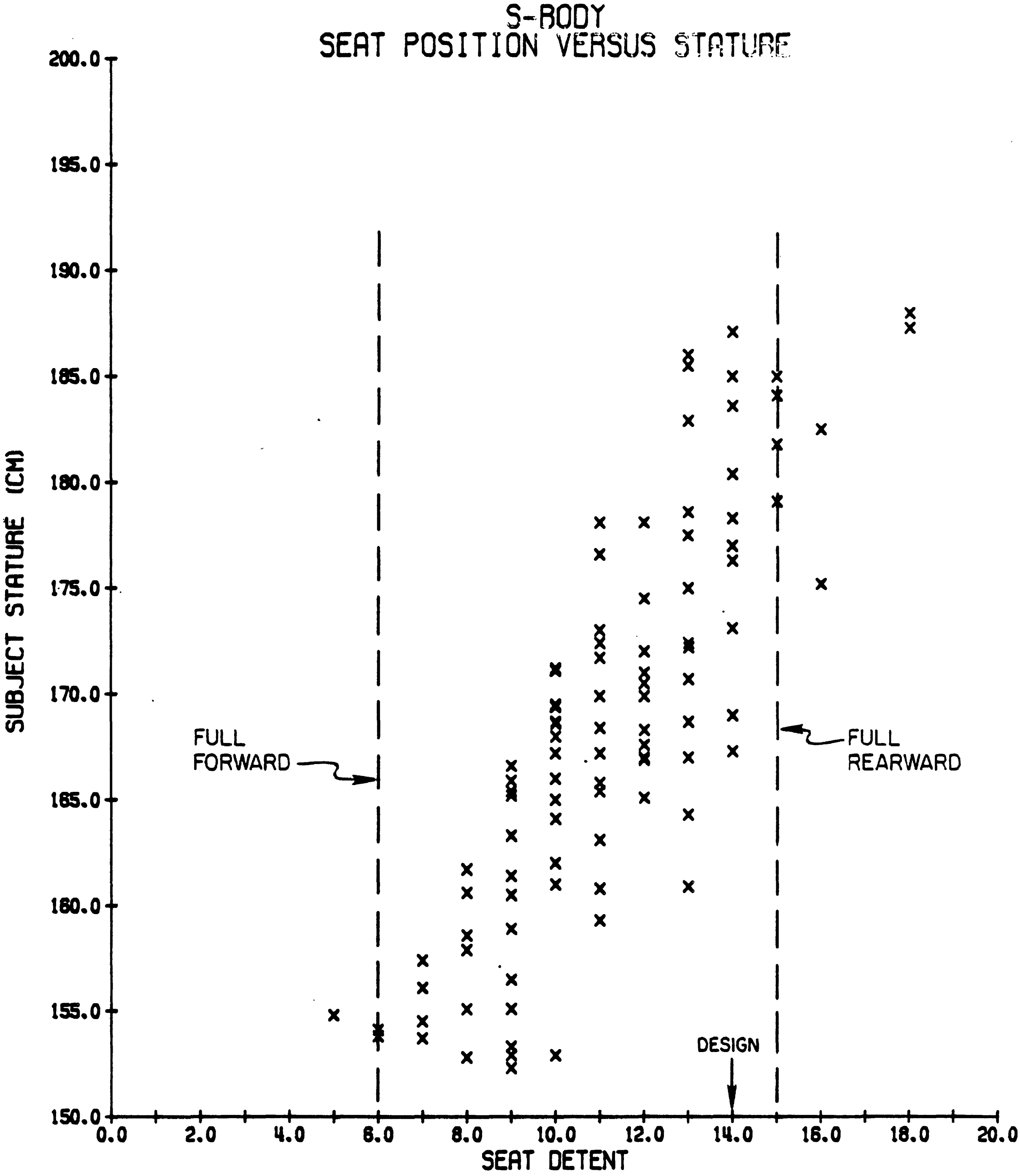

G-BODY
10
9
8
7
6
5
4
3
2
1
SUBJECTS
DESIGN
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
SEAT DETENT
FIRST
LAST

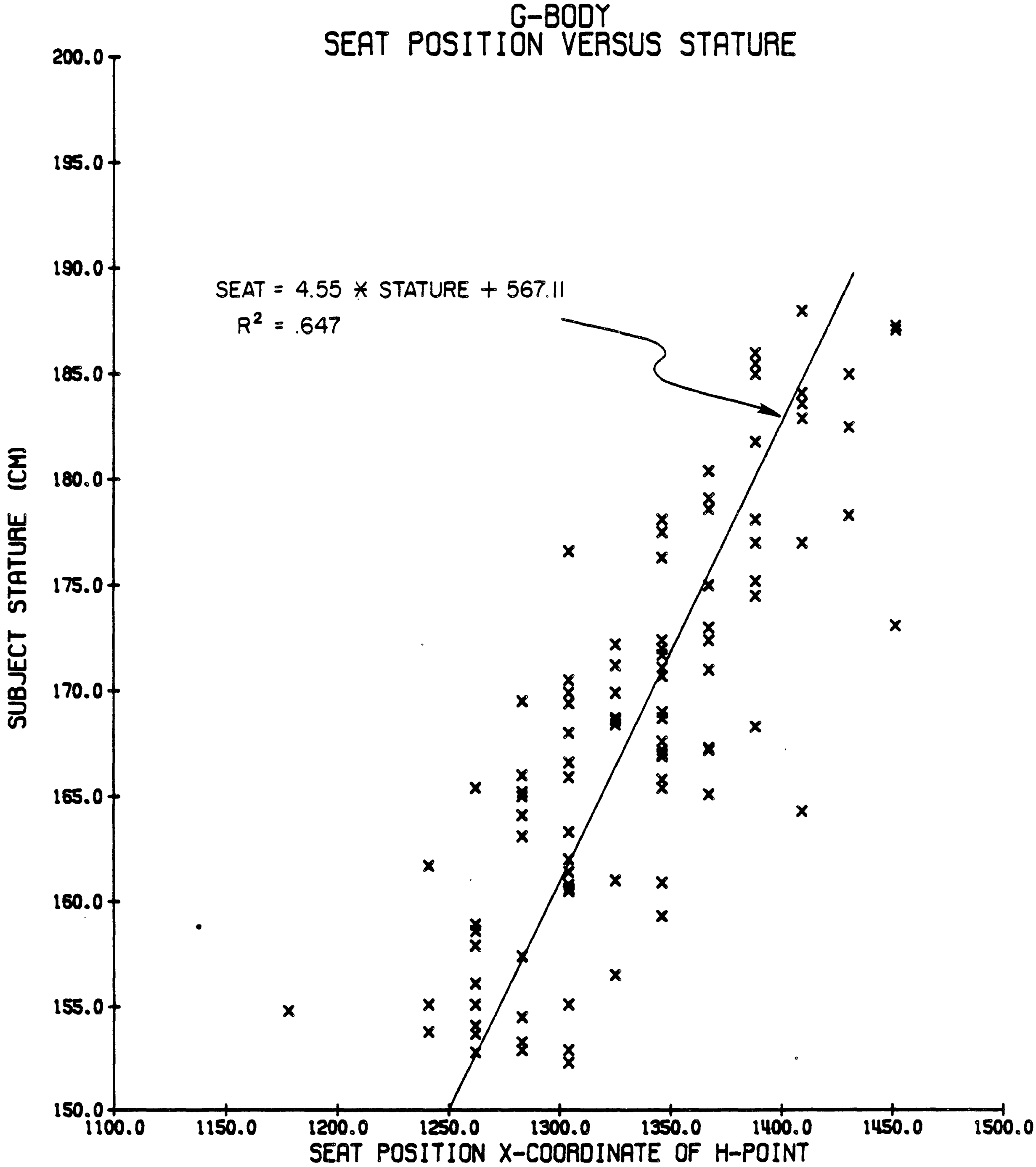

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
DESIGN
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
SEAT DETENT
FIRST
LAST


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
DESIGN
2.
4.
6.
8.
10.
12.
14.
16.
18.
20.
SEAT DETENT
FIRST
LAST

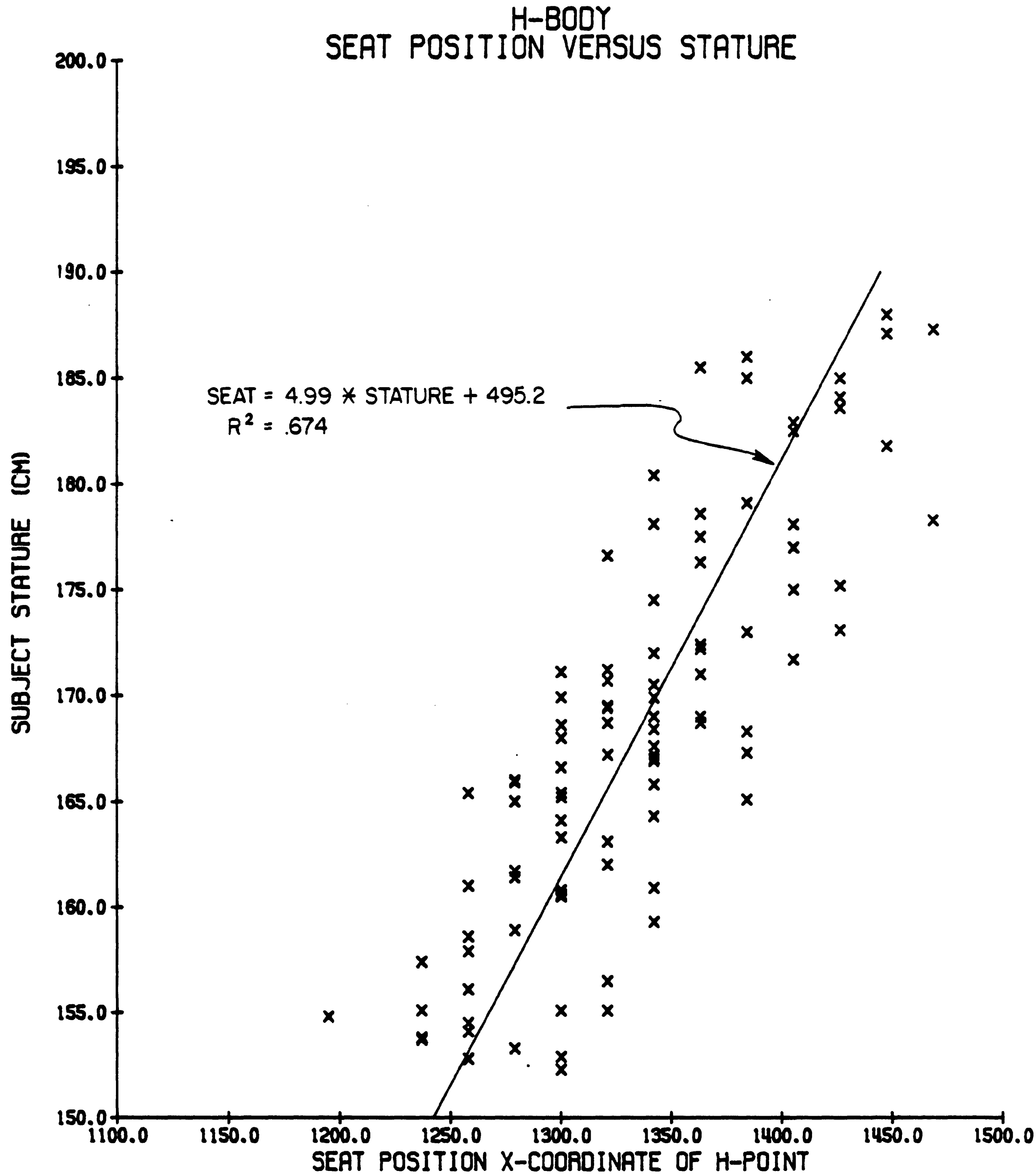

G-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
SEAT DETENT
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
FULL FORWARD
FULL REARWARD
DESIGN

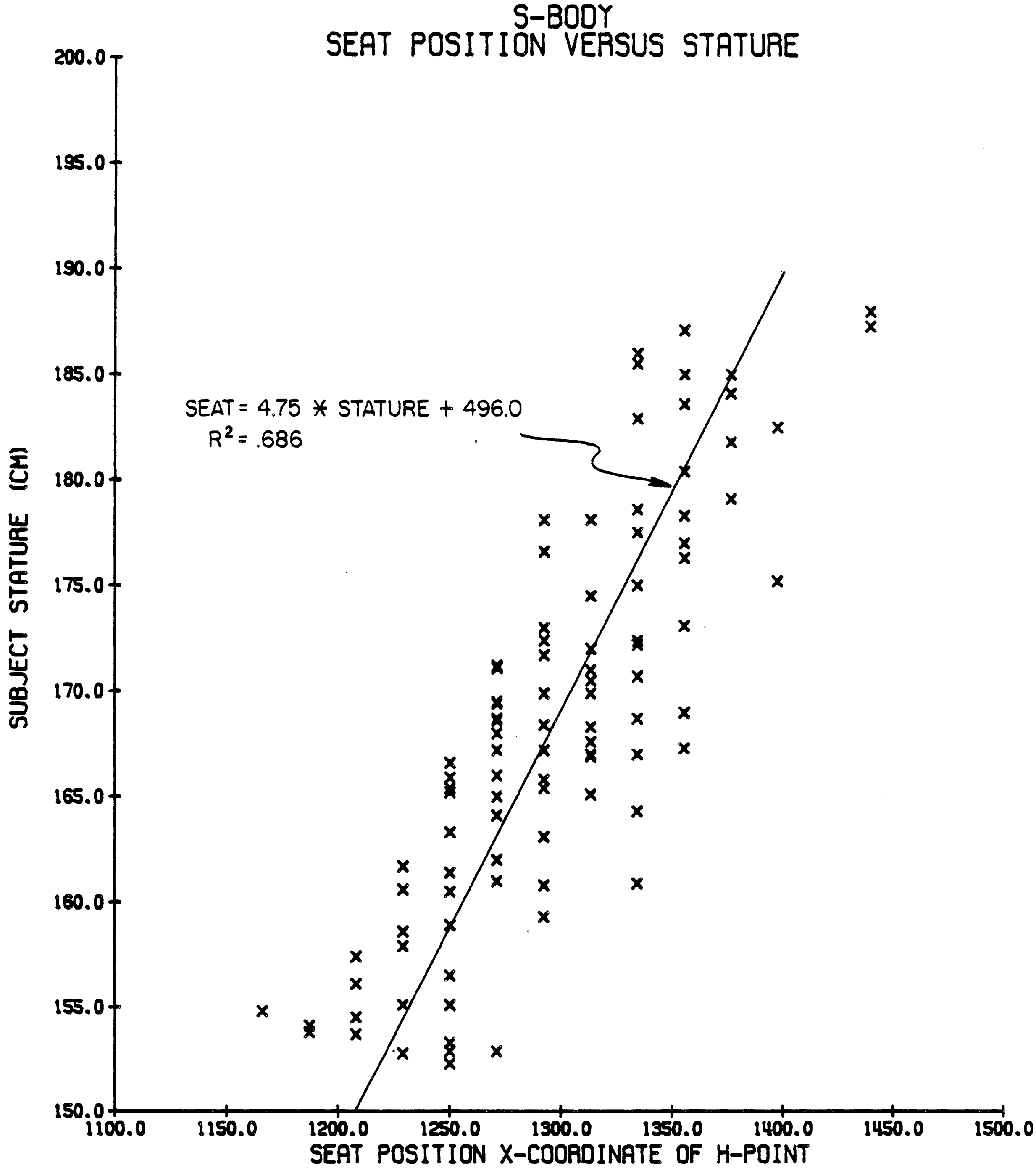

H-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SEAT DETENT
FULL FORWARD
FULL REARWARD
DESIGN


S-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
FULL FORWARD
FULL REARWARD
DESIGN
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SEAT DETENT



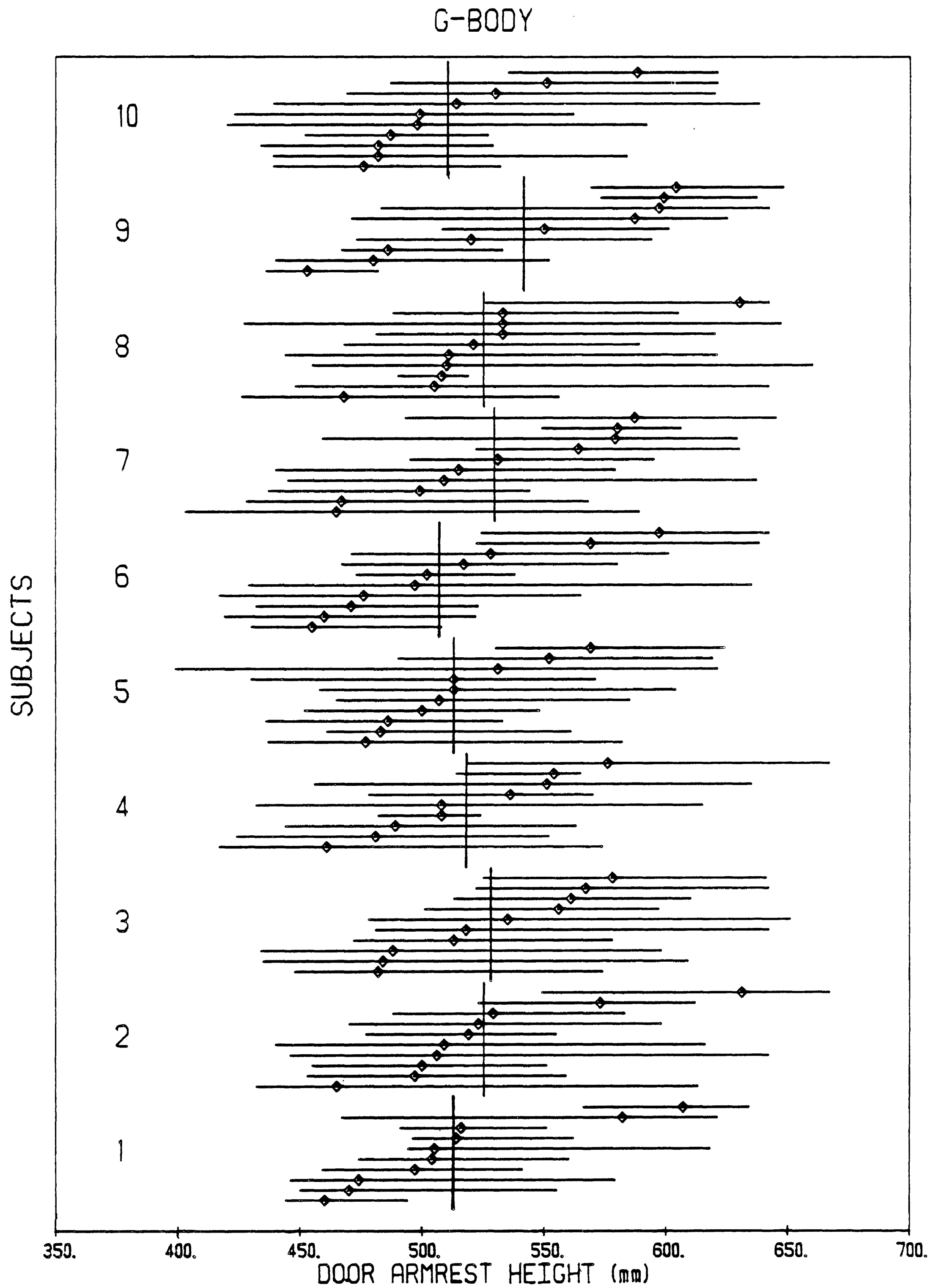
G-BODY
SEAT POSITION VERSUS STATURE
SEAT = 4.55 * STATURE + 567.11
R² = .647
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0
SEAT POSITION X-COORDINATE OF H-POINT

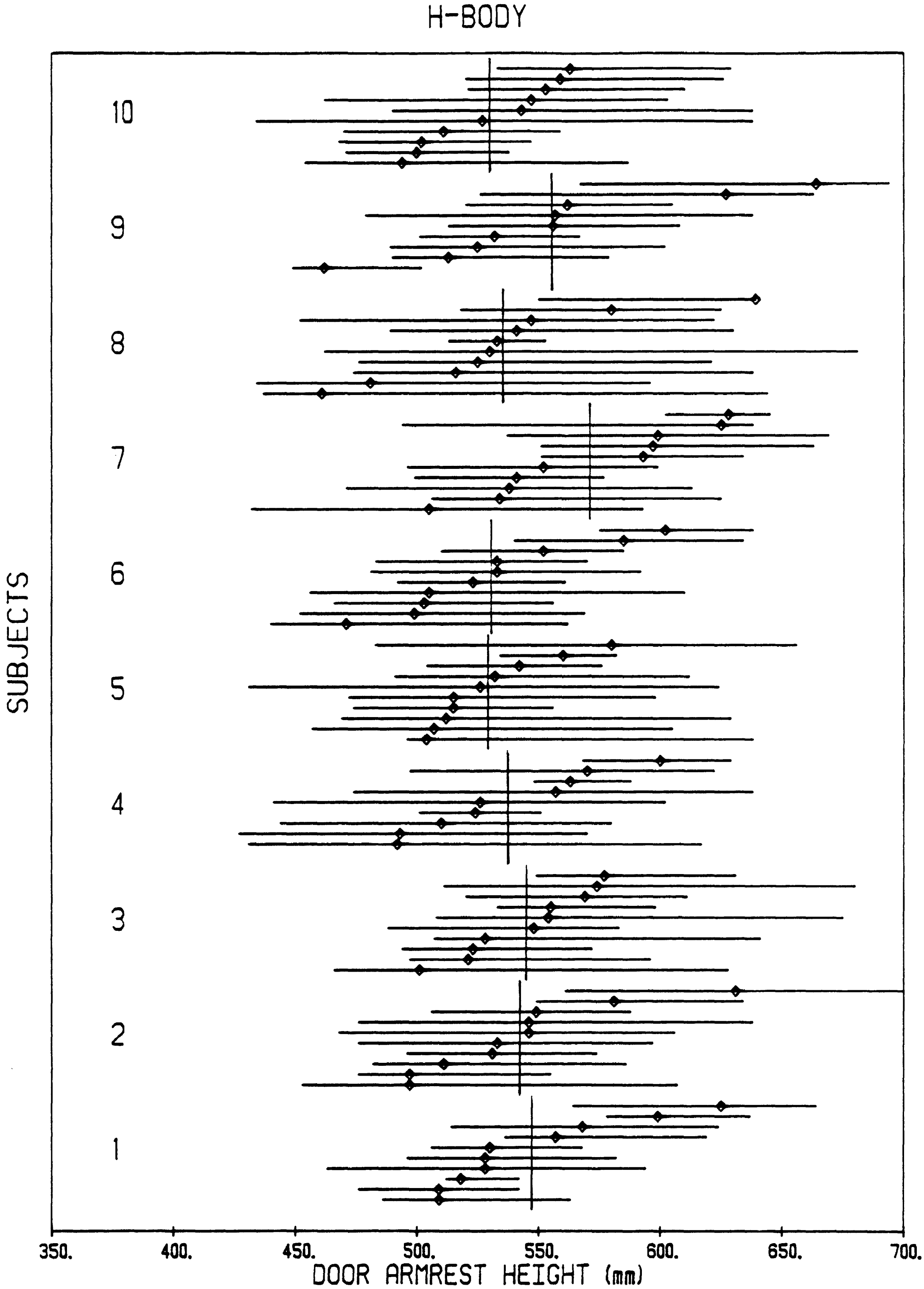

H-BODY
SEAT POSITION VERSUS STATURE
SEAT = 4.99 * STATURE + 495.2
R² = .674
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0
SEAT POSITION X-COORDINATE OF H-POINT

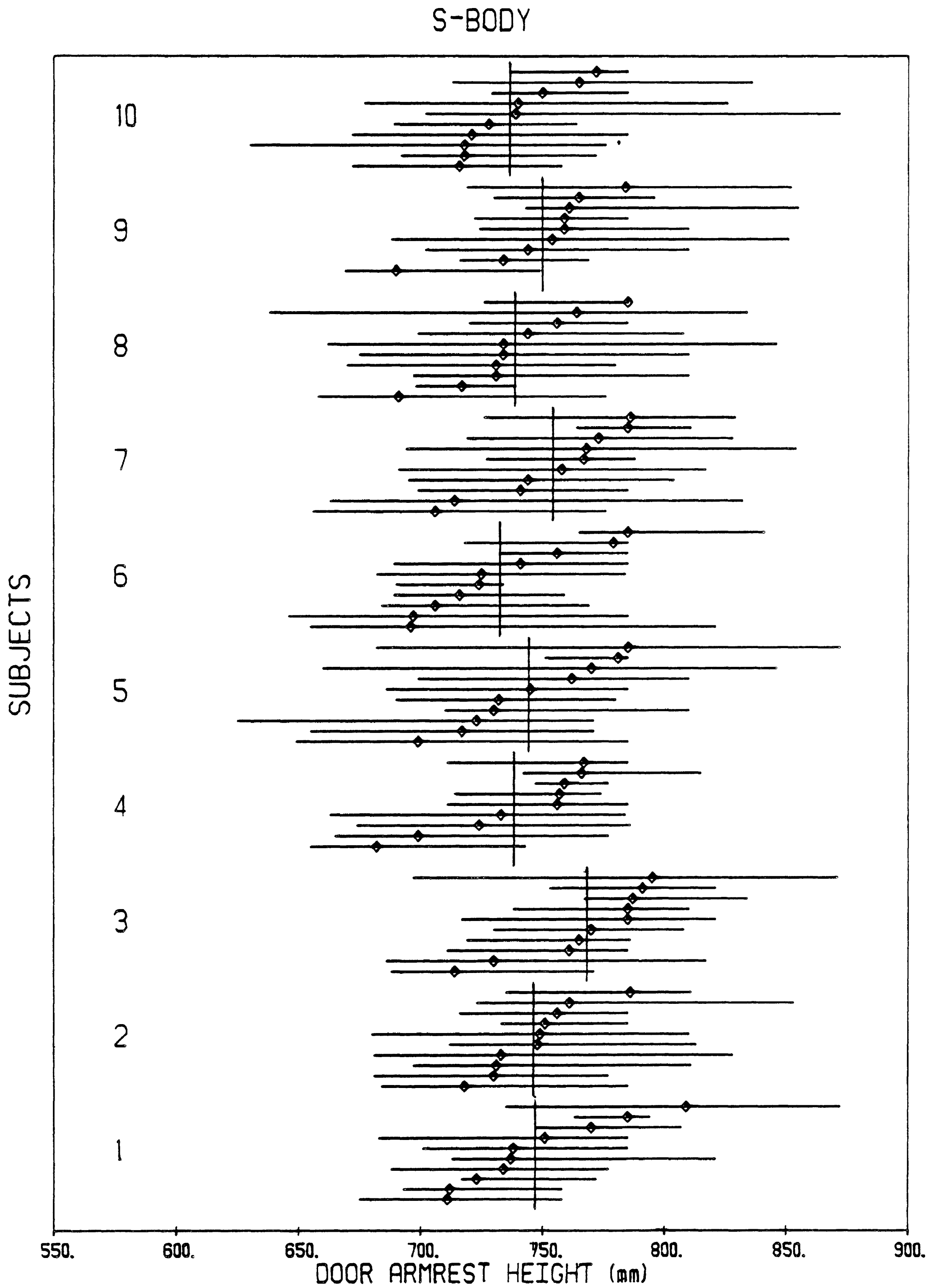

S-BODY
SEAT POSITION VERSUS STATURE
SEAT = 4.75 * STATURE + 496.0
R² = .686
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0
SEAT POSITION X-COORDINATE OF H-POINT

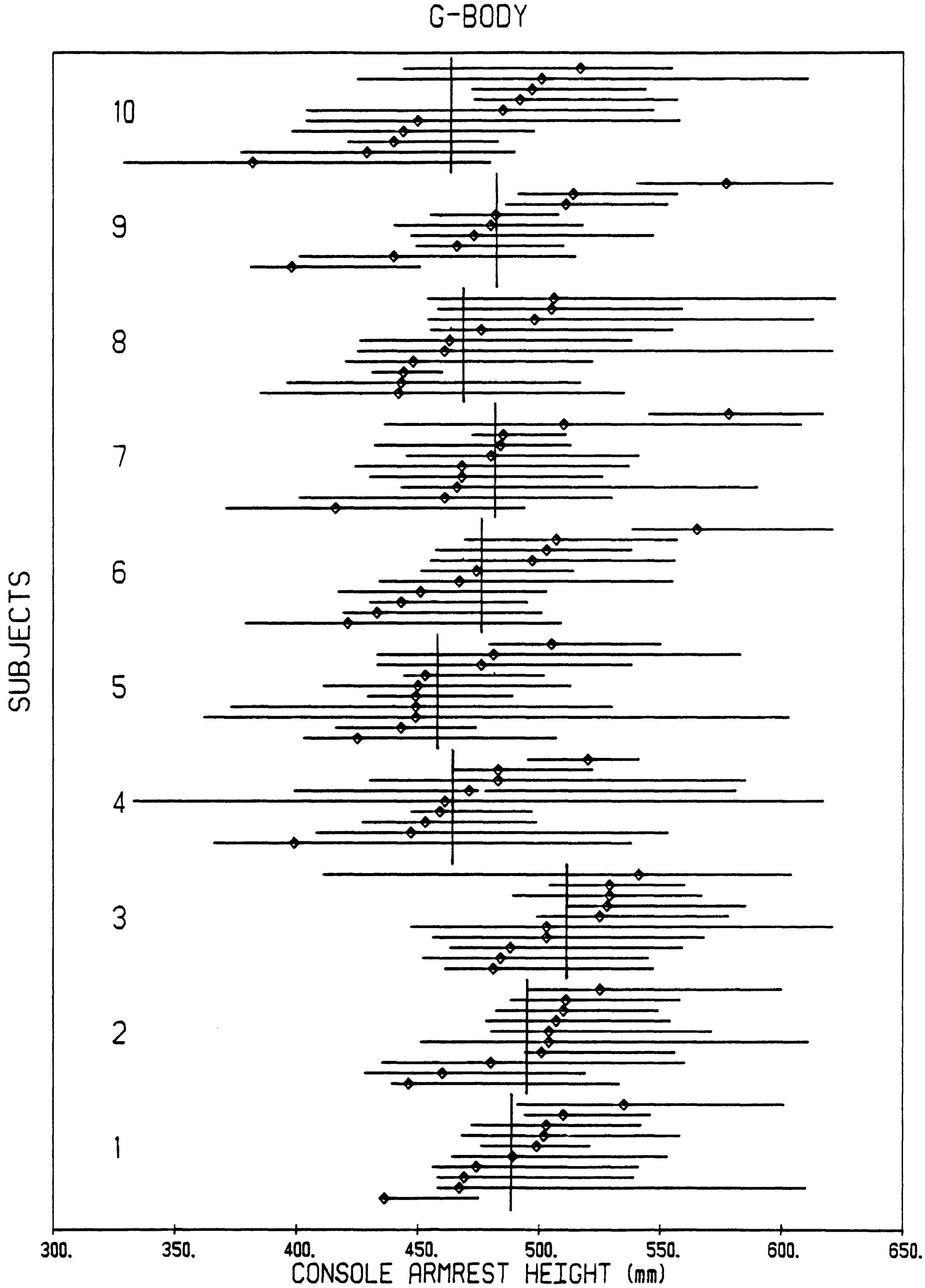
APPENDIX E

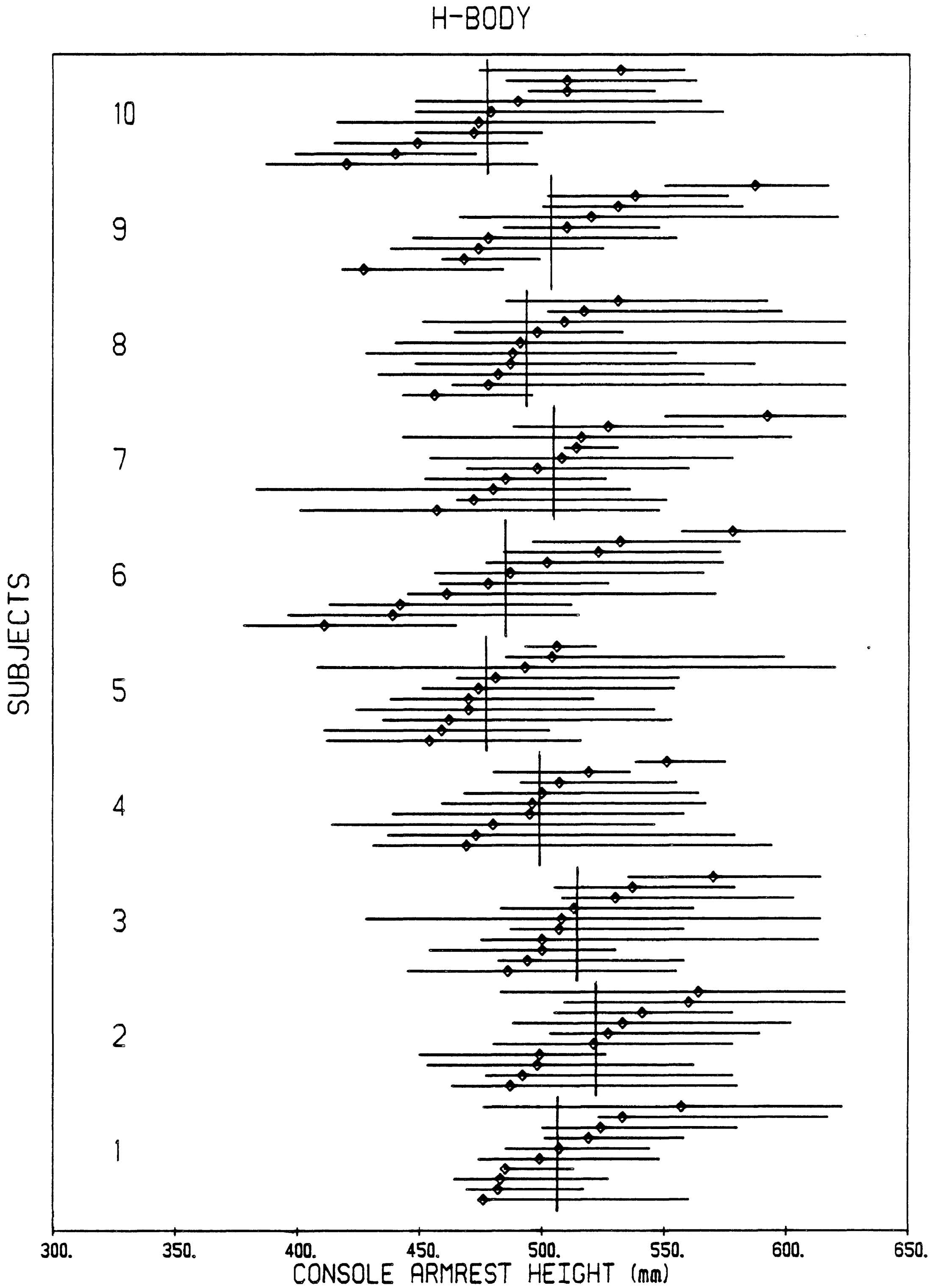
ARMREST AND ELBOW POSITION RESULTS BY SUBJECT


G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
DOOR ARMREST HEIGHT (mm)

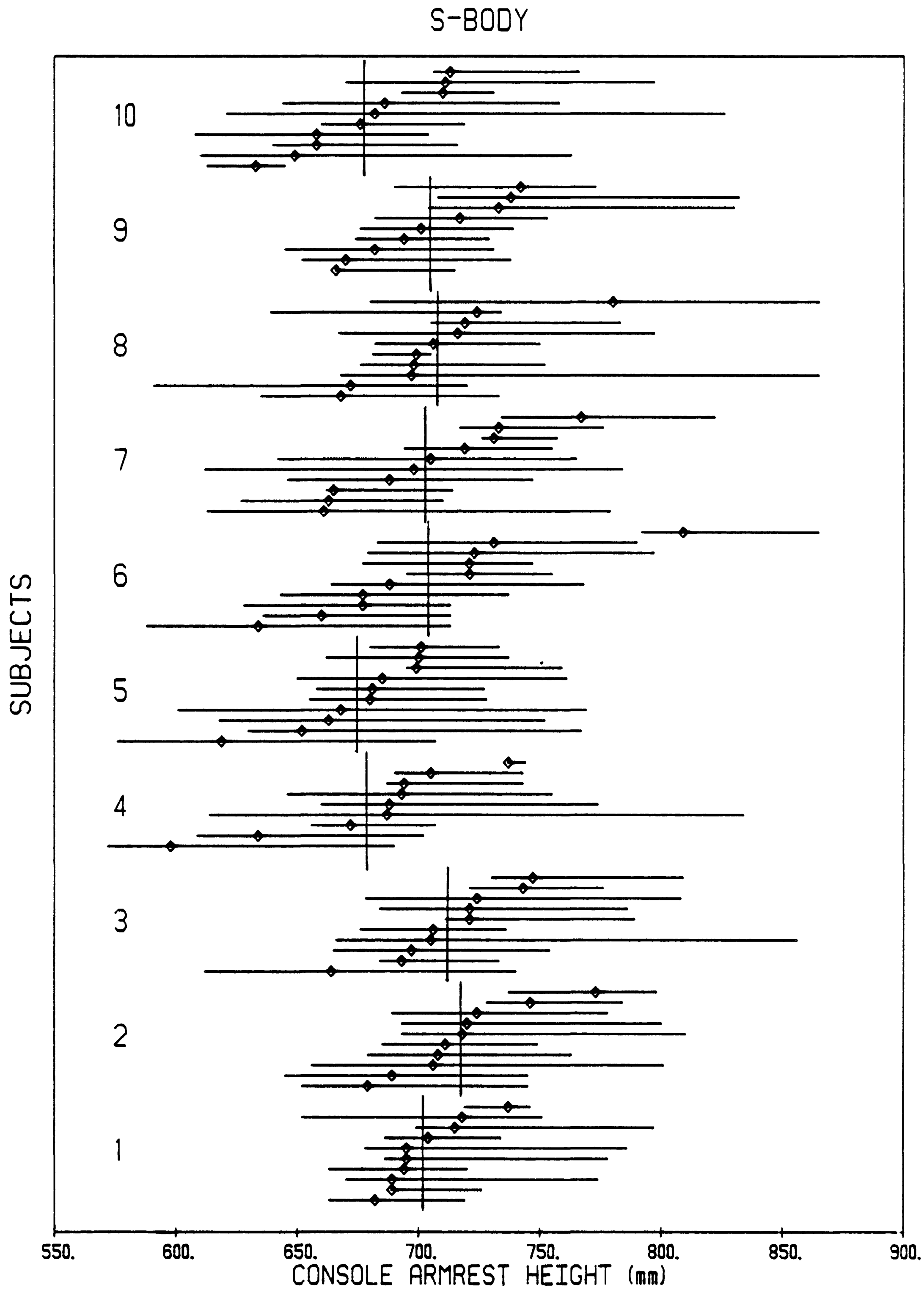

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
DOOR ARMREST HEIGHT (mm)

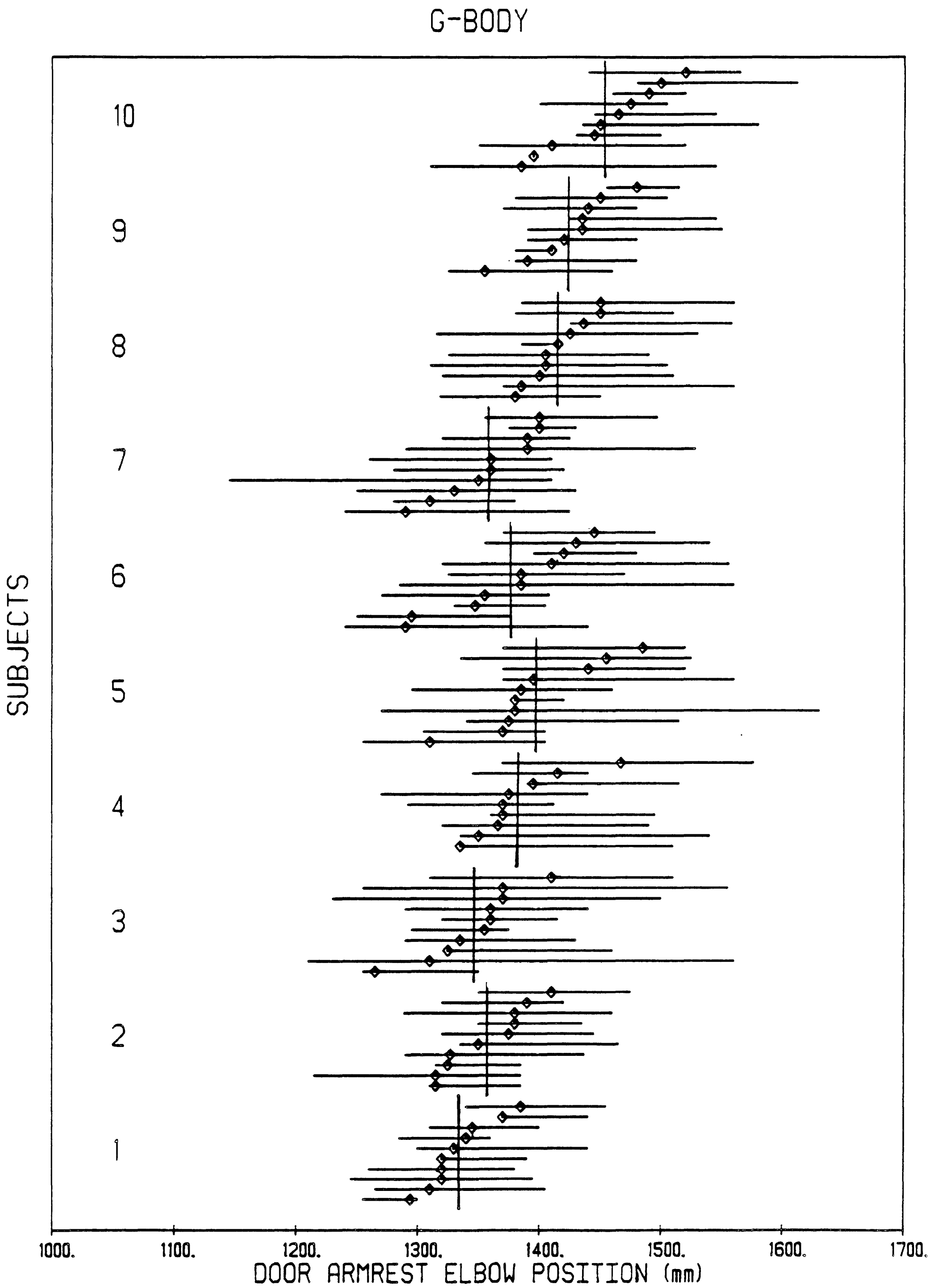

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
550.
600.
650.
700.
750.
800.
850.
900.
DOOR ARMREST HEIGHT (mm)


G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
CONSOLE ARMREST HEIGHT (mm)

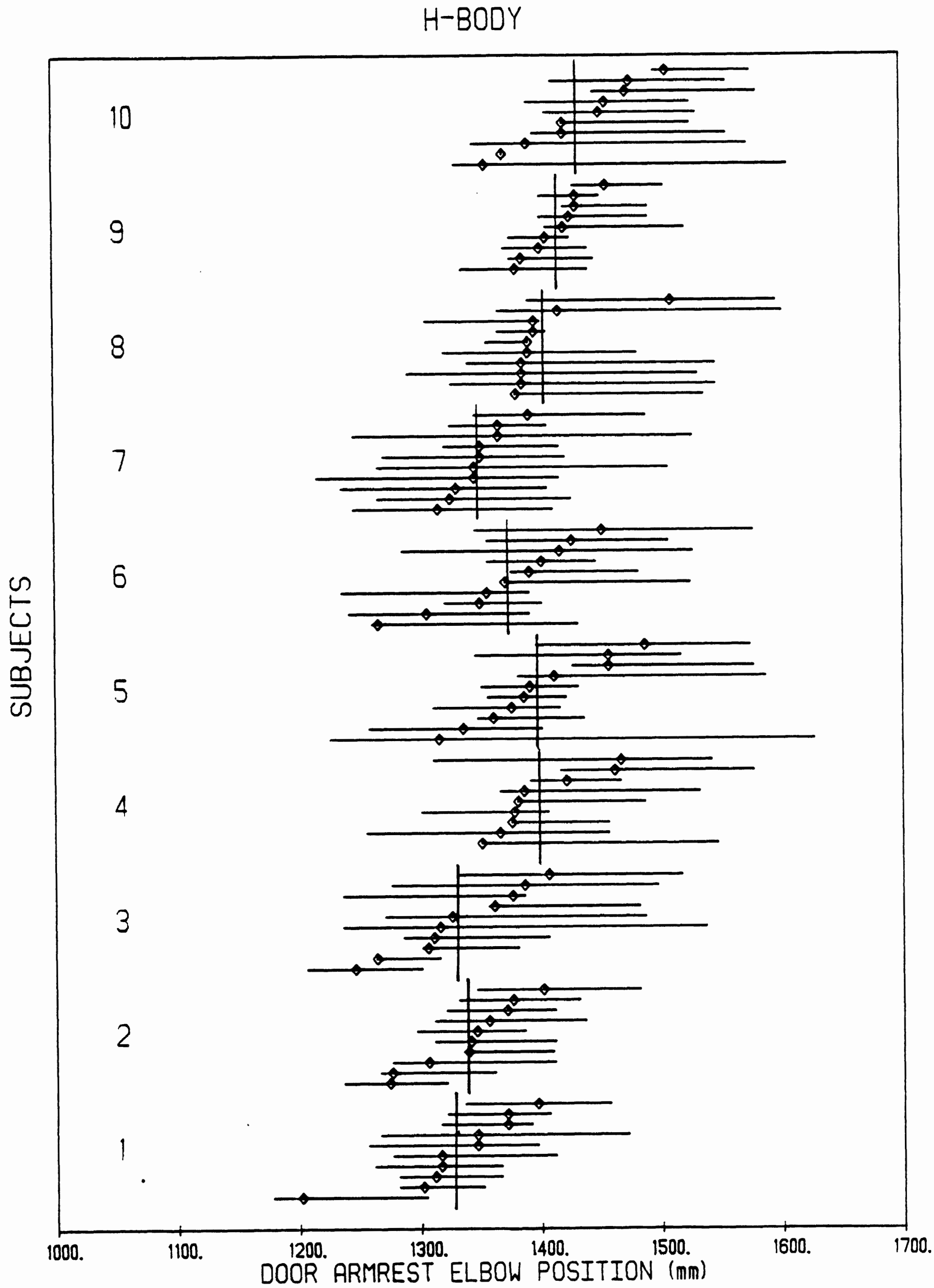


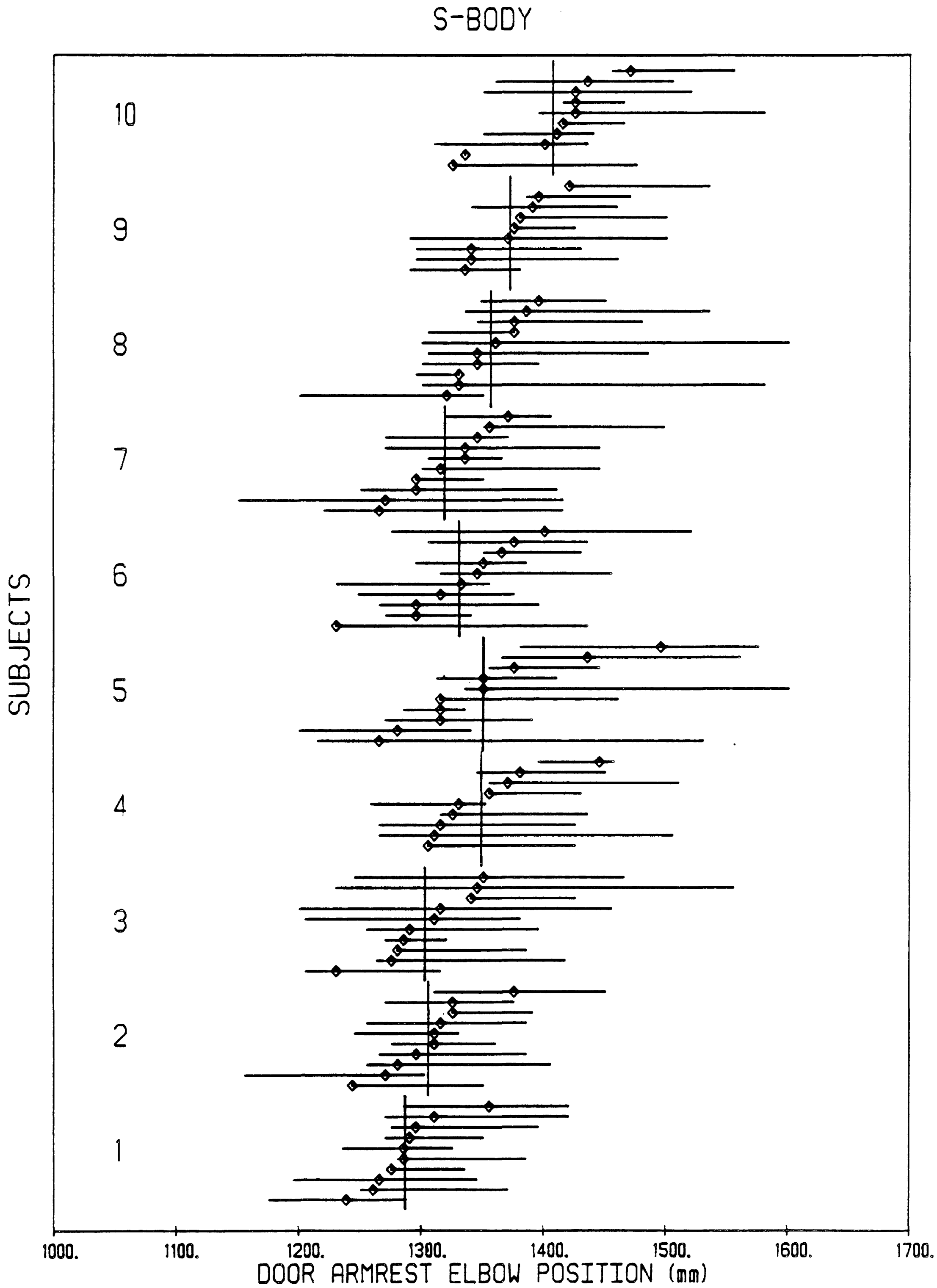
H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
CONSOLE ARMREST HEIGHT (mm)

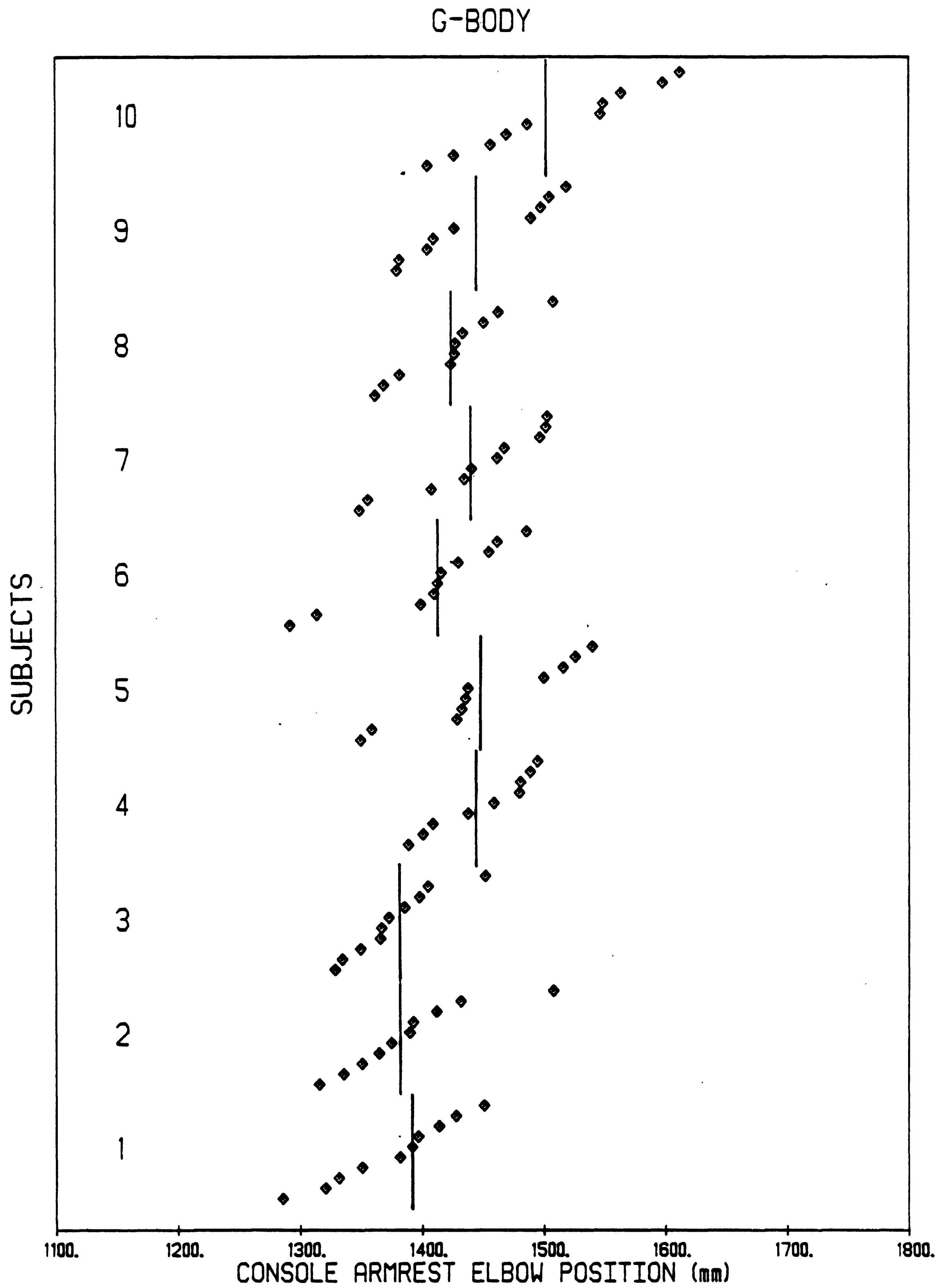

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
550.
600.
650.
700.
750.
800.
850.
900.
CONSOLE ARMREST HEIGHT (mm)

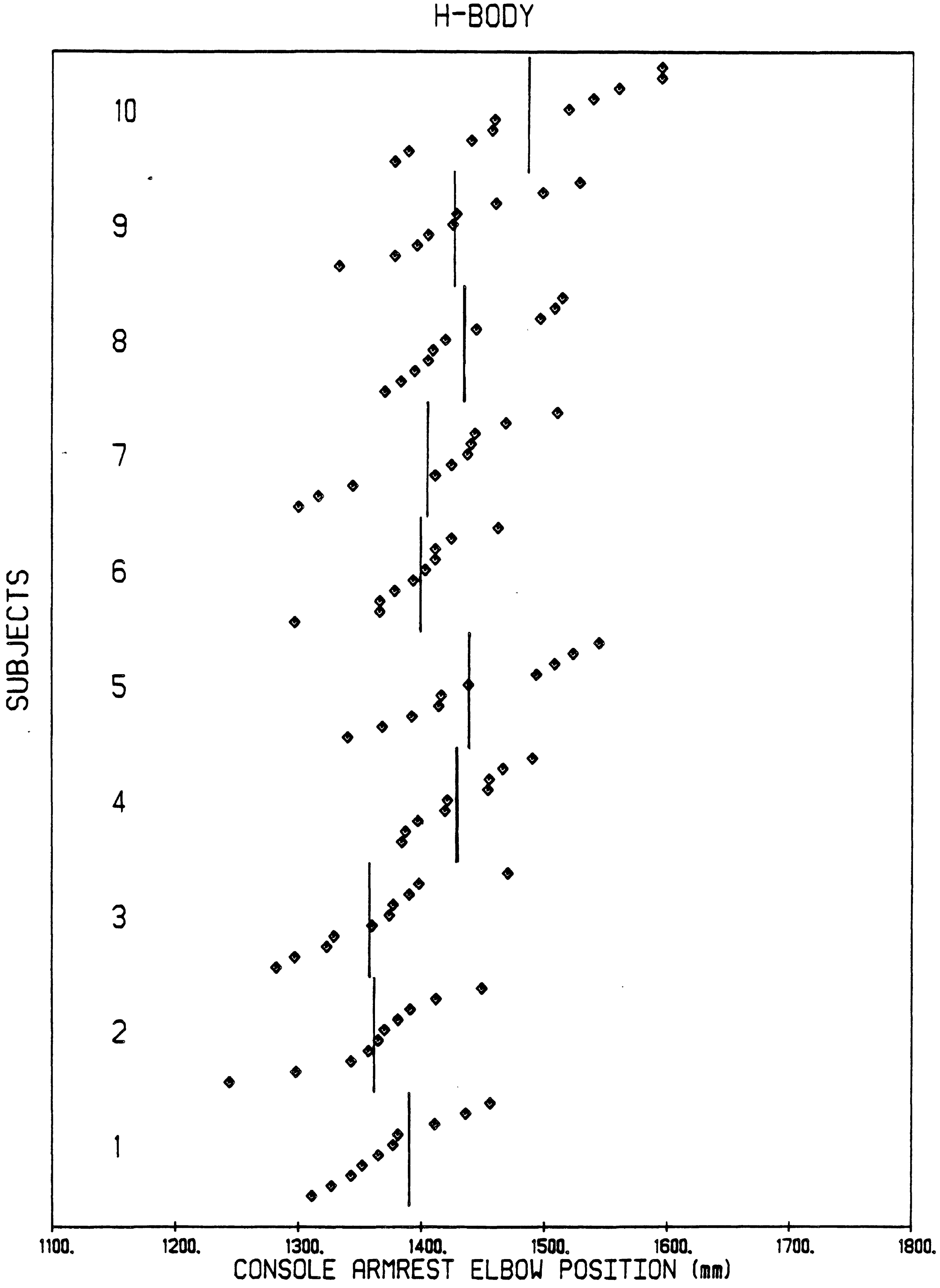


G-BODY
10
9
8
7
6
5
4
3
2
1
SUBJECTS
1000.
1100.
1200.
1300.
1400.
1500.
1600.
1700.
DOOR ARMREST ELBOW POSITION (mm)

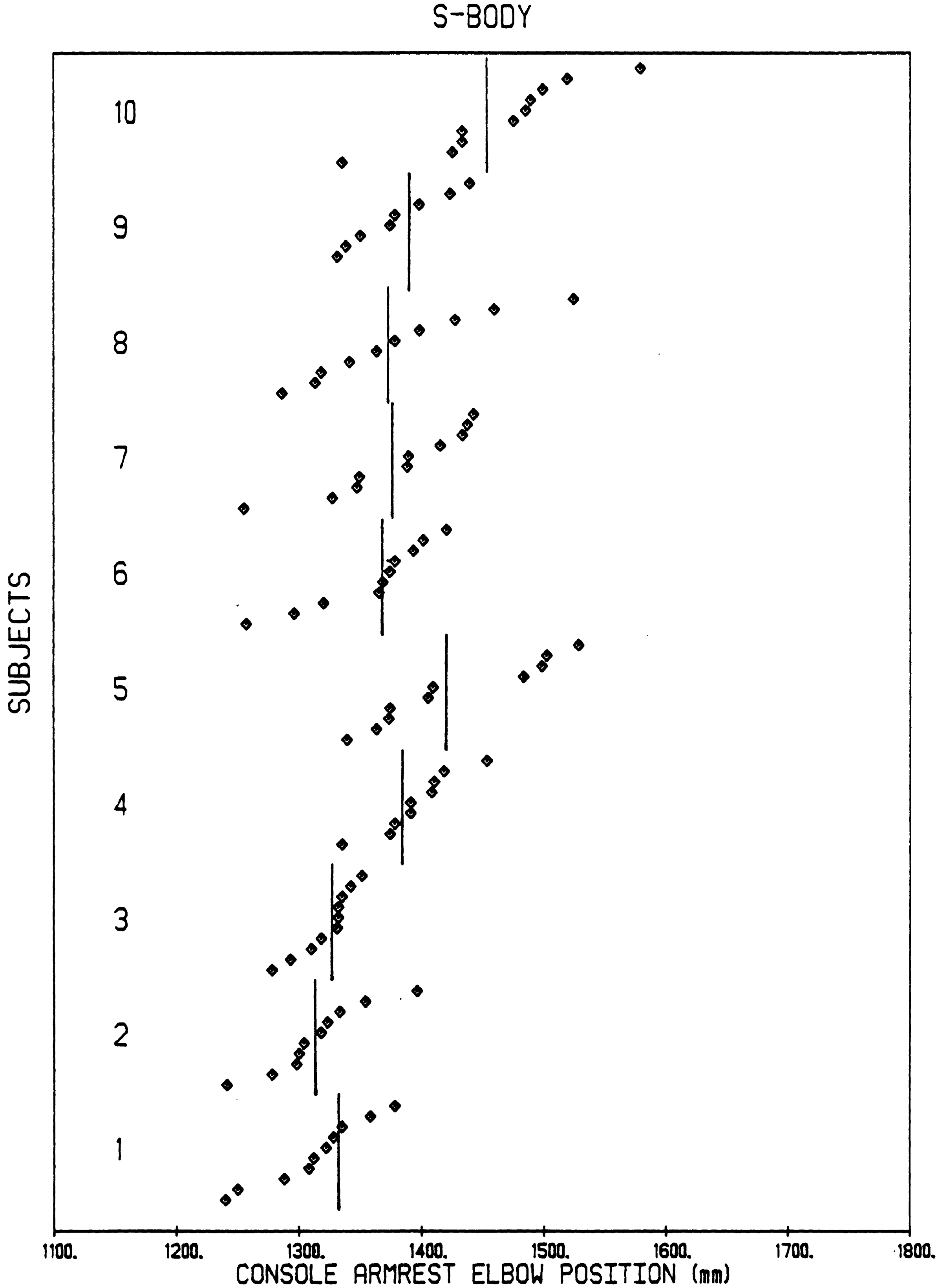

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
1000.
1100.
1200.
1300.
1400.
1500.
1600.
1700.
DOOR ARMREST ELBOW POSITION (mm)

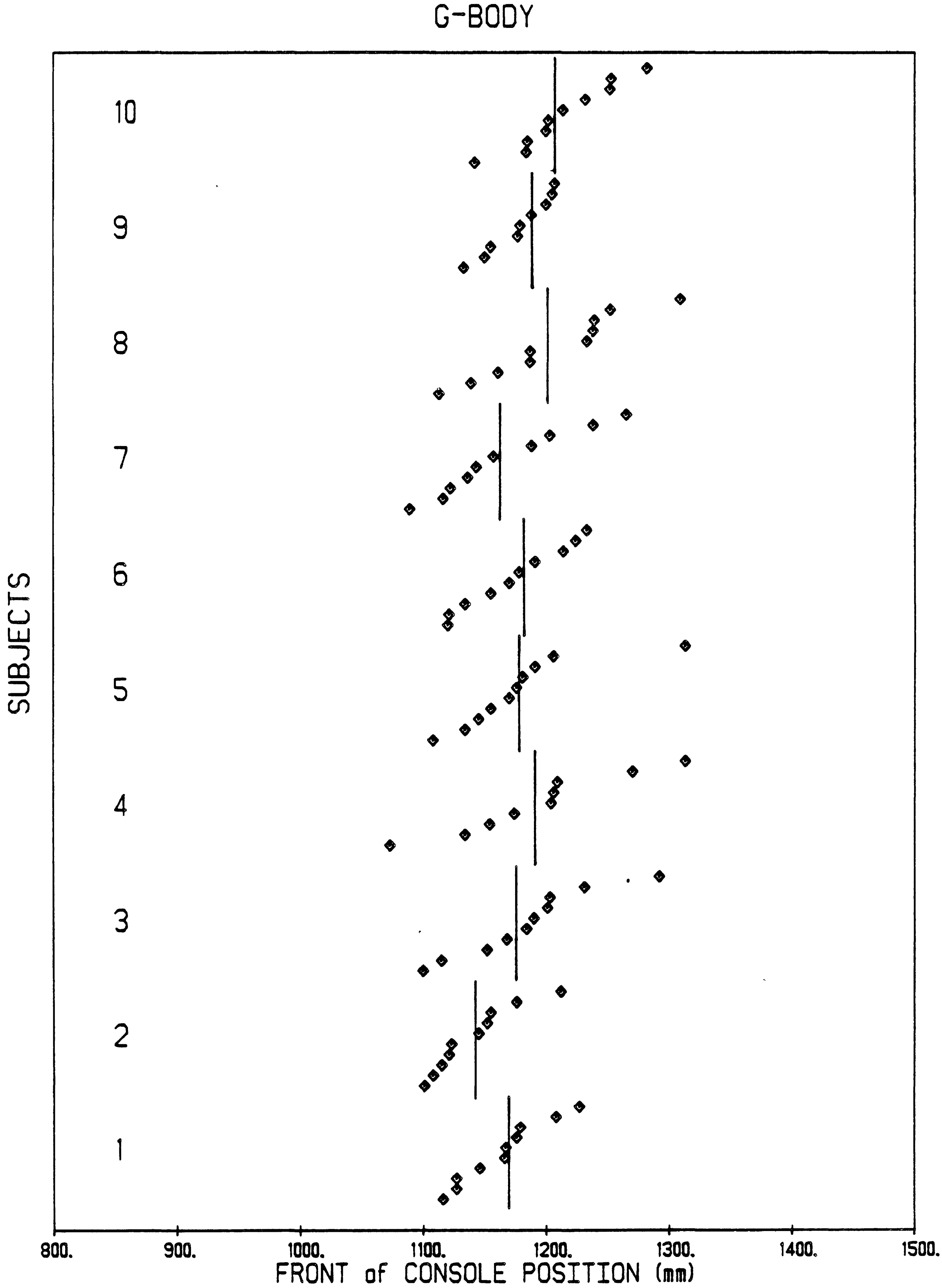

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
1000.
1100.
1200.
1300.
1400.
1500.
1600.
1700.
DOOR ARMREST ELBOW POSITION (mm)

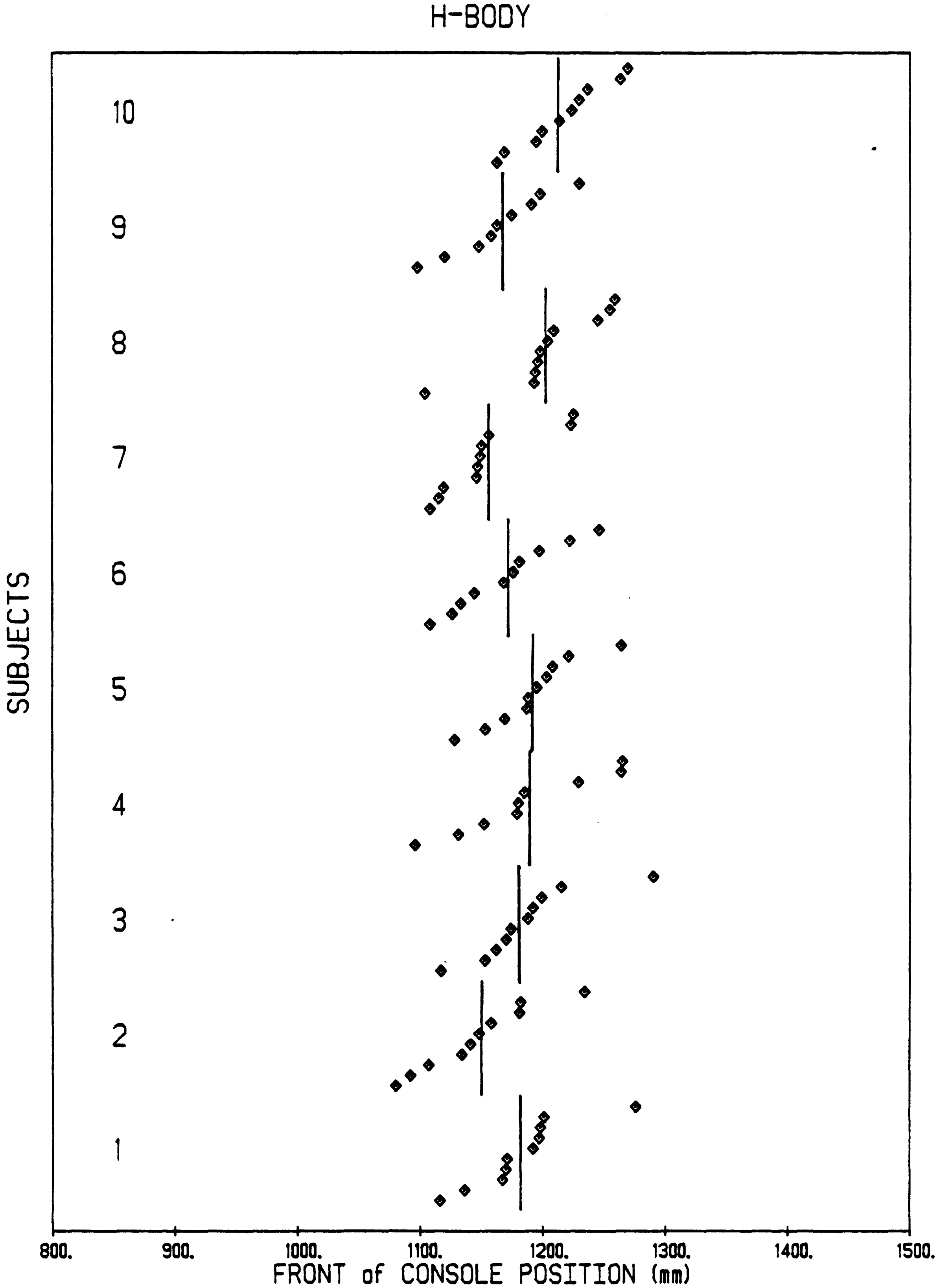

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
1100.
1200.
1300.
1400.
1500.
1600.
1700.
1800.
CONSOLE ARMREST ELBOW POSITION (mm)

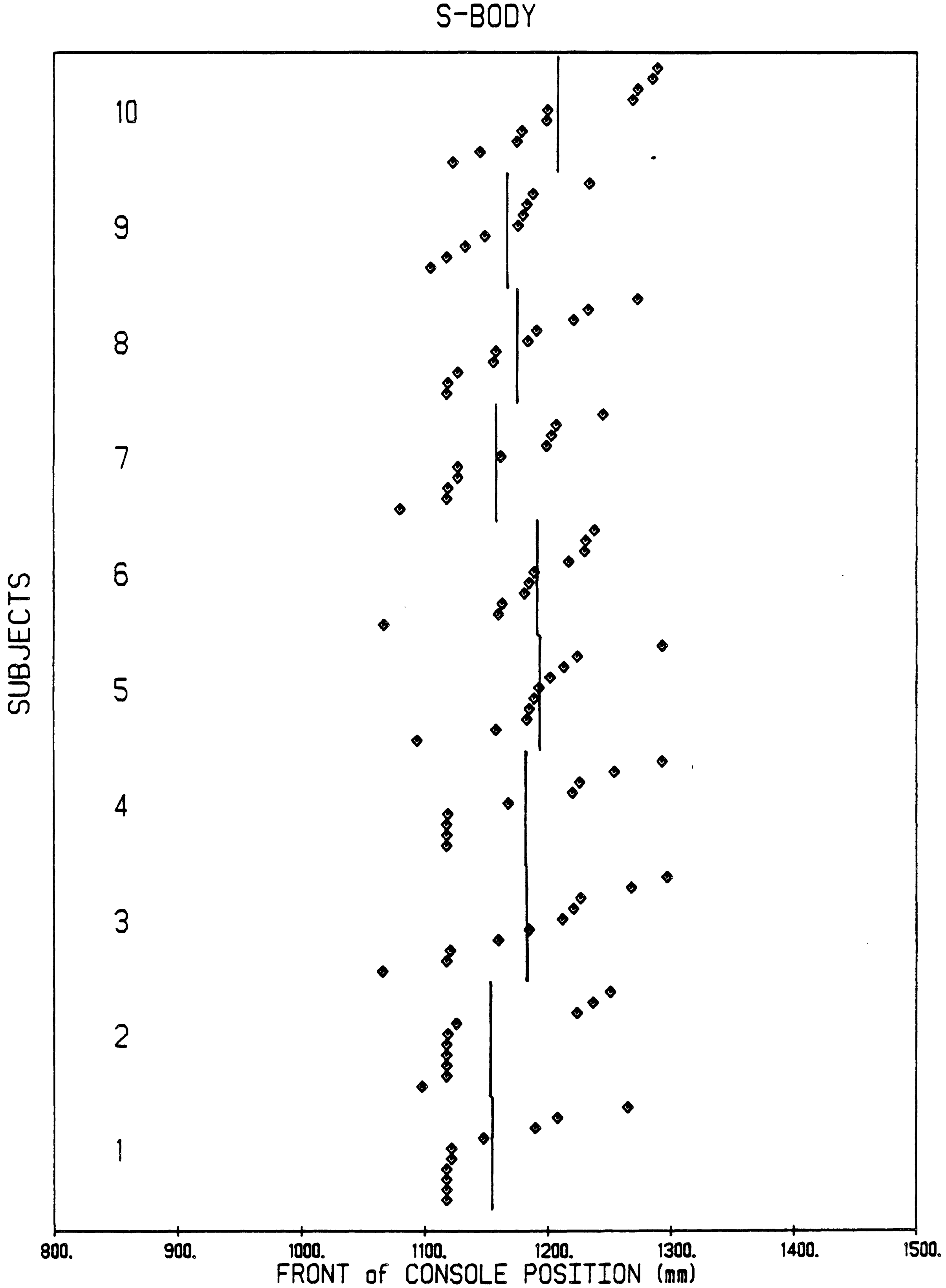


H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
1100.
1200.
1300.
1400.
1500.
1600.
1700.
1800.
CONSOLE ARMREST ELBOW POSITION (mm)


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
1100.
1200.
1300.
1400.
1500.
1600.
1700.
1800.
CONSOLE ARMREST ELBOW POSITION (mm)


G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
800.
900.
1000.
1100.
1200.
1300.
1400.
1500.
FRONT of CONSOLE POSITION (mm)


H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
800.
900.
1000.
1100.
1200.
1300.
1400.
1500.
FRONT of CONSOLE POSITION (mm)


S-BODY
10
9
8
7
6
5
4
3
2
1
SUBJECTS
800.
900.
1000.
1100.
1200.
1300.
1400.
1500.
FRONT of CONSOLE POSITION (mm)

APPENDIX F

ARMREST AND ELBOW POSITION RESULTS BY SUBJECT GROUP

Table F-1

Preferred Position and Acceptable Limit Results for
DOOR ARMREST HEIGHT in Vehicle Coordinates (mm)

Group	N	Preferred mean	Preferred (s.d.)	Upper Limit mean	Upper Limit (s.d.)	Lower Limit mean	Lower Limit (s.d.)	Mean Aceptable Range
G-BODY:								
1	10	512.9	(47.4)	571.5	(42.7)	478.7	(36.4)	101.9
2	10	525.2	(46.2)	599.6	(38.3)	473.3	(37.6)	147.3
3	10	528.2	(36.4)	614.2	(28.2)	480.9	(34.2)	140.4
4	9	518.2	(38.3)	585.0	(45.0)	462.9	(37.6)	122.1
5	10	513.1	(30.0)	584.8	(32.0)	455.8	(35.7)	129.0
6	10	507.2	(46.9)	575.2	(51.9)	458.4	(40.0)	116.8
7	10	529.6	(46.1)	602.2	(33.1)	467.1	(46.0)	152.4
8	10	525.2	(41.6)	610.1	(44.5)	465.3	(31.5)	144.8
9	9	541.8	(58.7)	590.4	(57.0)	491.1	(50.1)	116.1
10	10	510.7	(36.1)	582.6	(42.8)	453.7	(35.1)	128.9
H-BODY:								
1	10	547.1	(39.5)	593.5	(41.4)	513.1	(37.0)	107.0
2	10	542.2	(40.5)	608.5	(40.8)	494.3	(35.2)	138.7
3	10	545.0	(25.6)	621.5	(36.6)	507.3	(23.4)	125.3
4	9	537.2	(37.3)	599.7	(29.4)	481.2	(51.4)	129.4
5	10	529.3	(24.8)	607.6	(30.6)	481.1	(27.9)	132.5
6	10	530.6	(40.2)	587.7	(30.3)	489.5	(42.1)	98.2
7	10	571.2	(42.4)	625.6	(30.1)	513.9	(47.8)	123.5
8	10	535.3	(49.3)	624.8	(33.2)	480.5	(37.5)	144.3
9	9	555.3	(60.2)	606.4	(56.0)	503.8	(33.3)	117.8
10	10	529.9	(26.4)	597.5	(37.9)	482.3	(32.6)	115.2
S-BODY:								
1	10	747.0	(32.1)	784.2	(19.9)	711.5	(29.2)	87.0
2	10	746.3	(19.4)	805.8	(23.5)	704.2	(22.2)	120.1
3	10	768.3	(27.1)	812.4	(28.4)	720.6	(26.9)	110.7
4	9	738.1	(30.9)	780.7	(18.5)	698.0	(34.8)	108.2
5	10	744.4	(29.0)	801.6	(34.0)	680.7	(35.7)	129.6
6	10	732.5	(32.0)	784.8	(29.8)	695.1	(35.4)	101.6
7	10	703.0	(35.1)	812.4	(24.5)	703.4	(32.0)	141.9
8	10	738.7	(25.9)	797.3	(30.9)	684.3	(28.3)	119.4
9	9	750.0	(26.4)	808.6	(38.2)	712.6	(22.7)	110.9
10	10	736.7	(20.3)	797.0	(39.3)	691.3	(31.3)	109.2

Table F-2

Preferred Position and Acceptable Limit Results
for CONSOLE ARMREST HEIGHT in Vehicle Coordinates (mm)

Group	N	Preferred mean (s.d.)	Upper Limit mean	Upper Limit (s.d.)	Upper Limit mean	Upper Limit (s.d.)	Mean Acceptable Range
G-BODY:							
1	10	488.4 (27.8)	548.6	(38.0)	467.2	(17.4)	81.4
2	10	494.8 (24.9)	561.1	(27.7)	467.0	(94.1)	94.1
3	10	511.1 (21.9)	573.4	(24.3)	469.4	(31.2)	104.1
4	9	464.0 (32.7)	548.1	(40.4)	418.8	(49.4)	129.3
5	10	458.0 (22.9)	528.9	(40.8)	418.3	(34.0)	110.6
6	10	476.1 (43.1)	534.9	(38.9)	444.9	(41.7)	90.0
7	10	481.6 (41.5)	546.7	(42.9)	439.9	(45.7)	106.8
8	10	468.6 (26.1)	554.2	(52.1)	430.4	(25.6)	123.8
9	9	482.3 (50.1)	531.1	(46.5)	454.4	(47.7)	76.7
10	10	463.7 (41.7)	532.3	(42.8)	414.7	(43.4)	117.6
H-BODY:							
1	10	506.5 (26.5)	558.7	(38.2)	485.1	(18.1)	73.6
2	10	522.2 (27.8)	584.1	(28.9)	481.1	(21.0)	103.0
3	10	514.5 (24.9)	578.6	(30.4)	480.2	(31.8)	98.4
4	9	499.0 (25.3)	563.8	(17.6)	461.9	(37.8)	101.9
5	10	477.3 (18.3)	549.0	(37.1)	442.2	(30.7)	106.8
6	10	485.3 (50.2)	550.8	(45.5)	456.0	(52.4)	94.8
7	10	504.9 (37.6)	563.0	(31.8)	461.4	(48.5)	101.6
8	10	493.7 (21.3)	579.9	(42.7)	455.7	(23.3)	124.2
9	9	503.7 (47.3)	556.3	(48.1)	473.8	(40.0)	82.6
10	10	477.6 (34.7)	531.7	(36.5)	441.4	(36.5)	90.3
S-BODY:							
1	10	701.8 (16.8)	753.1	(28.8)	680.6	(19.8)	72.5
2	10	717.4 (26.9)	777.3	(25.2)	685.7	(30.3)	91.0
3	10	712.1 (24.6)	778.7	(39.4)	682.7	(33.6)	96.0
4	9	678.7 (40.7)	743.6	(43.6)	652.4	(49.8)	91.1
5	10	674.8 (25.6)	744.0	(20.6)	642.5	(36.4)	101.5
6	10	704.1 (48.6)	759.8	(48.0)	668.5	(54.0)	91.3
7	10	703.0 (35.1)	760.9	(33.1)	667.3	(46.9)	93.6
8	10	707.9 (31.3)	770.4	(56.8)	662.4	(32.5)	108.0
9	9	704.8 (29.2)	760.0	(43.4)	677.4	(21.4)	82.6
10	10	677.6 (28.1)	742.5	(51.1)	646.6	(35.0)	95.9

Table F-3

Preferred Position and Acceptable Limit Results
for ELBOW LOCATION ON DOOR ARMREST in Vehicle Coordinates (mm)

Group	N	Preferred mean	Preferred (s.d.)	Front Limit mean	Front Limit (s.d.)	Back Limit mean	Back Limit (s.d.)	Mean Acceptable Range
G-BODY:								
1	10	1333.4	(27.6)	1295.0	(40.6)	1396.5	(45.0)	101.5
2	10	1356.7	(34.6)	1309.4	(39.3)	1429.2	(71.3)	119.8
3	10	1346.0	(39.6)	1279.5	(41.1)	1459.5	(71.3)	180.0
4	9	1382.6	(39.2)	1339.0	(39.2)	1490.0	(52.5)	151.9
5	10	1397.5	(50.0)	1331.0	(48.2)	1496.0	(73.1)	165.0
6	10	1376.2	(53.9)	1314.0	(51.8)	1472.9	(65.9)	158.9
7	10	1358.0	(38.5)	1279.5	(64.5)	1435.5	(43.8)	156.0
8	10	1415.1	(24.8)	1353.3	(40.3)	1508.8	(48.0)	155.5
9	9	1423.9	(36.1)	1388.3	(36.0)	1491.1	(44.6)	102.8
10	10	1453.5	(45.5)	1414.5	(51.9)	1528.7	(58.5)	114.2
H-BODY								
1	10	1328.5	(54.2)	1278.1	(44.5)	1392.8	(49.1)	114.7
2	10	1339.6	(42.0)	1304.3	(35.0)	1406.8	(43.3)	102.5
3	10	1330.8	(52.2)	1277.3	(45.2)	1431.5	(83.8)	154.2
4	9	1399.4	(41.3)	1355.9	(53.1)	1497.0	(55.3)	141.1
5	10	1398.5	(55.0)	1340.9	(60.8)	1499.2	(86.0)	158.3
6	10	1374.4	(56.4)	1316.1	(54.3)	1468.3	(65.0)	152.2
7	10	1350.0	(21.9)	1275.0	(43.0)	1443.2	(45.8)	168.2
8	10	1404.8	(38.2)	1345.6	(32.9)	1504.5	(79.3)	158.9
9	9	1416.4	(24.0)	1391.8	(28.8)	1469.0	(33.8)	77.2
10	10	1433.2	(48.8)	1402.5	(47.8)	1541.2	(65.0)	138.7
S-BODY:								
1	10	1286.8	(31.6)	1252.7	(38.6)	1364.2	(42.9)	111.5
2	10	1305.8	(36.0)	1266.0	(46.4)	1374.2	(41.0)	108.2
3	10	1303.0	(37.5)	1256.3	(51.1)	1412.2	(70.9)	155.9
4	9	1349.3	(45.0)	1322.4	(49.9)	1444.2	(47.1)	121.8
5	10	1350.5	(70.5)	1306.2	(61.8)	1465.5	(97.3)	159.3
6	10	1331.2	(48.8)	1283.3	(34.8)	1413.5	(53.5)	130.2
7	10	1319.0	(35.8)	1279.5	(61.5)	1410.8	(47.5)	131.3
8	10	1357.0	(25.8)	1304.3	(41.5)	1459.0	(95.0)	154.7
9	9	1372.7	(28.8)	1342.1	(50.4)	1463.1	(46.7)	121.0
10	10	1407.5	(44.4)	1373.0	(45.7)	1478.5	(69.1)	105.5

Table F-4

Preferred Position Results for
ELBOW LOCATIONS ON CENTER ARMREST
in Vehicle Coordinates (mm)

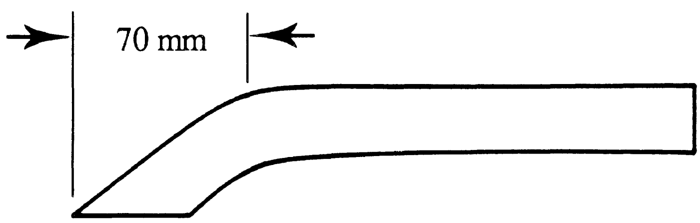
		Mean Preferred Position (s.d.)		
Group	N	G	H	S
1	10	1375 (52)	1376 (47)	1312 (43)
2	10	1387 (55)	1361 (57)	1315 (42)
3	10	1376 (36)	1360 (55)	1322 (23)
4	9	1449 (41)	1430 (38)	1395 (33)
5	10	1453 (67)	1444 (70)	1427 (69)
6	10	1408 (62)	1391 (44)	1357 (51)
7	10	1442 (56)	1409 (68)	1378 (59)
8	10	1425 (45)	1434 (54)	1381 (73)
9	9	1446 (56)	1428 (60)	1379 (39)
10	10	1512 (72)	1493 (80)	1467 (66)

Table F-5

Preferred Position Results for
FRONT EDGE OF CENTER ARMREST
in Vehicle Coordinates (mm)

Group	N	Mean Preferred Position (s.d.) G*	H*	S
1	10	1164 (36)	1182 (43)	1153 (51)
2	10	1141 (34)	1146 (46)	1153 (59)
3	10	1184 (55)	1186 (46)	1188 (72)
4	9	1193 (71)	1187 (58)	1182 (68)
5	10	1178 (55)	1192 (37)	1193 (50)
6	10	1174 (42)	1170 (44)	1186 (51)
7	10	1166 (56)	1154 (41)	1159 (53)
8	10	1205 (59)	1206 (44)	1178 (52)
9	9	1177 (26)	1165 (40)	1163 (40)
10	10	1215 (41)	1217 (36)	1214 (61)

* For G- and H-body vehicles, this coordinate is for the lower front edge of the sloped part of the armrest as indicated below. The coordinate for the front edge of the useable armrest is obtained by adding 70 mm to these coordinate values.

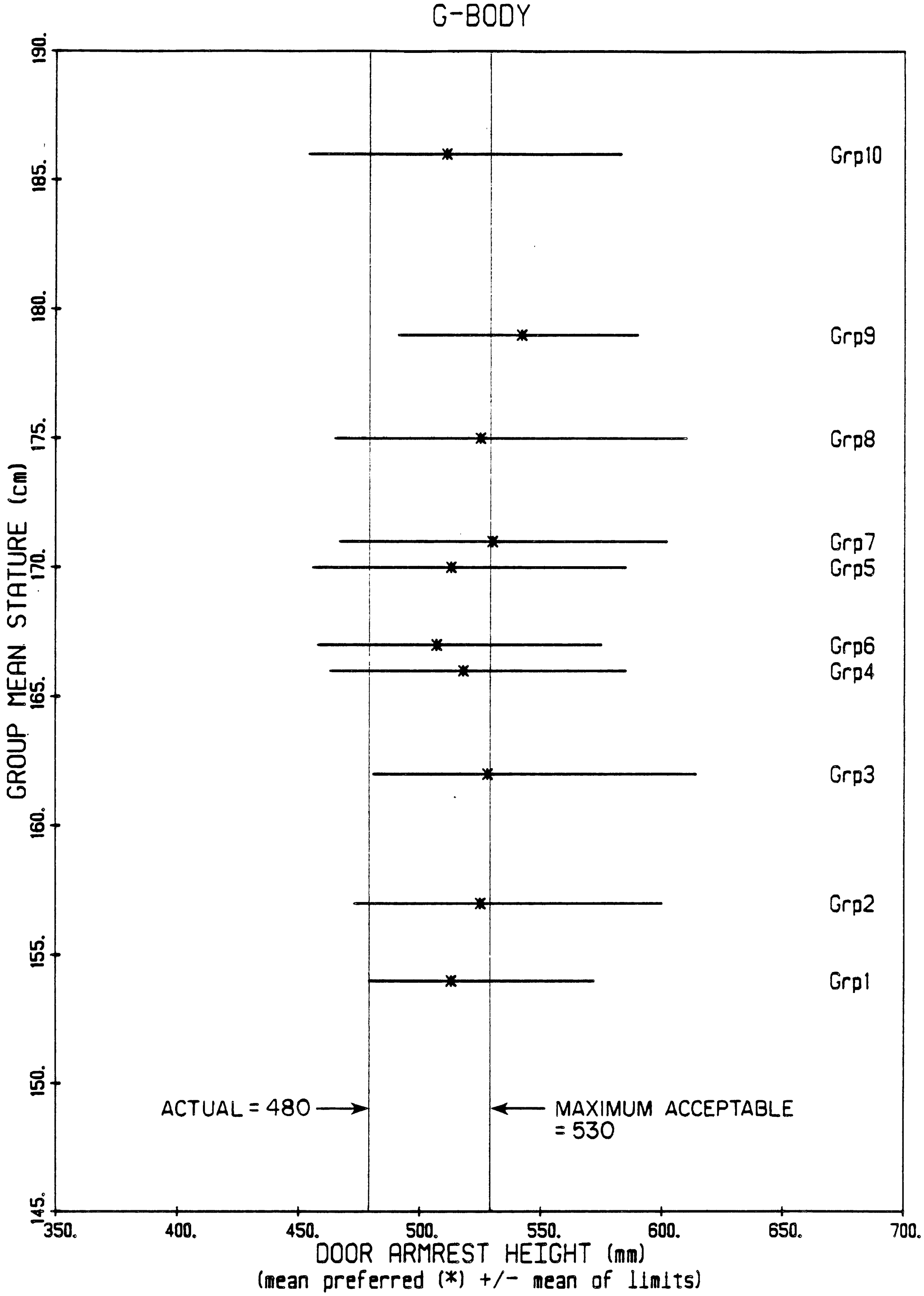


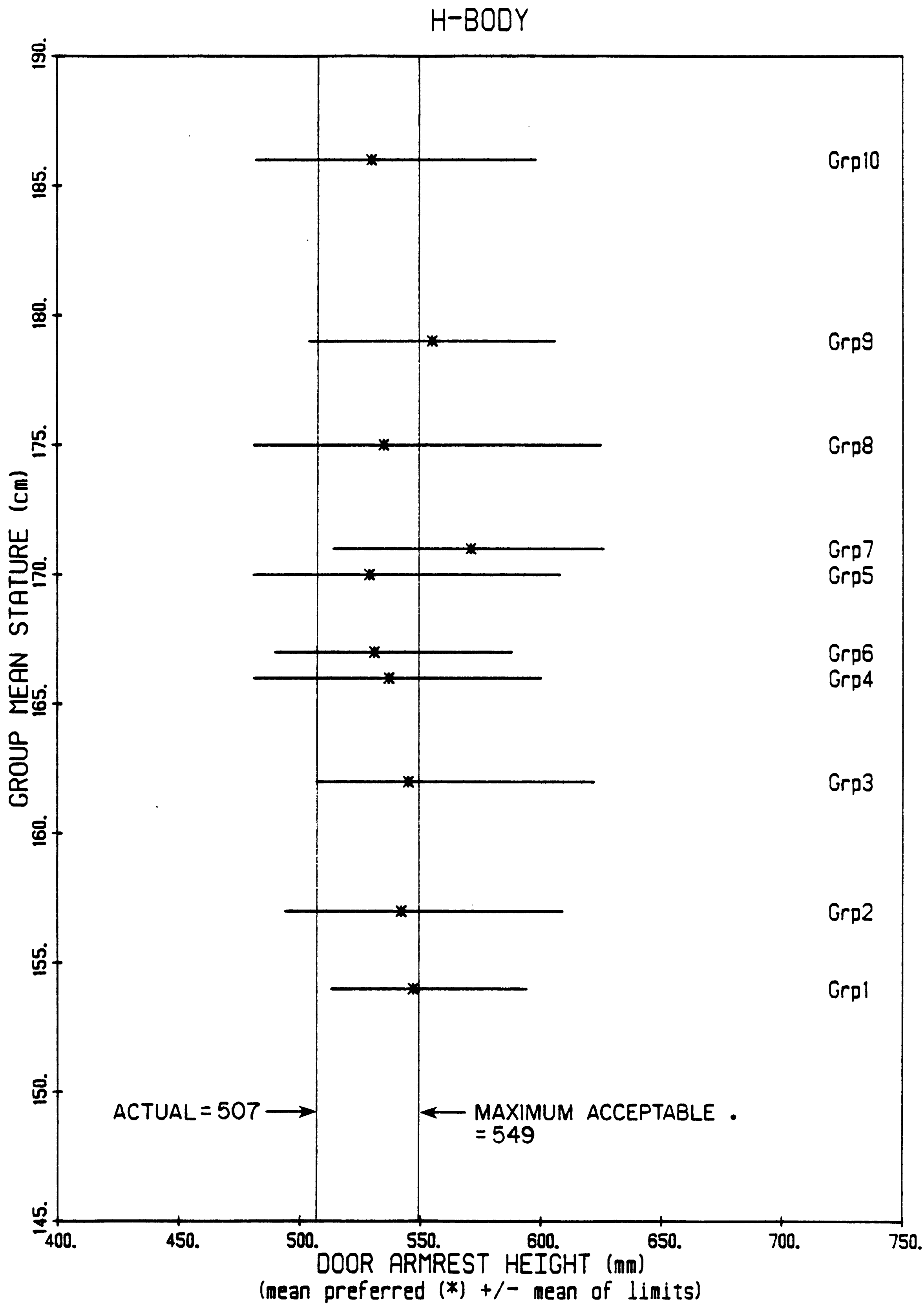
H-BODY CONSOLE COVER/ARMREST

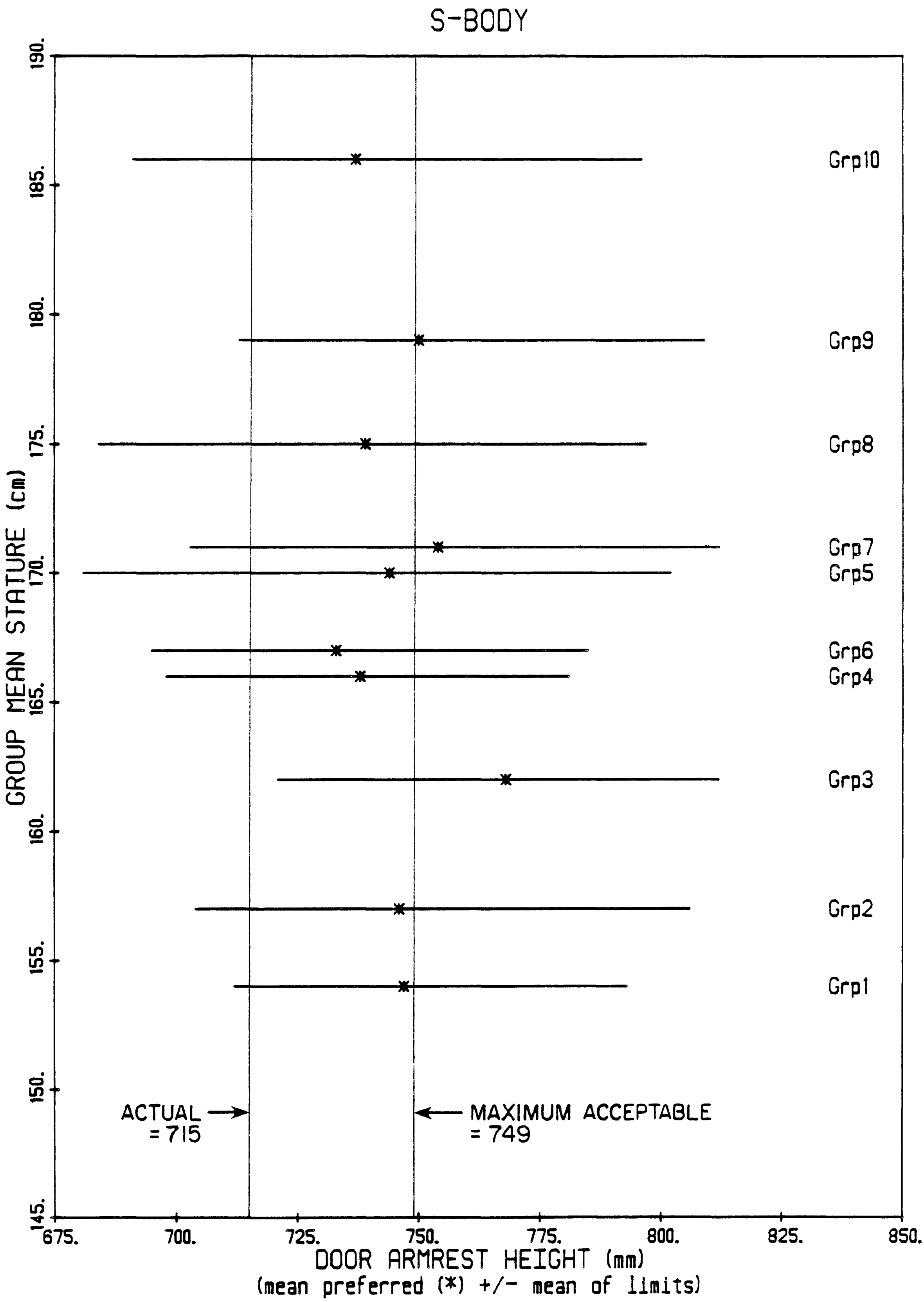
Table F-6

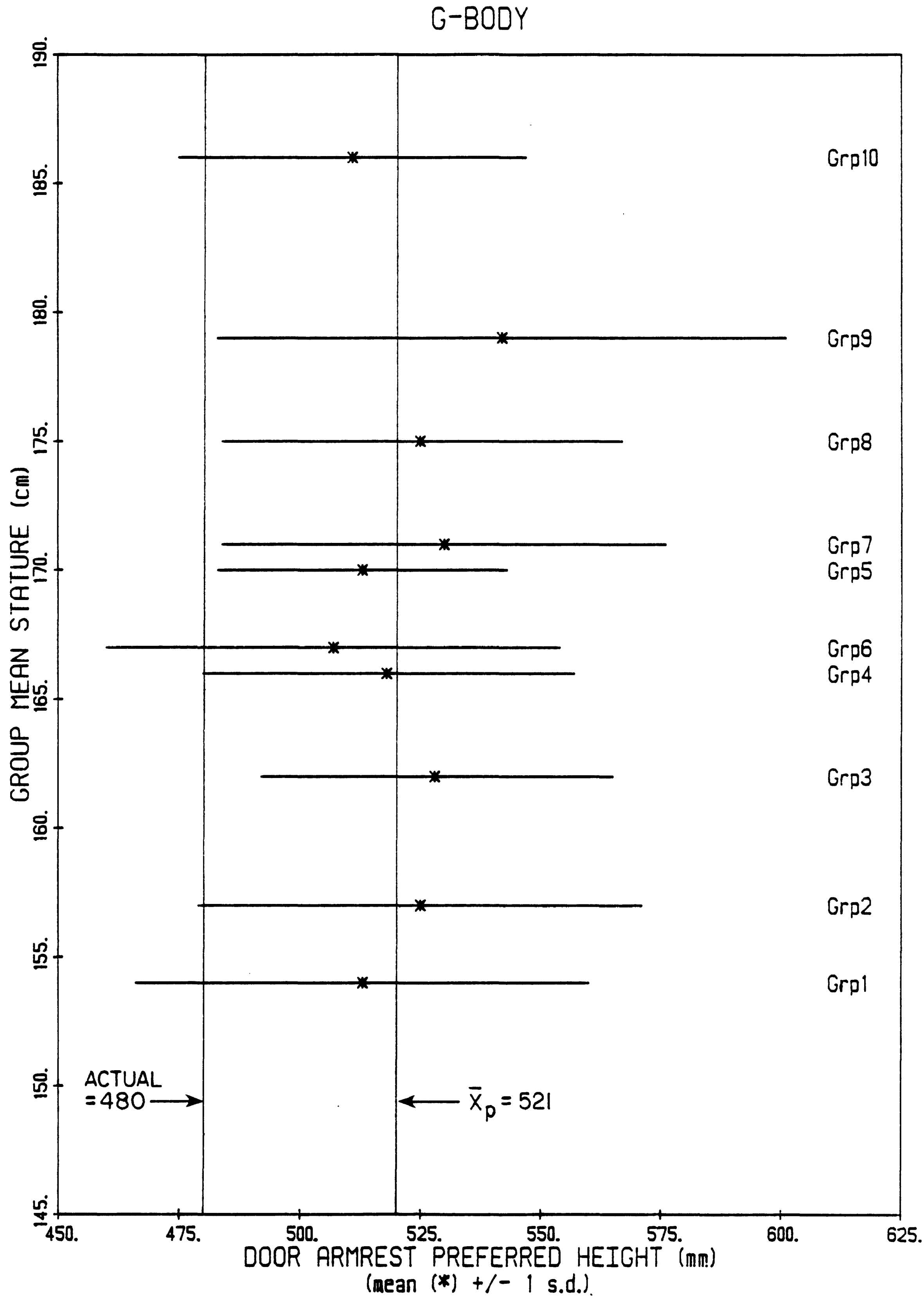
Preferred Position Results for
FINGER-TIP CONTROLS ON DOOR ARMREST
in Vehicle Coordinates (mm)

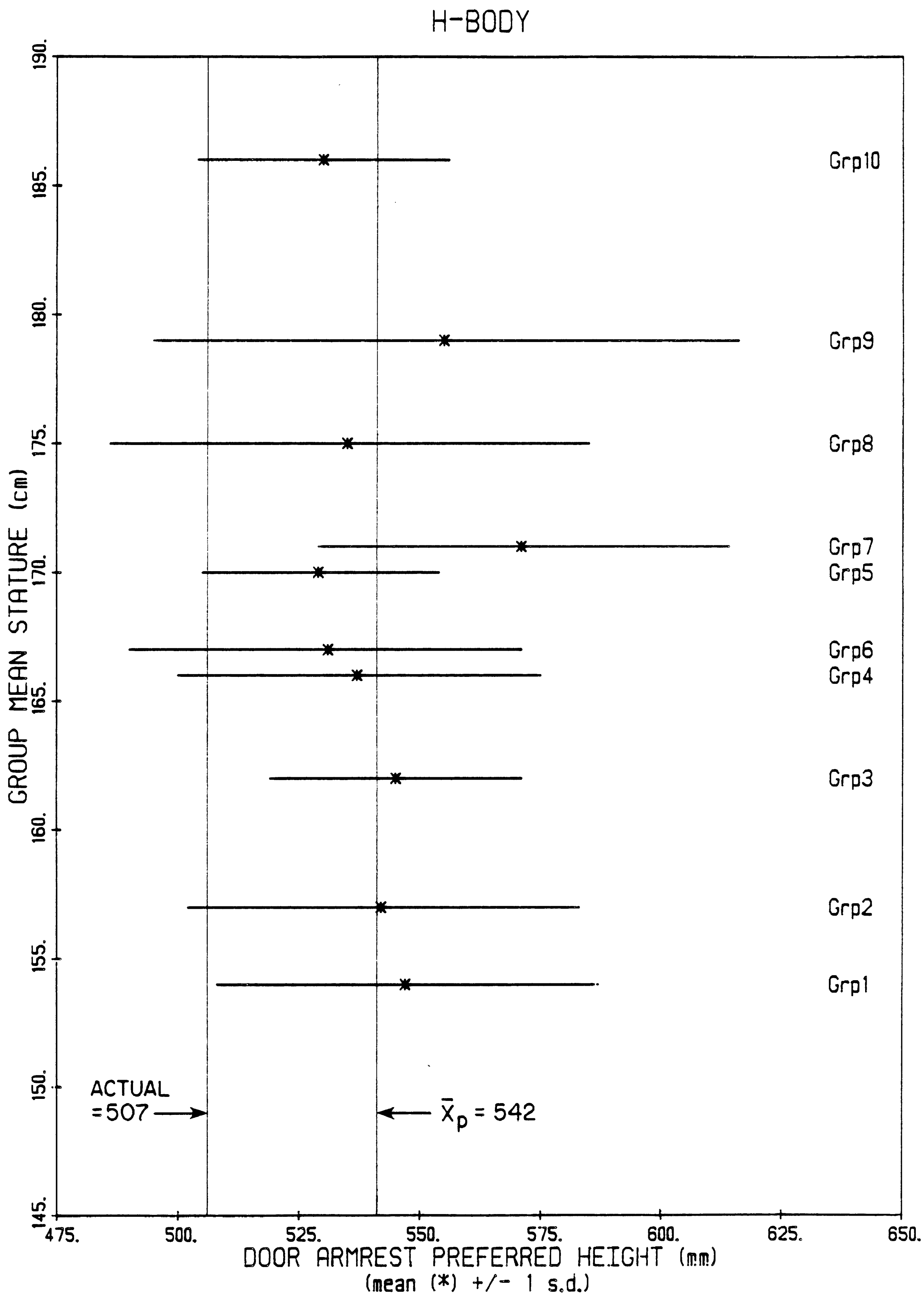
Group	N	Mean Preferred Position (s.d.) G	H	S
1	10	936 (32)	932 (58)	893 (40)
2	10	941 (32)	937 (45)	908 (37)
3	10	940 (38)	925 (47)	897 (33)
4	9	962 (38)	972 (46)	930 (46)
5	10	959 (46)	960 (49)	917 (65)
6	10	936 (41)	936 (54)	894 (43)
7	10	908 (58)	893 (29)	867 (34)
8	10	975 (44)	963 (45)	915 (35)
9	9	948 (54)	940 (35)	899 (38)
10	10	958 (48)	940 (46)	908 (50)

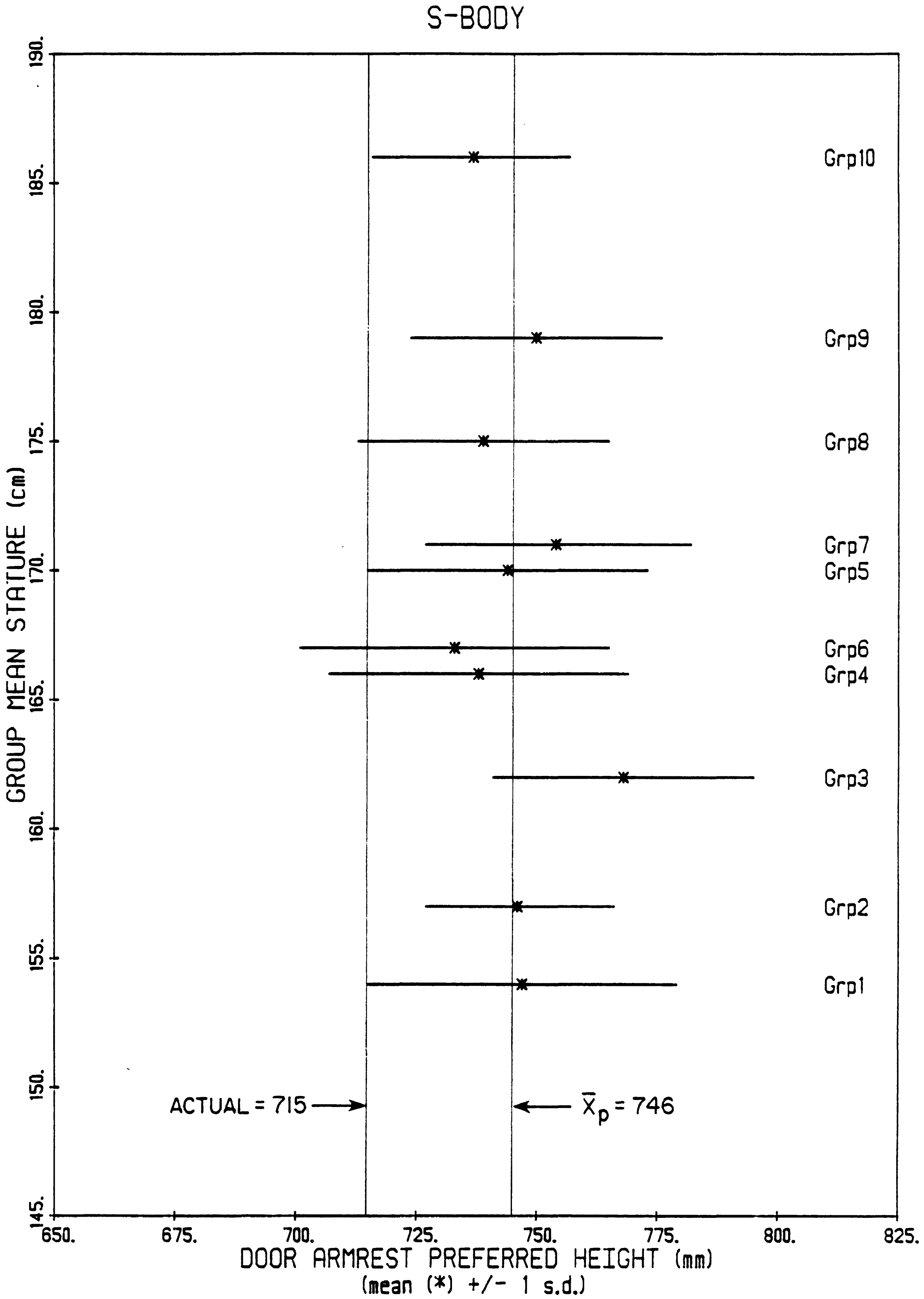

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 480
MAXIMUM ACCEPTABLE = 530
350.
400.
450.
500.
550.
600.
650.
700.
DOOR ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)


H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 507
MAXIMUM ACCEPTABLE = 549
400.
450.
500.
550.
600.
650.
700.
750.
DOOR ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)

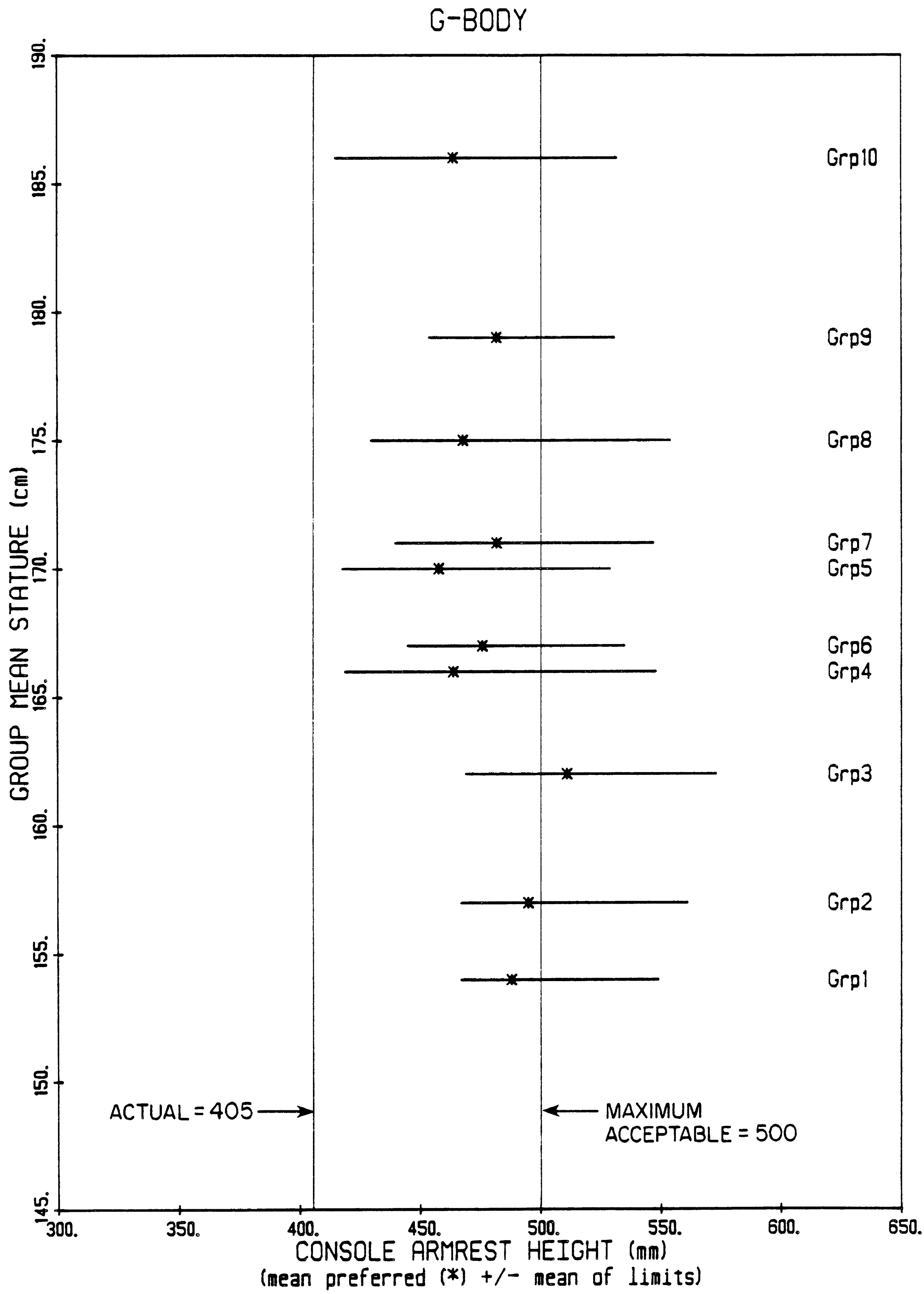

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 715
MAXIMUM ACCEPTABLE = 749
675.
700.
725.
750.
775.
800.
825.
850.
DOOR ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)

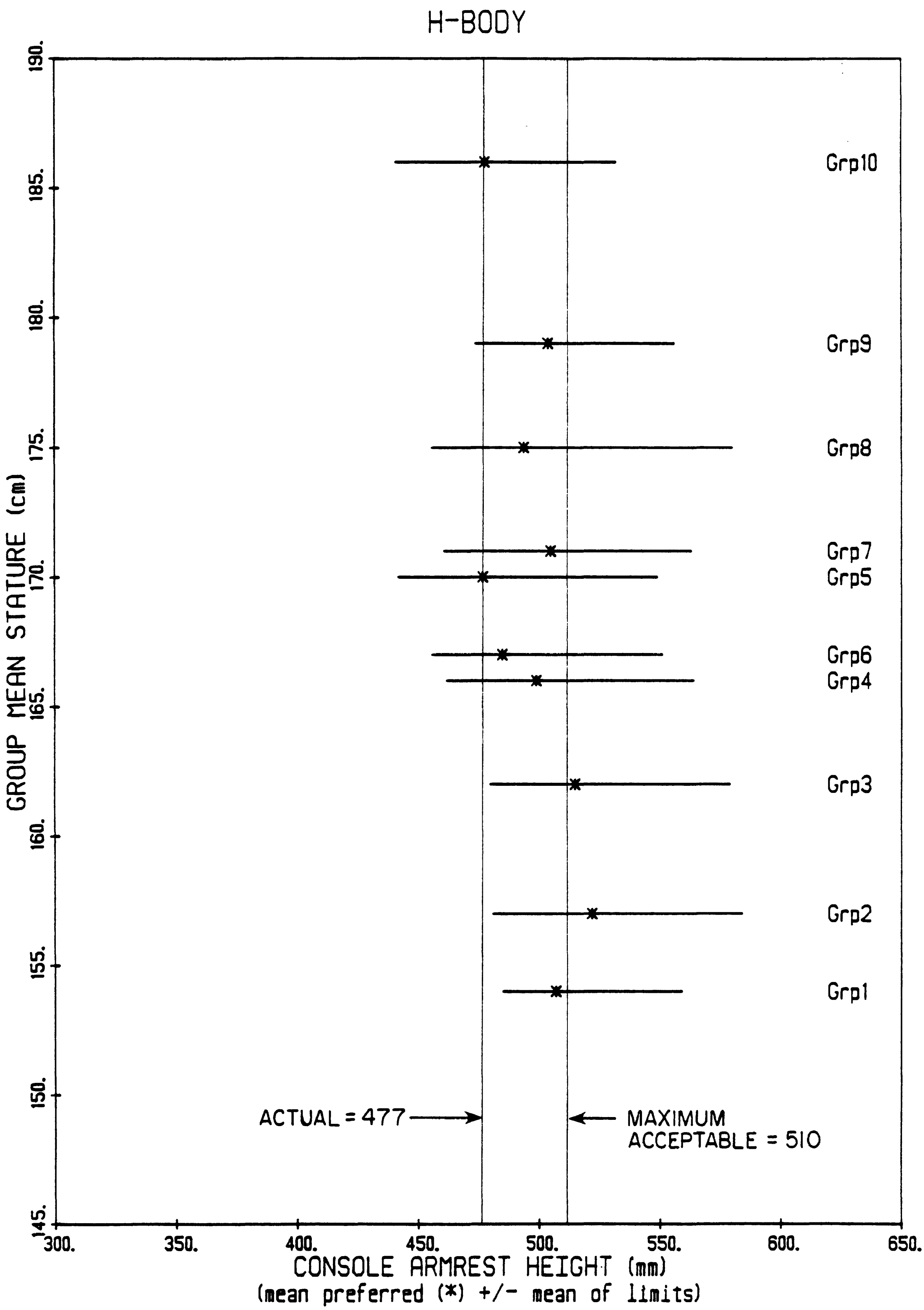

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL
=480
$\bar{X}_p = 521$
450.
475.
500.
525.
550.
575.
600.
625.
DOOR ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)

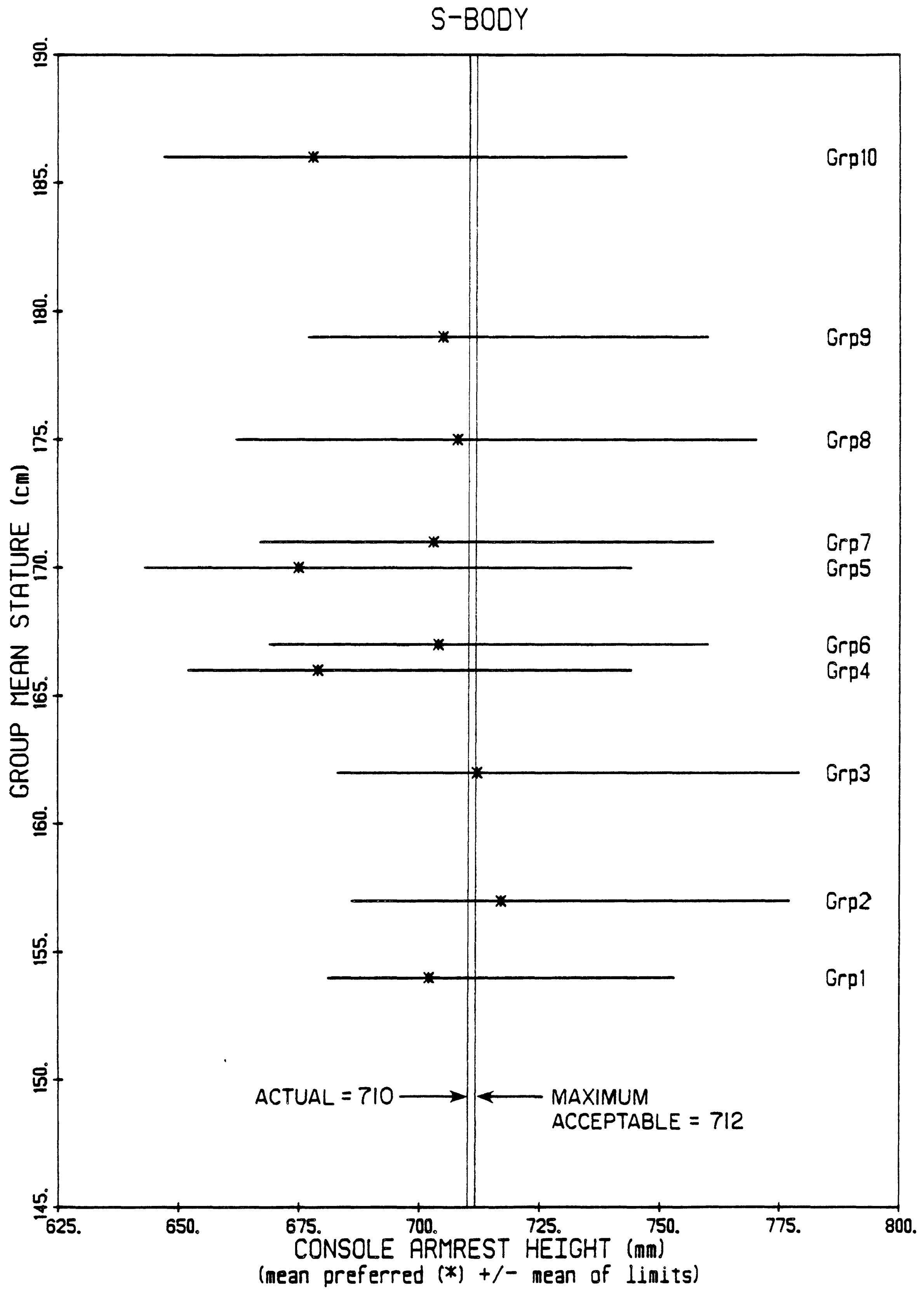

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL
=507
$\bar{X}_p$ = 542
475.
500.
525.
550.
575.
600.
625.
650.
DOOR ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)

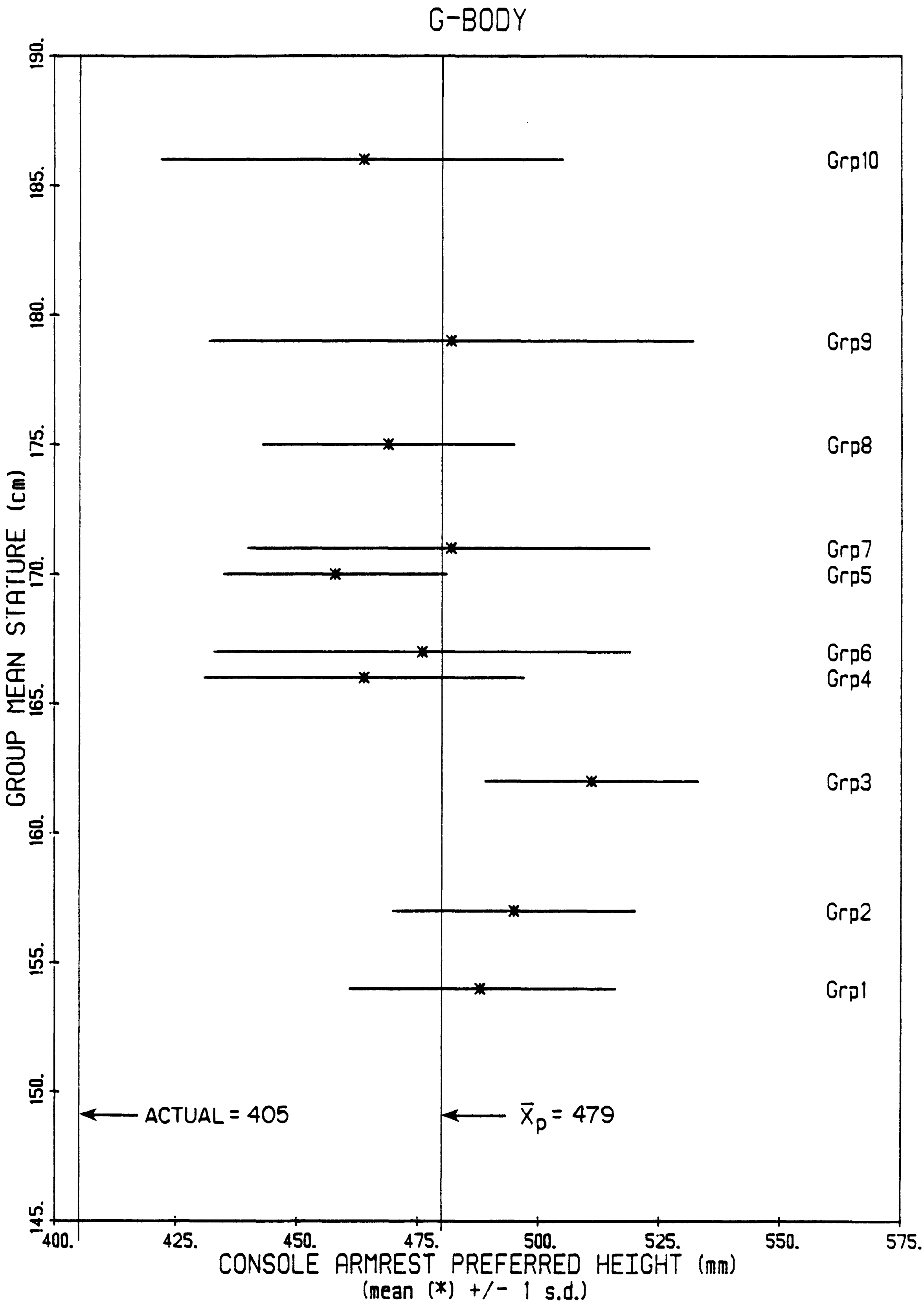


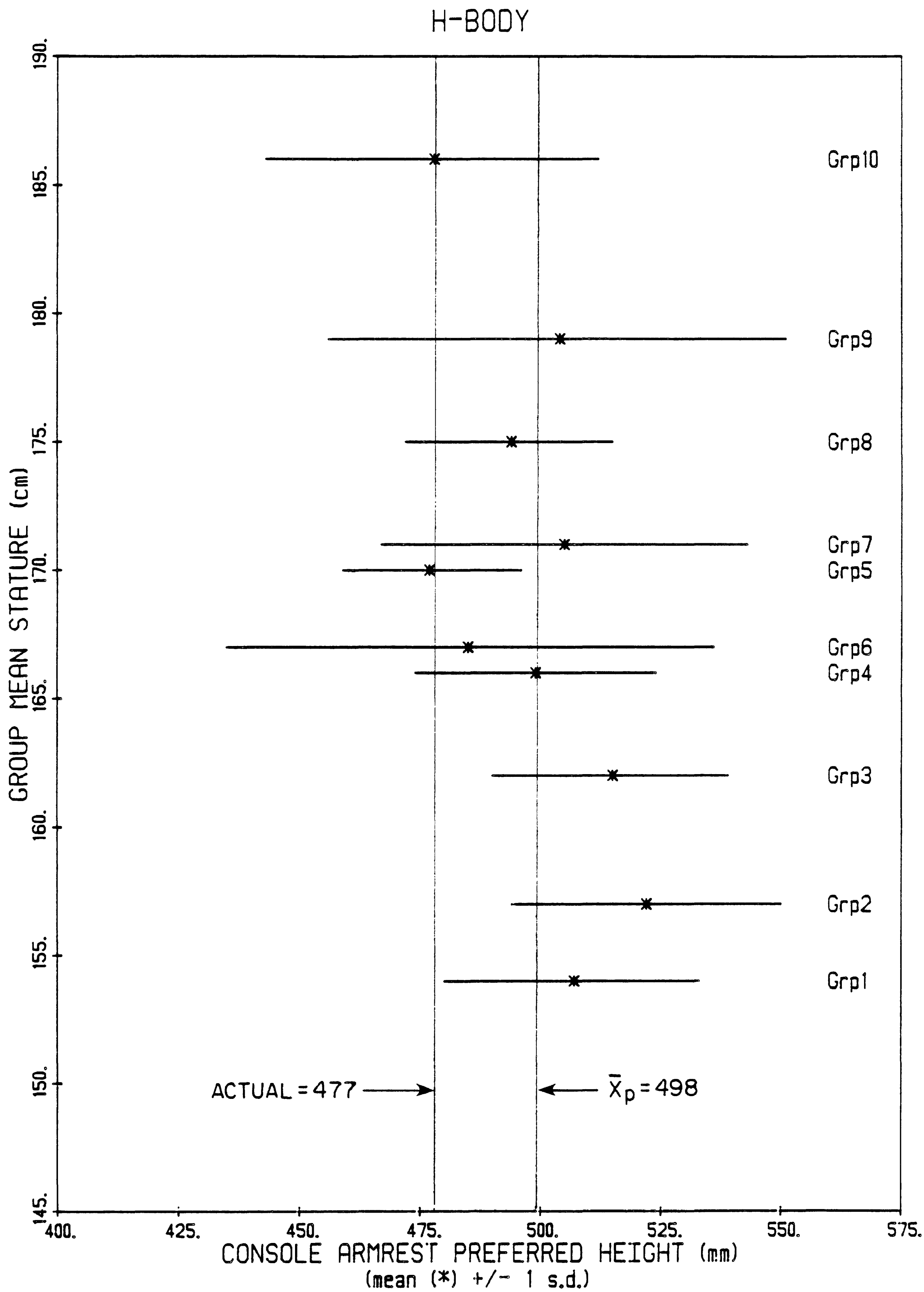
S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 715
$\bar{X}_p$ = 746
650.
675.
700.
725.
750.
775.
800.
825.
DOOR ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)


G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 405
MAXIMUM
ACCEPTABLE = 500
300.
350.
400.
450.
500.
550.
600.
650.
CONSOLE ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)

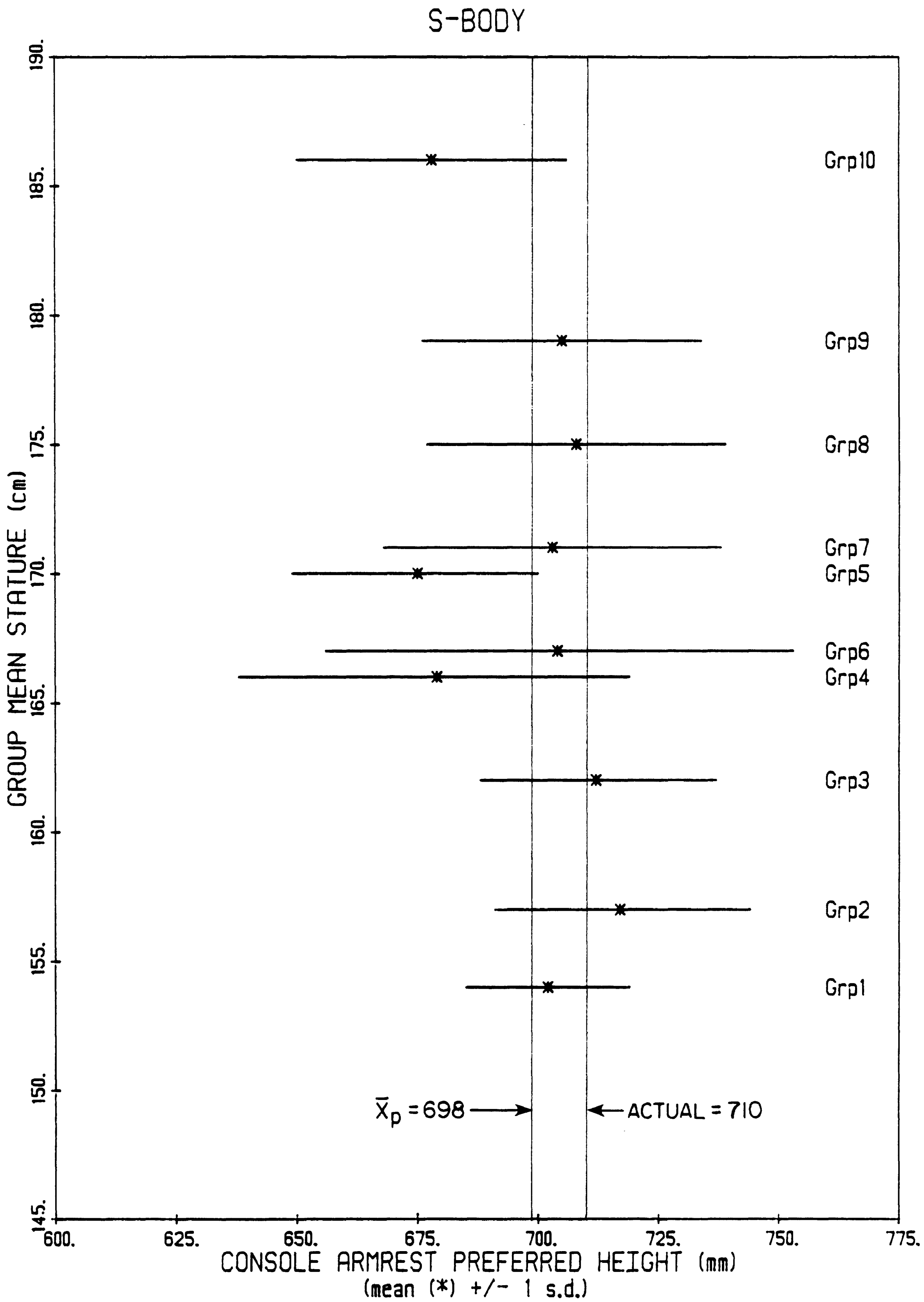

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
300.
350.
400.
450.
500.
550.
600.
650.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 477
MAXIMUM ACCEPTABLE = 510
CONSOLE ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)

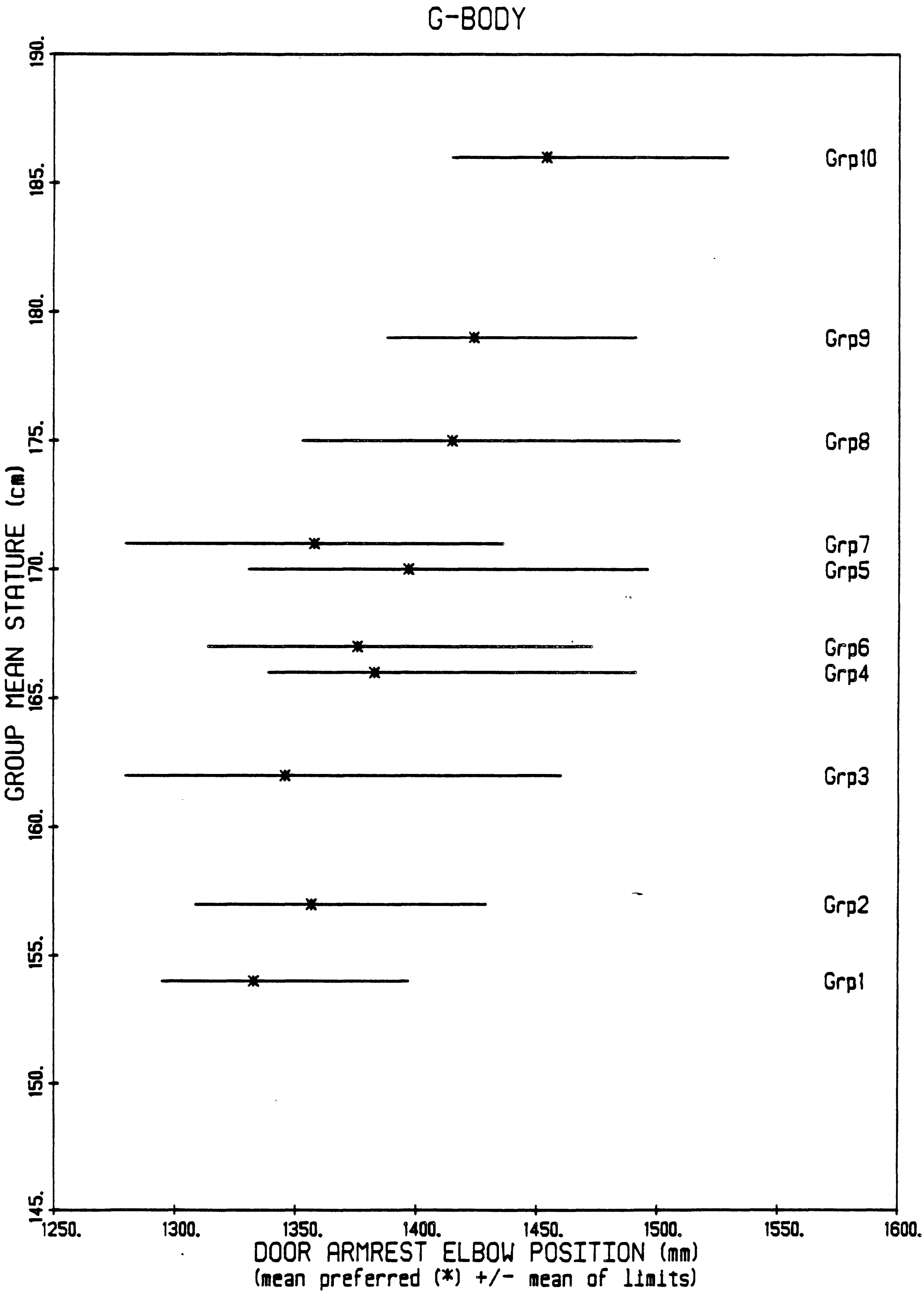

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 710
MAXIMUM
ACCEPTABLE = 712
625.
650.
675.
700.
725.
750.
775.
800.
CONSOLE ARMREST HEIGHT (mm)
(mean preferred (*) +/- mean of limits)

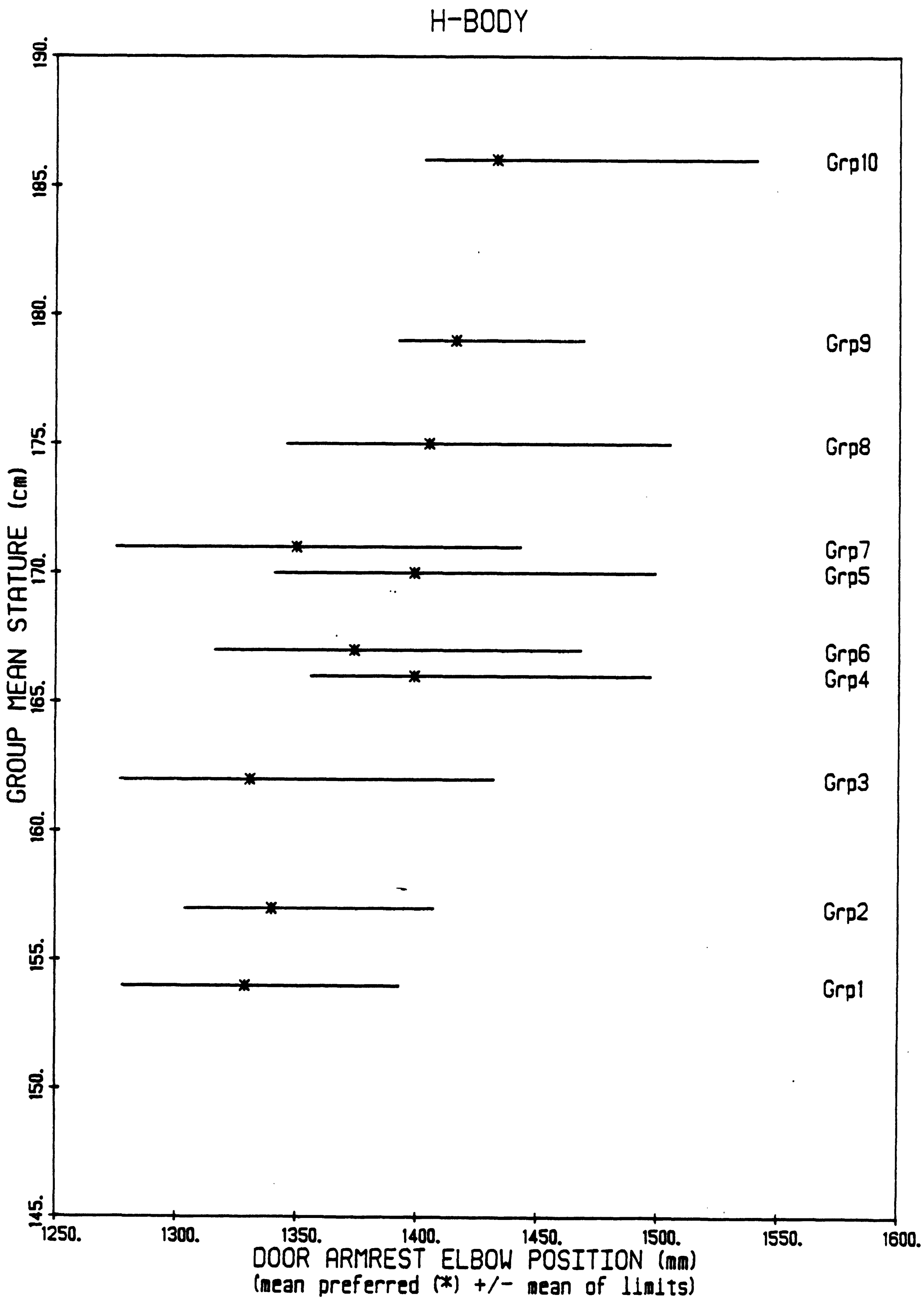

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 405
$\bar{X}_p$ = 479
400.
425.
450.
475.
500.
525.
550.
575.
CONSOLE ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)



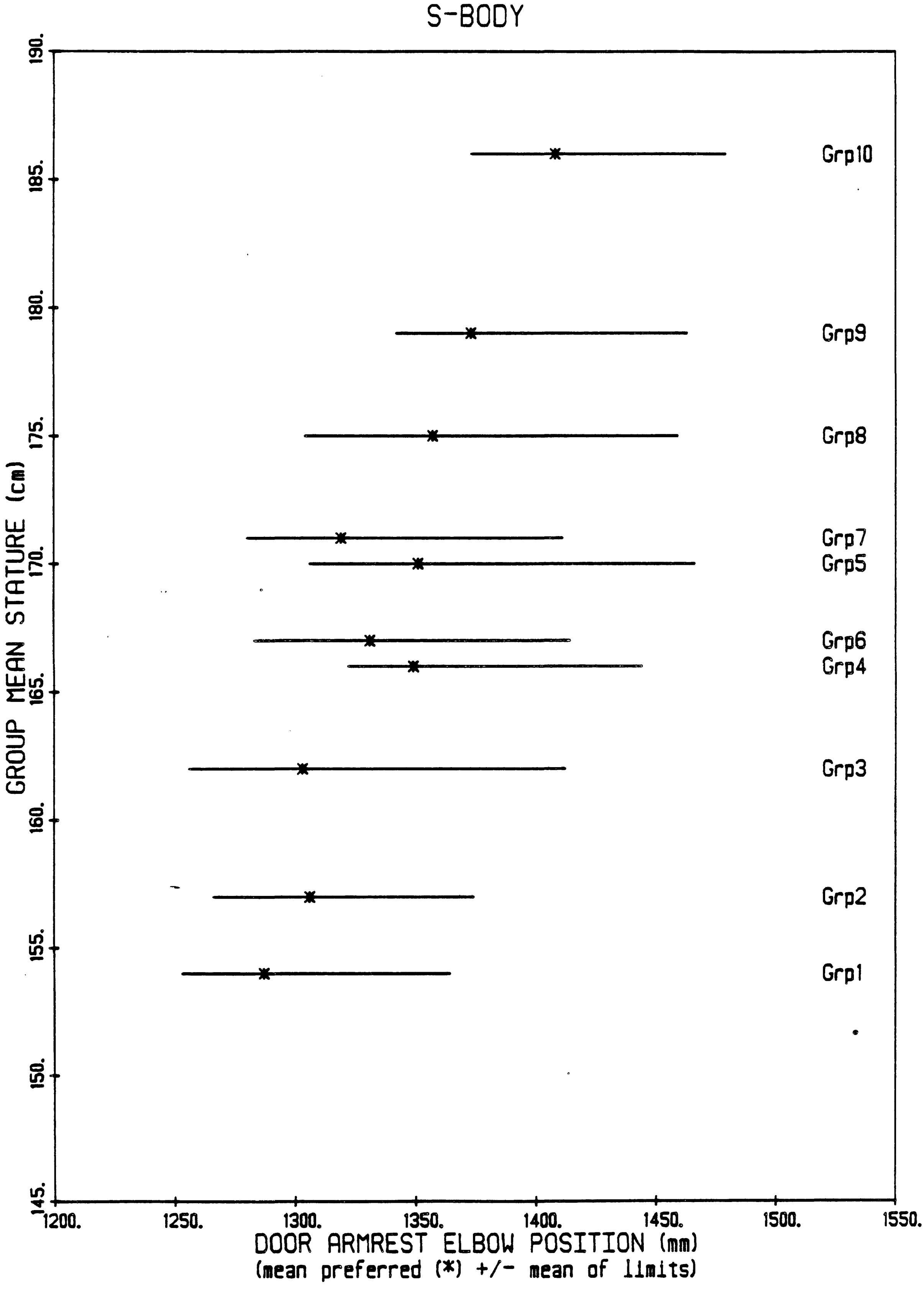
H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
ACTUAL = 477
$\bar{X}_p = 498$
400.
425.
450.
475.
500.
525.
550.
575.
CONSOLE ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)

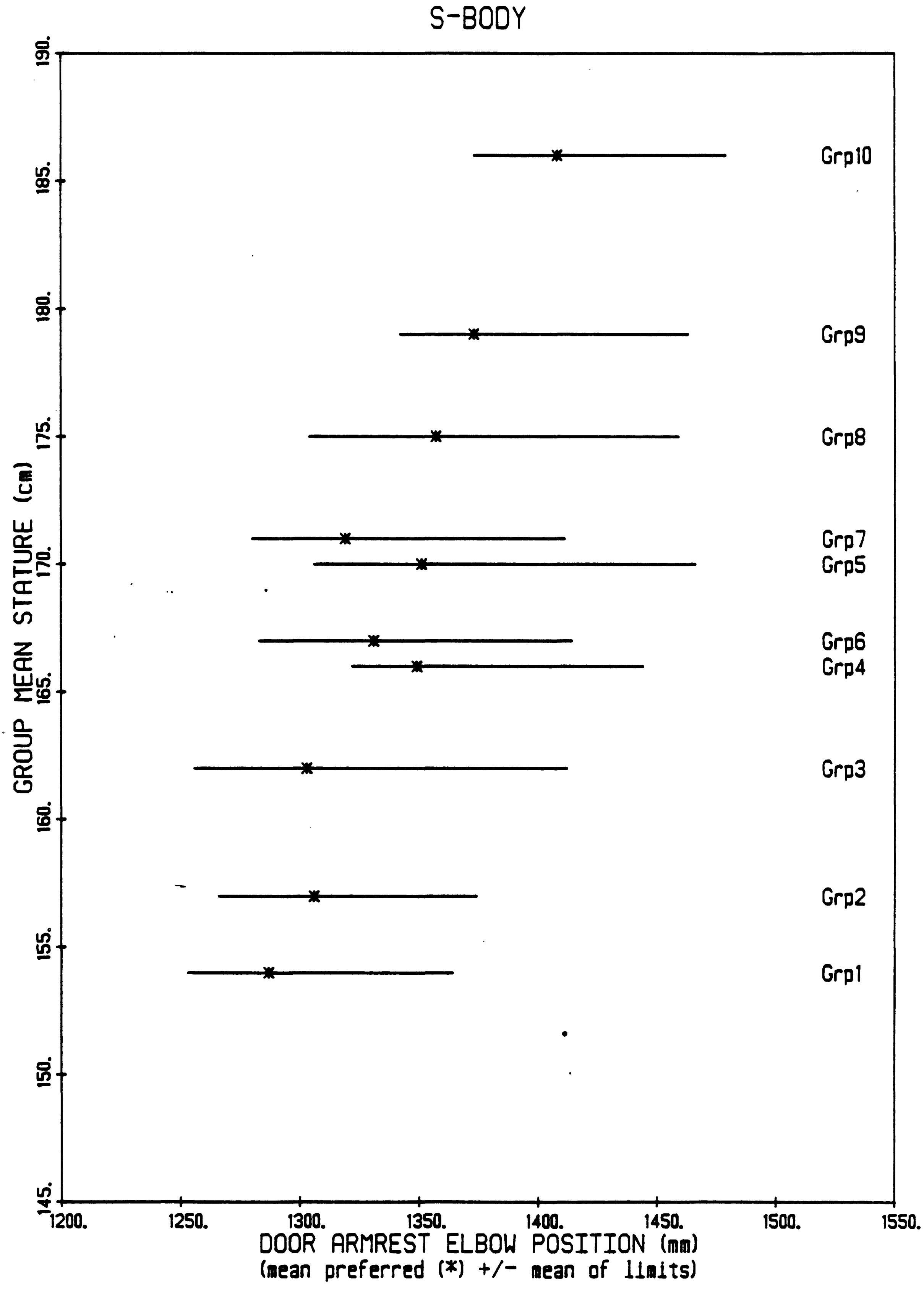

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
X̄p = 698
ACTUAL = 710
600.
625.
650.
675.
700.
725.
750.
775.
CONSOLE ARMREST PREFERRED HEIGHT (mm)
(mean (*) +/- 1 s.d.)

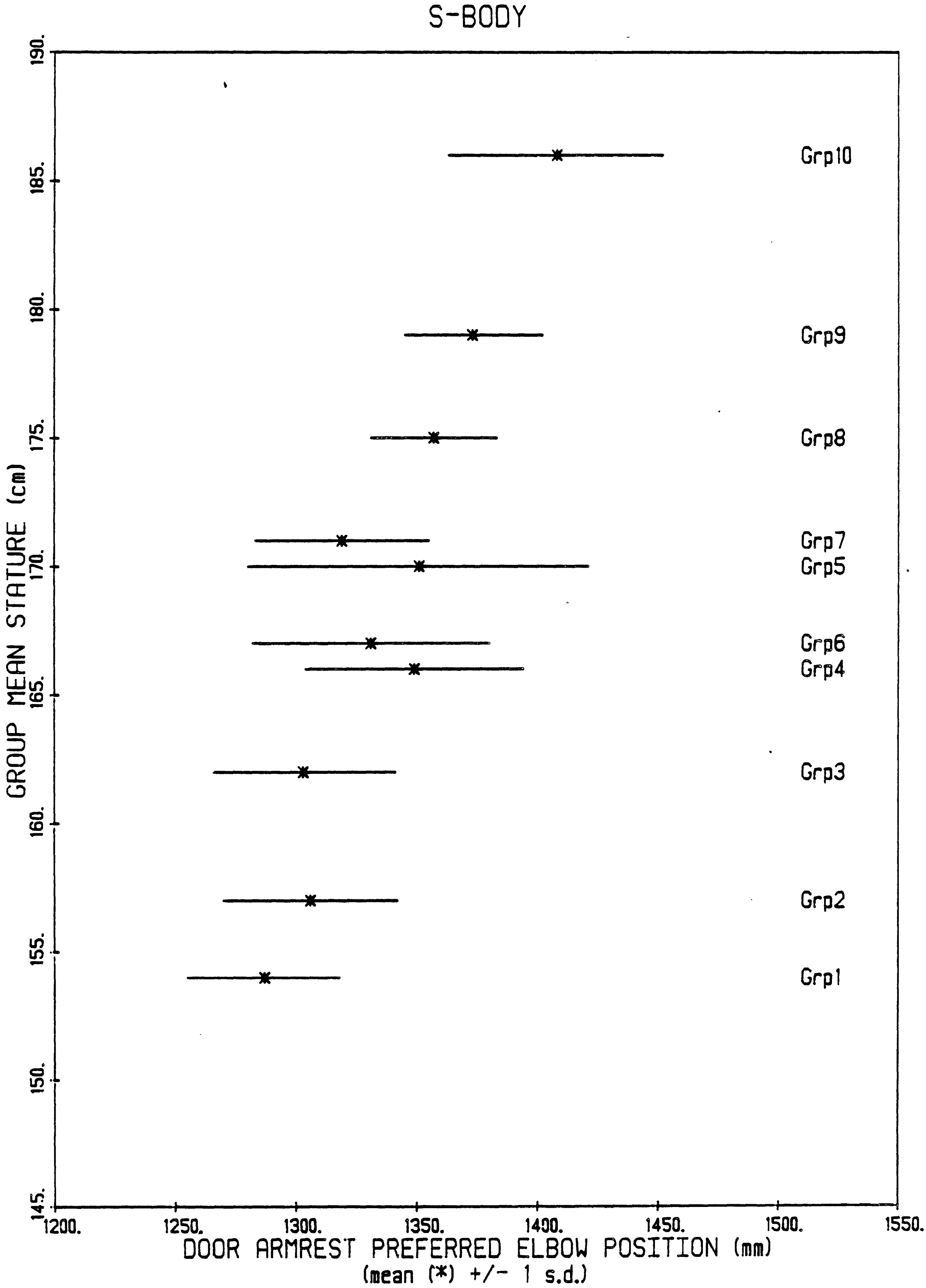

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
1250.
1300.
1350.
1400.
1450.
1500.
1550.
1600.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
DOOR ARMREST ELBOW POSITION (mm)
(mean preferred (*) +/- mean of limits)



H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1250.
1300.
1350.
1400.
1450.
1500.
1550.
1600.
DOOR ARMREST ELBOW POSITION (mm)
(mean preferred (*) +/- mean of limits)

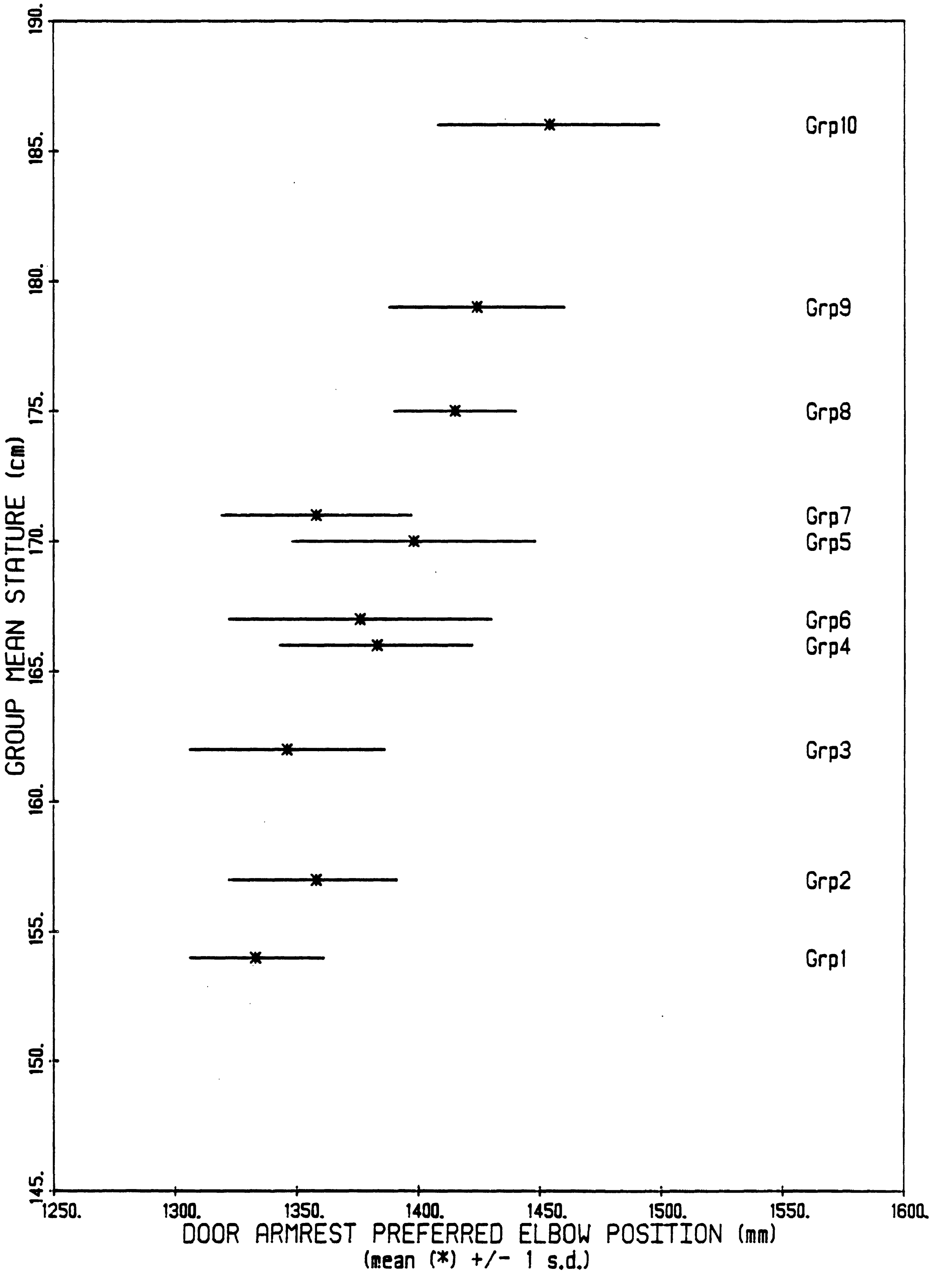

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1200.
1250.
1300.
1350.
1400.
1450.
1500.
1550.
DOOR ARMREST ELBOW POSITION (mm)
(mean preferred (*) +/- mean of limits)


S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1200.
1250.
1300.
1350.
1400.
1450.
1500.
1550.
DOOR ARMREST ELBOW POSITION (mm)
(mean preferred (*) +/- mean of limits)

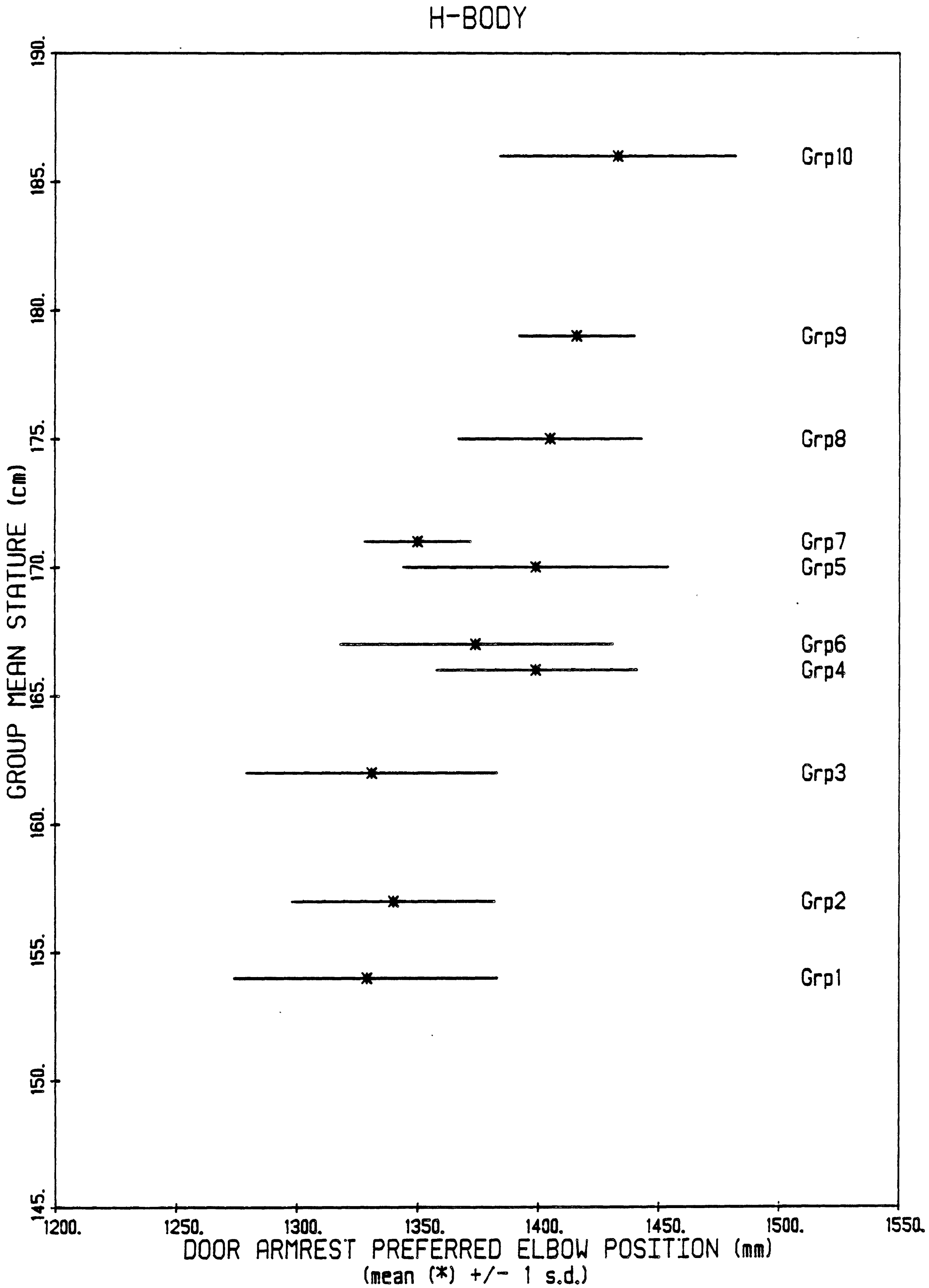


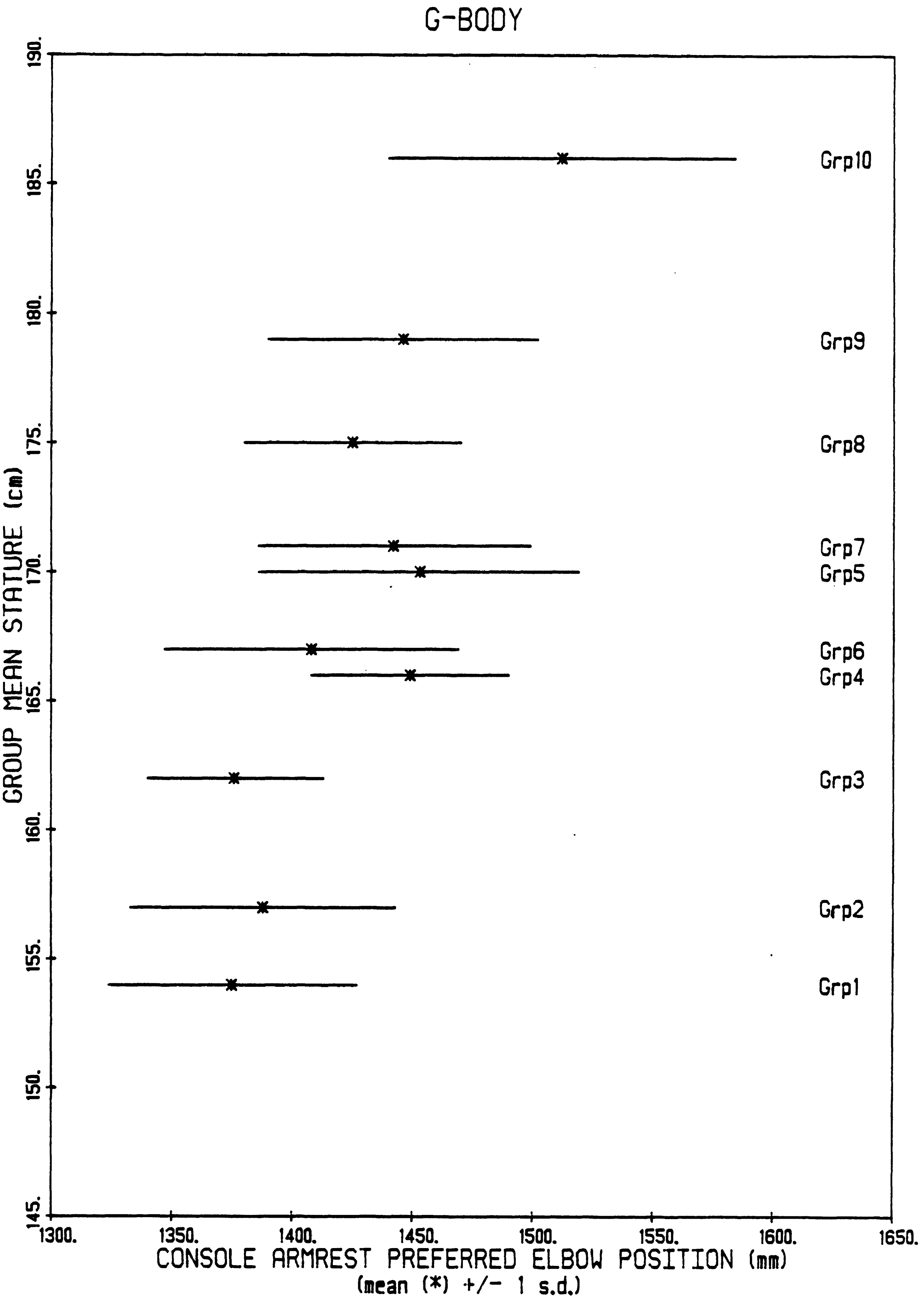
S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1200.
1250.
1300.
1350.
1400.
1450.
1500.
1550.
DOOR ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)

G-BODY

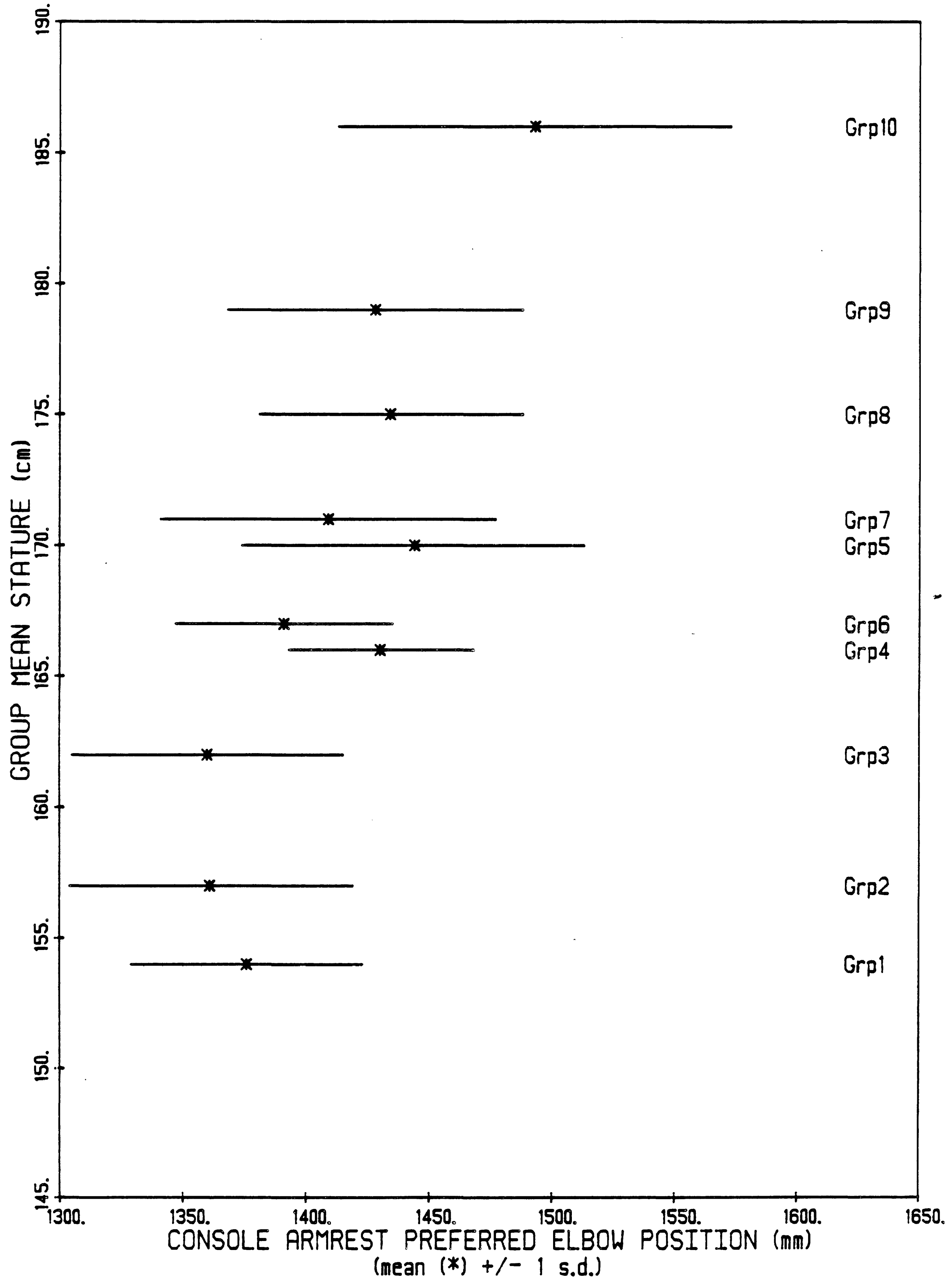


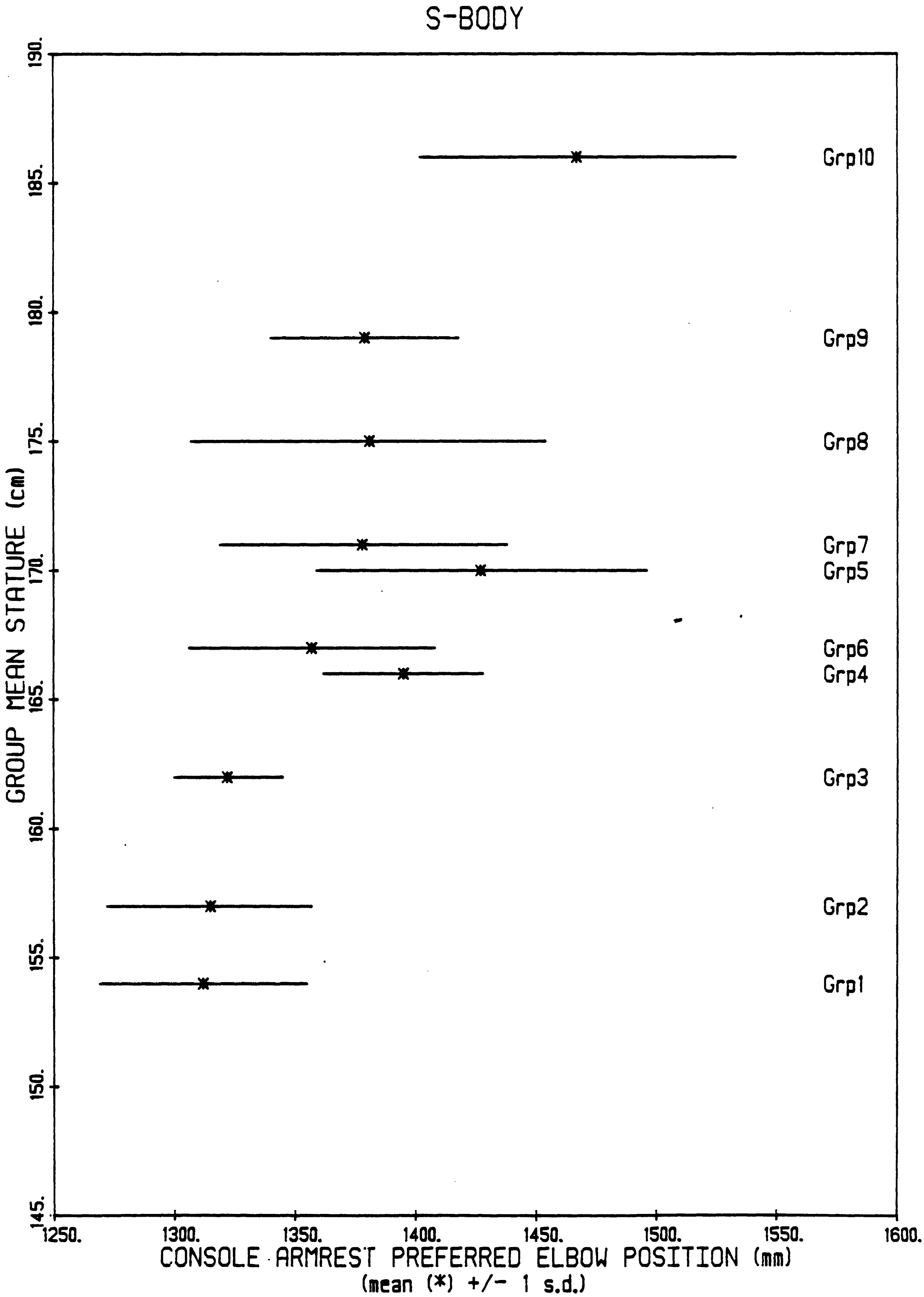
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1250.
1300.
1350.
1400.
1450.
1500.
1550.
1600.
DOOR ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)

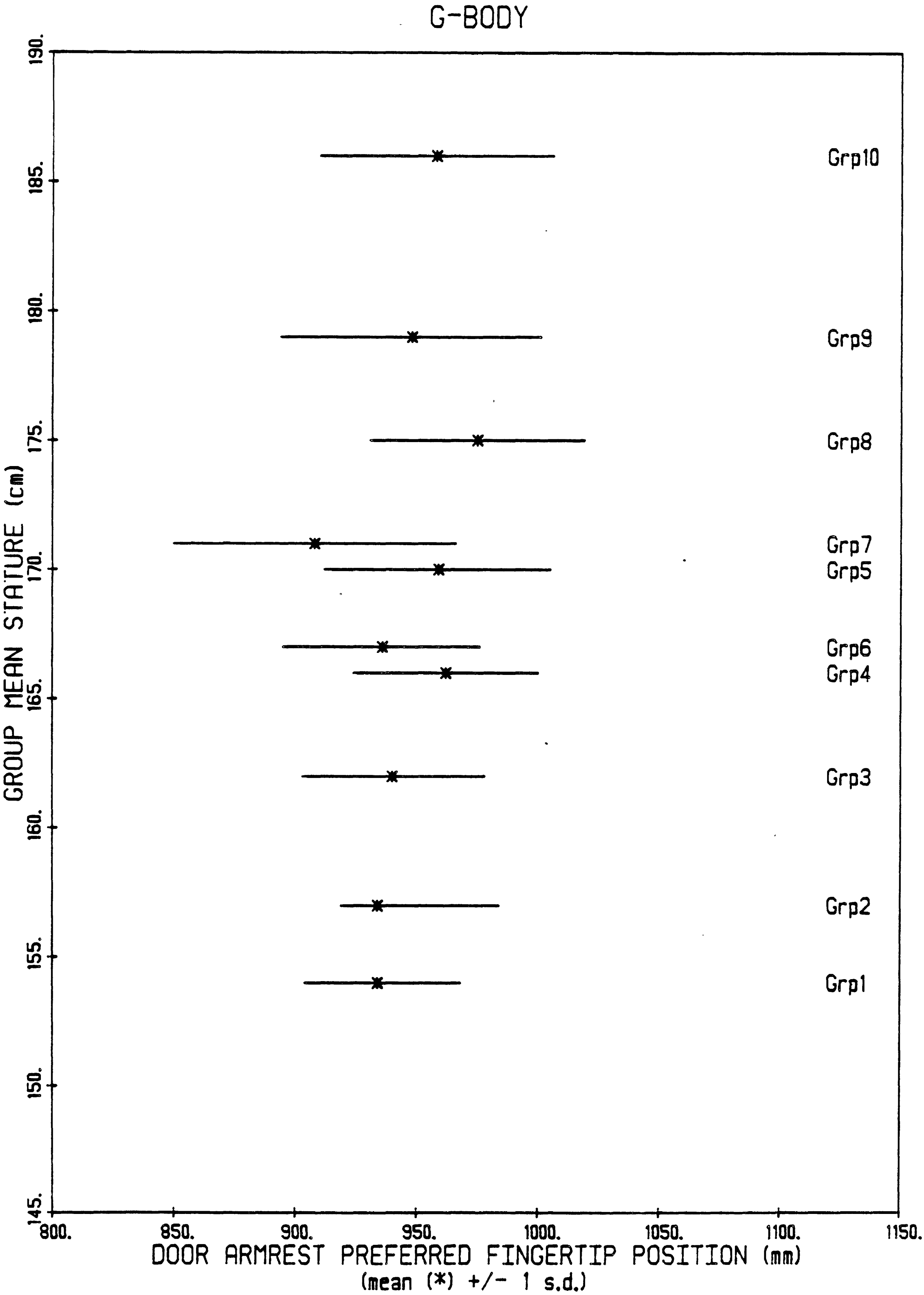

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1200.
1250.
1300.
1350.
1400.
1450.
1500.
1550.
DOOR ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)

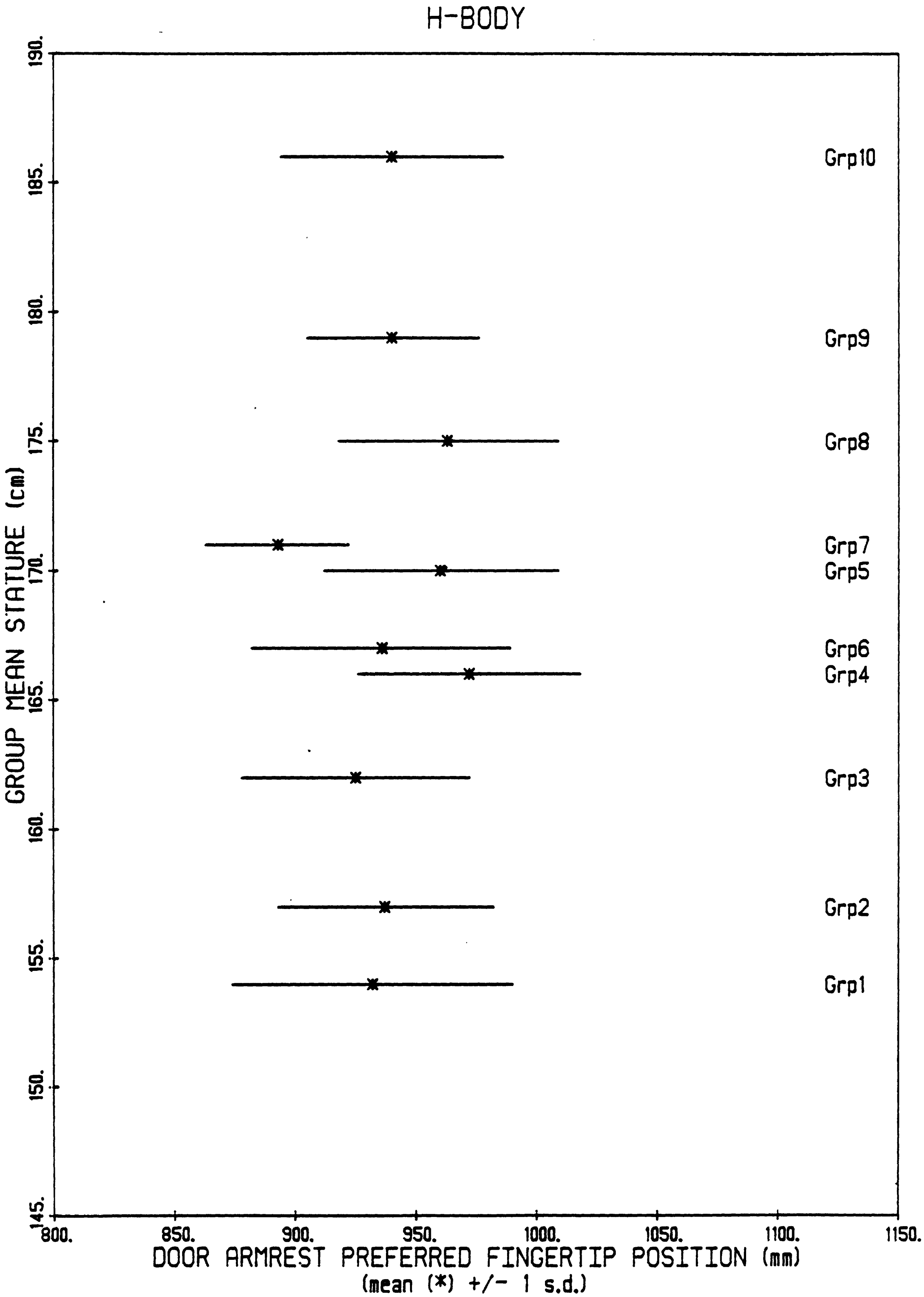

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1300.
1350.
1400.
1450.
1500.
1550.
1600.
1650.
CONSOLE ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)

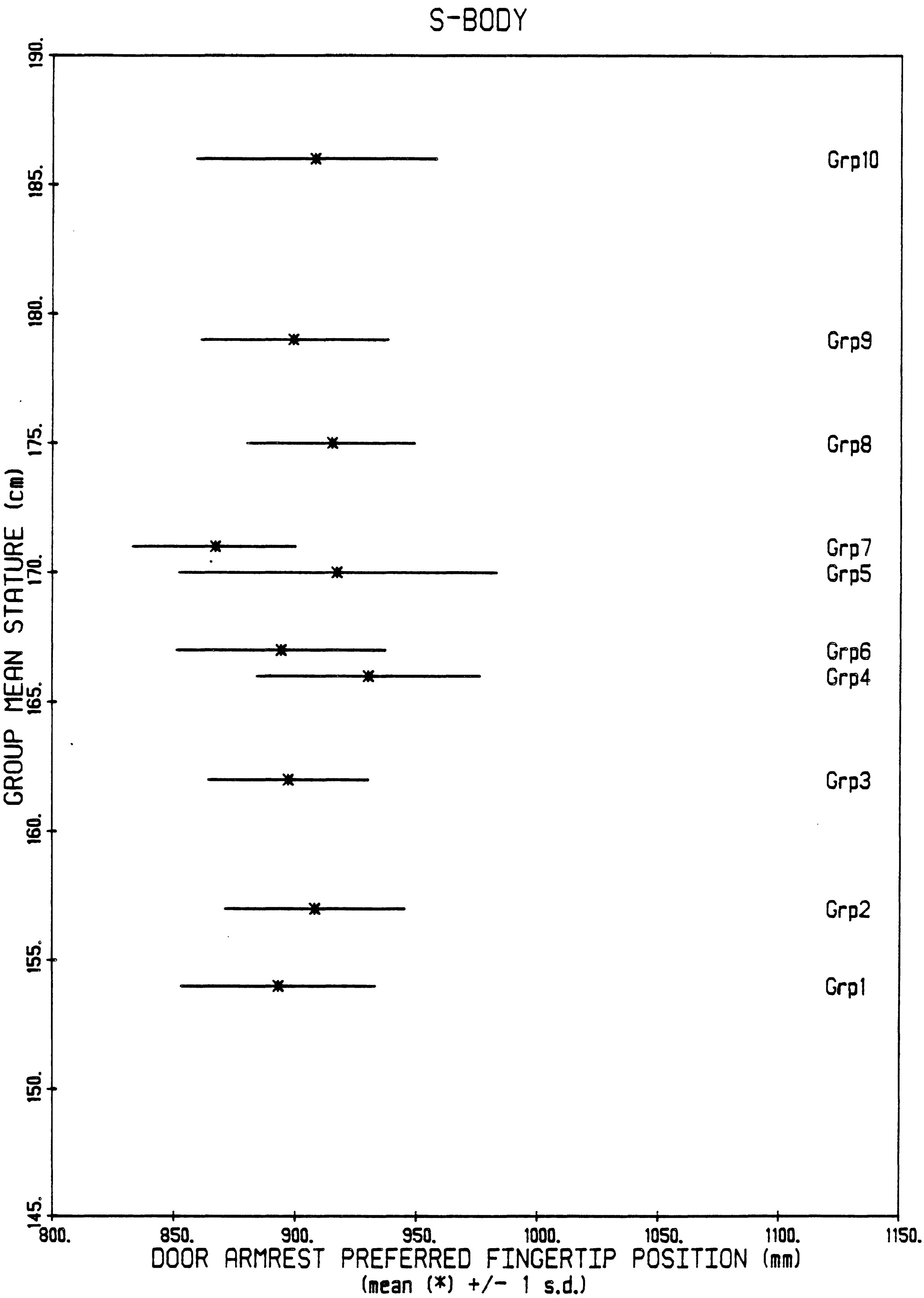
H-BODY


190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
GROUP MEAN STATURE (cm)
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1300.
1350.
1400.
1450.
1500.
1550.
1600.
1650.
CONSOLE ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)

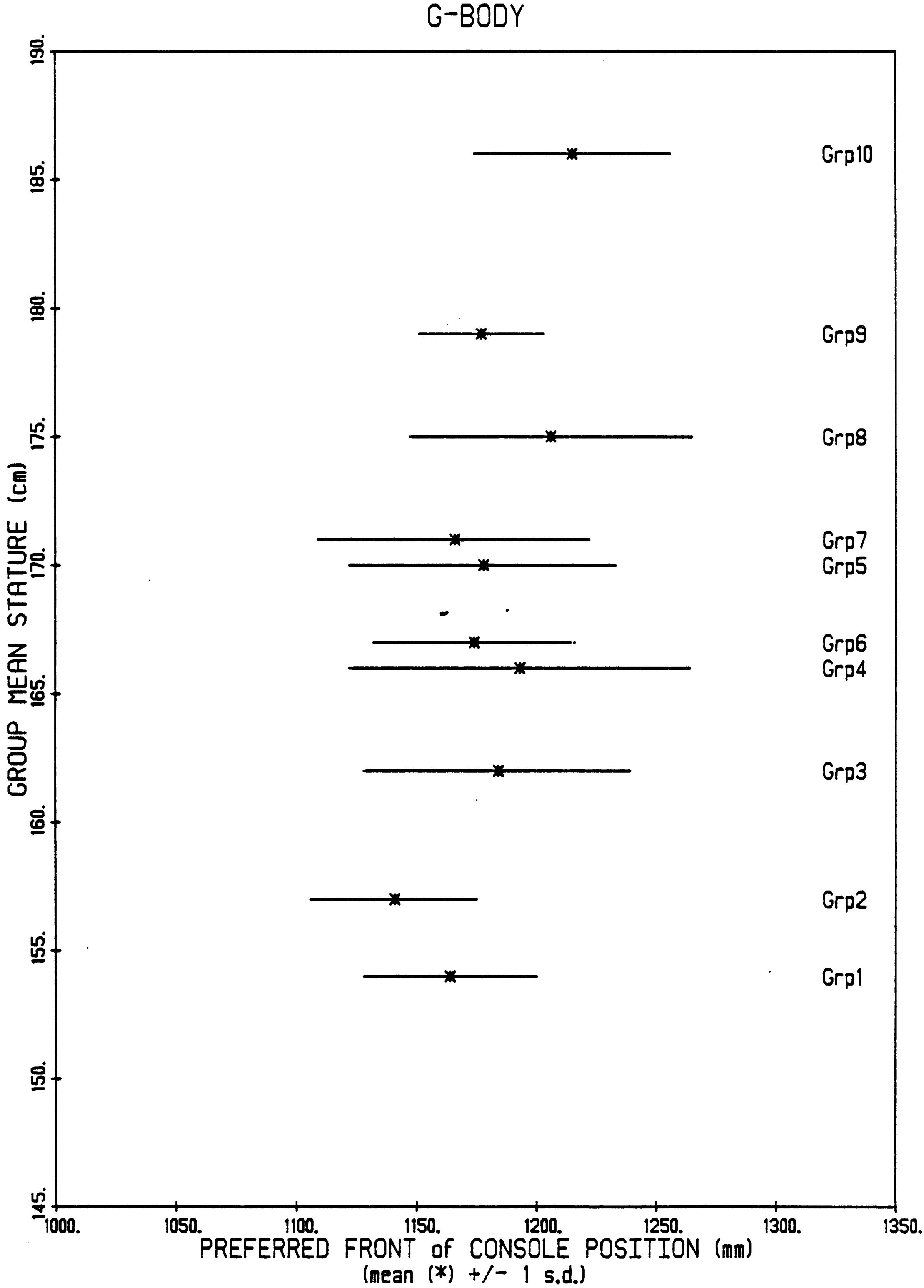

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1250.
1300.
1350.
1400.
1450.
1500.
1550.
1600.
CONSOLE ARMREST PREFERRED ELBOW POSITION (mm)
(mean (*) +/- 1 s.d.)


G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
800.
850.
900.
950.
1000.
1050.
1100.
1150.
DOOR ARMREST PREFERRED FINGERTIP POSITION (mm)
(mean (*) +/- 1 s.d.)

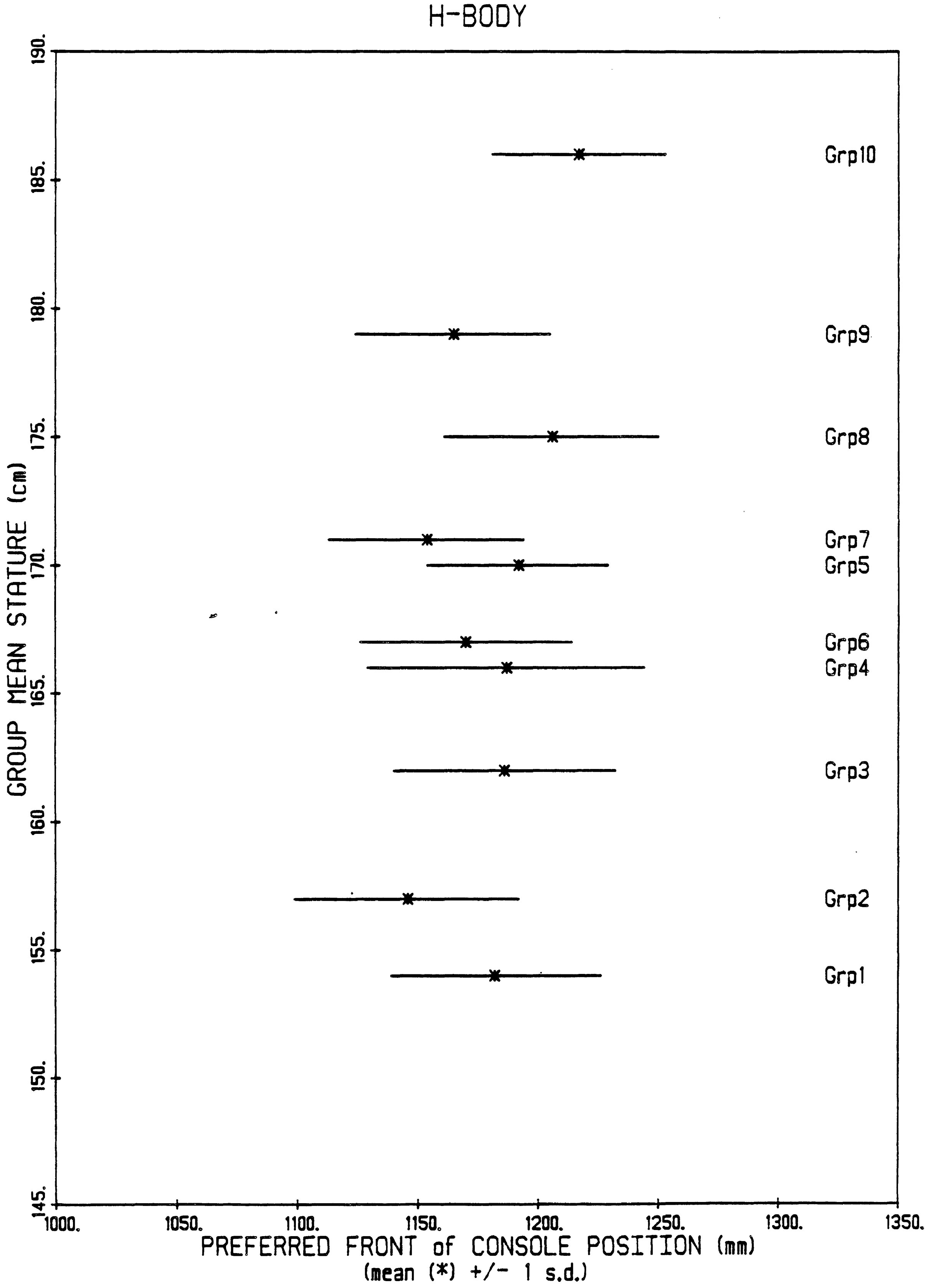

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
800.
850.
900.
950.
1000.
1050.
1100.
1150.
DOOR ARMREST PREFERRED FINGERTIP POSITION (mm)
(mean (*) +/- 1 s.d.)



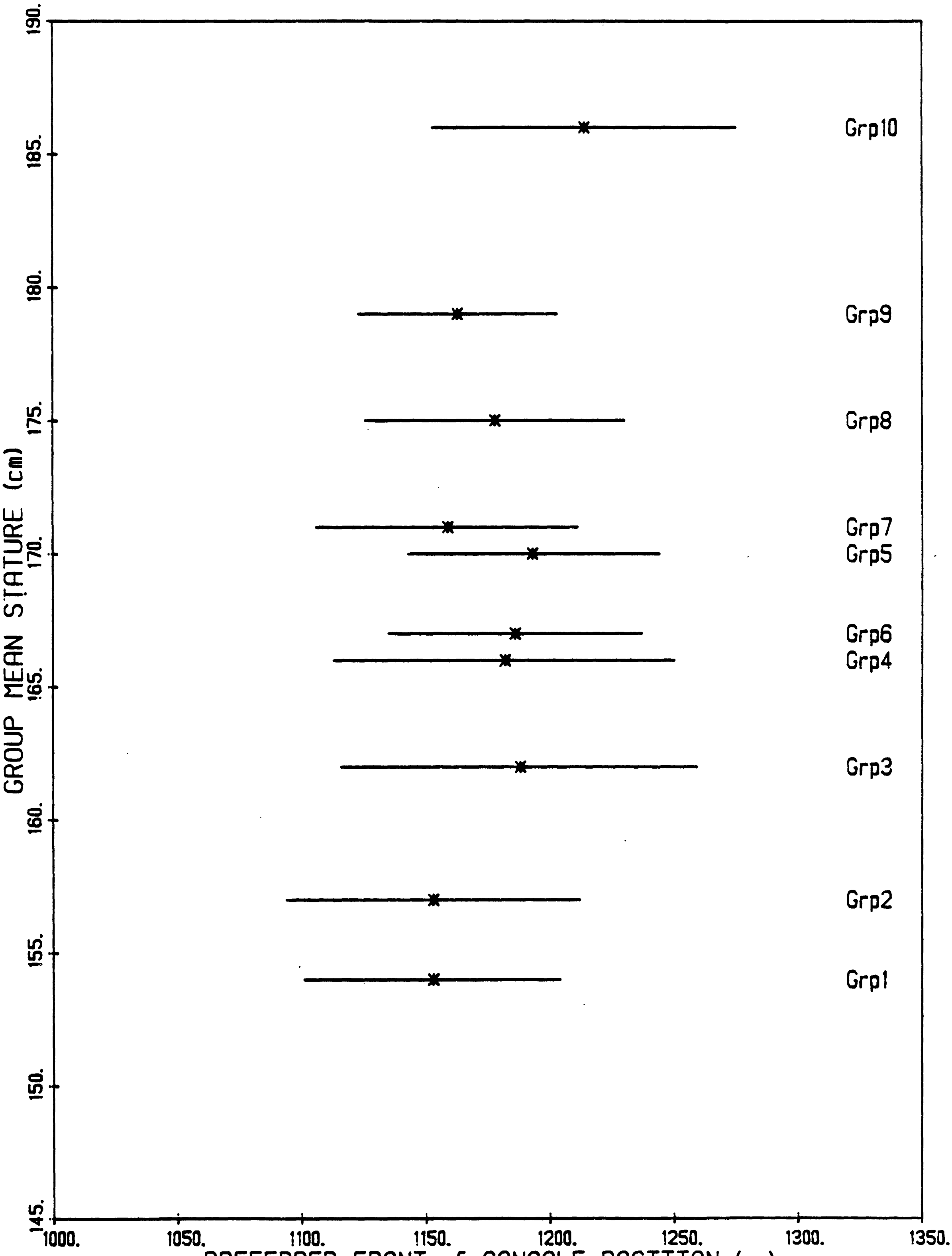
S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
800.
850.
900.
950.
1000.
1050.
1100.
1150.
DOOR ARMREST PREFERRED FINGERTIP POSITION (mm)
(mean (*) +/- 1 s.d.)



G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1000.
1050.
1100.
1150.
1200.
1250.
1300.
1350.
PREFERRED FRONT of CONSOLE POSITION (mm)
(mean (*) +/- 1 s.d.)


H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1000.
1050.
1100.
1150.
1200.
1250.
1300.
1350.
PREFERRED FRONT of CONSOLE POSITION (mm)
(mean (*) +/- 1 s.d.)

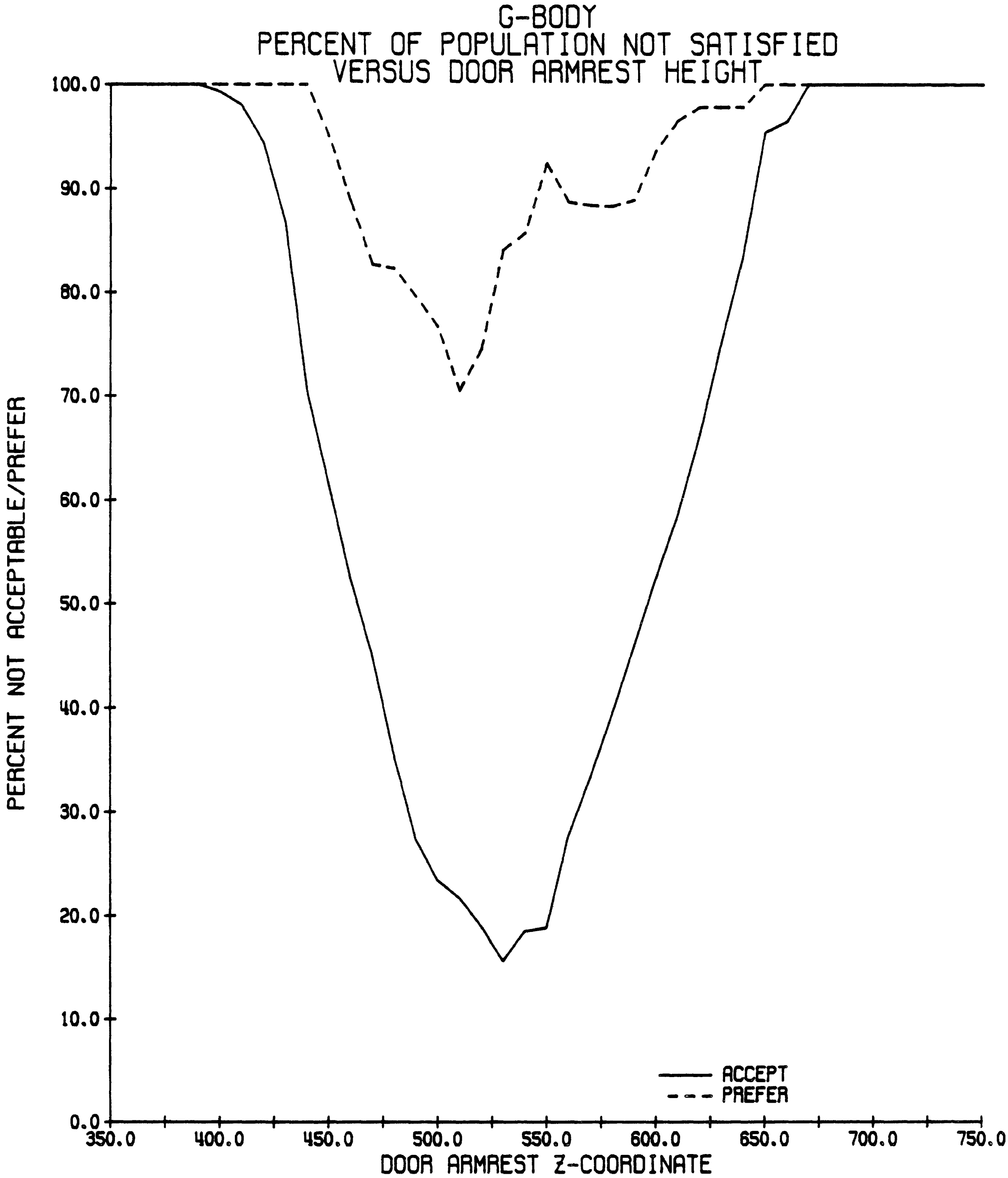
S-BODY

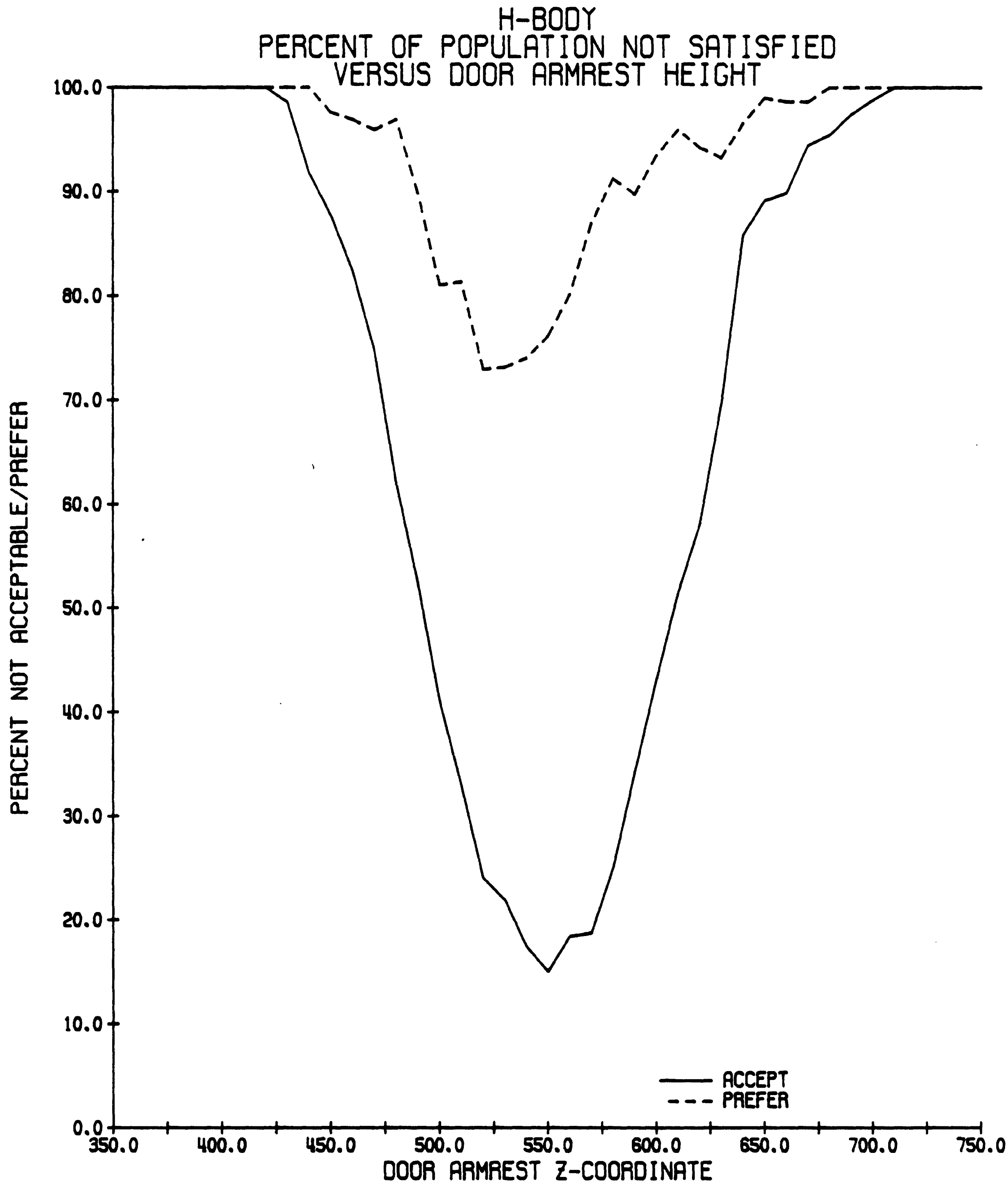


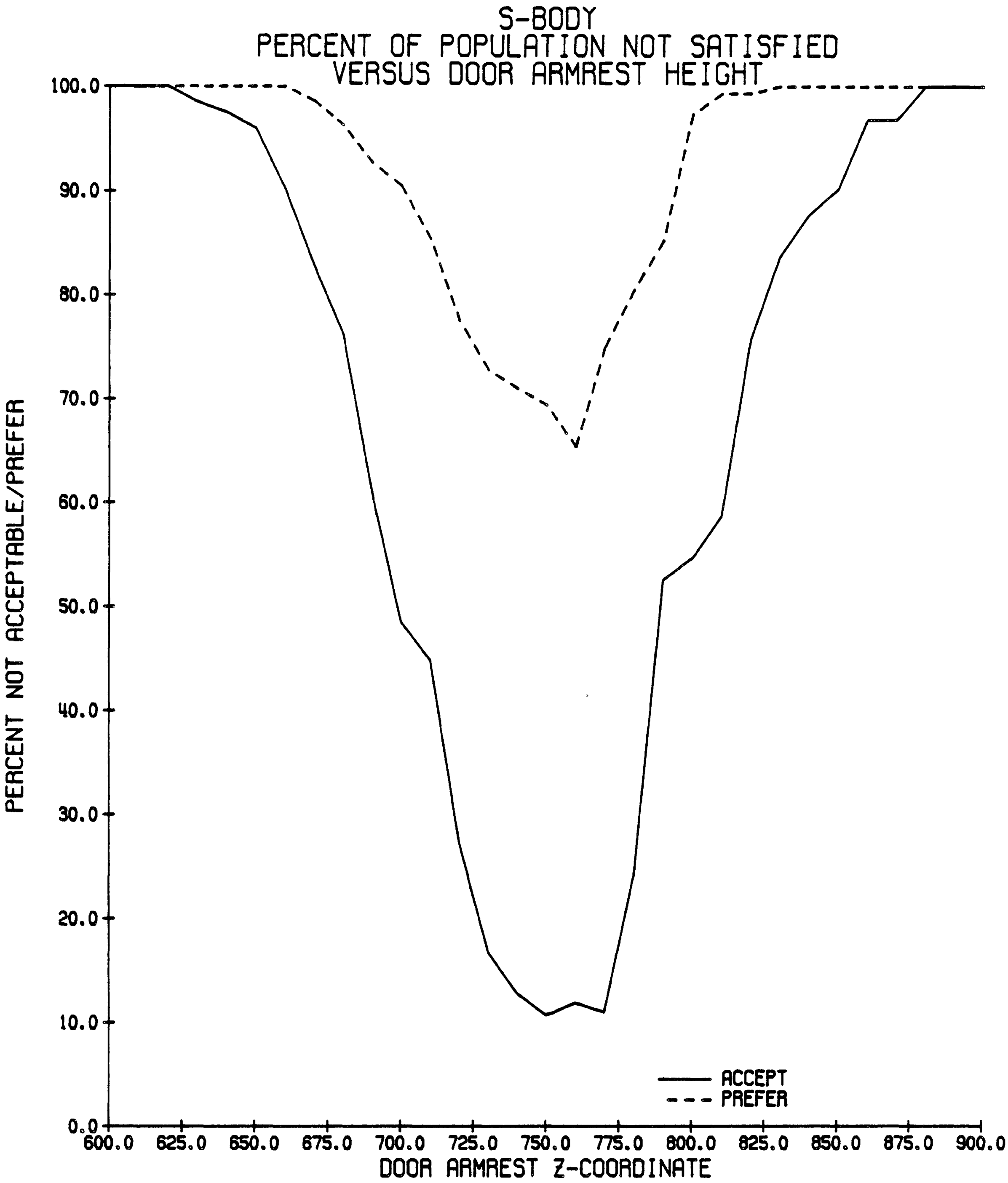
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
GROUP MEAN STATURE (cm)
Grp10
Grp9
Grp8
Grp7
Grp5
Grp6
Grp4
Grp3
Grp2
Grp1
1000.
1050.
1100.
1150.
1200.
1250.
1300.
1350.
PREFERRED FRONT of CONSOLE POSITION (mm)
(mean (*) +/- 1 s.d.)

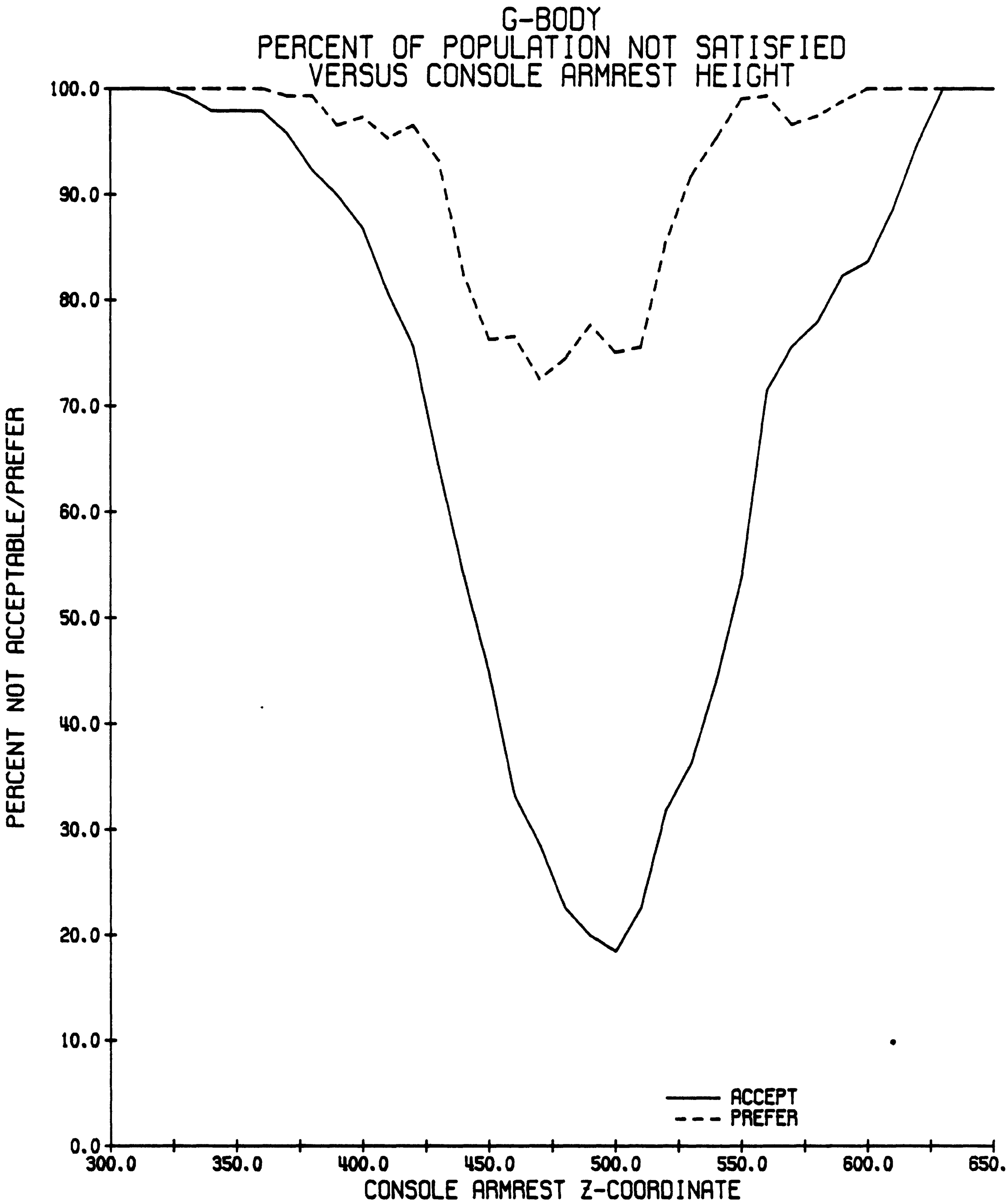
APPENDIX G

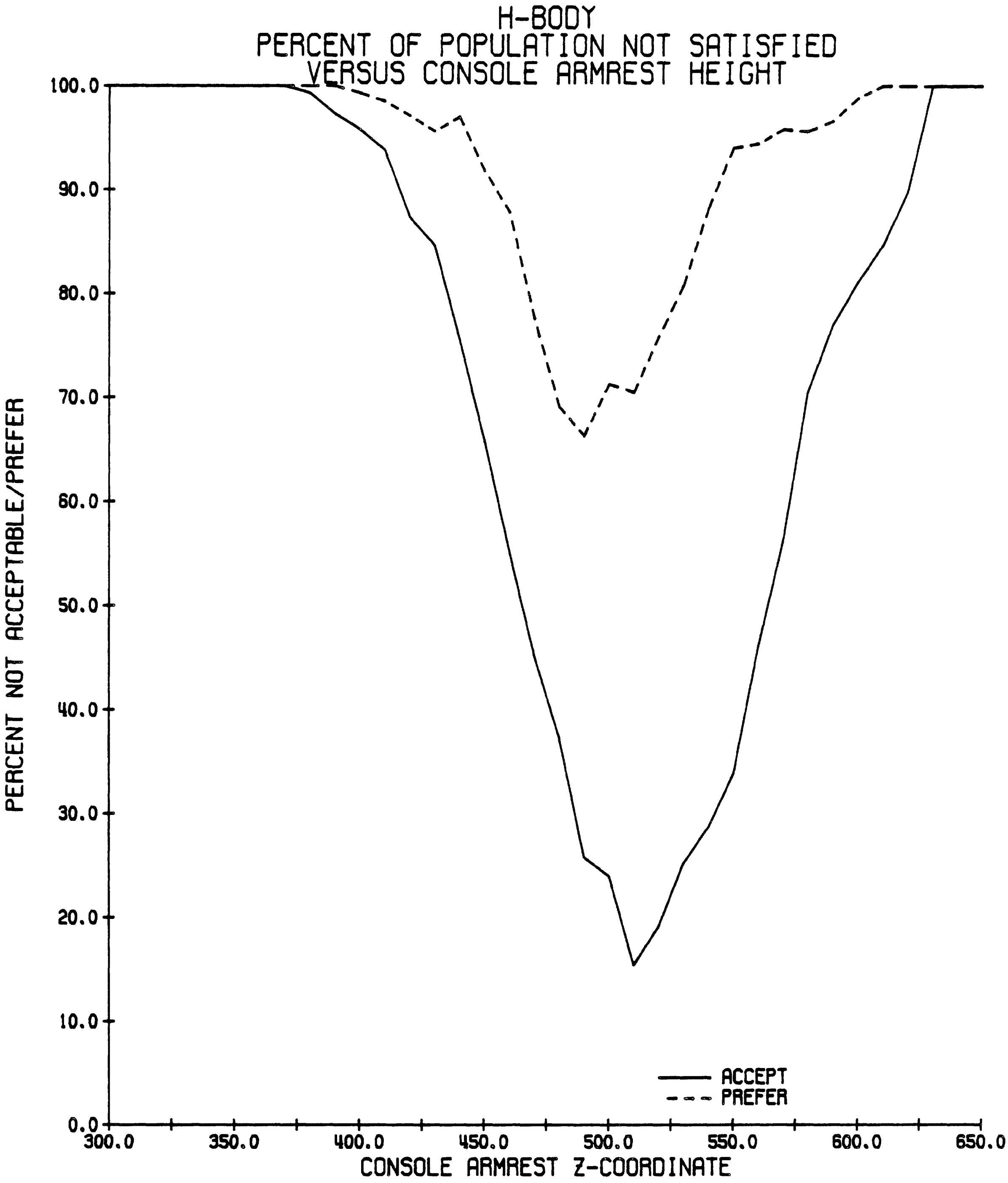
PLOTS OF ACCEPTABLE-RANGE AND PREFERRED-POSITION LOSS FUNCTIONS

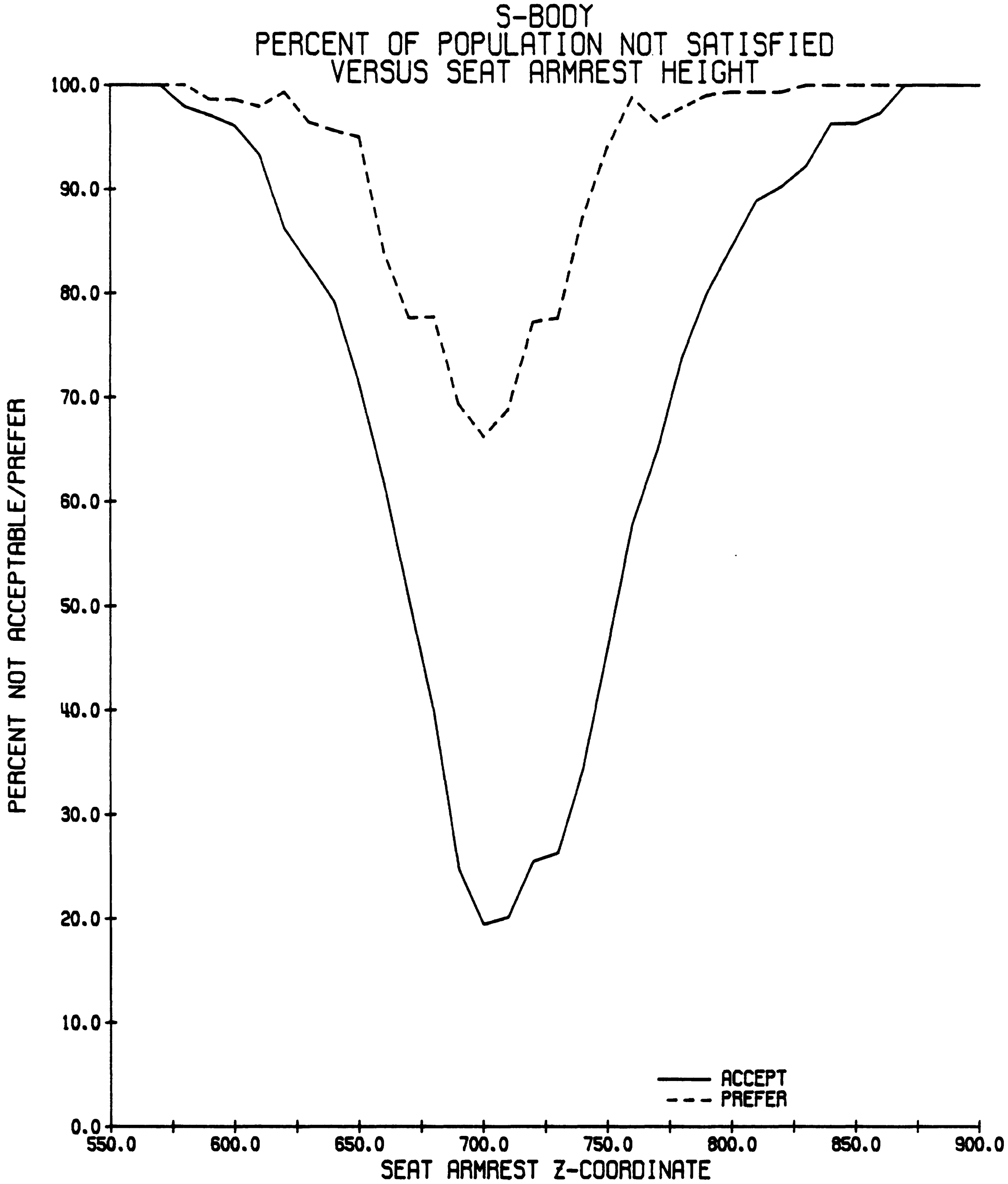

G-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST HEIGHT
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
700.0
750.0
DOOR ARMREST Z-COORDINATE
ACCEPT
PREFER

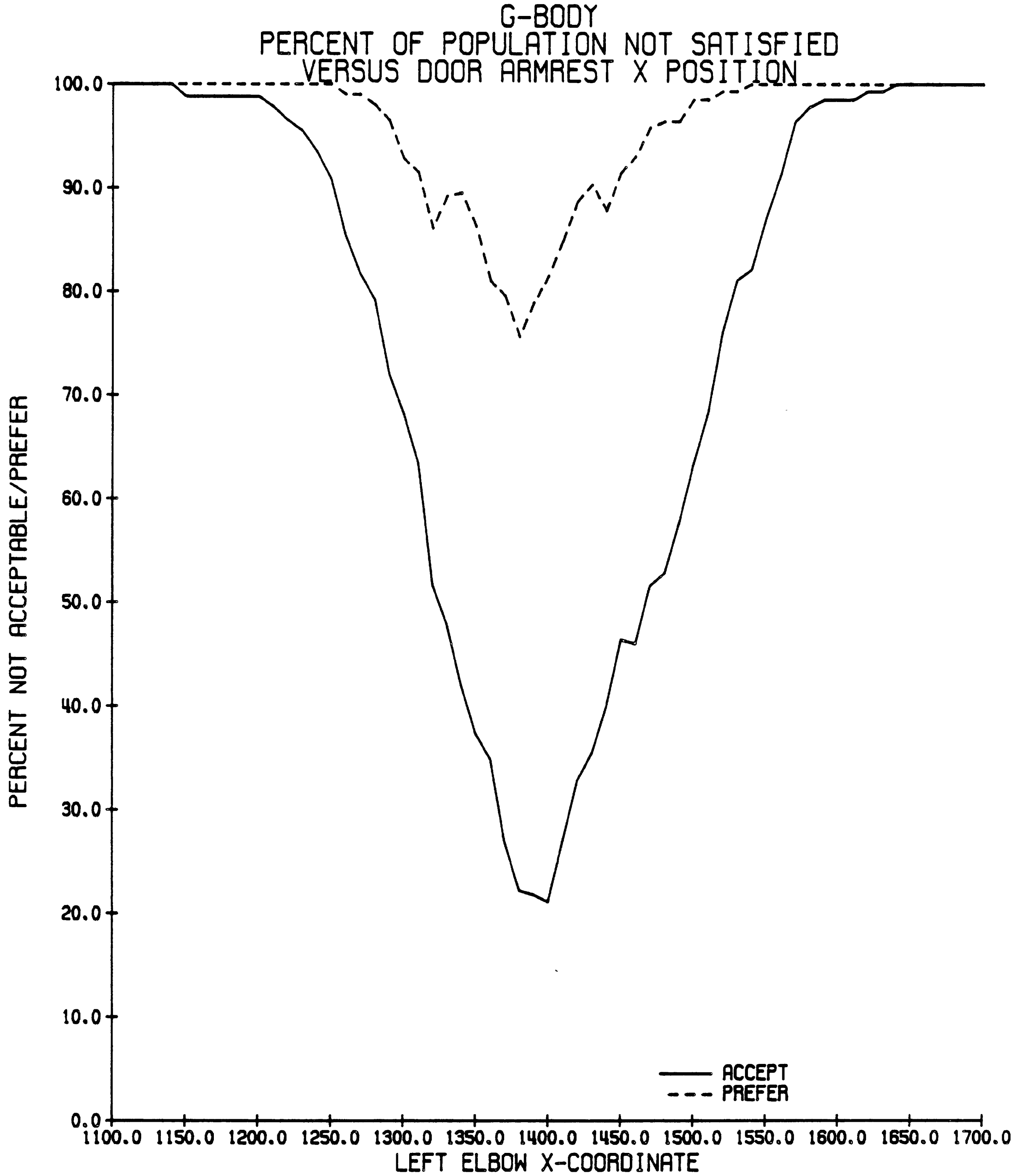

H-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST HEIGHT
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
700.0
750.0
DOOR ARMREST Z-COORDINATE
ACCEPT
PREFER

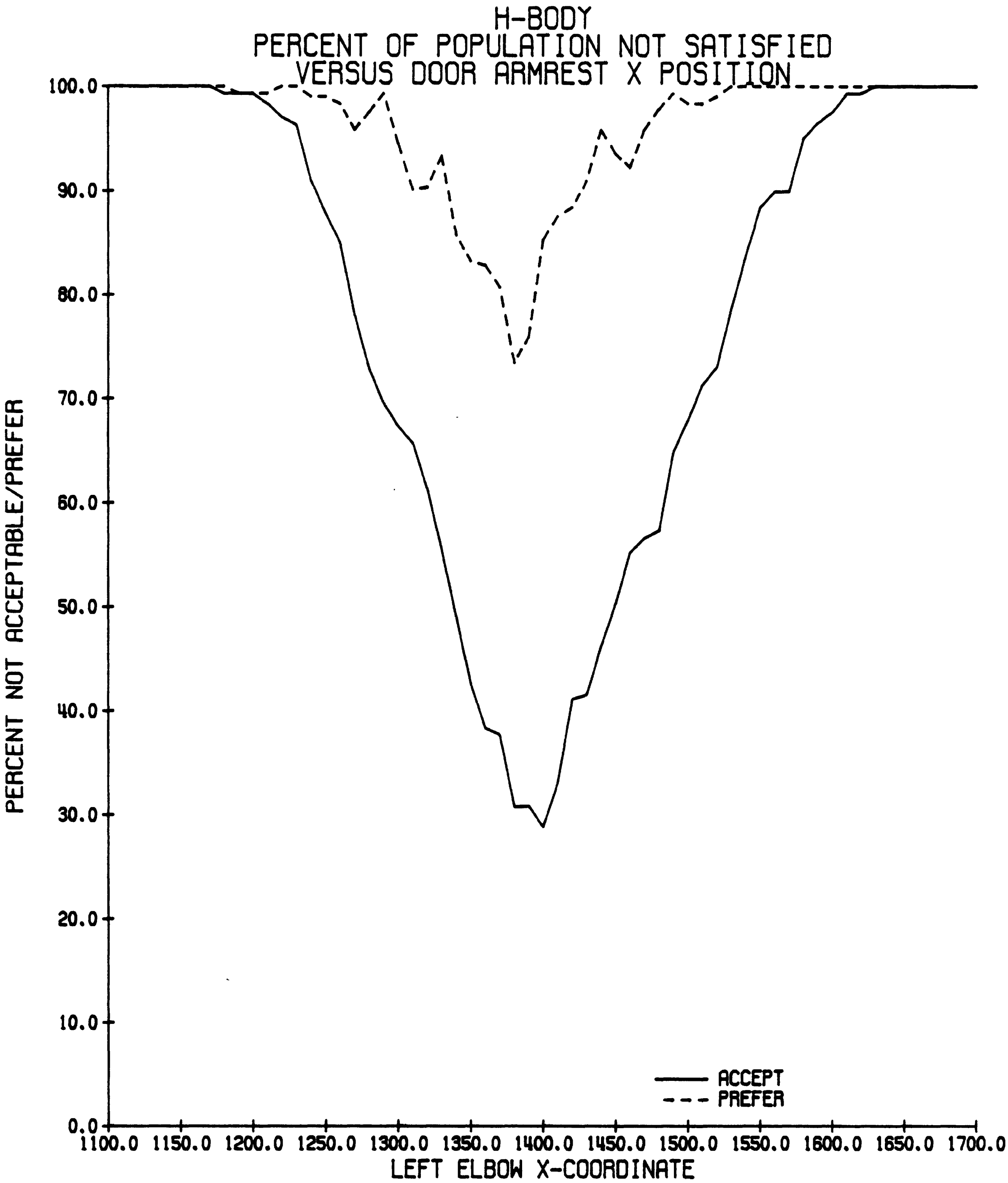

S-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST HEIGHT
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
600.0
625.0
650.0
675.0
700.0
725.0
750.0
775.0
800.0
825.0
850.0
875.0
900.0
DOOR ARMREST Z-COORDINATE
ACCEPT
PREFER


G-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS CONSOLE ARMREST HEIGHT
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
CONSOLE ARMREST Z-COORDINATE
ACCEPT
PREFER

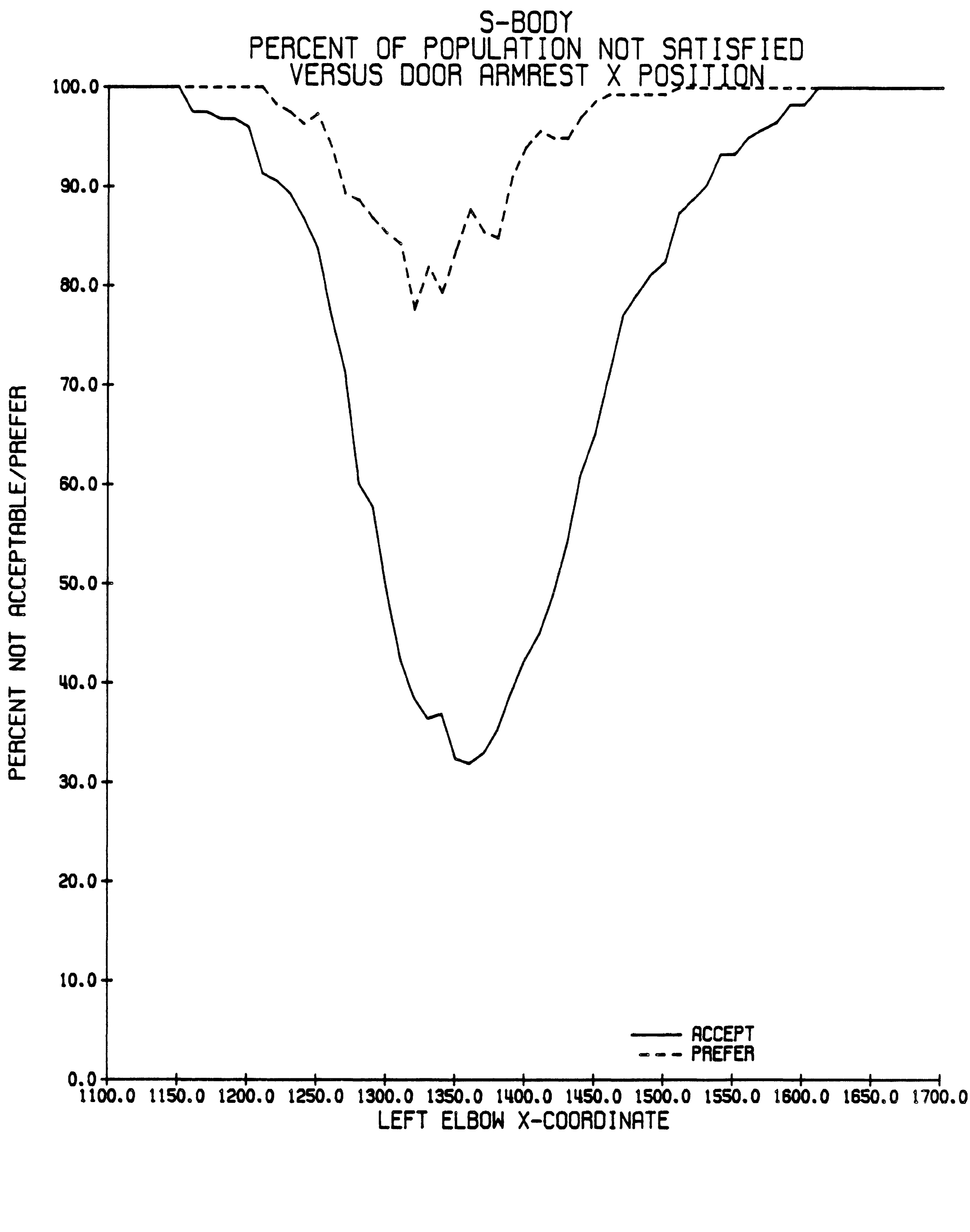

H-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS CONSOLE ARMREST HEIGHT
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
CONSOLE ARMREST Z-COORDINATE
ACCEPT
PREFER

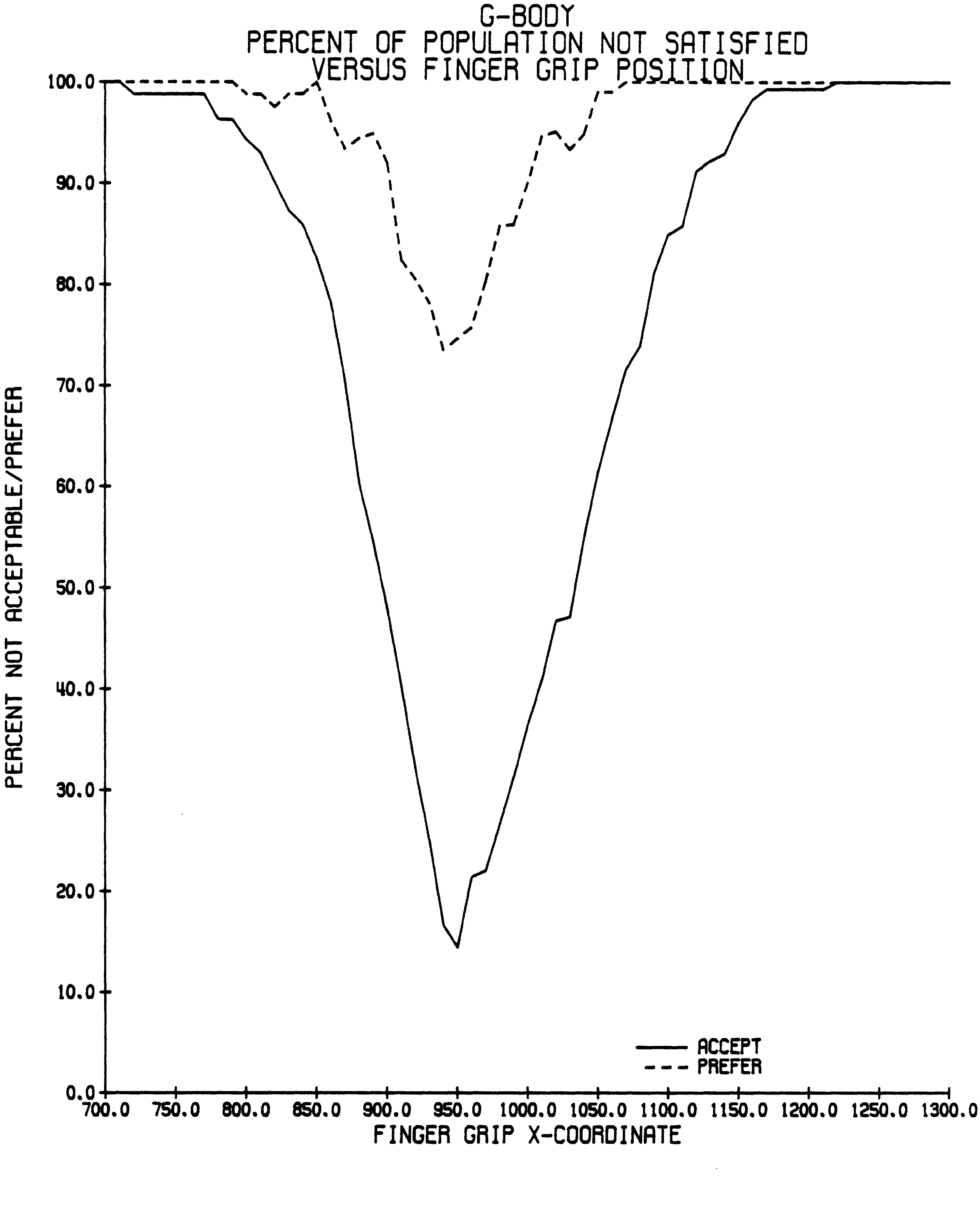

S-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS SEAT ARMREST HEIGHT
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
PERCENT NOT ACCEPTABLE/PREFER
550.0
600.0
650.0
700.0
750.0
800.0
850.0
900.0
SEAT ARMREST Z-COORDINATE
ACCEPT
PREFER

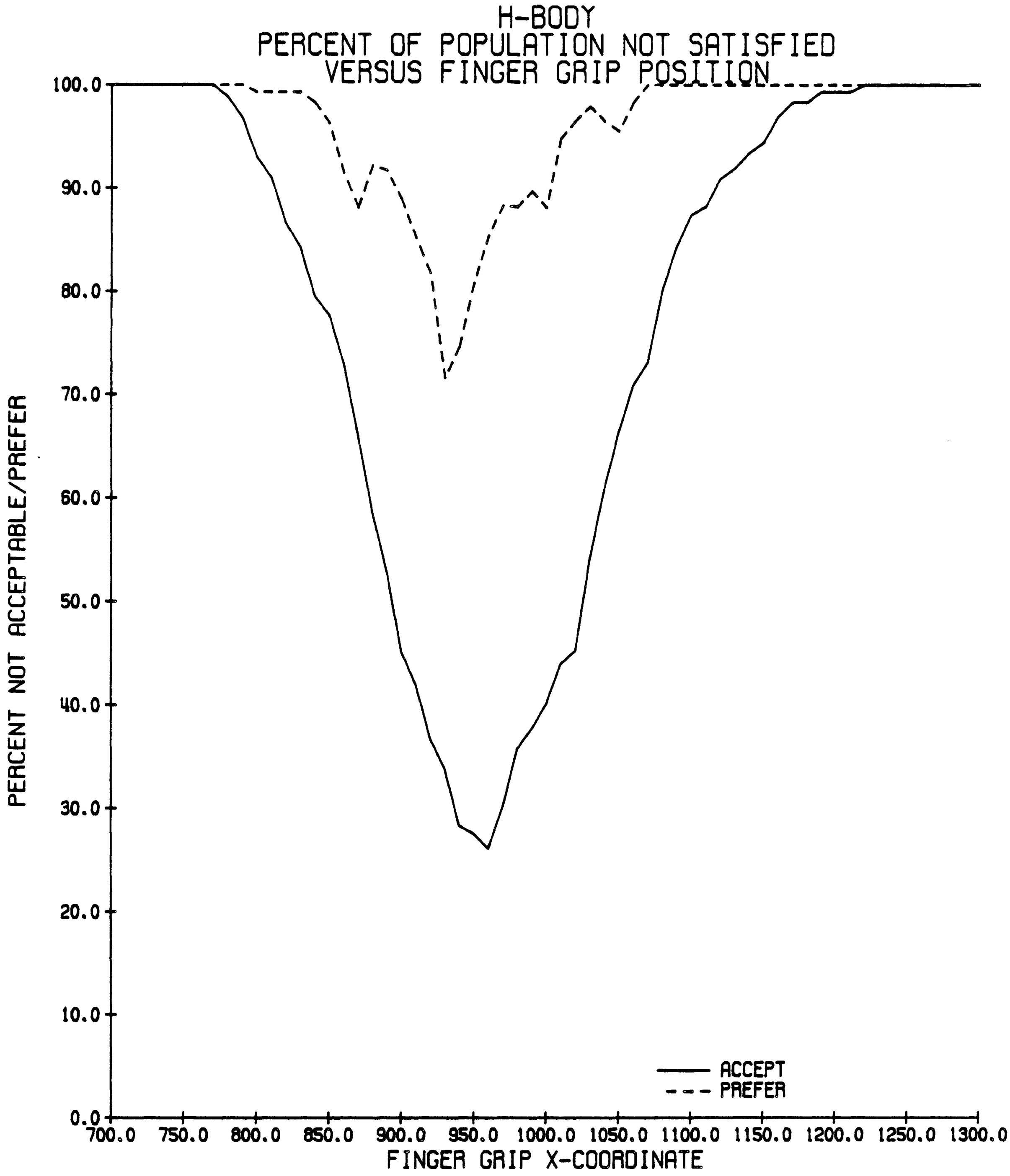

G-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST X POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1100.0 1150.0 1200.0 1250.0 1300.0 1350.0 1400.0 1450.0 1500.0 1550.0 1600.0 1650.0 1700.0
LEFT ELBOW X-COORDINATE
ACCEPT
PREFER

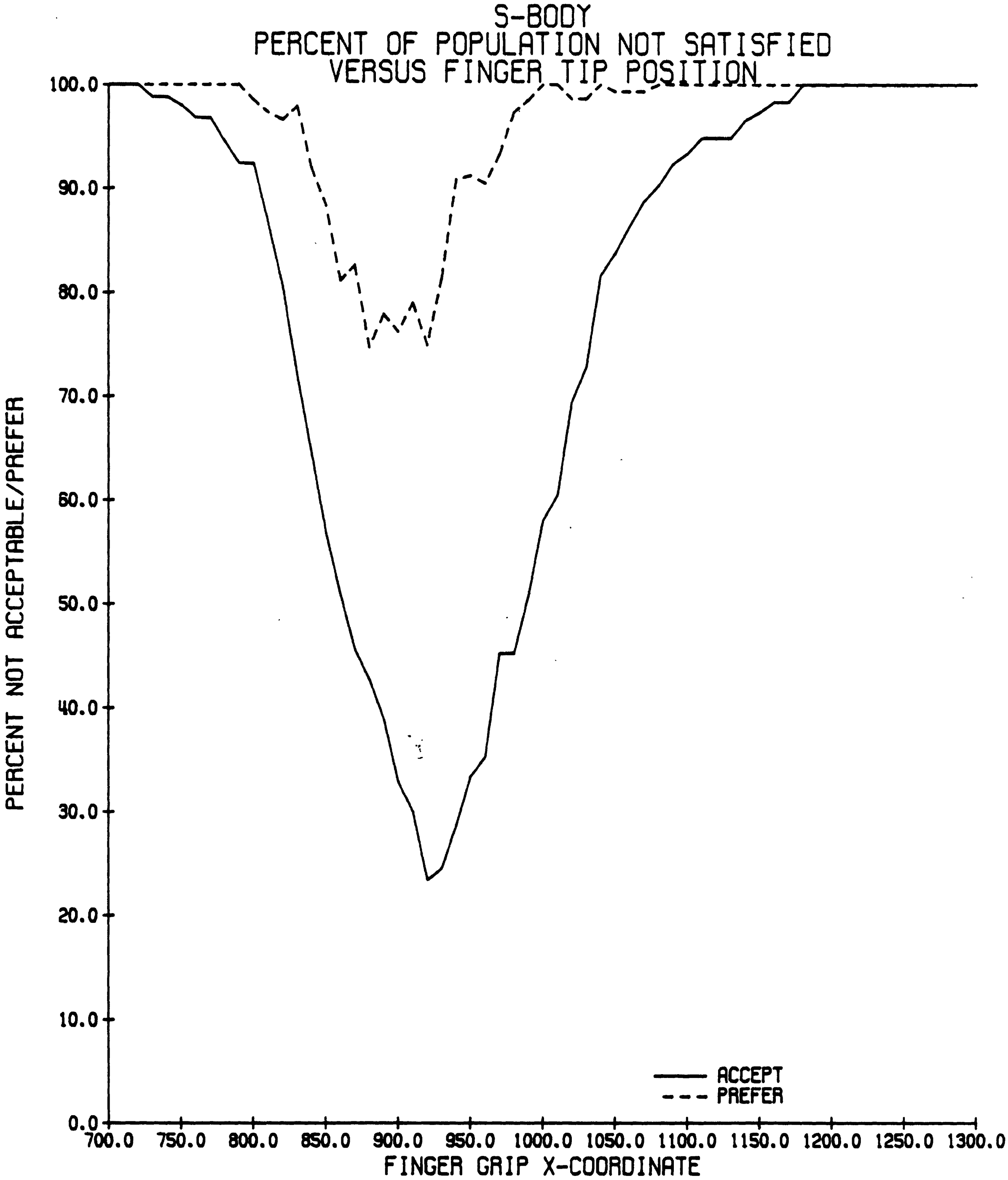


H-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST X POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1100.0 1150.0 1200.0 1250.0 1300.0 1350.0 1400.0 1450.0 1500.0 1550.0 1600.0 1650.0 1700.0
LEFT ELBOW X-COORDINATE
ACCEPT
PREFER


S-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS DOOR ARMREST X POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1100.0 1150.0 1200.0 1250.0 1300.0 1350.0 1400.0 1450.0 1500.0 1550.0 1600.0 1650.0 1700.0
LEFT ELBOW X-COORDINATE
ACCEPT
PREFER


G-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS FINGER GRIP POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
750.0
800.0
850.0
900.0
950.0
1000.0
1050.0
1100.0
1150.0
1200.0
1250.0
1300.0
FINGER GRIP X-COORDINATE
ACCEPT
PREFER


H-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS FINGER GRIP POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0 750.0 800.0 850.0 900.0 950.0 1000.0 1050.0 1100.0 1150.0 1200.0 1250.0 1300.0
FINGER GRIP X-COORDINATE
ACCEPT
PREFER


S-BODY
PERCENT OF POPULATION NOT SATISFIED
VERSUS FINGER TIP POSITION
PERCENT NOT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
750.0
800.0
850.0
900.0
950.0
1000.0
1050.0
1100.0
1150.0
1200.0
1250.0
1300.0
FINGER GRIP X-COORDINATE
ACCEPT
PREFER

APPENDIX H

ARMREST USE SURVEY RESULTS

ARMREST STUDY QUESTIONNAIRE: SUBJECT NO.________

At the time your appointment was scheduled, you were asked to take note of the armrests in your vehicle: how and when you use them. We request that you answer the following questions concerning automobile armrests before your armrest position test appointment. Please feel free to add comments where you think they may help clarify your answers.

PLEASE REMEMBER TO BRING THE COMPLETED QUESTIONNAIRE TO YOUR APPOINTMENT

PART A. VEHICLE INFORMATION

1. Please complete the following information regarding the vehicle you usually drive:

Vehicle Make________________________________

Vehicle Year and Model____________________________

Vehicle Body: ◊ 2-door ◊ 4-door

Vehicle Transmission: ◊ 4-speed ◊ 5-speed ◊ automatic

PART B. DOOR ARMREST

1. When driving, how often do you think you use the driver door armrest of your vehicle? (indicate by marking an "x" on the scale below: 1 = never, 2 = sometimes, ... , 5 = most of the time)

1 2 3 4 5
|______|______|______|______|

2. How important is the door armrest to you when you are driving? (indicate by marking an "x" on the scale below: 1 = not at all important, 2 = somewhat important, ... , 5 = very important)

1 2 3 4 5
|______|______|______|______|

3. If you DO use the door armrest, under which of the following driving conditions do you use it? (Check one or more)

◊ highway (cruising/not shifting)
◊ city (start/stop traffic)
◊ rural (shifting and cruising)
◊ daytime
◊ nighttime
◊ all of the above
◊ other (please specify)__________________________

4. If you seldom or never use the door armrest, please indicate your reason(s) below: (check one or more)

◊ I cannot steer comfortably with my left arm on it

◊ I do not feel comfortable driving with my left arm at rest

The door armrest in my vehicle is:

◊ too high
◊ too low
◊ too far away
◊ too close
◊ too far forward
◊ too far rearward
◊ too sloped
◊ too small
◊ too hard
◊ too soft

◊ I use something other than the door armrest for resting my left arm while I drive (please specify)______________________________

◊ Other (please specify)______________________________

5. Do you ever drive with your left arm resting on the door sill? (indicate by marking an "x" on the scale below: 1 = never, 2 = sometimes, ..., 5 = most of the time)

summer: 1 |____| 2 ____| 3 ____| 4 ____| 5

winter: 1 |____| 2 ____| 3 ____| 4 ____| 5

PART C. CONSOLE ARMREST

1. Does the vehicle you usually drive have a console (center) armrest? (circle one)

Y N

2. If your vehicle **DOES NOT** have a console (center) armrest, do you think you would use one if it did? (circle one and skip to PART D.)

Y N

If your vehicle **DOES** have a console armrest, answer questions 3-7 . . .

3. Please indicate the type of console armrest in your vehicle by marking the appropriate boxes below:

   POSITION:

   ◊ attached to seat:
     ◊ stationary
     ◊ flips up/down
     ◊ moves fore/aft

   ◊ attached to the floor between driver/passenger seats
     ◊ stationary
     ◊ flips up/down
     ◊ moves fore/aft

   MATERIAL:

   ◊ hard
   ◊ soft

4. When driving, how often do you use the console armrest?
   (indicate by marking an "x" on the scale below: 1= never, 2 = sometimes, ... , 5 = most of the time)

   1 2 3 4 5

5. How important is the console armrest to you when you are driving your vehicle?
   (indicate by marking an "x" on the scale below: 1= not at all important, 2 = somewhat important, ... , 5 = very important)

   1 2 3 4 5

6. If you **DO** use the console armrest, under which driving conditions do you use it?
   (check one or more)

   ◊ highway (cruising/not shifting)
   ◊ city (start/stop traffic)
   ◊ rural (shifting and cruising)
   ◊ daytime
   ◊ nighttime
   ◊ all of the above
   ◊ other (please specify)____________________

7. If you **DO NOT** use the console armrest while driving, please indicate your reasons below: (check one or more)

◊ I cannot steer comfortably with my right arm on it

◊ I cannot shift properly with my right arm on it

◊ I do not feel comfortable driving with my right arm at rest

The console [redacted] armrest in my vehicle is:

- ◊ too high
- ◊ too low
- ◊ too far away
- ◊ too close
- ◊ too far forward
- ◊ too far rearward
- ◊ too sloped
- ◊ too small
- ◊ too hard
- ◊ too soft

◊ I use something other than the console [redacted] armrest for resting my right arm while I drive (please specify)________________________________

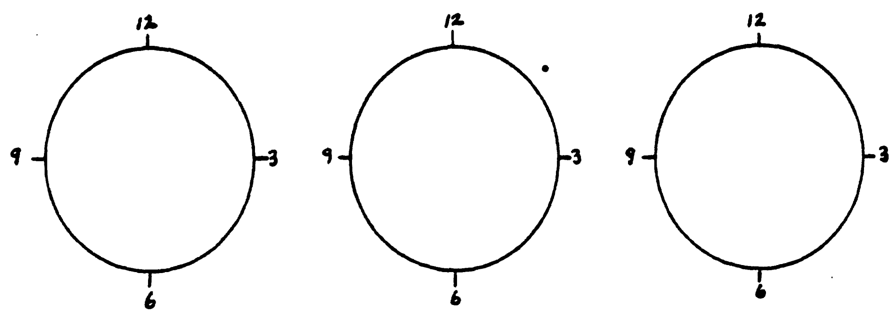
◊ Other (please specify)________________________________

PART D. GENERAL QUESTIONS

1. Do you usually drive with one hand or two on the steering wheel? (exclude shifting gears)

____

2. Label where you usually keep your hands on the steering wheel using the symbols (L) and/or (R) to indicate your hands on the wheel: (you may specify more than one position if you drive with your hands in a few different positions)



most frequent

least frequent

Questionnaire Results

Part A
Subject Vehicles by Group

Vehicle Make and Model	Group # 1	2	3	4	5	6	7	8	9	10	ALL
AMC:											
Hornet	0	1	0	0	0	0	0	0	0	0	1
Spirit	0	0	0	0	0	0	0	0	1	0	1
CHEVY-PONTIAC-OLDS-BUICK:											
Cavalier	1	0	0	0	0	0	1	0	0	0	2
Chevette	0	1	0	0	0	0	1	0	0	0	2
Citation	0	0	0	0	0	0	1	0	0	0	1
Corvette	0	0	0	0	0	0	0	0	1	0	1
Pick-Up	0	0	0	0	0	1	0	0	0	1	2
Firebird	0	0	0	0	1	0	0	0	0	0	1
Grand Am	0	0	0	0	0	0	0	0	1	0	1
LeMans	0	0	0	0	0	0	0	0	0	1	1
Sunbird	0	0	1	0	1	1	0	0	1	0	4
6000	0	0	0	0	0	0	0	1	0	0	1
Cutlass	0	0	0	0	2	0	0	0	0	1	3
Delta 88	0	0	0	0	0	1	0	0	0	0	1
Century	0	0	1	0	0	0	0	0	0	0	1
Skylark	0	0	0	0	0	0	0	0	0	1	1
CHRYSLER-PLYMOUTH:											
Horizon	0	1	0	0	0	0	0	0	0	0	1
LeBaron	0	0	0	0	1	0	0	0	0	0	1
Reliant	1	0	0	0	0	0	1	0	0	0	2
Voyager	0	0	0	0	1	0	0	0	0	0	1
Volare	0	0	0	0	0	0	0	0	0	1	1
DATSUN-NISSAN:											
Stanza	0	0	0	2	0	0	0	0	0	0	2
FORD-MERCURY:											
Bobcat	0	0	0	0	0	1	0	0	0	0	1
Bronco	0	1	0	0	0	0	0	0	0	0	1
Escort	1	1	0	0	2	0	0	1	0	1	6
Fairmont	0	0	0	0	0	0	0	0	1	0	1
Fiesta	0	0	0	0	0	0	1	0	0	0	1
LTD	0	0	1	0	0	0	0	0	0	0	1
Merkur	0	0	0	0	0	0	0	1	0	0	1
Mustang	0	0	0	0	0	2	0	0	0	0	2
Pick-Up	1	0	0	0	0	0	1	1	2	0	5
Pinto	0	0	0	0	0	0	0	0	0	1	1
Tempo	1	0	0	0	0	1	1	0	0	0	3

Part A (cont)

Vehicle Make and Model	Group # 1	2	3	4	5	6	7	8	9	10	ALL
HONDA:											
Accord	0	0	1	0	0	0	0	0	0	0	1
Civic	1	0	1	0	0	0	0	0	0	0	2
CRX	0	0	0	0	0	0	0	1	0	0	1
Wagon	0	0	0	0	0	0	0	1	0	0	1
MAZDA:											
GLC	0	1	0	0	0	0	1	0	0	0	2
626	0	0	0	0	1	0	0	0	0	0	1
PEUGEOT:											
504 Sedan	0	0	1	0	0	0	0	0	0	0	1
RENAULT:											
Alliance	0	0	0	0	0	1	0	0	0	0	1
Encore	0	0	0	0	0	0	0	1	0	0	1
Le Car	0	0	0	1	0	0	0	0	0	0	1
SAAB:											
900 EMS	0	0	0	0	0	0	0	0	1	0	1
VOLKSWAGON:											
Golf	0	1	0	0	0	0	0	0	0	0	1
Bug	0	0	1	0	0	0	0	0	1	0	2
Rabbit	1	0	1	1	0	0	0	0	1	0	4
VOLVO:											
DL	0	0	1	0	0	0	0	0	0	0	1
Wagon	0	0	0	1	0	0	0	0	0	0	1

Part B - Door Armrest

1.) How Often is the Door Armrest Used?

Scale	Group 1	2	3	4	5	6	7	8	9	10	ALL
1	5	3	2	2	2	1	3	2	0	1	21
2	4	4	4	4	2	3	2	2	2	0	27
3	1	1	0	3	5	3	2	2	1	2	20
4	0	2	3	0	1	1	1	2	2	4	16
5	0	0	1	0	0	2	2	2	3	3	13

2.) How Important is the Door Armrest?

Scale	Group # 1	2	3	4	5	6	7	8	9	10	ALL
1	5	4	4	4	1	4	3	2	1	1	29
2	4	2	1	2	5	3	2	2	1	2	24
3	1	0	1	2	2	1	2	2	1	0	12
4	0	3	1	1	2	0	2	3	1	3	16
5	0	1	2	0	0	2	1	1	4	4	15

3.) Driving Conditions for Door Armrest

Condition	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Highway (cruising)	3	5	6	5	5	3	4	5	3	4	43
City (stop/start)	0	2	1	1	2	0	0	1	2	2	11
Rural (shift/cruise)	1	1	2	1	2	0	1	0	1	2	11
Daytime	1	3	3	5	5	1	3	3	2	3	29
Nighttime	1	2	2	3	3	0	2	3	5	5	26
All of Above	0	0	2	0	3	5	3	3	4	5	25
No Answer	7	4	2	3	1	2	3	1	2	1	26

4a.) Reasons for not using the Door Armrest

Reason	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Uncomfortable Steering	2	5	5	4	5	6	7	5	8	10	57
Uncomfortable at Rest	7	3	5	1	3	3	3	2	0	0	27

4b.) The Door Armrest Is...

Description	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Too High	0	0	0	1	0	0	1	0	0	0	2
Too Low	5	2	3	3	2	3	4	2	1	1	26
Too Far Away	3	2	3	2	0	0	2	2	0	0	14
Too Close	0	1	0	1	1	0	0	0	0	0	3
Too Far Forward	0	0	0	0	0	0	0	0	1	0	1
Too Far Rearward	2	3	0	0	0	2	0	1	0	0	8
Too Sloped	1	0	0	0	0	0	0	0	0	0	1
Too Small	2	2	2	3	1	1	2	1	0	0	14
Too Hard	2	0	2	1	2	0	0	1	0	0	8
Too Soft	0	0	0	0	0	0	0	0	0	0	0
No Answer	1	6	5	3	7	7	5	6	7	9	63

5a.) Window Sill Used as Armrest in Summer

Scale	Group # 1	2	3	4	5	6	7	8	9	10	ALL
1	4	2	2	3	0	3	2	1	1	0	18
2	2	5	2	3	3	2	4	3	3	8	35
3	1	1	4	0	1	2	2	2	2	1	16
4	3	2	2	3	4	3	1	3	1	1	23
5	0	0	0	0	2	0	1	1	2	0	6

5b.) Window Sill Used as Armrest in Winter

Scale	Group # 1	2	3	4	5	6	7	8	9	10	ALL
1	5	7	6	6	5	7	5	6	4	8	59
2	3	2	2	2	3	1	5	2	3	0	23
3	0	0	1	1	1	1	0	0	0	0	4
4	2	1	1	0	0	1	0	1	1	1	8
5	0	0	0	0	0	0	0	1	0	0	1

Part C - Console Armrest

C1.) Does Vehicle Have A Console Armrest?

Answer	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Yes	2	1	2	2	2	5	1	4	2	5	26
No	8	9	8	7	8	5	9	6	7	5	72

2.) Would Use A Console If Vehicle Had One

Answer	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Yes	4	4	5	4	5	2	6	3	7	4	44
No	4	5	3	3	3	2	3	3	0	1	27
No Answer	2	1	2	2	2	6	1	4	2	5	27

3.) Type of Console Armrest

Type	1	2	3	4	5	6	7	8	9	10	ALL
ATTACHED TO SEAT:											
Stationary	0	0	0	0	0	0	0	0	0	0	1
Flips Up/Down	1	1	2	1	2	1	1	2	1	1	13
Moves Fore/Aft	0	0	0	0	0	0	0	0	0	0	0
ATTACHED TO FLOOR:											
Stationary	0	0	0	0	0	2	0	2	0	2	6
Flips Up/Down	1	0	0	1	0	2	0	0	0	1	5
Moves Fore/Aft	0	0	0	0	0	0	0	0	0	0	0
Soft Material	2	1	2	1	2	4	1	2	0	4	19
Hard Material	0	0	0	1	0	1	0	2	1	1	6
No Answer	8	9	8	7	8	5	9	6	8	5	73

4.) How Often is the Console Armrest Used?

Scale	Group # 1	2	3	4	5	6	7	8	9	10	ALL
1	1	0	1	1	0	1	0	0	0	3	7
2	1	1	0	0	0	2	0	2	0	0	6
3	0	0	1	1	1	1	0	0	0	0	4
4	0	0	0	0	0	0	0	1	0	1	2
5	0	0	0	0	1	1	1	1	1	1	6
No Answer	8	9	8	7	8	5	9	6	8	5	73

5.) How Important is the Console Armrest?

Scale	Group # 1	2	3	4	5	6	7	8	9	10	ALL
1	2	0	1	1	0	0	0	1	0	3	8
2	0	1	0	0	0	2	0	1	0	0	4
3	0	0	1	1	1	1	0	0	0	1	5
4	0	0	0	0	1	0	0	1	0	0	2
5	0	0	0	0	0	2	1	1	1	1	6
No Answer	8	9	8	7	8	5	9	6	8	5	73

6.) Driving Conditions for Console Armrest

Condition	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Highway (cruising)	1	0	1	1	0	3	0	2	0	1	9
City (start/stop)	0	1	0	0	0	2	0	1	0	0	4
Rural (cruise/shift)	0	0	1	1	0	1	0	0	0	1	4
Daytime	0	1	0	1	0	2	0	1	0	1	6
Nighttime	0	0	1	1	0	1	0	1	0	1	5
All of Above	0	0	0	0	2	1	1	1	0	1	6
No Answer	9	9	9	8	8	5	9	6	9	7	79

7a.) Reasons For Not Using Console Armrest

Reasons	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Uncomfortable Steering	1	0	1	0	0	1	0	1	0	0	4
Can't Shift Properly	0	0	0	0	0	1	0	0	0	0	1
Uncomfortable at Rest	0	0	1	1	0	0	0	1	0	1	4

7b.) The Console Armrest Is...

Description	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Too Low	1	0	1	0	0	1	1	1	0	1	6
Too High	0	0	0	0	0	0	0	0	0	0	0
Too Far Away	1	0	1	0	0	0	0	1	0	0	3
Too Close	0	0	0	0	0	0	0	1	0	0	1
Too Far Forward	0	0	0	0	0	0	0	0	0	0	0
Too Far Rearward	0	0	0	0	0	0	0	2	0	0	2
Too Sloped	0	0	0	0	0	0	0	0	0	0	0
Too Small	0	0	0	0	0	1	0	0	0	0	1
Too Hard	0	0	0	0	0	1	0	2	0	0	3
Too Soft	0	0	0	0	0	0	0	0	0	0	0
No Answer	9	10	9	9	10	9	9	7	9	9	90

Part D - Position of Hands and Body

1.) Number of Hands Usually on the Steering Wheel

# of Hands	Group # 1	2	3	4	5	6	7	8	9	10	ALL
One	3	1	1	1	3	4	3	3	6	4	29
Two	7	9	9	8	7	6	7	7	3	6	69

2.) Most Frequent Position of Left Hand

Hand Position	Group # 1	2	3	4	5	6	7	8	9	10	ALL
6 o'clock	0	0	0	0	0	0	1	0	0	0	0
7 o'clock	1	0	1	0	0	0	0	2	1	1	6
8 o'clock	3	0	1	2	1	3	2	2	4	2	20
9 o'clock	1	3	1	1	4	2	1	3	0	3	19
10 o'clock	1	6	5	4	1	4	2	2	0	2	27
11 o'clock	3	1	2	2	3	1	2	1	0	1	16
12 o'clock	0	0	0	0	0	0	2	0	1	0	3
None	1	0	0	0	1	0	0	0	3	1	6

3.) Most Frequent Position of Right Hand

Hand Position	Group # 1	2	3	4	5	6	7	8	9	10	ALL
12 o'clock	0	0	0	0	1	0	1	0	0	1	3
1 o'clock	1	2	3	1	2	1	3	1	2	1	17
2 o'clock	4	6	5	3	1	4	1	2	0	2	28
3 o'clock	0	0	0	1	1	1	2	2	1	2	10
4 o'clock	2	0	1	2	0	2	0	2	2	0	11
5 o'clock	0	0	1	1	1	0	0	2	1	0	6
6 o'clock	0	0	0	0	1	0	0	0	0	1	2
None	3	2	0	1	3	2	3	1	3	3	21

4.) Tendency to Use One Armrest More

Answer	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Door	4	5	8	6	2	7	3	6	4	7	52
Console	0	0	0	1	3	1	1	2	0	0	8
Neither	3	3	0	2	0	2	4	2	3	3	22

5.) Tendency to Lean to use an Armrest

Answer	Group # 1	2	3	4	5	6	7	8	9	10	ALL
Lean Left	3	3	4	1	1	1	2	2	1	4	22
Lean Right	0	0	0	1	1	0	1	1	0	1	5
Lean Back	0	1	5	1	0	0	0	0	0	0	7
Don't Lean	5	5	0	6	4	9	7	7	7	6	56
No Answer	2	1	1	0	4	0	0	0	1	0	9

List of Subject Comments from Questionnaire

Group #	Comment
1	"In city stop-and-go traffic, I rest my right hand on the gear shift at all times. In alert traffic situations I keep both hands toward the top of the wheel. When cruising and relaxed, I use either both or one hand toward the bottom of the wheel and I brace my elbows against the seat. At that time I would probably use and armrest. It wasn't until I took this survey that I noticed I had one in my car. It is so far away I would have to contort my body to reach it."
1	"Armrests are just not important to me. I feel safe driving requires both hands on steering wheel."
1	"Don't remember ever using armrest in 25 years driving. Was taught best control is with hands at 10 and 2. and got comfortable that way. Sometimes extend left arm along door sill if on long trip, but ususally prop left elbow on sill with hand or fingertips on wheel."
1	"Since I was called about this survey, I have become more conscious of armrests while driving several different cars besides my own. In none of the cars was the armrest comfortable (Ford Escort, Ford Tempo). The Escort console was useable, and comfortable to use. If I had a console I would probably use it."
1	"I never in my life remember using the door armrest in a car for anything except pulling the door closed. Heavy people use the armrest to help lift themselves out of the back seat. This has resulted in the armrest being torn away from the door."
1	"Would probably only use console armrest on long drives or with a floor stick shift."
2	"If armrests were adjustable (up, down, forward, backward) I'd probably use it at least 50%."
2	"I feel safer with both hands on the wheel when driving... my children all reinforced this teaching received in Driver Ed courses in high school. The only time I find myself using the door armrest is while waiting for a red light, for traffic to clear before making a turn, etc. Being right handed, I can't imagine ever resting my right arm on an armrest."
3	"Do you feel that the positioning of seat belt affects use of armrest? (Particularly for shorter torso-length individuals). Would responses vary if test subject was left-handed or right-handed? How much would responses vary if vehicle were equipped with power steering?
3	"I don't have a console armrest in my car, but I have often used the console armrest when I drive a car that does have one. I like to rest my arm against the door above the armrest just at the base of the window quite often."

Table C-2 (continued)
Summary of Subject Comments During Testing

Group #	Comment
3	"I didn't know it was for resting your arm. I use it to shut the door."
3	"Armrests should adjust to accomodate varying relative arm lengths. A center armrest is important which is why I use my large hand bag as a center armrest."
4	"I'm not sure how armrests can be benificial in a manual transmission car. Obviously a console armrest is out (If you have the gear shift on the floor). If the armrest on the door could be larger without interfering with comfortable driving, or softer, or higher, maybe that would work. I think one arm (at least) deserves a rest now and then. If there's some way to do it, especially in a tight space within a car, it would be a good idea."
4	"There is sufficient room in my car so that my arms don't touch the armrest while driving in a relaxed position. I use it when I'm stopped and waiting."
5	"I normally drive standard transmission cars so I would drive with my left hand and my right hand was usually on the gear shift unless I was on the expressway, then I used both hands. In our second car, a '78 Oldsmobile, I sometimes drive with my left hand and use the console which is soft and folds down."
5	"Too narrow, not enough padding, effects nerves in arm."
5	"My door armrest is shaped: the angled part is the door handle. When using the armrest, I ususally have my elbow on the horizantal part, and my hand on the angled part. I prefer this arrangement to horizantal-only armrests. I don't rest the arm that's driving on the armrest, because of reaction time in an emergency."
5	"Door armrest are good for closing the door and need to be sturdy enough to take being pulled shut often. Single console armrests (as compared to dual) with padding and that open, are the best kind. Console armrests that retract into the seat are nice."
6	"I commute 50 miles each way to and from work and feel uncomfortable and miss not having a console armrest. The door armrests seem to be too low and too far rearward to be comfortable for me. I generally prefer to use the top of the door sill for my left hand armrest."
6	"In my opinion, driving a vehicle properly requires use of both hands on the wheel - armrests, if positioned so the driver can easily rest his armrs and keep his hands on the wheel would restrict the driver's movement if he had to make sudden course corrections if some unforeseen thing happened. If the driver wants easy chair comfort he should stay home in his living room."

Table C-2 (continued)
Summary of Subject Comments During Testing

Group #	Comment
6	"I always drive with both hands on the wheel and find it difficult to reach the armrest comfortably. Maybe that is because I have short arms."
6	"The Bobcat door grip/armrest/door release guard is an excellent idea. I miss its usefulness when driving other cars."
6	"I think armrests (left and right) are important to comfortable driving. They seem to relieve strain and make one's arms less tired on long trips. I will definitely choose my next car with left and right armrests."
6	"I think the experience of many drivers has been such that most vehicle armrests are for looks more than actual use. Most vehicles I've driven have not had useful armrests and I do not expect them to be functional."
7	"Generally, they are too low and/or too far away. I'm not sure that I would use then much anyway except possibly on highways where I am not turning the vehicle. Around town I think they would be a hindrance and I am reasonably certain I wouldn't use them. Consoles are ok for storing stuff but I can't remember one ever making a suitable armrest. It seems to me that armrests are meant to make up for the lack of support of a poorly designed seat. The best I have experienced is a bucket seat in a Porsche. What is generally needed is better lateral and lumbar support."
7	"I don't miss armrests in city driving because frequent shifting and turning make it impossible to rest the arms. Armrests are useful on long freeway trips - seem to reduce tension in my arms, shoulders, and back."
8	"I think console armrests should move with the seat and should be able to be flipped up and down."
8	"Position of seat is important - i.e. too far back and armrest is too far forward. Side of door is perhaps best position for left arm."
8	"I tend to lean to the driver's side of the car to utilize the door sill for rest. I doubt whether I would prefer an armrest at any height."
9	"On my own vehicles and many others which I have driven, the armrest is too far away although I still use it. The armrest should extend far enough toward the driver so that the elbow can remain under the wrist instead of flaring out."
9	"The next automobile I buy will have a console armrest."

Table C-2 (continued)
Summary of Subject Comments During Testing

Group #	Comment
9	"Armrests could be very useful, but not without being adjustable. I use the window sill all the time in summer as it is more comfortable than armrest, not forcing me to lean left. Given the economics of car manufacture, I think snowballs could more easily be stockpiled in hell than an adjustable armrest ever be manufactured."
9	"I now realize that I use the door armrest more than I thought I did. If you had asked me prior to this study, and without my taking the time to be aware of my use, I probably would have said that I hardly ever use it. In fact, I use it quite a bit without being conscious of it. The door armrest in my Rabbit is somewhat low although I can use it without leaning. I think its position dictates where I place my hand on the wheel (at 7:00). If it were higher, I would probably put my hand at 9:00."
10	"The position of the door arrmrest in my Cutlass must be perfect for me because I was completely unaware that I use it until I checked for the purpose of this questionnaire. I like having a console box/armrest, but I never use it as an armrest - only to store things."
10	"I sure hope armrests don't go the way of vent windows - that is, excluded form vehicles. Armrests would be of greater benefit is higher or even adjustable."
10	"Seems to me the armrests are too low and I feel myself slouching down to use them. Also, in some instances the armrests are bent and tend to go down in front and I sense I am going to slip out."
10	"I would like to see swing down adjustable armrests in cars and light trucks of the type used in heavy trucks and class a motor homes."
10	"The door armrest in my Celebrity is too hard and has that silly hole in it to make it a door closer also. My elbow does not like having that hole. Make the armrest just that - an armrest, and have a seperate handle for closing the door."

APPENDIX I

SUBJECT COMMENTS DURING TESTING

Summary of Subject Comments during testing by Group

Comment		1	2	3	4	5	6	7	8	9	10	ALL
		# per Group										
SEAT POSITION -												
Subject felt too close to the steering wheel if seat was positioned to allow reaching the pedals												
	G-Body:	2	5	4	3	1	5	1	1	1	1	24
	H-Body:	3	2	1	1	1	3	0	0	0	0	11
	S-Body:	1	0	0	0	0	0	0	0	0	0	1
Would like the seat back to be capable of being positioned more vertical												
	G-Body:	1	1	1	2	0	0	0	0	0	0	5
	H-Body:	1	0	0	1	0	0	0	1	0	0	3
	S-Body:	0	1	0	1	0	0	0	1	0	0	3
SHIFT -												
The shift knob is too low in the S-Body												
		2	4	5	0	1	4	2	0	2	2	22
ARMRESTS -												
The console armrest in the G-Body is too far from the seat laterally												
		5	6	6	5	5	5	3	5	2	4	46
Could take the door armrest upper limit higher than the maximum upward travel that the buck allows												
	G-Body:	0	1	1	1	0	0	1	2	1	0	7
	H-Body:	0	1	2	0	1	0	3	2	2	0	11
	S-Body:	3	6	7	1	4	2	7	5	6	3	44
Never uses either armrest in own vehicle												
		3	0	2	2	0	1	1	0	0	0	9
Doesn't have or never uses console armrest in vehicle - would rather not have one												
		1	2	2	0	1	0	2	1	1	1	11
Would never use both armrests at the same time												
		1	5	2	1	2	1	3	2	0	2	19