PREFERRED AND ACCEPTABLE LOCATIONS OF PRIMARY DRIVER CONTROLS IN G-, H-, AND S-BODY VEHICLES

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16. Abstract

A computer-controlled adjustable seating buck was used to determine the preferred and acceptable locations of primary controls and armrests for G-, H-, and S-body vehicles. The seating buck was designed to be manually changed among the three seating packages in a single measurement session and allows the subject to make adjustments in eight different component/direction variables by push-button controls. These include the front/back positioning of the brake/clutch pedal assembly and the steering wheel; front/back, left/right, up/down positioning of the shift knob; up/down positioning of the door armrest; and up/down and front/back positioning of the console armrest.

The study tested one hundred subjects stratified equally into ten gender/stature groups from short females to tall males. Data collected include preferred locations of the steering wheel, pedals, shift knob, and armrests and acceptable ranges for the pedals, steering wheel, and shift knob. In addition, preferred locations were determined with and without consideration of the clutch pedal, and shift knob/console armrest interaction was investigated. Other measurements included driver sitting height and driver tolerance for steering wheel offset or cant angle.

Data were analyzed to determine the optimal control locations for the driver population as well as percentage-acceptance ranges for the different control/direction variables. Relationships of control locations with driver stature and vehicle design features were also evaluated.

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SUMMARY

In order to gain a better understanding of driver's needs and preferences for locations of primary controls and armrests, a computer-controlled seating buck, with adjustable control locations, was designed and fabricated. The test facility provides for simulation of sport car, sedan, and minivan seating packages by means of manual adjustments in the locations and orientations of controls and armrests. It also provides for subject adjustment, using a pushbutton control stick, of eight control/direction variables including front/back position of the steering wheel and brake/clutch pedal assembly, front/back, left/right, and up/down position of the shift knob, up/down position of the driver door armrest, and front/back and up/down position of the center or console armrest. The seat has provision for seat back angle adjustment and is manually adjustable front to back along a seat track with extended travel range.

One hundred subjects were recruited and tested in the three seating packages for preferred and acceptable locations of controls. The subjects were distributed equally among ten stature/gender groups spanning 95 percent of the male and female population by stature. Data were collected for preferred locations of the steering wheel, pedals, shift knob, and armrests. Acceptable range data were collected for the steering wheel, pedals, and shift knob. Other measurements included armrest elbow locations, in-vehicle sitting heights, selected anthropometric measurements, and driver tolerance for steering wheel offset or cant angle.

Data for each subject group were weighted to represent the driver population by stature and optimal control locations, and percentage-acceptance ranges were determined from the weighted results.

I. INTRODUCTION AND OBJECTIVES

Along with pressures to make the automobile more fuel efficient and crashworthy, ergonomic design of vehicle interiors and controls has become an increasingly important issue for the automotive engineer in recent years. One important aspect of ergonomic design is related to the locations of the primary driver controls (i.e., steering wheel, pedals, shift knob) with respect to each other and within the vehicle. Given the large range in stature and weight of potential drivers, the automotive designer is faced with a challenging task to locate controls so that they optimally accommodate the driving population.

In order to move the decision-making of control locations from the realm of art and educated guesswork to sound engineering design practice, information is needed that describes both the preferred and acceptable control locations of the driver population. In other words, there is need to establish a scientific ergonomic data base upon which driver workspace and seating design decisions can be made. Ultimately, such a data base can lead to the establishment of a set of driver workspace design criteria for which predictive design parameter relationships and values can be established. Such a data base must deal not only with the range of vehicle types and seating packages, but also with the range of driver sizes and physical characteristics.

It was the aim of the Chrysler Challenge Fund Program on Ergonomics of Primary Controls and Armrests to begin to fill this need. In the first phase of this program, a laboratory seating buck was designed and developed for collecting data about preferred and acceptable locations of primary driver controls and armrests. Initially, this facility was used to determine driver preferences for armrest locations, and the results of this study are documented in a separate report (Schneider, 1987).

Because of the importance of the design and features of the ergonomic seating buck to the data for locations of driver controls, the description presented in the armrest study report is repeated here with minor modifications. The remainder of this report describes the procedures used and results obtained from the second study of primary driver control locations and includes some additional findings with regard to armrest locations. Because of the large number of graphs and plots used to present the results, most are included in the appendices to this report.

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 MEASUREMENT FACILITY

1. General Description

During the first year of the Chrysler Challenge Fund Program, a computer-controlled universal seating buck was designed and developed for collection of both armrest and primary control position information in G-, H-, and S-body vehicle seating packages. In order to meet the needs of the research program, several general design criteria were established for the development of this unique test facility.

First, the facility had to be capable of simulating a range of passenger car seat package configurations, including the Chrysler G-body (sport 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 measurement and recording of position data be as automated as possible.

Figures 1 and 2 show the completed seating buck that resulted from these basic design considerations, and the IBM-XT computer system used to collect position data and sequence through the test protocol. The base structure is made of 2" by 2" steel tubing and 3/4-inch plywood forms the platforms for seat attachment, subject entry and exit, and the accelerator-heel-point (AHP) reference surface. Separate modules are bolted to the base unit to provide support and position adjustment for the different controls and components. Black cloth is used to cover most of the hardware and structures to reduce subject distraction. During testing, a more realistic driving environment is produced by projecting a road scene onto a screen mounted to the buck in front of the subject.

The clutch/brake pedal assembly and the steering wheel hardware are supported by an aluminum frame mounted to the left front area of the base unit. As shown in Figure 3, this module also houses the electronic interface hardware and power supplies for component positioning and readout of position described subsequently. The shift linkage assembly and console armrest support and positioning modules are located and attached along the right

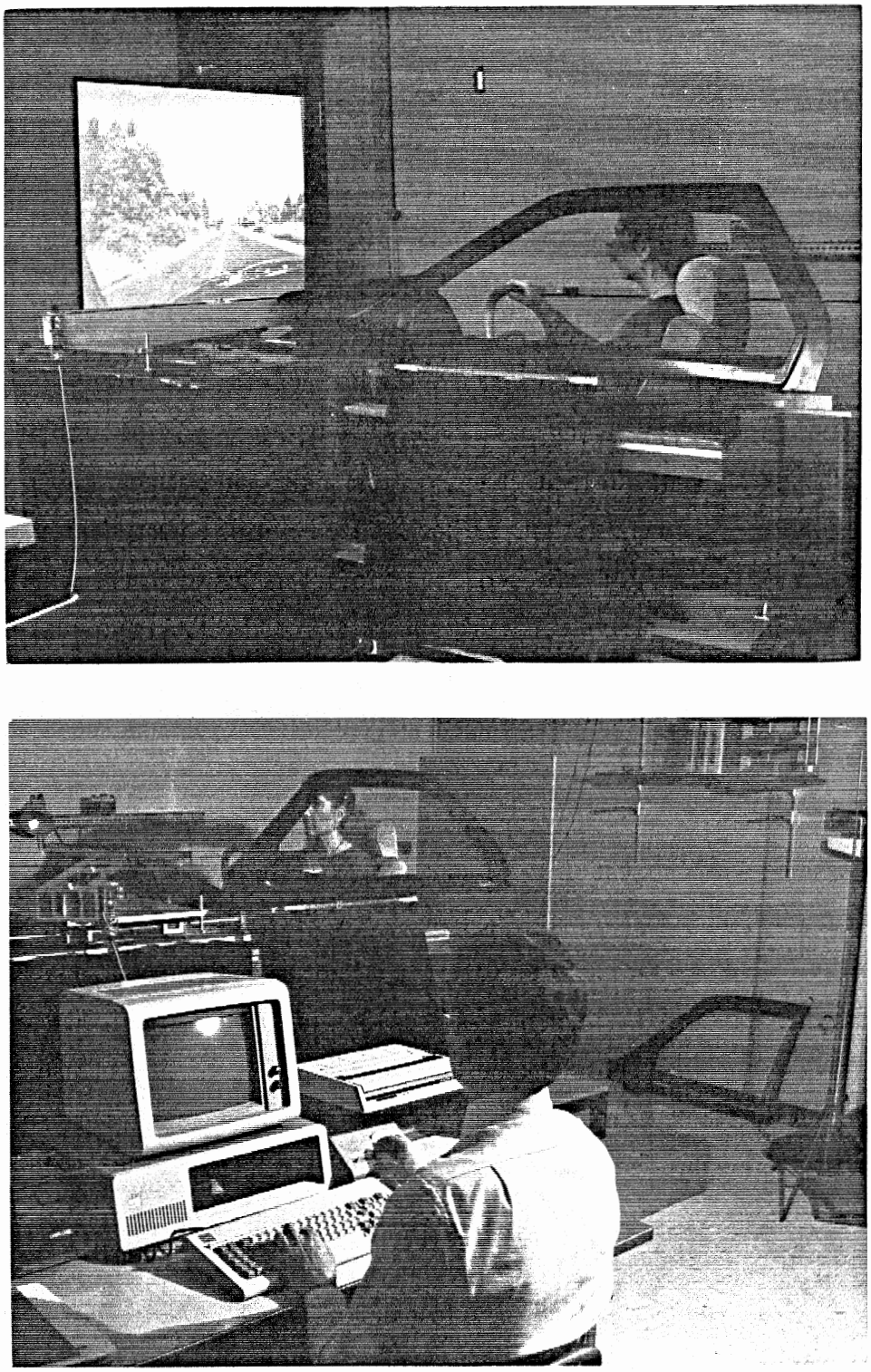


Figure 1. UMTRI computer-controlled "universal" seating buck.

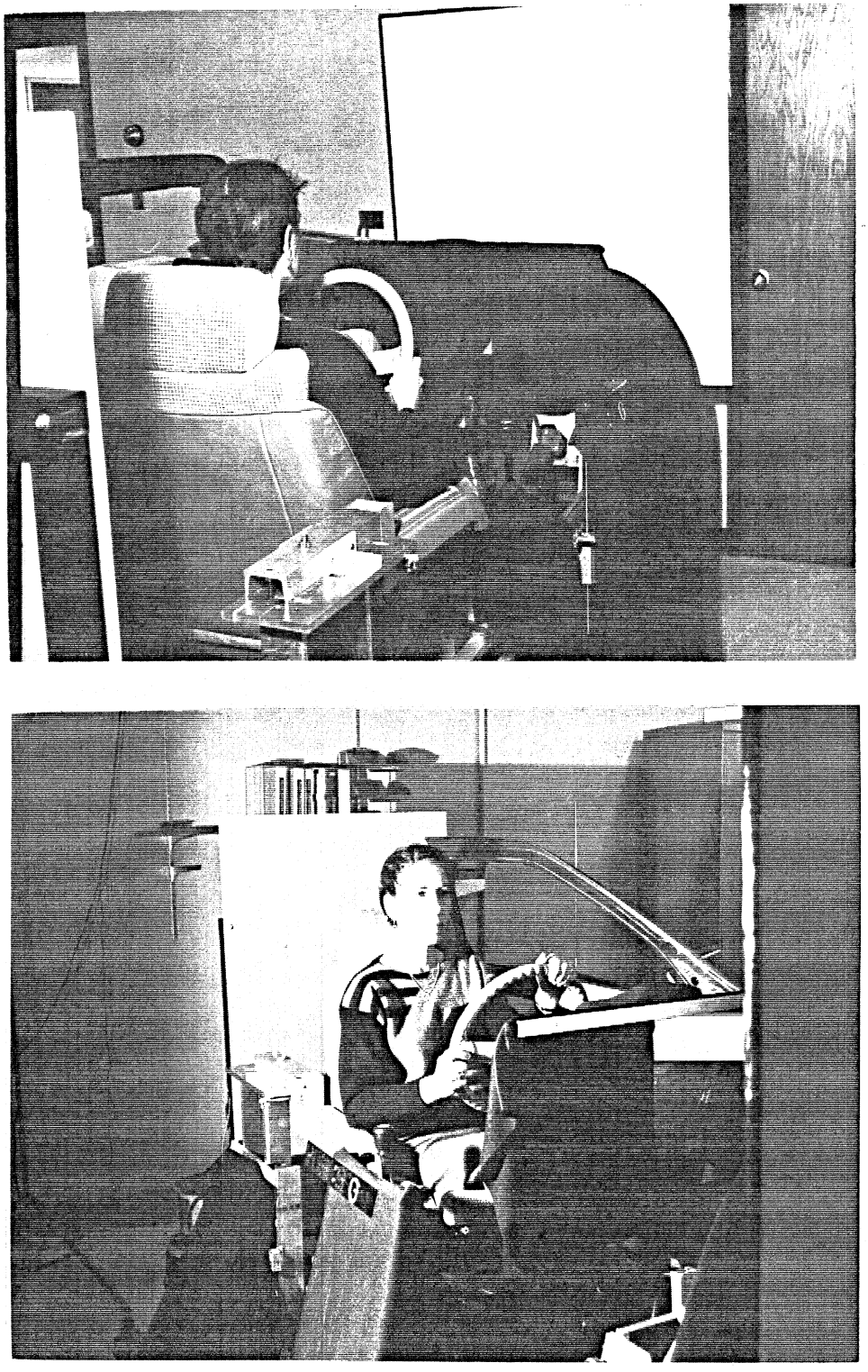


Figure 2. UMTRI "universal" seating buck.

side of the main frame, while the door structure and door armrest unit are attached to the base structure to the left of the seat area. This modular design approach provides for easy system modification since any of the 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 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 on the top of the unit and the direction of motion is controlled by two push-button switches on the side of the plexiglas cylinder. Keyboard control allows the actuator (i.e., component) selected by the investigator to be controlled in small increments using the "PgUp" and "PgDn" keys or by alternating starts and stops using the "up-arrow" and "down-arrow" keys.

Dimensions and coordinates from the G-body, H-body, and S-body package drawings and J826 H-point specifications were used to establish basic positions and orientations for the steering column, pedals, seat, and door window frames for the sport 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.

2. Vehicle Components

In order to facilitate adjustment from one seating package configuration to another, the same vehicle 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 mechanism were used in all three vehicle setups. However, as described below, adjustments in the positions, orientations, and movements (e.g., clutch pedal travel) of these assemblies and components were made for 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 simulated driver door armrest surface, and a center armrest surface. For the H- and G-body styles, the center armrest surface consists of the H-body plastic console lid. For the S-body configuration, this is replaced by the seat-mounted pivoting type armrest from an S-body vehicle seat.

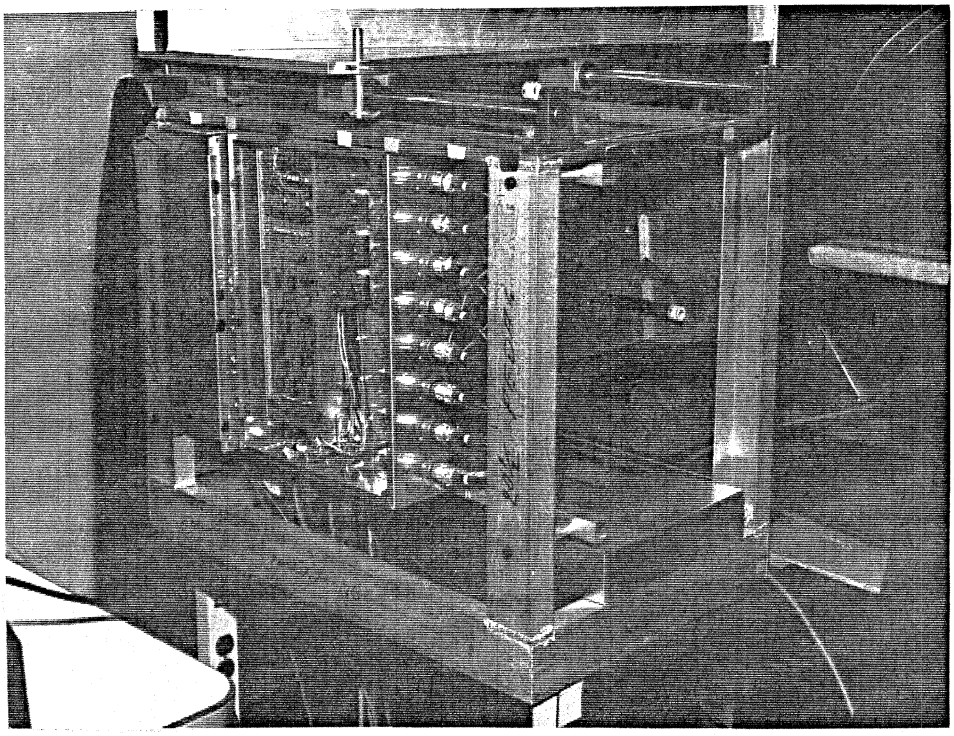


Figure 3. Pedal and steering wheel support structure containing electronic interface hardware.

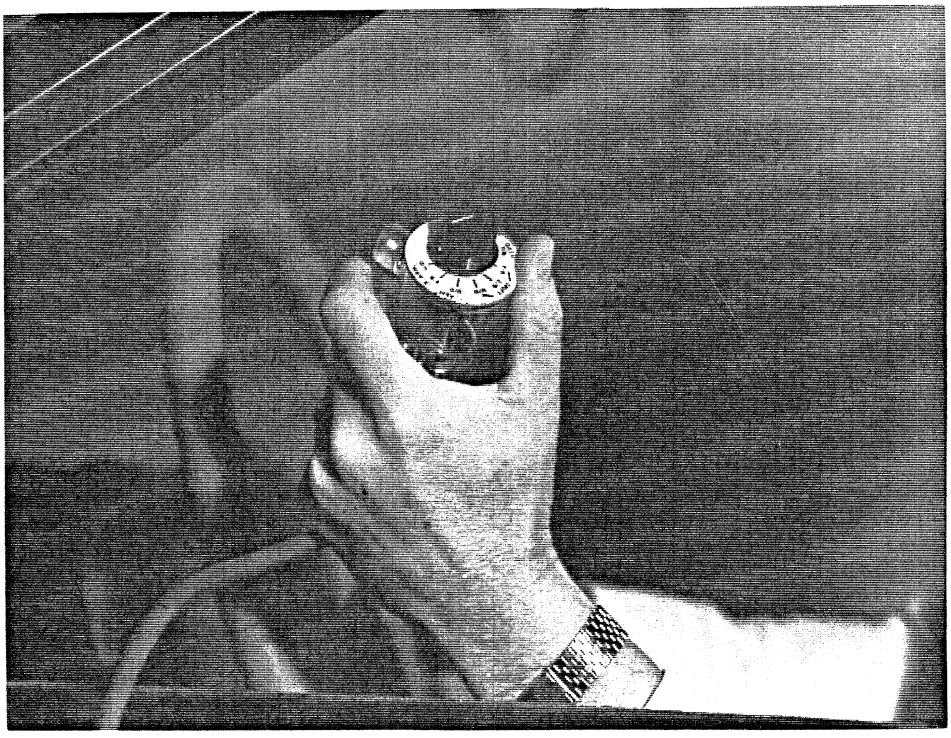


Figure 4. Hand-held module used by subjects to adjust positions of vehicle components.

3. Buck Reference System and Seat Calibration

The accelerator heel point (AHP) was established as a common and fixed reference point on the buck for all three seating packages. The buck reference system was defined with the X axis positive toward the rear, the Z axis positive up, and the Y axis positive toward the right. The origin of the buck coordinate system can then 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 horizontal line in the Y-direction passing through the AHP. The X and Z coordinates of the AHP for each of the vehicle package drawings (see Table 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. Figure 5 illustrates the buck coordinate axes, AHP, and power-adjustable components/directions.

Calibration of the measurement system and validation 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.

4. Seat and Seat Track

The seat used for all three package configurations is Chryslers' 1986 Enthusiast high-performance seat with manual seat-track mechanism and seat-back angle adjuster. The seat track was anchored to a 3/4-inch-thick plywood board by means of aluminum spacers and fitted with linear measuring scales for manual readout of seat detent and back angle. In order not to limit selected seat position, the standard seat track was extended at each end to allow additional seat travel beyond that of the production model. This extended track is shown in Figure 6 and has a total of 21 detents with detent spacings of 0.83 inches (21 mm) for a total seat travel range of about 15.7 inches (400 mm). The modified seat track was also slightly curved and inclined so that, when oriented to achieve J826 H-point specifications, the S-body seat was 1.3 inches (33 mm) higher in detent 1 (i.e. full forward) than in detent 21 (i.e. full rearward). Similarly, the G- and H-body seat positions were 1.75 inches (45 mm) higher in detent 1 than in detent 21.

When the buck was near completion, 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 G-, H-, and S-body packages would be achieved.

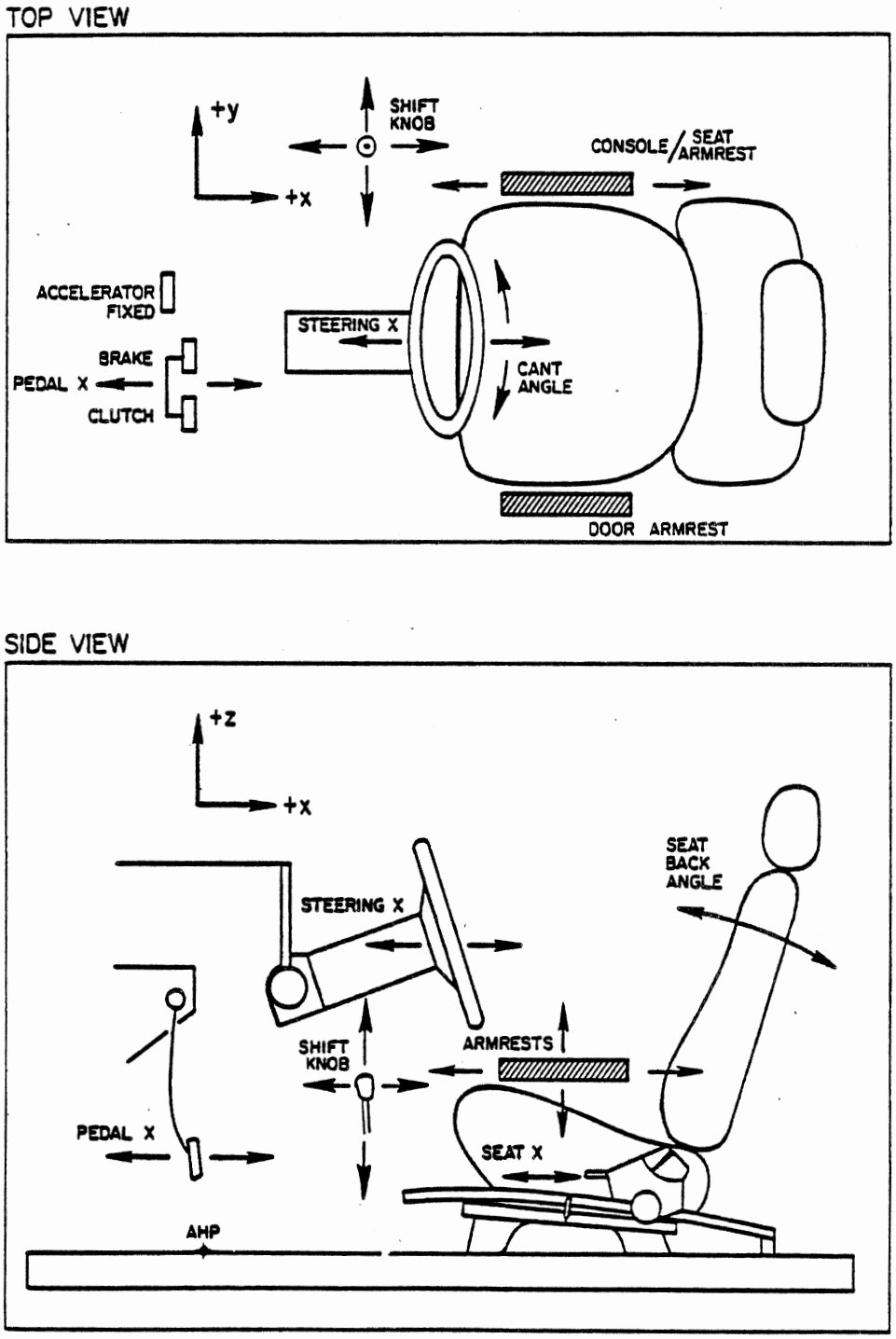


Figure 5. Schematic drawing of seating buck illustrating buck and vehicle coordinate axes and vehicle components that can be positioned by subjects.

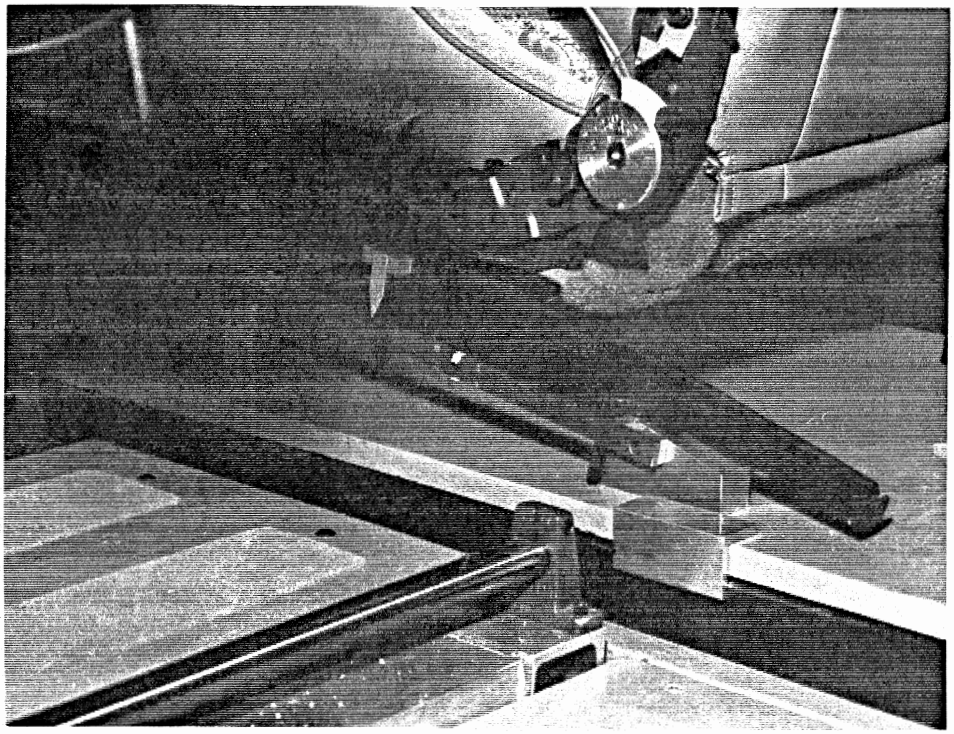


Figure 6. Seat with extended track mounted to plywood board via aluminum spacers. Note detent indicator and seatback angle scale.

This calibration also determined which detent on the extended seat track corresponded to the design position in each case. The thigh and lumbar inflatable bags provided in the seat were kept deflated during all calibration and testing.

Figure 7 shows the H-point machine on the seat during the calibration 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, fixtures and spacers were fabricated to locate and orient the seat mounting board and provide for easy seat adjustment among the different vehicle packages. Upon completion of these fixtures, the H-point machine was used again to verify the initial results. Table 1 compares the results obtained for the two trials. The differences are small and well within acceptable tolerances. Figures 8 and 9 show the seat board positioned to the G- and S-body locations, respectively.

5. Power-adjusted Control Locations

In its present configuration, the test facility provides for push-button control of eight component/direction variables by either the hand-held module or by the computer keyboard as follows:

1.) front/back steering wheel adjustment
2.) front/back brake/clutch pedal adjustment
3.) front/back shift knob adjustment
4.) left/right shift knob adjustment
5.) up/down shift knob adjustment
6.) up/down door armrest adjustment
7.) up/down center armrest adjustment
8.) front/back center armrest adjustment

6. Electrical Readout of Position

In order to record the positions of power-actuated components selected by subjects quickly and reliably, and to enable the computer to position these components to locations specified in computer programs, ten-turn potentiometer/cable transducers have been incorporated into the facility to provide electrical signals proportional to component locations. Figure 10 shows the position-monitoring unit for the steering wheel front/back location. The potentiometer is fastened to the non-moving structure and a flexible cable that winds around and attaches to a pulley on the shaft of the potentiometer is attached to the moving component. A coil spring inside the pulley maintains tension on the cable and rewinds it when the component moves toward the potentiometer. The voltages across the

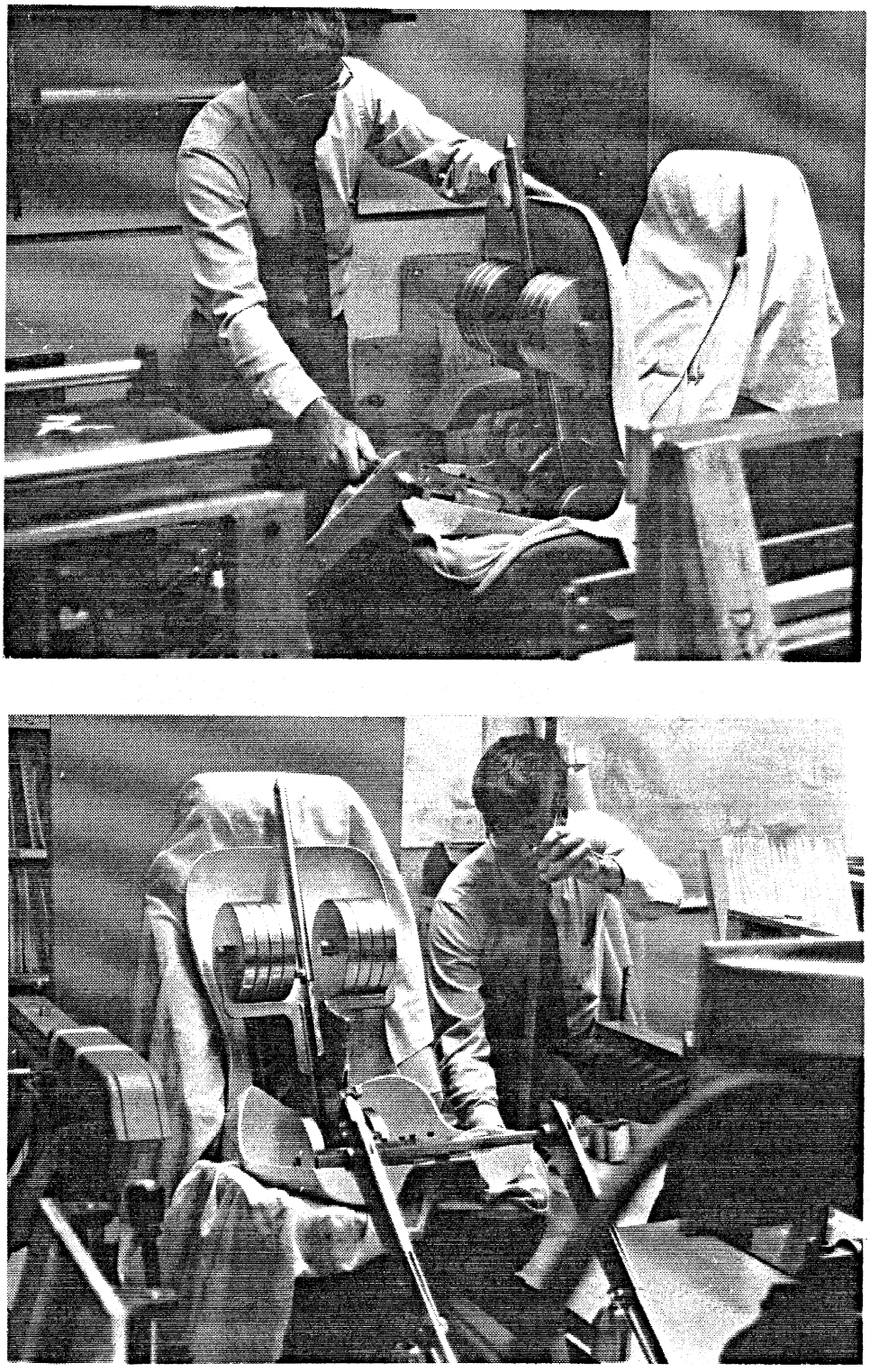


Figure 7. H-point calibration of seating buck.

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

H-Point Measurement	Specification Desired	Measured	Difference
G-BODY: Detent=15, Back Angle=22			
AHP to H-POINT (horiz.)	880	879	1.0
AHP to H-POINT (vert.)	231	230	1.0
FOOT ANGLE	65	65	1.0
ANKLE ANGLE	87	87	0.0
KNEE ANGLE	128	129	1.0
HIP ANGLE	98	98	0.5
BACK ANGLE	26	26	0.0
H-BODY: Detent=14, Back Angle=22			
AHP to H-POINT (horiz.)	828	828	0.0
AHP to H-POINT (vert.)	264	264	0.0
FOOT ANGLE	59	59	0.0
ANKLE ANGLE	87	87	0.0
KNEE ANGLE	119	120	0.0
HIP ANGLE	94	94	0.0
BACK ANGLE	24	24.5	0.5
S-BODY: Detent=13, Back Angle=20			
AHP to H-POINT (horiz.)	698	700	2.0
AHP to H-POINT (vert.)	352	345	7.0
FOOT ANGLE	43	43	0.0
ANKLE ANGLE	87	87	0.0
KNEE ANGLE	103.3	103.5	0.2
HIP ANGLE	91	91.5	0.5
BACK ANGLE	22	24	2.0

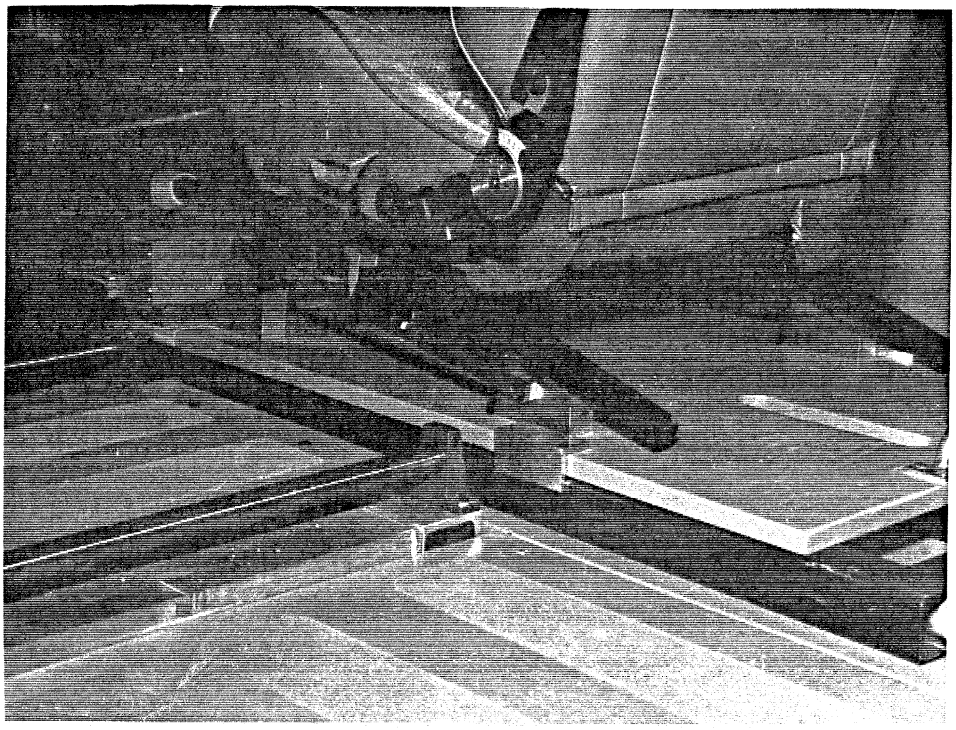


Figure 8. Seat positioned in G-body location.

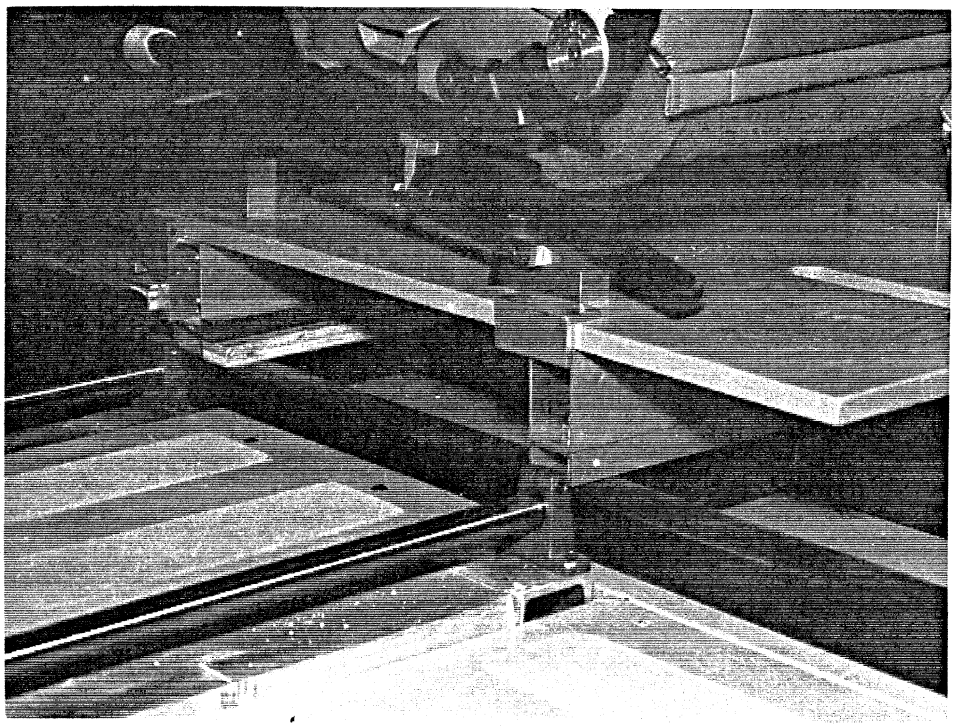


Figure 9. Seat positioned in S-body location.

wiper arms of the potentiometers are proportional to the locations of the different components and are input to the XT computer through eight A/D channels.

Calibration of each measurement system was achieved by reading A/D values at specified locations of each component (e.g., center of steering wheel, top of armrest surface) measured in buck coordinates. These data were plotted to check the linearity of the relationships and to determine the slope and intercept of each linear calibration equation. The equations were then adjusted for the different vehicle package configurations by adding appropriate offset constants to produce component coordinates in the different vehicle reference systems.

7. Steering Wheel Positioning

Steering wheel height and steering column tilt were designed to be manually adjustable to accommodate the differences for the three vehicle types. Figure 11 shows the 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 in an arc about two inches to either side of the seat center line. Steering wheel front-to-back adjustment is by means of the screw-motor actuator and control circuitry.

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 for the different body styles. Figure 12 shows the support structure for the brake/clutch pedal assembly. Tables 4, 5, and 6 of Appendix A show the desired lateral spacing of the pedals in the three vehicles compared with the lateral spacing used in the test facility. The relative locations of the undepressed brake and clutch pedal surfaces in the X-Z plane view (i.e., side view) were also set to minimize the errors for the different vehicles.

Differences in clutch and brake travel specified for the different vehicle packages are accomplished by attaching and interchanging wooden blocks of different heights to the aluminum plate behind the pedal linkage. Realistic clutch pedal force is achieved by attaching the clutch cable to a clutch/transmission assembly mounted just forward of the pedals. Brake actuation force is simulated by means of a block of rubber placed between

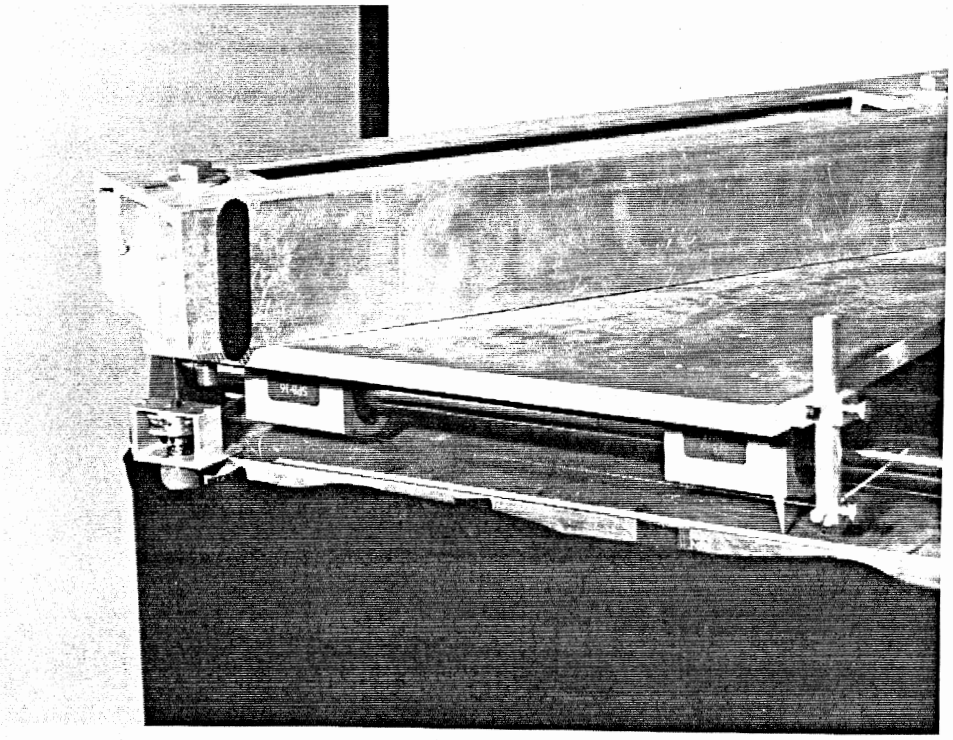


Figure 10. Position sensing unit for steering-wheel front/back location (i.e., X-coordinate).

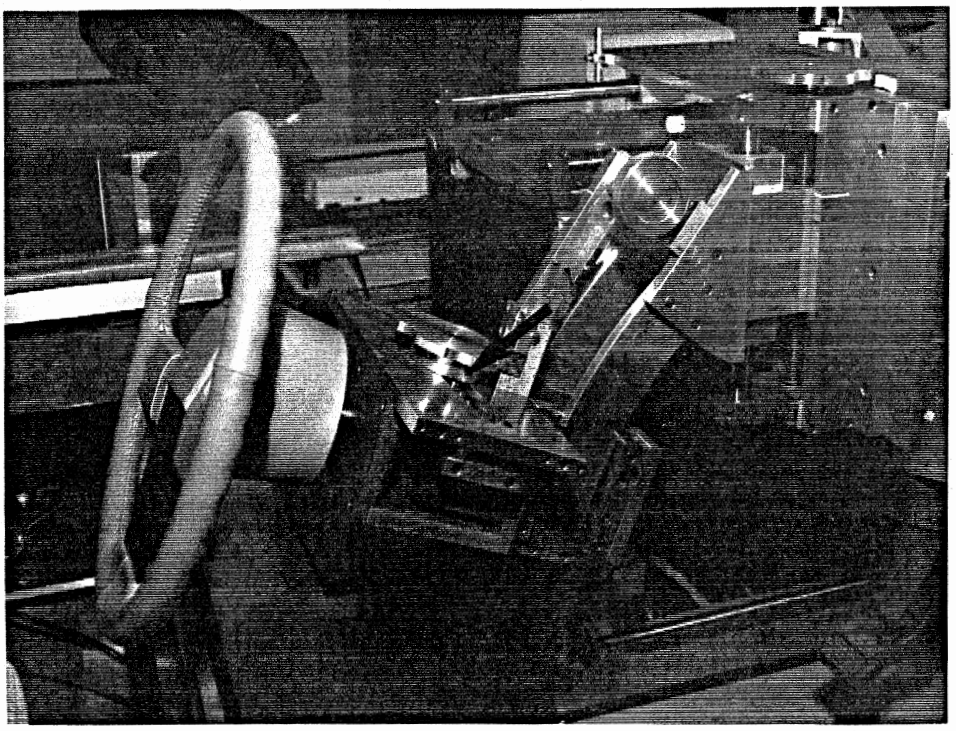


Figure 11. Steering-wheel angle and height adjustment mechanism. The arrow indicates the cant angle adjustment mechanism.

the pedal linkage and the pedal mounting plate. The heights and orientations of the brake/clutch pedal assembly are different for the three body styles and are achieved by means of a pair of bolts traveling in specially contoured slots in the pedal support plate as shown in Figure 13. Adjustment of the brake/clutch pedal assembly from one configuration to another is achieved by manually sliding the assembly along these slots to one of three detents which correspond to the three vehicle pedal orientations. At each of the these detents, a knurled-handled bolt is used to lock the pedal assembly in position.

9. Accelerator Pedal Positioning

A single accelerator pedal was used and located at the same lateral position relative to the seat centerline for all three vehicles. The inclination of the accelerator pedal is manually adjusted by the mechanism shown in Figure 14 in order to achieve the desired vehicle differences. Accelerator pedal force is accomplished by means of a simple tension spring that hooks the pedal linkage to the mounting plate.

10. Shift Knob Positioning

The shift linkage is the same 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 assembly used in the study of driver controls was different than that used in the study of armrest positions in that the length of the shift lever was 2 inches shorter in the study of control positions. Calibration of the shift knob location was determined using the top center of the shift knob in both studies. The shift linkage connects 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 operation.

11. Armrests and Driver Door/Window

The seating buck includes two armrests and armrest supports, one for the driver door and one for the center armrest. The driver door armrest consists of a three-inch wide 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 of the vinyl covering of the armrest to enable manual measurement of elbow position in the X direction (i.e., front to back). The door/armrest assembly slides laterally on linear bearings

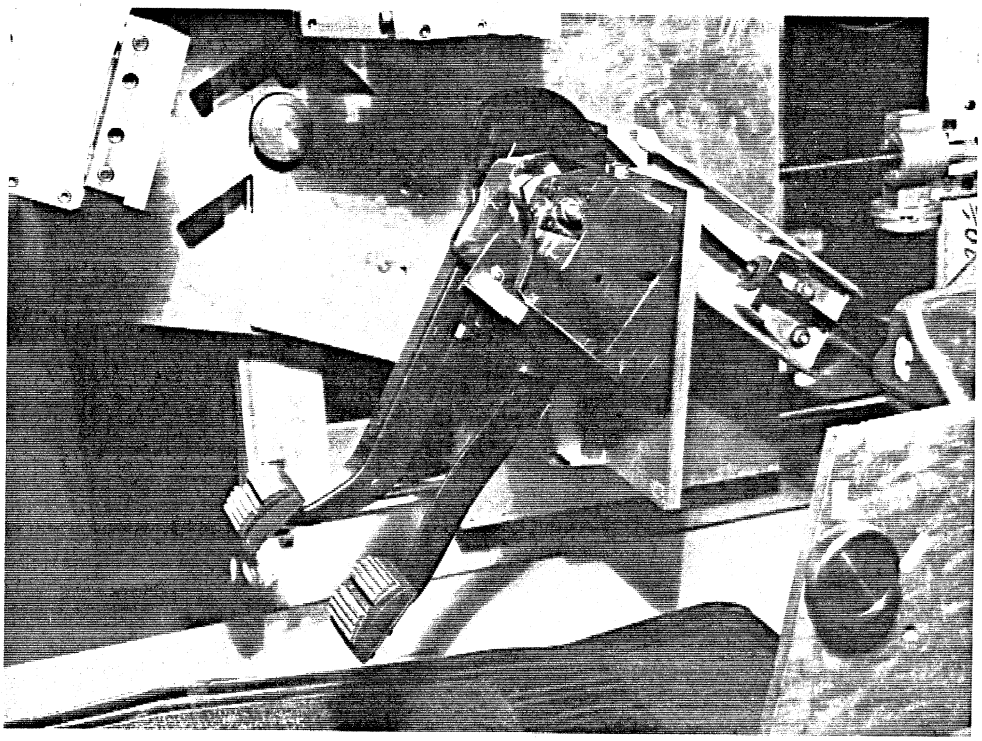


Figure 12. Support structure for brake/clutch pedal assembly.

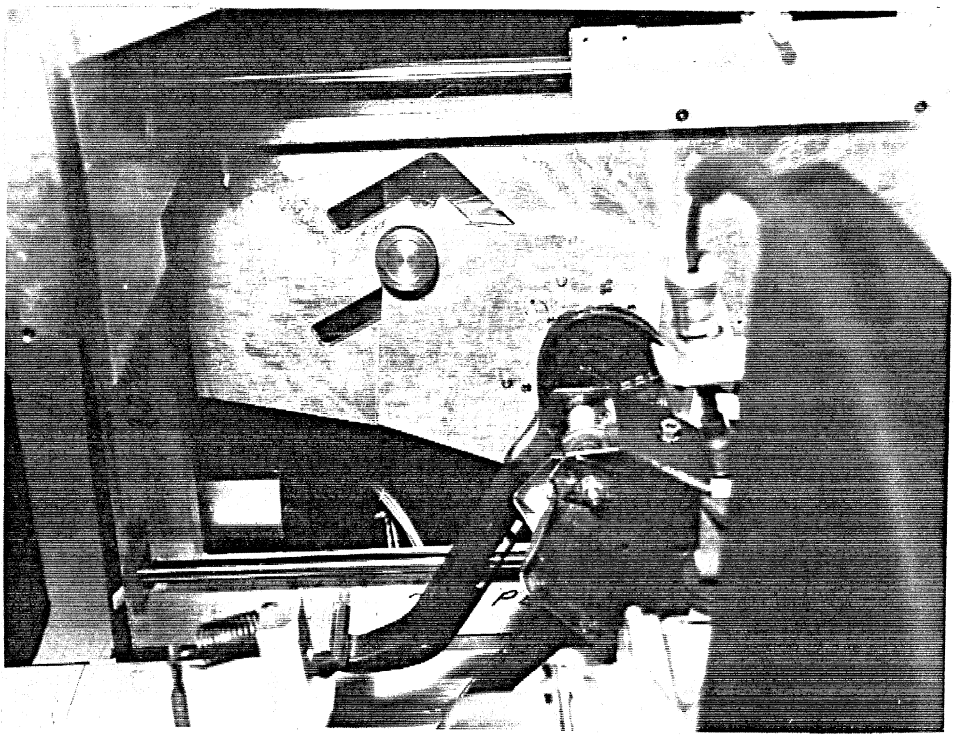


Figure 13. Contoured slots in pedal assembly mounting plate for manual adjustment of brake/clutch pedal height and orientation.

Figure 14. Accelerator pedal support and adjustment module.

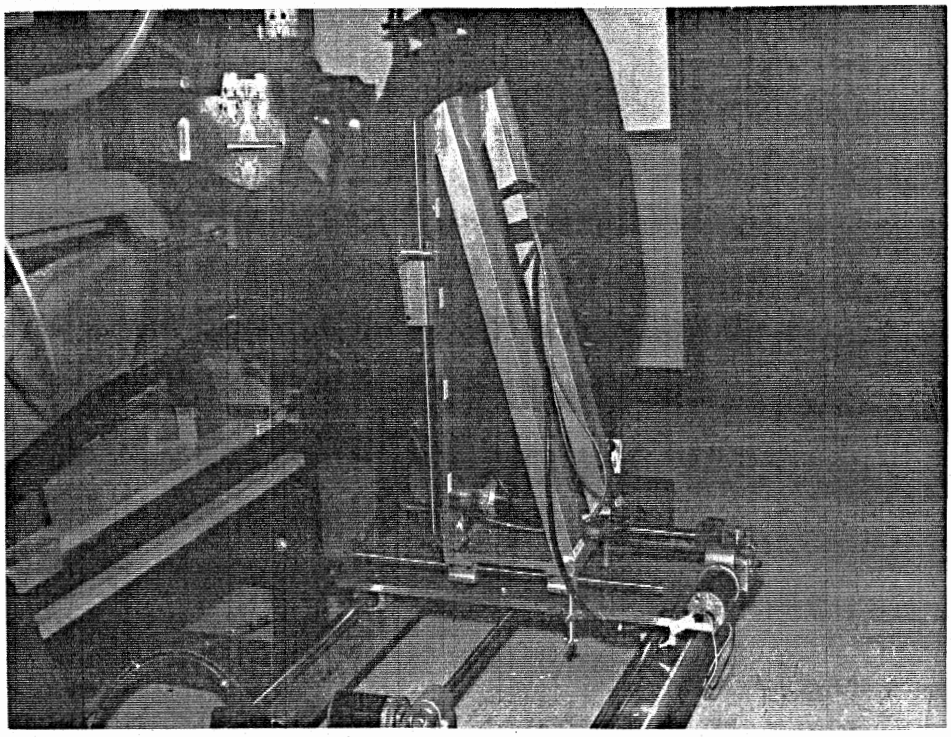


Figure 15. Shift knob/linkage support and adjustment module.

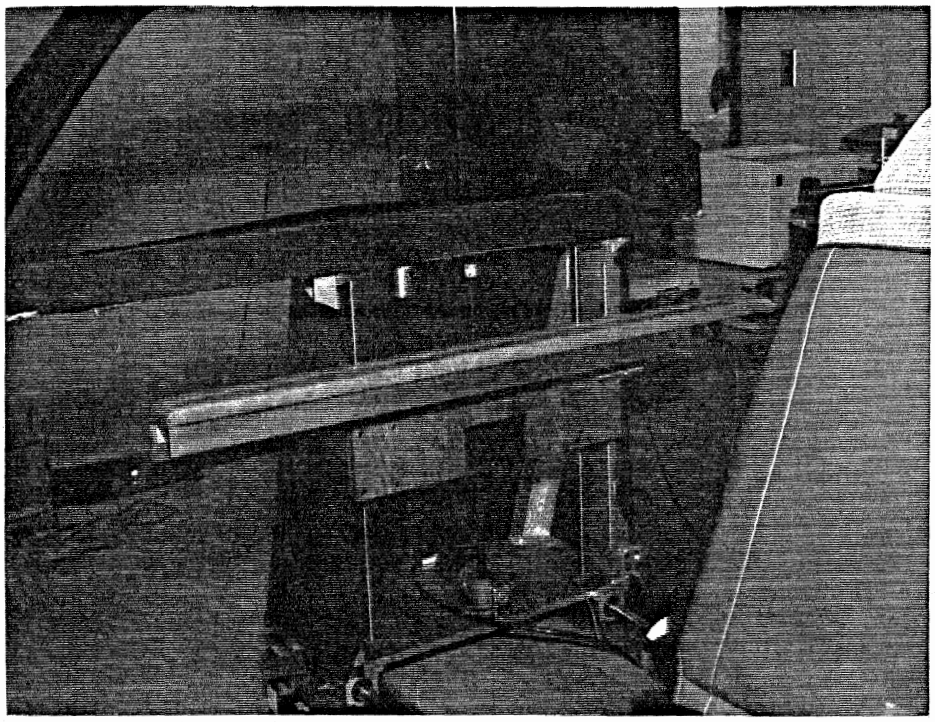


Figure 16. Driver door module and adjustable armrest.

to provide for manual adjustment of door and armrest lateral positions relative to the seat centerline. This also enables easy ingress and egress for the subject. Driver-door window frame units were fabricated from vehicle doors from G-, H-, and S-body cars and are manually attached and exchanged on the door armrest support structure.

The center or console armrest attaches to a cantilevered 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 to back by means of screw-motor actuators and can be manually adjusted in the lateral direction to accommodate the different lateral positions of the center armrest with respect to the seat centerline. As previously mentioned, the H-body plastic 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 the S-body.

12. Steering Wheel Cant Angle Adjustments

In addition to the height and tilt adjustment features of the steering assembly unit, a cant angle mechanism allows for a lateral movement of the steering wheel in an arc whose radius is approximately equal to the length of a steering column. Figure 11 shows the curved slot on the top of the steering assembly providing for lateral movement and the large threaded knob for locking the wheel in place. The total range of motion is equal to 22 degrees of offset from the seat centerline (i.e., eleven degrees in each direction). This translates to approximately 5 inches of travel to each side at the steering wheel center. As the wheel is moved along the track, a pointer and scale (not shown) indicate the amount of steering wheel offset.

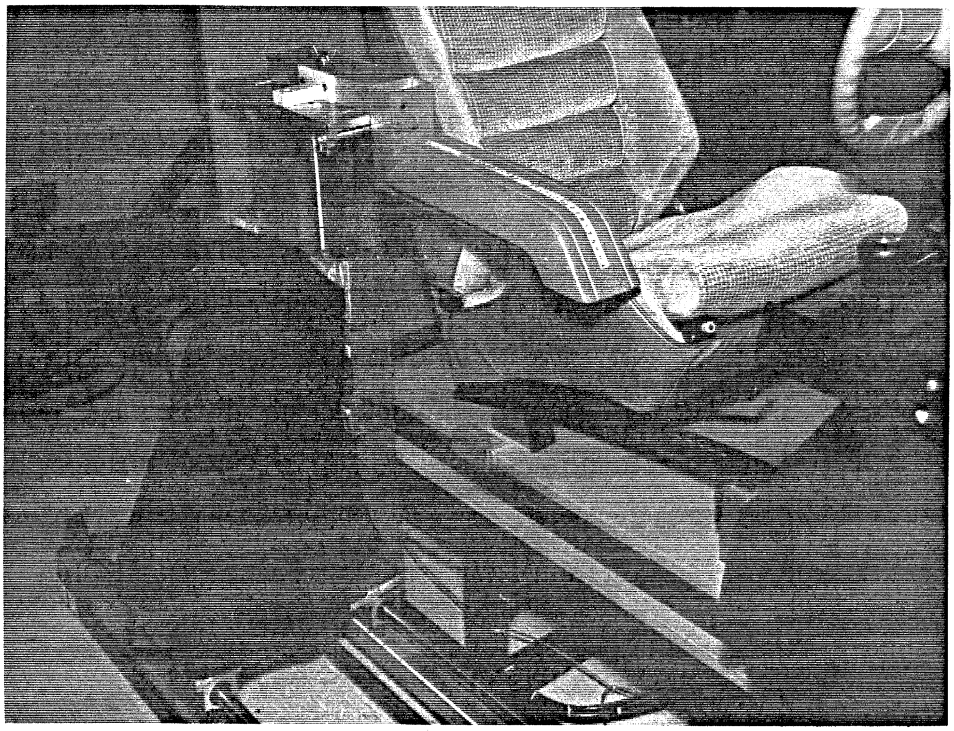


Figure 17. Center armrest support and adjustment module with H- and G-body console cover in place.

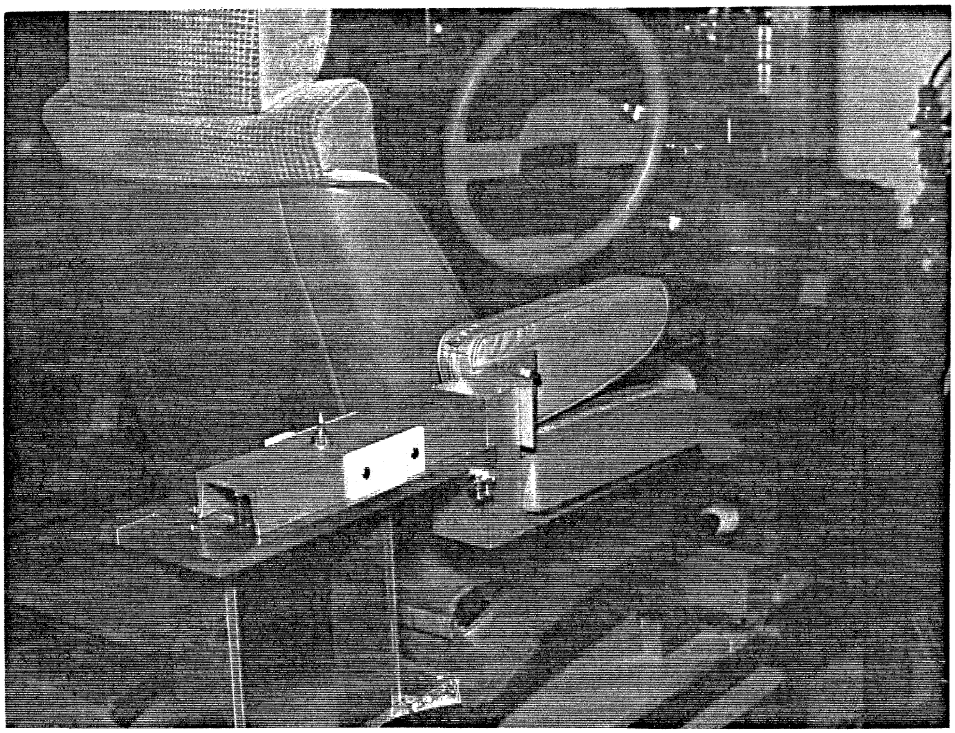


Figure 18. S-body seat armrest unit in place on center armrest support structure.

B. SELECTION AND RECRUITMENT OF SUBJECTS

As in the armrest study, ten subject groups were defined by the 10th, 25th, 50th, 75th, and 90th percentile values of stature for males and females, respectively based on the 1971-74 Health and Nutrition Examination Survey (HANES Abraham et al., 1979). In each group, ten subjects were recruited for a total sample size of 100. Table 2 shows selected percentile values of stature for U.S. population males and females, while Table 3 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 considered secondary factors and 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, and to not use extremely obese individuals. Subjects were also required to have recent experience driving a 4- or 5-speed manual transmission vehicle.

Since the subject sampling procedures were the same as those for the initial Armrest Location Study, a subject pool was readily available. Recruitment of previously-tested subjects was quite successful considering the length of time between testing for the two studies, with 59 of the one hundred total returning to be re-tested in the Control Position Study. Additional subjects were recruited by word-of-mouth and postings of notices in the local area. Newly recruited subjects were scheduled for a brief measurement session during which their stature was verified and a standard health questionnaire and subject consent form were filled out. Additional anthropometric measurements shown in Table 4 were taken if the subject met the stature requirements.

Table 2.
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 3.
Subject Group Definitions by Stature

Group #	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

Table 4.
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

C. MEASUREMENT PROCEDURES AND PROTOCOL

1. Computer Program for Data Acquisition

A new data collection computer program was developed for the Control Position Study that sequenced through the test protocol and retrieved the position information by keyboard input (e.g., seat detent) or A/D conversion. At each step in the protocol, the video screen displays an appropriate message to the investigator indicating the test to be conducted (e.g., location of shift knob) in addition to the A/D value and corresponding vehicle coordinates (determined using the calibration equations described previously) for the particular control direction being adjusted. For example, when the subject is adjusting the shift knob to his/her preferred position, the video screen will display the X-, Y-, and Z-A/D and vehicle coordinate values simultaneously. When the subject has completed the adjustments, the investigator strikes the Carriage Return key and the vehicle coordinates corresponding to the control positions are recorded and stored in a structured data base file.

2. Subject Testing

Subjects were scheduled by phone approximately one week in advance and, as with the armrest study, were informed that a questionnaire (see Appendix B) regarding the locations of the primary driver controls in their own vehicle would be mailed to them. Before each test appointment, preliminary preparations were made by the investigators including powering up the computer and seating buck electronics, entering previously collected anthropometric data into a hold file on the IBM XT, loading and running the data collection program, and making manual adjustments to the buck to establish the desired seating package. The order for testing in the three seating packages was changed sequentially for each test session to remove possible bias in the test results due to order of testing or subject fatigue.

Table 5 illustrates the general sequence of events in the test protocol which was designed to help each subject "build" his/her ideal vehicle and determine his/her acceptable limits for control positions. Prior to instructing the subject to enter the buck, the vehicle seat was positioned well rearward of the design position so that all subjects would need to adjust the seat forward to their preferred location. The seat-back angle was set in an upright position, the steering wheel and pedals were set as far forward as possible, the shift knob was moved forward, down, and to the right, and the armrests were moved down with the console moved backward as well.

Table 5.
Summary of Test Protocol

I. PREFERRED LOCATIONS

- Adjust seat position to accelerator pedal
  Adjust seat back angle
- Adjust pedals and steering wheel without clutch.
  Readjust seat, if desired
- Readjust pedals and steering wheel with clutch.
  Readjust seat, if desired
- Select preferred position for shift knob in X, Y, and Z directions without armrests
  Readjust pedals and steering wheel, if desired
- Select preferred positions for armrest heights and console fore/aft without shift knob
- Readjust shift knob and armrests together

II. MANUAL MEASUREMENTS

- Measure elbow positions
- Measure sitting height
- Take side-view photograph
- Determine limits of steering wheel cant angle

III. ACCEPTABLE LIMITS

- Pedals back limit
- Pedals front limit
- Steering wheel back limit
- Steering wheel front limit
- Shift knob X back limit
- Shift knob X front limit
- Shift knob Y right limit
- Shift knob Z upper limit
- Shift knob Z lower limit

3. Preferred Control and Armrest Locations

Upon arrival for the test session, each subject was reinformed as to the general purpose of the study (i.e., to determine their preferred and acceptable locations for primary driver controls). After providing the subject with a general description of the seating buck and the test sequence, the slide projector was turned on to display the road scene and the subject was instructed to enter the seating buck and to adjust the seat and seat-back angle relative to the accelerator pedal. At this time, the subject was reminded that, in making all adjustments during the course of testing, he/she should take what ever time was necessary, to try out a range of positions before deciding, and to verbalize any thoughts, concerns, or comments that were experienced. The latter were recorded by one of the investigators for inclusion in the final data base.

After a brief time of practice with the hand-held control knob, the subject was instructed to select the pedal control and to position the brake/clutch assembly such that, while only considering the brake, a preferred location was found. In determining this preferred brake location, the key factor was the relationship between the brake and accelerator pedals and the subject was reminded to move the right foot between the two pedals as would be done in actual driving. He/she was also allowed to make further adjustments in the seat and seat-back angle locations if so desired.

Following location of the preferred brake location, the subject was instructed to dial in and adjust the position of the steering wheel to his/her preferred location. In making this adjustment, the subject was instructed to operate the steering wheel in the normal manner and to rotate the wheel as would be done in making right- and left-hand turns at intersections. The subject was again encouraged to experiment with different seat positions and back angles. Following location of the preferred steering wheel position, the positions of the seat detent, seat-back angle, and pedal and steering wheel were retrieved and stored in the structured data file using both manual and automatic readout, respectively. This compared the set of initial preferred positions. Immediately thereafter, the subject was instructed to consider the operation of the clutch pedal by pushing it through its full stroke length (which was different for each seating package), and to reposition the brake/clutch pedal assembly, steering wheel, seat, and seat-back angle if desired. Upon completion of any adjustments based on consideration of the clutch pedal, the positions of the seat, seat-back angle, pedals, and steering wheel were recorded as the second set of preferred locations for these components.

With the preferred locations for the seat, steering wheel, and pedals established, the subject was next instructed to adjust the shift knob in all three directions to his preferred location, switching among the three shift-knob dial settings as desired. In doing this, the subject was asked to operate the shift knob through the five forward gear positions in a realistic sequence, and to consider the relationship between the steering wheel and the shift knob. Opportunity to readjust either the pedals and/or the steering wheel, but not the seat, was also available although only a few subjects chose to do so. When the subject indicated achievement of his/her optimal location, the A/D channels corresponding to shift knob X-, Y-, and Z-positions as well as the pedals and steering wheel locations were sampled, converted to vehicle coordinates, and stored as the third set of preferred position data file.

In order to independently determine preferred armrest locations without the influence of a shift knob, the shift was moved to its most forward position by a computer-controlled command within the test program. The door structure was then moved into the correct lateral position for the represented body style and the subject was instructed to dial in and adjust the door armrest height and the console armrest height and fore/aft positions to locations that felt most comfortable. Investigators encouraged the subject to search for an optimal position while considering different steering situations to assure that his/her elbows were not significantly interfering with the armrests or causing any awkwardness. Once an optimal armrest combination was found, the armrest locations were sampled and stored in the data file. At this point, instructions were given to position the elbows on the armrests in the most comfortable steering position. The fore/aft elbow locations were manually measured from the tape measure attached to the top of the armrests and were typed on the keyboard into the computer.

A final preferred configuration determined by the total arrangement of all the controls and armrests was then determined. This was achieved by first allowing the computer to return the shift knob from its most forward position back to the subject's preferred location while the armrests remained in place. The subject was instructed to consider the interaction of the shift knob and console armrest and to make any desired adjustments in the independently obtained armrest and shift knob positions. When the subject had completed this task, the locations of all vehicle components were recorded as the final and fourth set of preferred position data. As before, elbow recordings from the tape measure were entered in the computer.

At this time, additional measurements were taken prior to the "acceptable range" portion of the testing. With the subject looking forward in a natural and relaxed driving

posture, a right-side photograph was taken and the subject's sitting height was measured with an anthropometer. These side-view photographs are presented in Appendix C. Next, the steering wheel cant angle was moved to the furthest left position (about 2.5 inches from the centerline of the seat) and slowly adjusted inward in small increments until an acceptable position was found. This was repeated on the right side and the two limits of cant angle indicated by a scale and pointer on the steering wheel support structure were input to the data file by computer keyboard entry.

4. Acceptable Control Locations

Having established the subject's preferred locations for the primary controls and armrests for the different conditions described above, the remaining tests in each seating package were aimed at determining the range of acceptable control positions about these ideal or preferred locations. With other controls in the subject's preferred location, one control was moved away from the preferred location by the investigator using the numeric keypad (i.e., the arrow and PGUP, PGDN keys) on the keyboard until the subject indicated that the position was unacceptable. At this point, the control was moved back toward the preferred location, pausing at 5 mm increments for the subject to evaluate the position, until the subject indicated that the location was once again acceptable. The control was then returned to the preferred location, the subject was notified when this was achieved, and the process was repeated in the opposite direction.

Part III of Table 5 indicates the order in which the acceptable limits of the different controls were determined. When testing for maximum and minimum acceptable limits of the shift knob, the console armrest was moved into its furthest rearward position so as not to interfere with the limit testing. Also, because of interference with the buck platform, the acceptable limits of the shift knob toward the left (i.e., toward the subject) were not evaluated.

After completion of the acceptable limit testing for the steering wheel, brake/clutch pedal assembly, and shift knob (acceptable limits for the armrests were not determined in this study), the subject was instructed to exit the seating buck and to relax for five minutes while manual adjustments were made to configure the buck for the next seating package in the sequence. The test protocol described above was then repeated until the subject had established his/her preferred and acceptable positions in the three seating packages.

D. DATA PROCESSING AND ANALYSIS

As in the data analysis from the study on driver armrest locations, the data collected on the IBM XT were transferred to the University's main frame computer where the MIDAS statistical package was available for editing, sorting, and displaying the results. A first step in the analysis of the data was to generate histograms and scatter plots of each variable in order to determine if any "outliers" or "bad" data points were present. Identified outliers or questionable data points were traced back to the specific subject and body type, and were either determined to be errors or valid data, after which appropriate editing was accomplished.

When the data set was considered "clean", further analysis and comparison of the results was undertaken using MIDAS and other plotting and analysis routines. Results were displayed in graphical and tabular form by individual subject, by subject group (i.e., means and standard deviations) to examine for relationships within groups, among groups, and among position measurements and other subject and vehicle parameters. Where relationships could be visually observed, linear regressions were computed for the variables involved and scatter plots were made.

In searching for the optimal location within the vehicle for each primary control, it would be ideal to find a location, or even a range of locations, which was acceptable for all subjects and which was near the overall mean of preferred locations. As with the data for the armrest heights and elbow positions from the previous study, there was no position for any control/location variable that fell within the acceptable range of all subjects. The goal was then to maximize the number of persons accommodated.

The procedure used for determining these optimal control locations is similar to that developed for the armrest study in which optimal locations were determined from the acceptable range data. Figure 19 illustrates the process by which a computer program counts the number of subjects whose acceptable range for a given control position variable encompassed coordinate values taken at ten millimeter increments over the range of acceptable positions for all subjects. At each coordinate, the count for each subject is weighted according to the subject group percentile representation as indicated in Table 6, and the total weighted count at each coordinate is expressed as a percentage of all 100 subjects. This percentage represents the "PERCENT OF THE POPULATION ACCOMMODATED" or "PERCENT SATISFIED" at each coordinate value. The curve connecting the percent acceptance at different coordinates forms the "acceptable-location

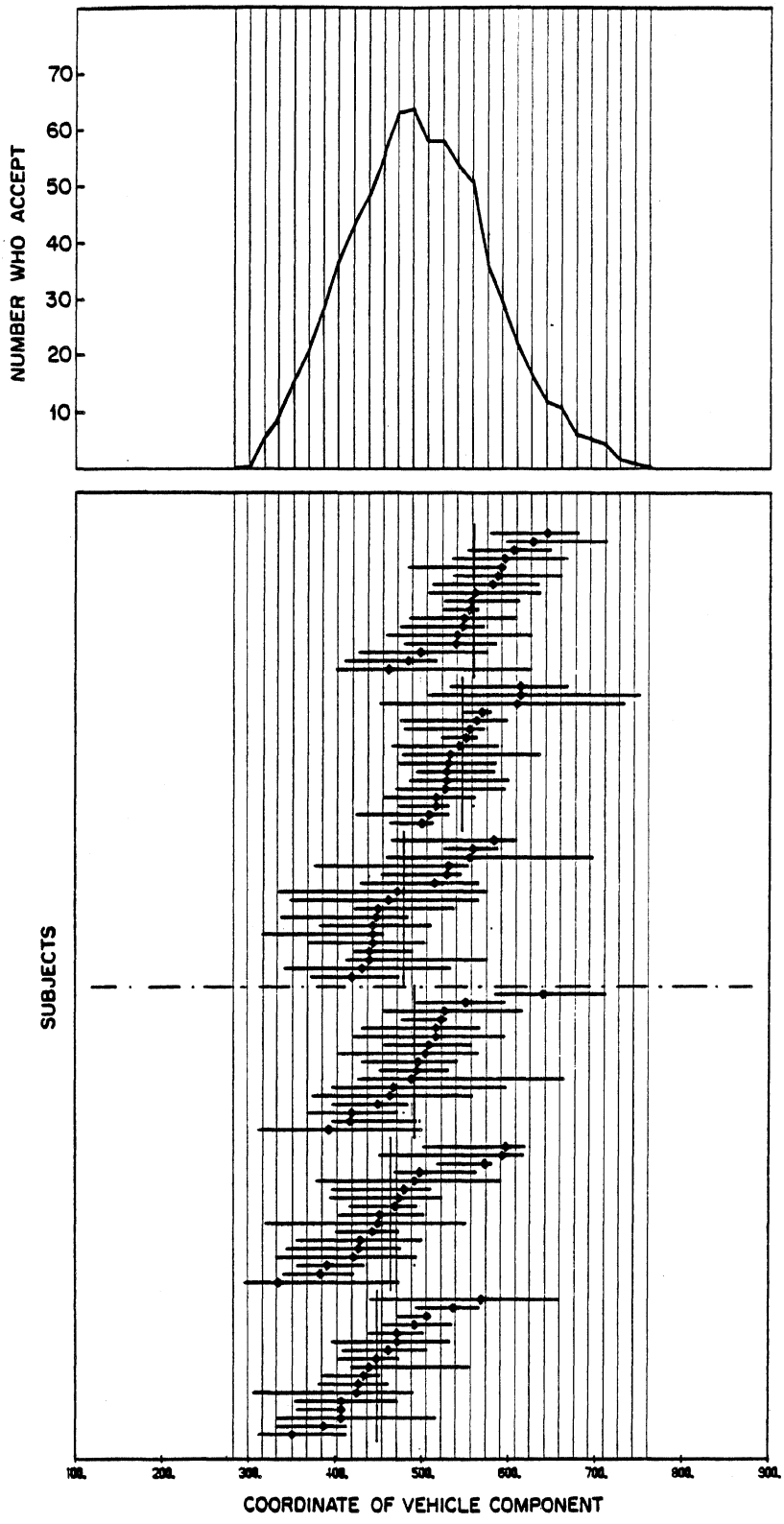


Figure 19. Procedure for counting the number of subjects who would accept a vehicle component of discrete coordinates.

function" for a particular control position variable. Unlike the armrest study, the acceptable-location function was not converted to a "loss function" which gave the percent of population not satisfied instead of the percent satisfied.

In a similar way, the coordinate value at which a maximum percent of the population would prefer each primary control was determined by counting the number of subjects whose preferred location fell inside a one-inch-wide window as it moved in increments of 5 mm along the coordinate scale. As for the acceptable-location function, the preferred-location function was determined by weighting the counts from each subject by the factors listed in Table 6.

Because the peaks of the acceptable-location functions were often irregular due to the relatively small sample, the optimal control locations were obtained by determining the location of the central maximum of each acceptable-function curve, rather than using the actual maximum. This was done graphically by finding the midpoint of the two intersections of the acceptable-function with a horizontal line drawn where the function was relatively symmetric. The locations of these midpoints were taken as the optimal control locations for the respective control variable.

In a similar manner, the "percent acceptance zones" were determined by finding the coordinate values of the intersection points created by a horizontal line drawn at selected values of acceptance. For example, and as illustrated in Figure 20, the 60, 50, and 30 percent acceptance zones for the steering wheel in the G-Body vehicle are defined by the vehicle coordinates values at the respective intersection points.

Table 6.
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	10	12.5	1.25
5	10	7.5	.75
6	10	7.5	.75
7	10	12.5	1.25
8	10	10.0	1.00
9	10	12.5	1.25
10	10	7.5	.75

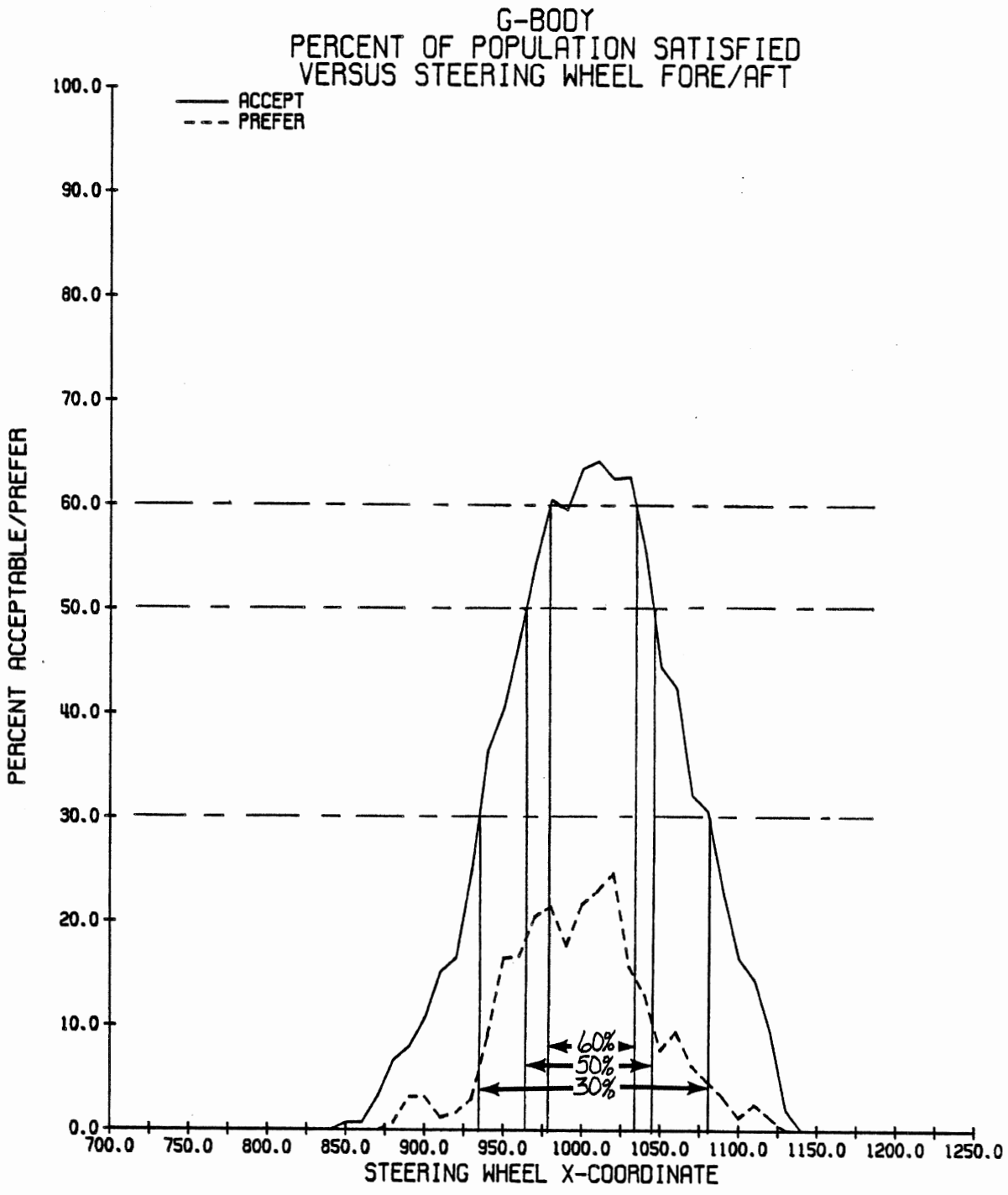


Figure 20. Percent of population who would accept (solid line) and percent of population who would prefer (dashed line) the steering wheel at specific vehicle coordinates of G-body vehicle.

III. RESULTS

A. SUBJECT GROUP DESCRIPTIONS AND IN-VEHICLE SITTING HEIGHT

Mean anthropometric data for the ten subject groups are presented in Table 7. Each subject group defines a specific stature range, with female groups 4 and 5 corresponding closely in height to male groups 6 and 7. Within each stature group, an attempt was made to evenly distribute age and weight. An overall mean age of 38.5 years (ranging from ages 20 to 66) has been represented. Of the one hundred subjects tested, 59 were recruited from the original subject pool used for the Armrest Position Study. As illustrated in Table 8, the group mean values of stature, weight, sitting height, and buttock knee measurements are in excellent agreement between the two studies.

In each vehicle configuration, the driver's sitting height was measured with a standard anthropometer. The results are shown in Tables 9 and 10 which give the group mean vehicle Z-coordinates and distances to AHP and design H-point, respectively, for the top of the head. The expected trend of increasing sitting height with increasing stature is obvious as are the differences for the three vehicle seat heights. Similar results were observed and plotted in Figure 25 of the armrest study (Schneider, 1987).

Table 7.
Mean Values of Physical and Anthropometric Measurements by Subject Group

Measurement	FEMALE GROUPS 1	2	3	4	5
Stature (cm)	152.7	157.2	161.5	166.2	170.4
Stature (w/shoes)	155.5	159.5	163.6	167.7	173.0
Weight (lbs)	126.0	126.0	140.0	155.6	142.6
Sitting height	81.9	84.2	84.9	85.9	88.4
Eye height	70.7	73.5	74.3	76.3	76.8
Shoulder height	54.7	57.1	56.6	59.3	59.3
Knee height	46.9	48.2	49.9	52.1	52.7
Hip breadth	35.6	36.5	37.8	37.4	37.7
Buttock-knee length	53.7	55.4	58.2	57.0	59.5
Shoulder breadth	38.9	39.4	40.7	45.7	40.8
Shoulder-elbow breadth	32.5	33.8	34.5	35.6	36.5
Elbow-hand length	41.3	42.6	44.2	44.0	46.0
Maximum reach	75.2	76.4	78.6	78.5	82.0
Grasping reach	66.8	66.6	70.0	70.5	73.6
Age (yrs.)	39.9	40.9	39.8	36.4	32.9

Measurement	MALE GROUPS 6	7	8	9	10
Stature (cm)	165.8	170.3	174.8	178.6	184.6
Stature (w/shoes)	168.4	172.6	177.1	180.1	186.3
Weight (lbs)	173.3	162.3	168.5	179.1	187.9
Sitting height	87.2	88.2	90.4	92.7	95.7
Eye height	74.6	76.7	78.5	81.1	83.5
Shoulder height	59.3	59.3	61.0	63.8	64.8
Knee height	51.4	52.8	54.0	55.7	56.9
Hip breadth	37.4	35.8	36.5	37.8	38.1
Buttock-knee length	57.4	58.9	60.4	61.4	63.5
Shoulder breadth	44.5	45.4	43.7	47.6	45.9
Shoulder-elbow length	35.1	37.2	37.8	38.8	40.8
Elbow-hand length	50.0	46.5	48.0	48.7	50.5
Maximum reach	82.5	83.7	84.7	86.9	89.7
Grasping reach	74.3	74.0	76.7	76.5	80.8
Age (yrs.)	40.0	40.4	44.3	36.1	34.6

Table 8.
Comparison of Mean Anthropometric Measurements for two Chrysler Studies

Group #	Stature			Weight			Sitting Height			Buttock-knee Length		
	I	II	Difference	I	II	Difference	I	II	Difference	I	II	Difference
1	154	153	1	143	126	17	83	82	1	53	54	-1
2	157	157	0	129	126	3	84	84	0	55	55	0
3	162	161	1	145	140	5	86	85	1	57	58	-1
4	166	166	0	152	156	-4	86	86	0	60	57	3
5	170	170	0	151	143	8	89	88	1	60	60	0
ALL FEMALES												
	162	162	0	144	138	6	86	85	1	57	57	0
6	166	166	0	172	173	-1	89	87	2	57	57	0
7	171	170	1	170	162	8	89	88	1	59	59	0
8	175	175	0	166	169	-3	91	90	1	60	60	0
9	179	179	0	189	179	10	93	93	0	62	61	1
10	186	185	1	193	188	5	97	96	1	64	64	0
ALL MALES												
	175	175	0	177	174	3	92	91	1	60	60	0
ALL SUBJECTS												
	168	168	0	161	156	5	89	88	1	59	59	0

Table 9.
Group Mean Sitting Heights
In Vehicle Coordinates

Group	N	Group Mean Stature	Top-of-head Z-coordinates (mm)		
			G mean (s.d.)	H mean (s.d.)	S mean (s.d.)
1	10	153	981 (26)	1014 (24)	1228 (25)
2	10	157	998 (22)	1028 (19)	1241 (20)
3	10	161	997 (30)	1025 (29)	1240 (28)
4	10	166	1009 (31)	1039 (33)	1268 (61)
5	10	170	1012 (22)	1044 (23)	1292 (64)
6	10	166	1013 (20)	1052 (16)	1283 (52)
7	10	170	1030 (20)	1063 (15)	1293 (53)
8	10	175	1031 (24)	1074 (21)	1286 (20)
9	10	179	1038 (36)	1077 (38)	1299 (39)
10	10	185	1061 (28)	1100 (31)	1307 (29)

Table 10.
Group Mean Sitting Heights
re AHP and Design H-Points

Group	Top-of-head Z-distance (mm)					
	re AHP			re DESIGN H-POINT		
	G	H	S	G	H	S
1	926	959	1029	690	690	817
2	943	973	1042	707	704	830
3	942	970	1041	706	701	829
4	954	984	1069	718	715	857
5	957	989	1093	721	720	881
6	958	997	1084	722	728	872
7	975	1008	1094	739	739	882
8	976	1019	1087	740	750	875
9	983	1022	1100	747	753	888
10	1006	1045	1108	770	776	896

B. PREFERRED SEAT POSITIONS AND SEAT BACK ANGLES

Table 11 summarizes preferred seat position results by subject group and presents the data by seat detent and by the H-point coordinate obtained by translating the design H-point the appropriate distance forward or rearward of the design detent. Group mean detent values as well as detent ranges are tabulated for the ten subject groups in the three vehicle seating packages. The data support the well established relationship between stature and seat position wherein taller people tend to position the seat further rearward. Variability within each stature group ranges from four to nine detents and the distributions overlap considerably across the subject groups.

Figures D-1 through D-3 in Appendix D show the individual preferred seat position results where the data are clustered by subject group and ordered within each group. The vertical lines indicate the mean detent positions for each group. The arrows located along the bottom scale indicate the corresponding first, last, and design detent positions in the actual vehicles. In contrast to the results for the Armrest Position Study, a number of subjects, especially in the G- and H-body vehicles, chose to sit further forward than would be allowed by the seat track in a production vehicle. This is more easily seen in Figures D-4 through D-6 which are scatter plots of preferred seat detent versus stature. As subsequent data will show, this is due to the fact that subjects were allowed to position the brake and clutch pedals and the general tendency was to position them further forward than they are in current production vehicles. As indicated in Table 12, the overall mean seat positions in the three vehicles were further forward in the Control Position Study due to the differences in mean pedal positions.

Table 12.
Comparison of Overall Mean Detent and
Translated H-point Positions for Two Studies

	G		H		S	
	detent	H-pt	detent	H-pt	detent	H-pt
Armrest Position Study	10.4	1334	10.7	1335	11.2	1297
Control Position Study	9.3	1310	9.2	1304	10.2	1276

Table 11.
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	4.2	1 - 6	1203.2	(36.8)	1241 - 1136	= 105
2	10	5.6	3 - 9	1232.6	(39.8)	1304 - 1178	= 126
3	10	8.4	5 - 14	1291.4	(52.6)	1409 - 1220	= 189
4	10	8.5	5 - 12	1293.5	(45.6)	1367 - 1220	= 147
5	10	10.7	6 - 14	1339.7	(43.2)	1409 - 1241	= 168
6	10	9.4	5 - 12	1312.4	(43.4)	1367 - 1220	= 147
7	10	9.6	6 - 12	1316.5	(39.8)	1367 - 1283	= 126
8	10	10.4	8 - 12	1333.4	(33.1)	1367 - 1283	= 84
9	10	12.7	10 - 16	1381.7	(45.4)	1451 - 1325	= 126
10	10	13.2	11 - 16	1394.3	(35.8)	1451 - 1346	= 105
H-BODY:							
1	10	4.4	2 - 6	1203.4	(31.6)	1237 - 1153	= 84
2	10	5.7	4 - 8	1230.7	(28.1)	1279 - 1195	= 84
3	10	8.6	5 - 14	1291.6	(57.0)	1405 - 1216	= 189
4	10	8.5	5 - 11	1289.5	(42.3)	1342 - 1216	= 126
5	10	10.8	6 - 15	1337.8	(47.3)	1426 - 1237	= 189
6	10	8.8	5 - 11	1295.8	(39.4)	1342 - 1216	= 126
7	10	9.5	7 - 11	1310.5	(28.4)	1342 - 1258	= 84
8	10	10.4	8 - 12	1329.4	(30.0)	1363 - 1279	= 84
9	10	12.3	10 - 15	1369.3	(38.4)	1426 - 1321	= 105
10	10	13.1	9 - 16	1386.1	(41.4)	1447 - 1300	= 147
S-BODY:							
1	10	5.7	2 - 8	1180.7	(46.5)	1229 - 1103	= 126
2	10	7.7	5 - 12	1222.7	(47.5)	1313 - 1166	= 147
3	10	9.7	7 - 14	1264.7	(46.5)	1355 - 1208	= 147
4	10	9.4	6 - 12	1258.4	(38.6)	1313 - 1187	= 126
5	10	11.8	9 - 14	1308.8	(39.4)	1355 - 1250	= 105
6	10	9.8	8 - 12	1266.8	(27.6)	1313 - 1229	= 84
7	10	10.2	8 - 13	1275.2	(36.8)	1334 - 1229	= 105
8	10	11.1	9 - 14	1294.1	(33.5)	1355 - 1250	= 105
9	10	13.2	11 - 16	1338.2	(38.1)	1397 - 1292	= 105
10	10	13.8	12 - 17	1350.8	(34.0)	1418 - 1313	= 105

Figures D-7 to D-9 display scatter plots for the translated X-coordinate of the design H-point versus subject stature. Least-square linear regressions for the three vehicle seats are also shown in these figures. Figure D-10 presents an overlay of these scatter plots for the three vehicles with position given as the translated H-point distance relative to accelerator heel point (AHP). As expected and observed in the Armrest Position Study, the horizontal distance between preferred seat position and AHP is inversely related to the vertical distance from AHP to H-point.

Group statistics for the seat-back angle measurements, given in terms of H-point calibration angles, are tabulated in Table 13. As before, there is no evidence of a relationship between the mean preferred angle and group mean stature for any seating package. The differences in the overall mean back angles for the three vehicles are small with the largest recline angle for the G-body and the smallest, unexpectedly, for the H-body. Table 14 compares the overall mean back angles for the two studies which are seen to be slightly smaller in the control study. This is also somewhat unexpected, although perhaps not significant, since people tended to sit further forward in the Control Position Study and, with the curved seat track, this produces a more upright seat-back.

Table 13.
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	24.9	2.0	23.5	2.4	25.0	2.1
2	10	25.4	2.5	23.6	2.7	24.5	1.1
3	10	24.0	0.0	22.0	0.0	24.0	0.0
4	10	24.9	2.2	23.0	2.2	24.5	1.1
5	10	25.2	2.3	23.1	1.8	24.9	1.9
ALL FEMALES	50	24.9	2.0	23.0	2.0	24.6	1.4
6	10	25.0	1.9	23.9	2.6	24.1	0.3
7	10	24.2	0.6	22.0	0.0	24.1	0.3
8	10	25.2	2.5	22.7	1.9	25.2	2.5
9	10	27.6	3.7	24.2	3.6	25.8	3.0
10	10	25.4	2.3	23.3	2.1	25.4	2.3
ALL MALES	50	25.5	2.6	23.2	2.4	25.0	2.1
ALL SUBJECTS	100	25.2	2.3	23.1	2.2	24.8	1.8

Table 14.
Comparison of Overall Mean Seat Back
Angles for Two Studies

	G	H	S
Armrest Position Study	26.2	24.4	25.0
Control Position Study	25.2	23.1	24.8

C. PREFERRED AND ACCEPTABLE PRIMARY CONTROL POSITIONS

The figures in Appendix E present the data by individual subject for preferred control locations as well as acceptable boundaries for each control. This information is displayed for the pedals, steering wheel, and shift knob for all three body styles. In all cases, the preferred position results are the final preferred locations which were used during acceptable limit testing. Thus, for the pedals, these data include consideration of both the clutch and brake pedals and, for the shift knob, the data include armrest/shift knob interaction.

In each plot, the data are clustered by subject group with small females (Group 1) at the bottom and tall males (Group 10) at the top. Within each group, results are ordered according to preferred control location indicated by diamond symbols. In the first group of figures of Appendix E, acceptable range data are indicated by a horizontal line through the diamond symbol. Since only a maximum acceptable limit for the shift knob Y-coordinate was recorded, the corresponding acceptable range lines only extend to the right of the preferred values. The mean preferred position for each group is shown by a vertical line within the group cluster. The remaining figures present the individual preferred control positions without acceptable range data and include results for preferred armrest heights, for which acceptable range data were not collected.

The tables in Appendix F summarize the group mean preferred positions and acceptable limits for the pedals, steering wheel, and shift knob and include the group mean acceptable ranges for control locations in the right most column. These group data are graphically summarized in the figures that follow. In the first fifteen figures, the group mean preferred locations, indicated by an asterisk, are plotted along with group mean acceptable limits indicated by a horizontal line from the group lower limit to upper limit mean values. The plots of the last fifteen figures show the means of preferred locations plus and minus one standard deviation as indicated by a horizontal line through the asterisk. From these results, the following observations can be made:

1. There are no apparent relationships with driver stature for preferred pedal, shift Y, or shift Z positions.

2. There are relationships with driver stature for preferred steering wheel and shift knob front/back positions. Taller subjects tend to place both of these controls further rearward than shorter subjects.

3. The tolerance to acceptable positions of the controls within each subject group and overall is greatest for the shift knob vertical position and least for the pedals front/back position.

In addition to these observations from the data, the following comments can be made based upon investigator observation and subject comments during testing:

- In positioning the pedals, limitations for acceptable ranges often required that the subject compromise a desire for reduced brake-to-accelerator distance with a need to depress the clutch through its full stroke.
- Determination of acceptable limits for the steering wheel involved maximum reach considerations and interference with the knees in the forward direction and elbow clearance in the rearward direction.
- The rearward limit of the shift knob largely depended on interaction of the arm with the side of the seat. The forward limit of the shift knob was often determined by the subject's maximum comfortable reach.
- Maximum acceptable values for the Y-position of the shift knob depend largely on maximum reach and ease of operation while shifting.
- Maximum acceptable positions for shift height were often influenced by the manner in which a subject handled the knob; i.e. shifting with hand on top of the knob or grasping hand around the side of the knob.
- A common factor involved in shift knob location for all three coordinates was the ease of movement of the subject's right hand from the steering wheel to the shift and vice versa.

Figure 21 shows the overall mean ranges of acceptable positions for each control in the three vehicles. Acceptable ranges were about the same for the three seating packages. The widest margin of acceptability was for shift knob height and the smallest for the pedals. Table 15 lists the overall ranges for preferred locations and the lengths of these ranges for the primary controls. The X- and Z-directions of the shift knob had the greatest variability for preferred locations.

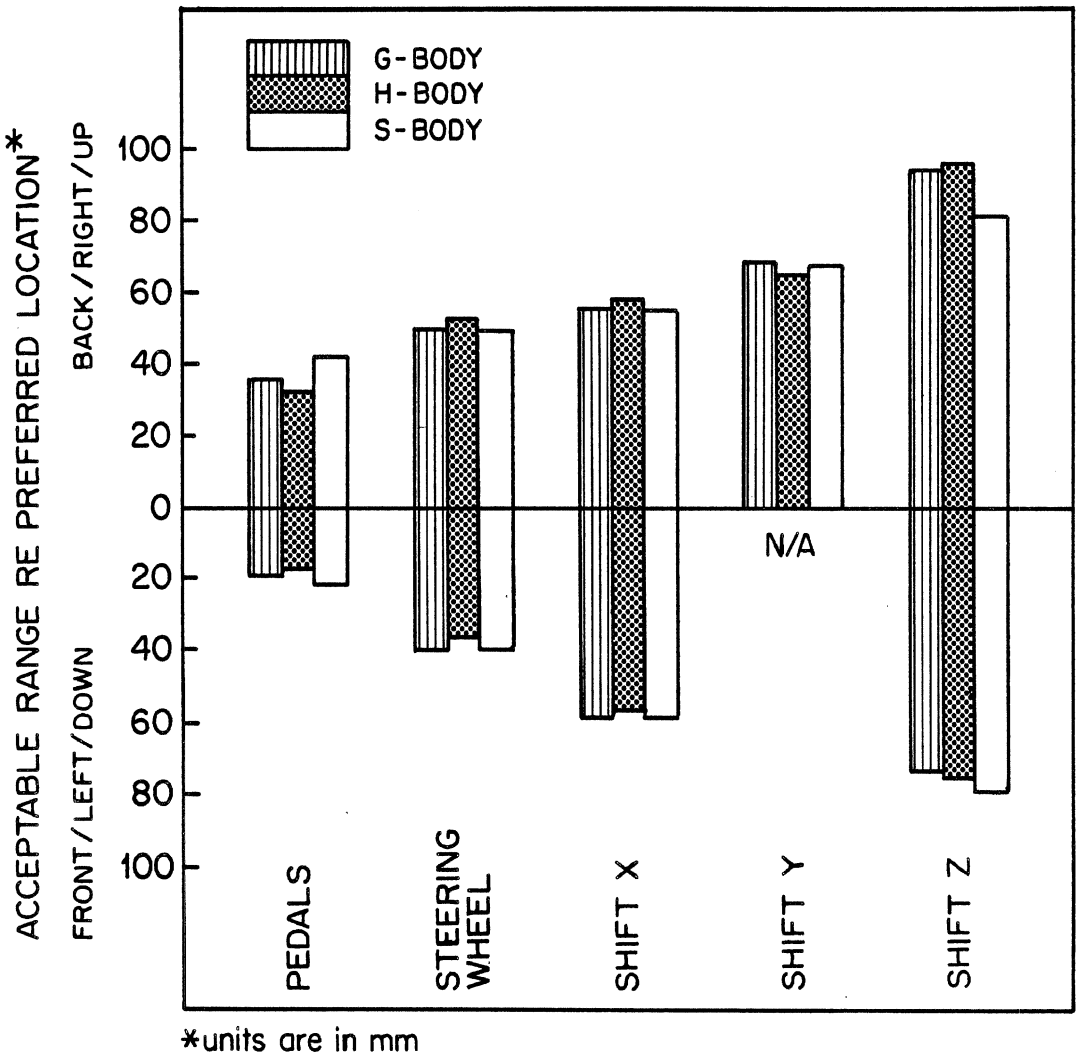


Figure 21. Comparison of overall mean acceptable ranges for different control position variables.

Table 15.
Ranges For Preferred Locations
(All Subjects)

	G			H			S		
	veh. coord.	mm	in	veh. coord.	mm	in	veh. coord.	mm	in
Pedals	426-554	128	5.0	443-598	155	6.1	447-587	140	5.5
St. Wheel	889-1116	227	8.9	868-1058	190	7.5	878-1065	187	7.4
Shift X	846-1181	335	13.2	889-1177	288	11.3	879-1220	341	13.4
Shift Y	306-445	139	5.5	292-444	152	6.0	303-438	135	5.3
Shift Z	304-576	272	10.7	356-663	307	12.1	563-844	281	11.1
Left Elbow	1162-1533	371	14.6	1190-1535	345	13.6	1148-1495	347	13.7
Right Elbow	1126-1451	325	12.8	1148-1438	290	11.4	1122-1434	312	12.3

D. OPTIMAL CONTROL POSITIONS AND PERCENTAGE ACCEPTANCE RANGES

Optimal fore/aft control locations were determined for the pedals and steering wheel, and for the shift knob in the fore/aft and up/down directions using the acceptable-location functions previously described (see Section II., D.). The figures in Appendix G show plots of these acceptable-location functions (solid lines) and preferred-location functions (dashed lines) for the different control variables and for the three vehicles. In each case, the horizontal scale gives the vehicle coordinates and the vertical scale is the percent of the U.S. population (i.e., weighted subject data) that would accept or prefer the corresponding location of the primary control.

Table 16 summarizes the optimal control coordinates obtained from the acceptable-location functions and compares these locations to the current locations in production vehicles. For the pedals, steering wheel, and shift knob front/back directions, it will be noted that approximately 65 to 70 percent of the population accepted the controls at these optimal locations, while for shift knob height, approximately 90 percent of the subjects accept the optimal location. Because acceptable-limit data were not obtained for lateral position of the shift knob to the left, the coordinate at which the preferred-location functions (dashed lines) were maximums were taken as the optimal shift Y locations.

1. Pedals and Steering Wheel

For all the vehicles, the optimal location for the brake/clutch pedal assembly is between 0.5 and 1.1 inches further forward (i.e. closer to the accelerator pedal - see Table 17) than in the production vehicles. This is important to remember when using the optimal locations of the other controls since, as has already been indicated, the preferred seat position moves forward with the pedals. In both the G- and H-body vehicles, the optimal steering wheel location is about 2.5 inches forward of the existing position. Part of this is due to the more forward position of the pedals and part of it reflects the fact that, overall, the driver population prefers a shorter steering wheel-to-pedal distance than currently provided in these vehicles. For the S-body, it is interesting to note that the optimal steering wheel location is nearly identical to the current design location even though the subjects preferred the pedals moved forward the most in this vehicle. This indicates that, for the minivan, the steering wheel-to-pedal distance is too small for the driving population in the current vehicle.

Table 16.
Optimal Control Locations Based on Estimated Peak of Acceptable-Range Acceptance Functions (mm)

Control Variable	Optimal Coordinate	Percent Satisfied	Current Design Coordinate	Optimal re Design mm	in.	
G-BODY:						
Pedals (X)	506	68	527	21	0.8	forward
Steering Wheel (X)	1003	64	1067	64	2.5	forward
Shift Knob (X)	1032	65	1061	29	1.1	forward
Shift Knob (Y)*	370	--	364	6	0.2	right
Shift Knob (Z)	490	90	525	35	1.4	below
H-BODY:						
Pedals (X)	514	65	527	13	0.5	forward
Steering Wheel (X)	987	66	1052	65	2.6	forward
Shift Knob (X)	1007	69	1074	67	2.6	forward
Shift Knob (Y)*	370	--	350	20	0.8	right
Shift Knob (Z)	511	89	527	16	0.6	below
S-BODY:						
Pedals (X)	518	72	545	27	1.1	forward
Steering Wheel (X)	976	68	977	1	0	forward
Shift Knob (X)	1016	60	1067	51	2.0	forward
Shift Knob (Y)*	381	--	390	9	0.4	left
Shift Knob (Z)	719	91	560	159	6.3	above

* Y-direction is w.r.t. seat C/L and based on the optimal preferred-location function rather than the acceptance function.

Table 17.
Optimal Pedal Locations
re Design Accelerator
Position (mm)

	G	H	S
Optimal Pedal Coordinate	506	514	518
Design Accelerator Coordinate	461	466	489
Optimal Pedal re Accelerator	***45***	***48***	***29***
Design Pedal Coordinate	527	527	545
Design Pedal re Accelerator	***66***	***61***	***56***

Tables 18 and 19 give the optimal pedal and steering wheel locations determined from the acceptable-location functions and compare these locations to the overall mean coordinates for the preferred locations. As indicated, the differences between the two are small for all vehicles and therefore the mean preferred location is also a good estimate of the optimal location. Included in these tables are the vehicle coordinate values that define the limits of different population percentage-acceptance ranges defined by the weighted subject data.

2. Shift Knob

Following a similar trend, optimal shift X-location values are also further forward than current design parameters by 1.1 to 2.6 inches for the different seating packages. It is also interesting to note that the optimal shift knob locations are between 20 mm (H-body) and 40 mm (S-body) rearward of the center of the steering wheel. In the S-body vehicle, this tendency to place the shift knob close to, but slightly rearward of the center of the steering wheel resulted in an optimal shift knob position that is about two inches forward of the design location. As previously noted, the optimal steering wheel location was very close to the design location in the S-body.

As previously noted, since acceptable limit testing was not completed for the lateral shift knob location, the optimal value was obtained by maximizing the percentages of drivers who would prefer, rather than accept, a given coordinate. The resulting optimal values are quite close to the design positions for all three vehicles. In the G-body vehicle, the optimal shift knob height was found to be about 1-1/2 inches below the current design location, while in the H-body the optimal height was about 1/2 inch lower than design. Given the high percentages of acceptance and the large acceptance ranges for shift knob height, these differences from current design locations are probably not too important. For the S-body, however, the optimal shift knob position was found to be almost 6-1/2 inches above the current design position and this difference, which is not unexpected, is considered to be quite significant.

Tables 20 and 21 compare the optimal shift knob fore/aft and up/down coordinates with the overall mean preferred locations and also present the coordinates for the limits of the different percentage-acceptance ranges. Again, the means of the preferred locations agree very closely with the optimal locations. The percentage-acceptance ranges are not given for the shift knob lateral position due to the lack of data to the left.

Table 18.
Results for Pedals Positioning
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	496	504	510
Maximum Acceptable	506	514	518
% Accept	68	65	72
Range for 70% Accept	-	-	507-524
Range for 60% Accept	491-522	503-529	498-545
Range for 50% Accept	482-531	489-537	490-551
Range for 30% Accept	464-545	475-553	477-568

Table 19.
Results for Steering Wheel Positioning
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	999	976	971
Maximum Acceptable	1003	987	976
% Accept	64	66	68
Range for 60% Accept	975-1033	964-1015	948-1002
Range for 50% Accept	963-1047	942-1034	936-1018
Range for 30% Accept	934-1082	910-1058	907-1044

Table 20.
Results for Shift Knob Positioning
X-Direction
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	1028	1014	1019
Maximum Acceptable	1032	1007	1016
% Accept	65	69	60
Range for 60% Accept	1000-1062	975-1047	-
Range for 50% Accept	984-1075	959-1064	957-1077
Range for 30% Accept	948-1114	920-1095	929-1107

Table 21.
Results for Shift Knob Positioning
Z-Direction
(Vehicle Coordinates)

	G	H	S
Mean of Preferred	480	505	714
Maximum Acceptable	490	511	719
% Accept	90	89	91
Range for 80% Accept	449-518	472-552	678-741
Range for 70% Accept	436-537	451-565	666-768
Range for 50% Accept	414-565	434-599	639-803
Range for 30% Accept	388-612	402-634	611-826

E. OPTIMAL LOCATIONS RELATIVE TO VEHICLE DESIGN FEATURES

In attempting to establish design criteria for control locations, it is useful to examine the differences and similarities in the optimal locations for the different seating packages. In order to do this, it is necessary to convert the locations in vehicle coordinates to a reference system that is common among vehicles. The accelerator heel point or AHP is probably the most useful and meaningful common reference point for doing this. Table 22 summarizes the optimal control locations with respect to AHP for the G-, H-, and S-body vehicles and Figures 22 through 28 compare these relative distances for the three vehicles.

In Figure 22, the distances of the optimal brake/clutch pedal assembly (as measured by the center of the brake pad) relative to AHP are shown. As expected, due to decreasing foot angle (relative to the horizontal) with increasing seat height, the distance of the pedals forward of AHP increases with vehicle seat height. The horizontal distances of the optimal pedal locations relative to the accelerator pedal (measured by the center of the accelerator pad) can be calculated and are 45, 48, and 29 mm rearward for the G-, H-, and S-body vehicles, respectively. While the distances for the G- and H-body vehicles are very similar, the lower value for the S-body may suggest a desire to have the brake pedal closer to the accelerator pedal for more upright seating postures.

In Figures 23 and 24, which show the optimal steering wheel and shift knob fore/aft locations relative to AHP, the expected relationship of shorter distance with increasing seat height is clearly demonstrated. Also, in Figure 25, the expected relationship of higher shift knob position with higher seat height is apparent. In Figure 26, the AHP to H-point vertical distance is plotted versus optimal shift knob height relative to AHP for the three vehicles and it is seen that the relationship between the two is quite linear. Figure 27 plots the AHP to steering wheel height versus optimal shift knob height with nearly linear results. In Figure 28, the optimal lateral shift knob locations (determined by the preferred-location functions) are plotted relative to seat centerline. As indicated, distances for all vehicles are very similar at about 375 mm.

Table 22.
Optimal Control Positions Relative to
Accelerator Heel Point

Control	G	H	S
Pedals	-44	-63	-118
Steering Wheel	453	410	340
Shift X	482	430	380
Shift Y*	370	370	381
Shift Z	435	456	520

* Shift Y optimal value are re seat centerline rather than AHP.

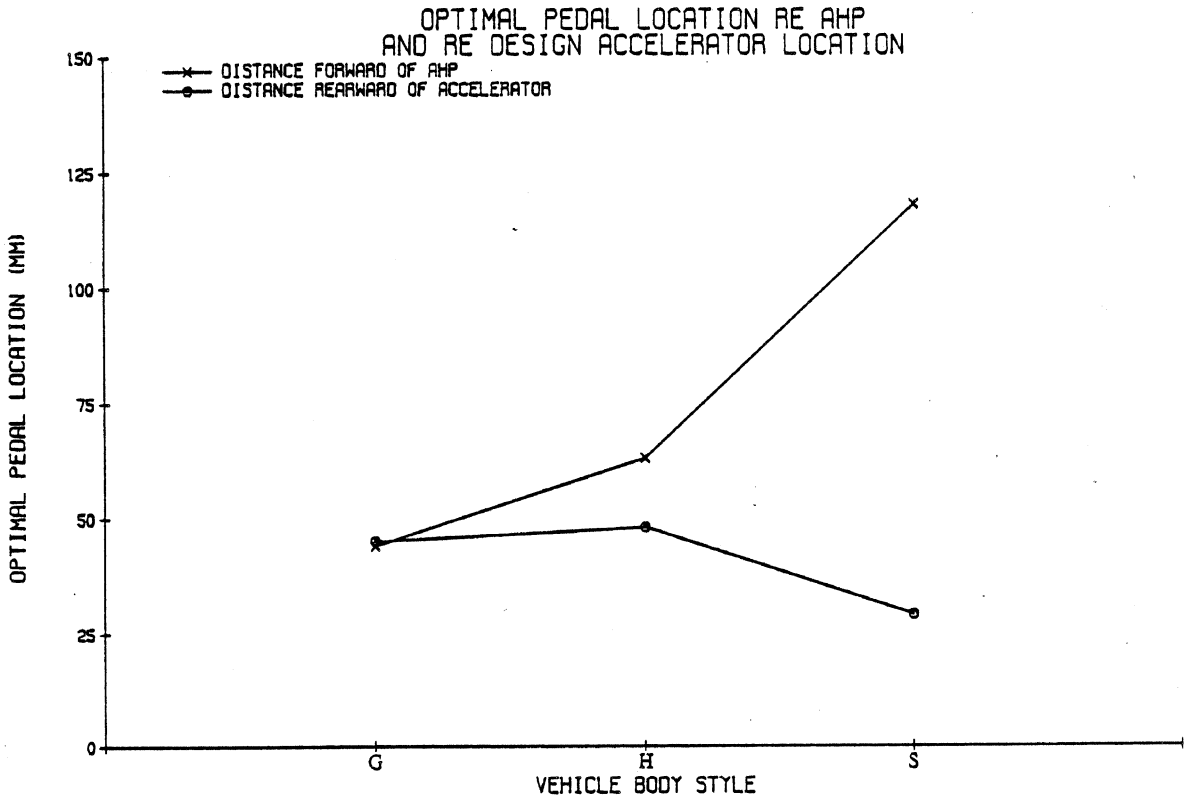


Figure 22. Optimal brake pedal locations relative to accelerator heel point and relative to accelerator.

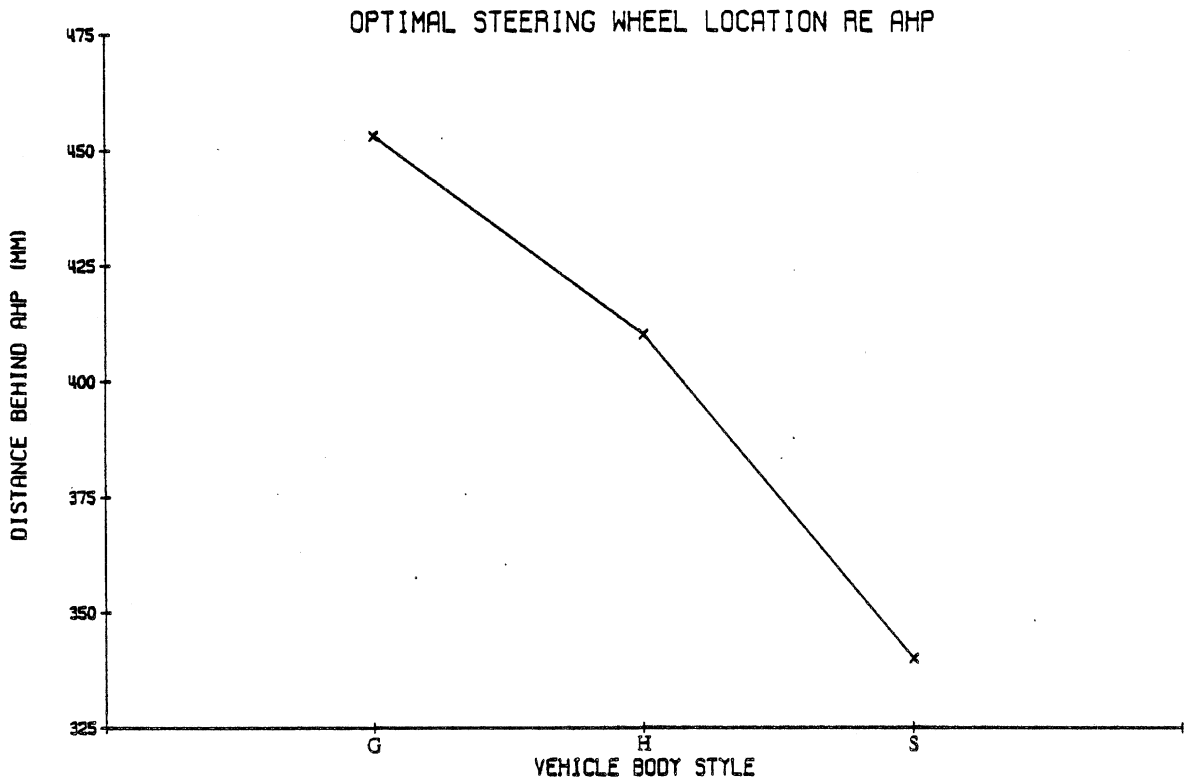


Figure 23. Optimal steering wheel location relative to accelerator heel point.

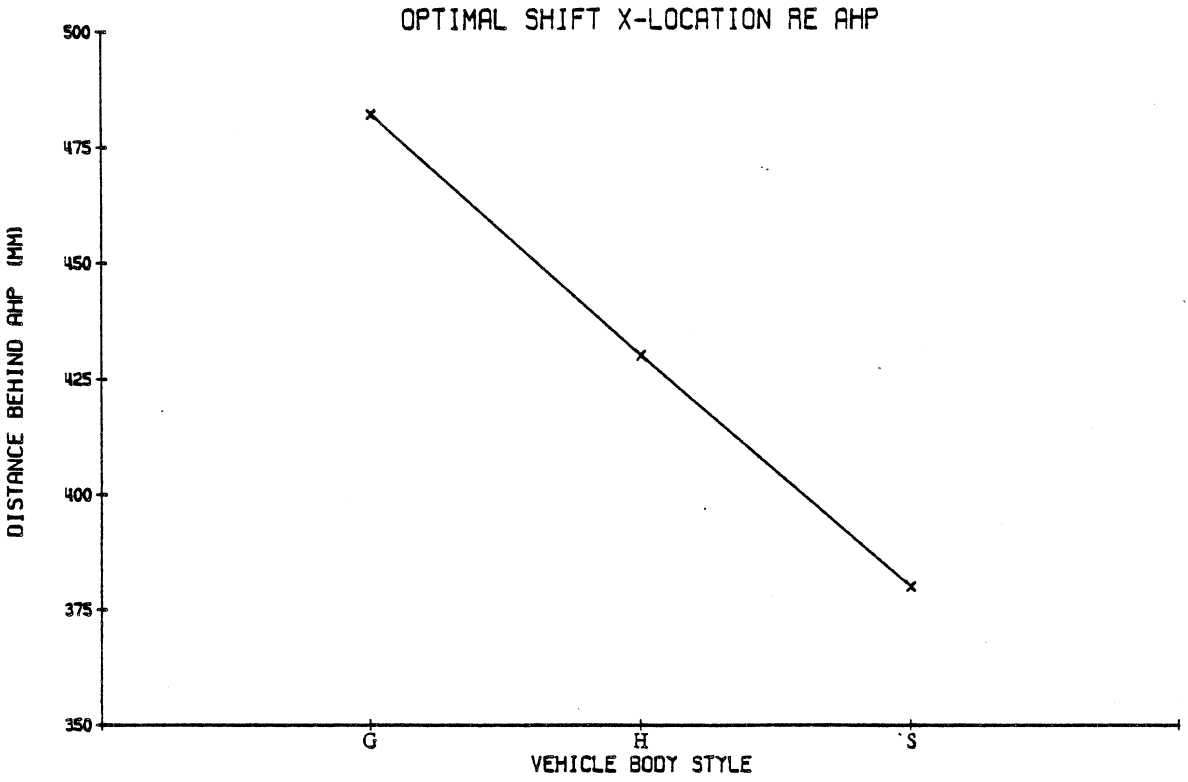


Figure 24. Optimal shift knob (X) location relative to accelerator heel point.

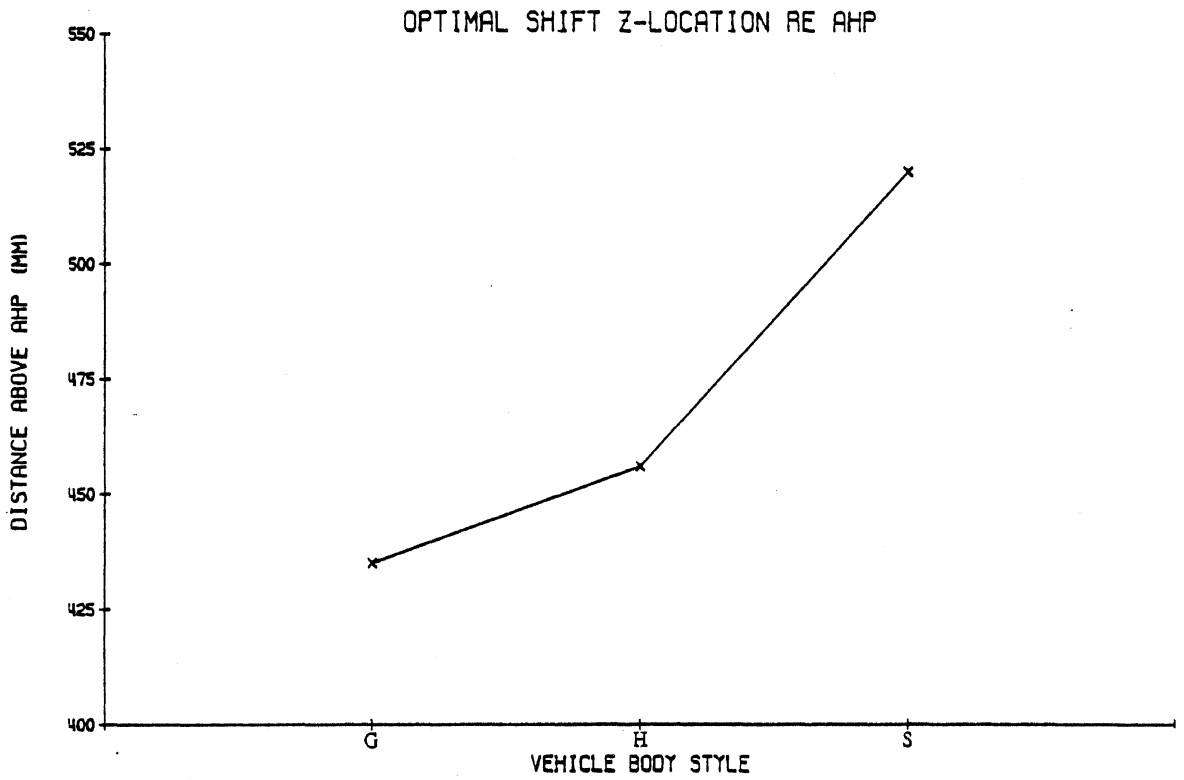


Figure 25. Optimal shift knob (Z) location relative to accelerator heel point.

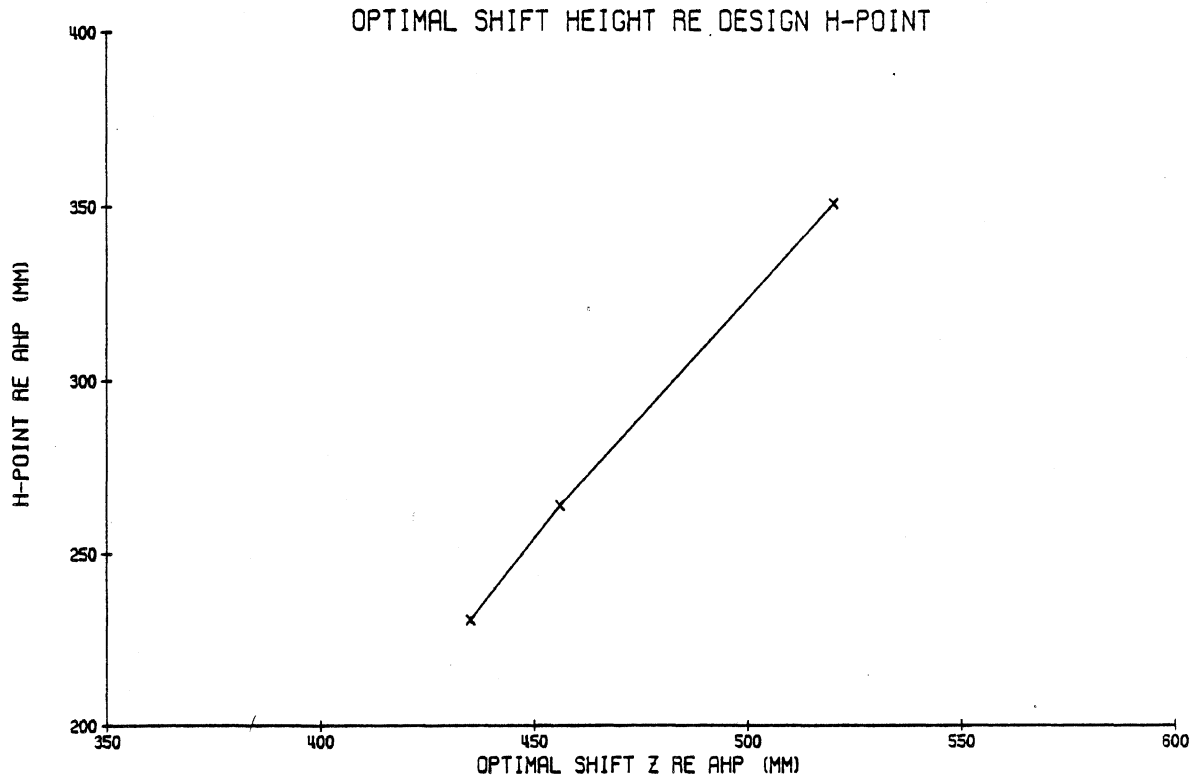


Figure 26. Optimal shift knob (Z) location relative to design H-point.

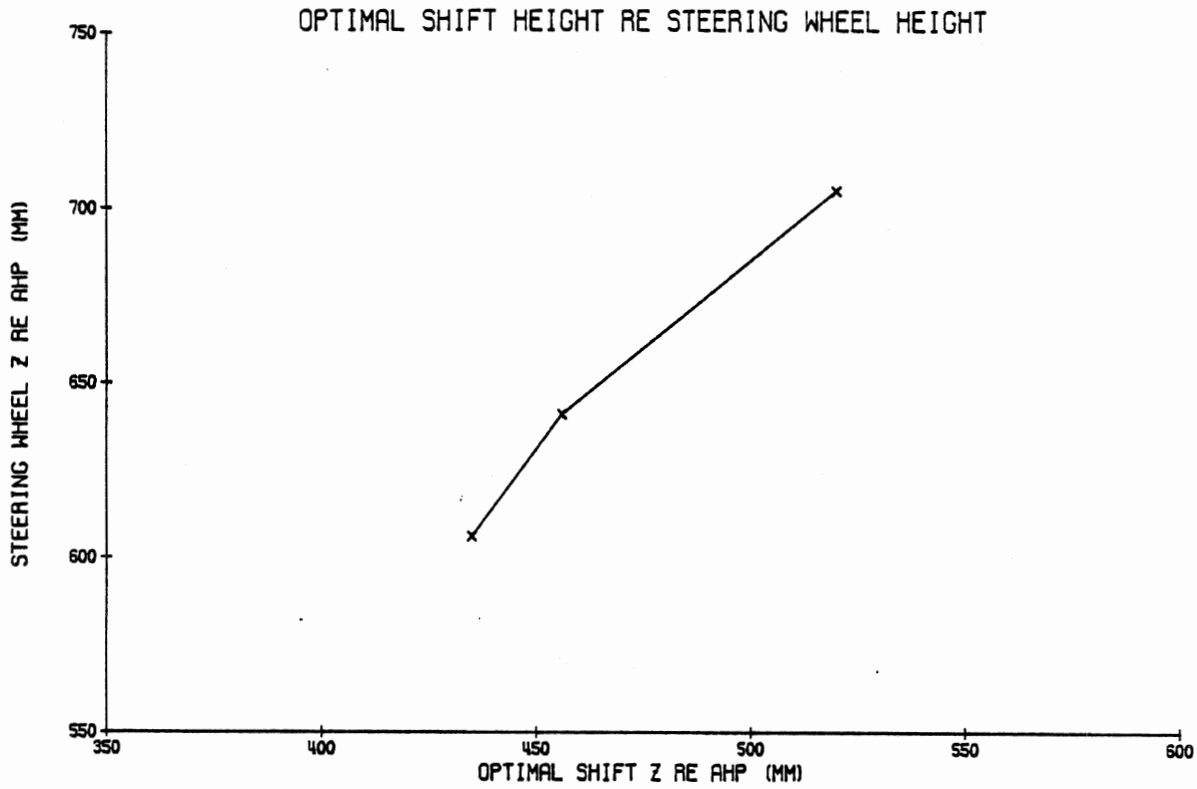


Figure 27. Optimal shift knob (Z) location relative to center of steering wheel height.

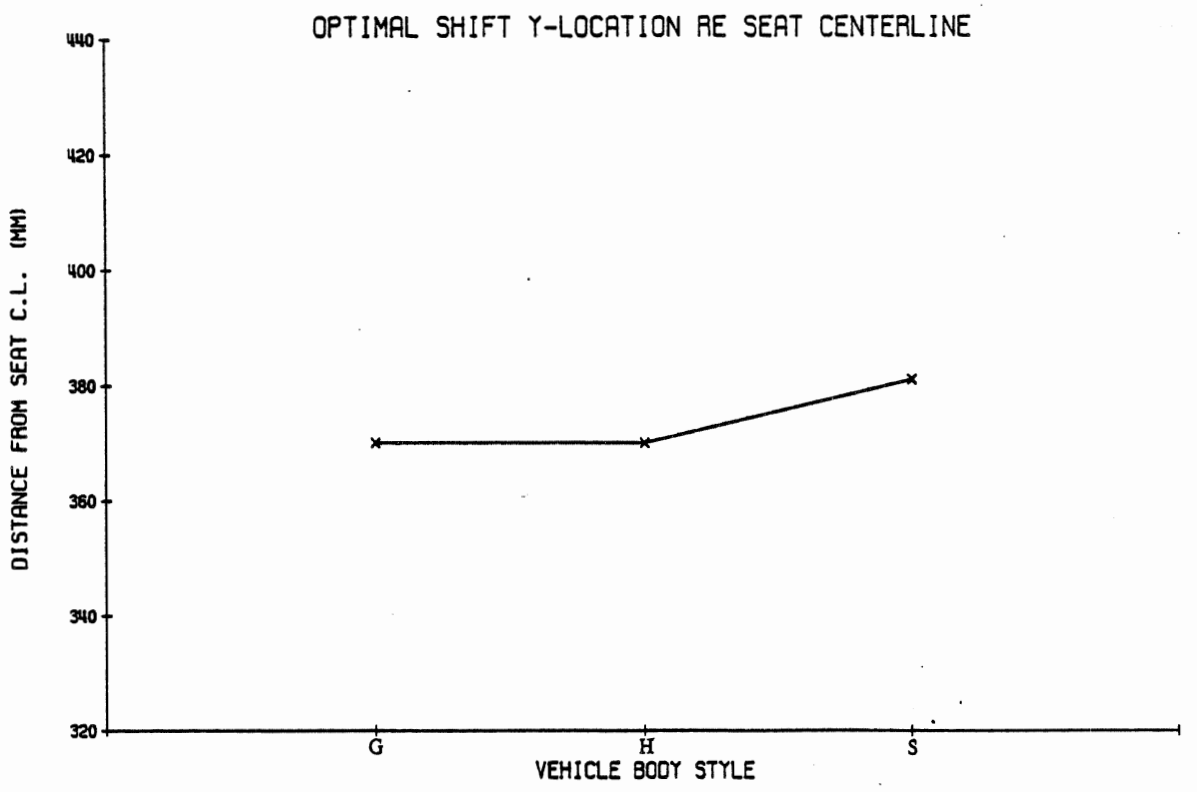


Figure 28. Optimal shift knob (Y) location relative to seat centerline.

F. RELATIVE CONTROL POSITIONS

Relative distances and relationships among the preferred positions of seats and controls were also compared. These variables were examined by subject group for all three seat heights (G, H, and S). The results are presented graphically in Figures 29 through 35. Tabulations of relative distances are in Tables 23 to 25.

Figure 29 shows the group mean preferred steering wheel-to-pedal distances plus and minus one standard deviation for the three vehicles. These were determined by computing the mean and standard deviations of a new variable obtained by subtracting each subject's preferred pedal location from his preferred steering wheel location. As indicated, for each vehicle there is a relationship between preferred steering-to-pedal distance and stature, whereby taller subjects tend to prefer larger distances. It is also observed that the preferred steering-to-pedal distance tends to be shorter for increasing seat height. The G-body package produced the greatest steering wheel-to-pedal distances and the S-body produced the shortest. As indicated by the lines with arrows, the desired distances for the G- and H-body vehicles tend to be less than the design distances, while, for the S-body vehicle, subjects tended to prefer larger distances than available in today's minivan.

Looking at the steering wheel-to-shift knob front/back distances in Figure 30, it is seen that the group mean values are quite small and there are no relationships with stature. Subjects of all anthropometric groups preferred to locate these controls relatively close together when given the choice. For the S-body, the design distance appears to be somewhat larger than subjects prefer while for both G- and H-body styles subjects generally desired a larger steering wheel-to-shift distance than currently designed.

As shown in Figure 31, for steering wheel-to-shift knob fore/aft distances, the location of the brake pedal relative to the accelerator pedal does not show any relationship to driver size. All groups preferred the brake pedal to be closer to the accelerator pedal than currently designed for all three seating packages. Also, the distances for the S-body tend to be smaller than for G- and H-body vehicles.

Figure 32 shows the results for steering wheel center-to-shift knob height values which indicate that the current design distances for the G- and H-body are well within the preferred range for most drivers. In the S-body, drivers preferred a much higher shift knob than the design and therefore steering wheel-to-shift height distances are much smaller than in the manufactured vehicle (design position not shown on scale). There does not appear to be any pattern of stature versus preferred steering wheel-to-shift height. Many subjects

noted that preferred shift height was influenced by a desire for every hand movement from the wheel to the shift knob.

As shown in Figures 33 through 35, horizontal (X-direction) distances of the seat (as measured by translated design H-point) relative to the controls show the previously-noted trend of increasing distance for increasing stature.

Table 23.
Comparison of Optimal and Group Mean Distances
with Actual Design Distances (mm)
G-BODY

Group	St. Wheel to Pedals (X)	Shift Knob St. Wheel (X)	Pedals to Accelerator (X)	St. Wheel Center to Shift Knob (Z)	H-Point to to Pedals (X)	H-Point St. Wheel (X)	H-Point Shift Knob (X)
Optimal*	497	29	45	171	NA	NA	NA
G-Design	540	-6	66	187	903	363	369
1	484	39	29	183	712	229	210
2	478	31	29	198	743	264	255
3	481	30	36	194	795	312	282
4	498	41	28	197	795	305	269
5	519	53	30	235	848	330	285
6	499	16	34	203	822	318	311
7	504	54	37	209	818	314	273
8	498	32	39	190	834	336	309
9	540	34	41	184	879	340	305
10	543	53	31	192	900	360	318
ALL	504	38	34	198	815	311	282

* Based on weighted acceptable range loss functions.

Table 24.
Comparison of Optimal and Group Mean Distances
with Actual Design Distances (mm)
H-BODY

Group	St. Wheel to Pedals (X)	Shift Knob to St. Wheel (X)	Pedals to Accelerator (X)	St. Wheel Center to Shift Knob (Z)			
Optimal*	473	20	48	185	NA	NA	NA
H-Design	525	22	61	220	878	353	331
1	441	38	51	195	686	246	227
2	442	40	35	210	729	287	255
3	471	34	35	228	790	321	289
4	460	74	39	201	782	325	285
5	476	75	43	236	828	353	284
6	474	31	30	215	791	324	298
7	474	52	40	219	805	330	303
8	464	44	41	211	823	358	317
9	493	52	36	15	868	365	331
10	511	60	32	204	888	376	317
ALL	470	50	38	212	799	328	290

* Based on weighted acceptable range loss functions.

Table 25.
Comparison of Optimal and Group Mean Distances
with Actual Design Distances (mm)
S-BODY

Group	St. Wheel to Pedals (X)	Shift Knob to St. Wheel (X)	Pedals to Accelerator (X)	St. Wheel Center to Shift Knob (Z)			
Optimal*	458	40	29	185	NA	NA	NA
S-Design	432	90	56	395	789	357	267
1	457	35	17	188	675	218	192
2	409	62	33	206	701	283	240
3	459	43	14	218	761	302	269
4	448	49	19	224	750	302	257
5	472	86	22	219	797	326	244
6	446	35	25	221	753	307	268
7	465	59	21	228	765	300	245
8	464	55	12	208	791	330	277
9	497	57	26	211	824	326	281
10	497	80	16	209	843	349	298
ALL	462	56	21	213	766	304	257

* Based on weighted acceptable range loss functions.

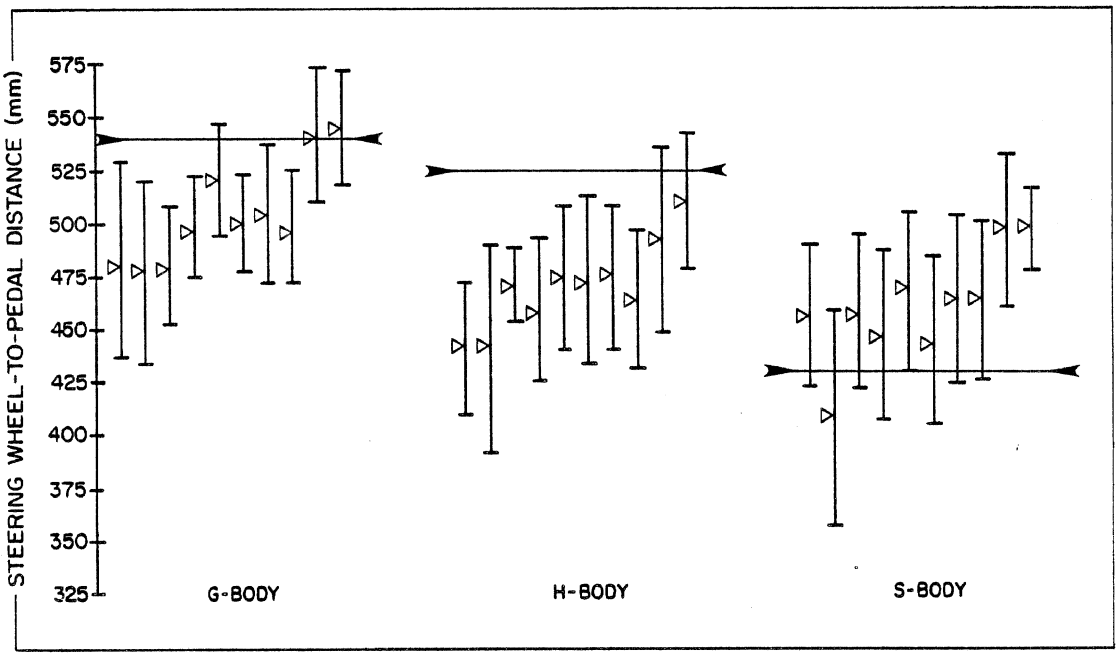


Figure 29. Group mean steering wheel-to-pedal distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

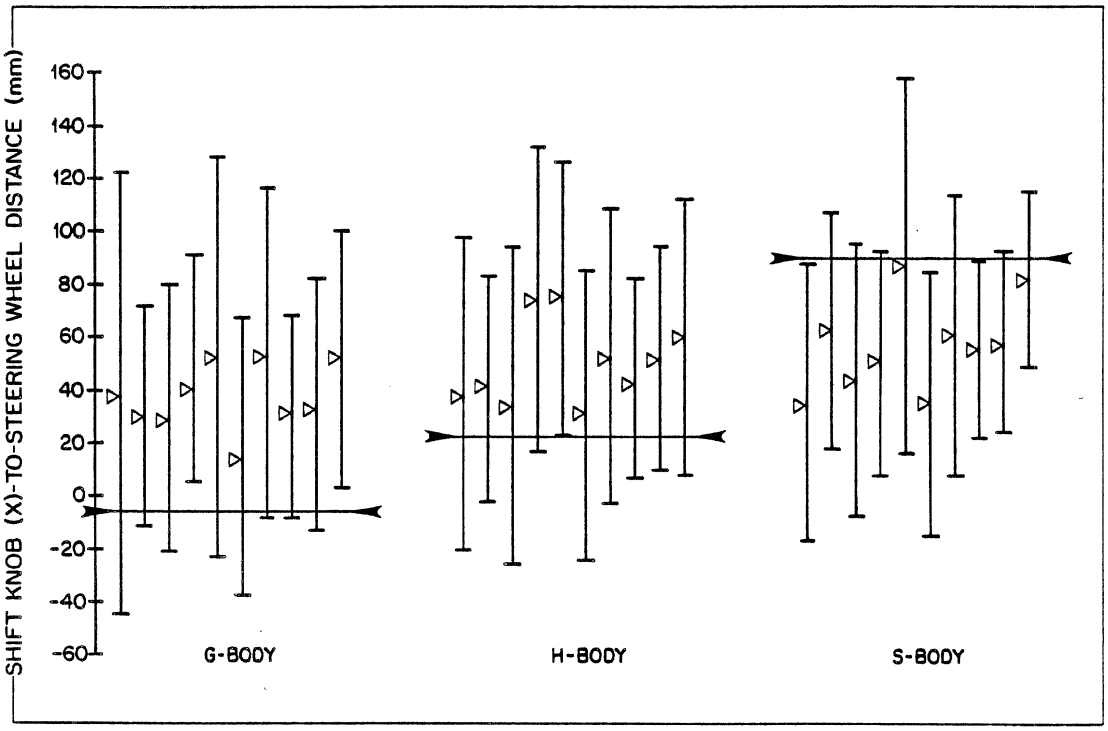


Figure 30. Group mean shift knob (X)-to-steering wheel distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

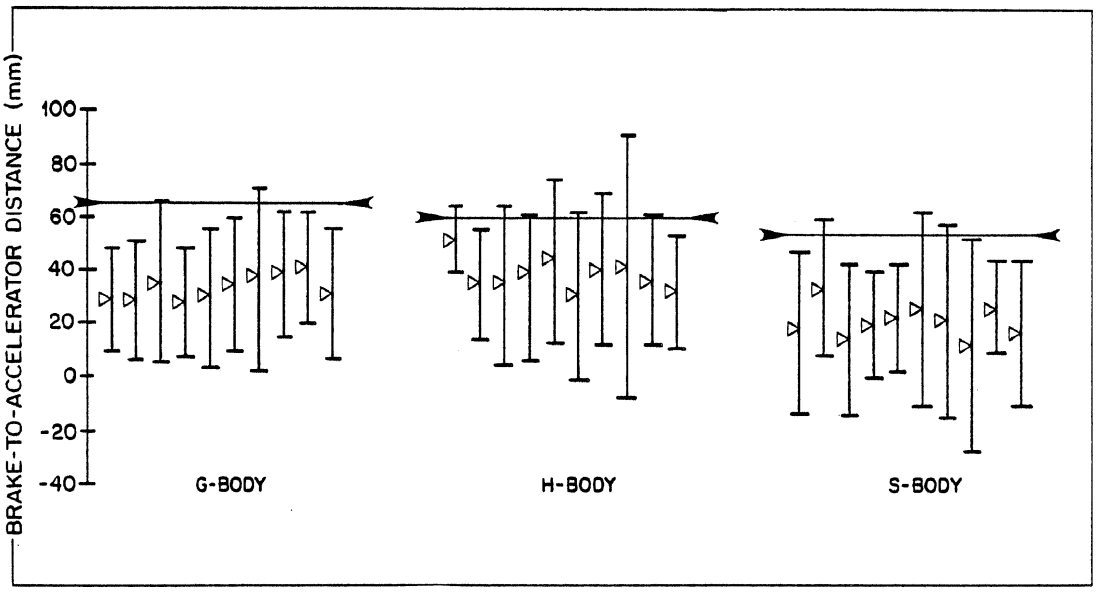


Figure 31. Group mean brake pedal-to-accelerator pedal distances +/- one standard deviation. Lines will arrows indicate current distances in vehicles.

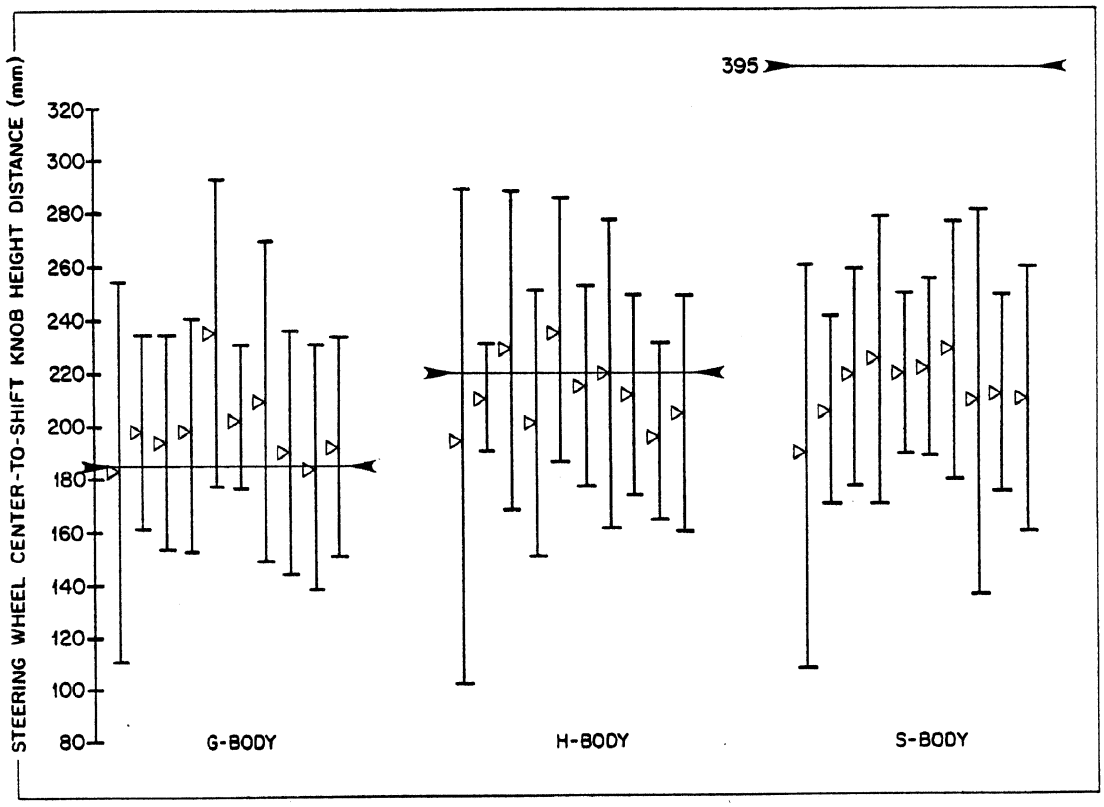


Figure 32. Group mean steering wheel center-to-shift knob height distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

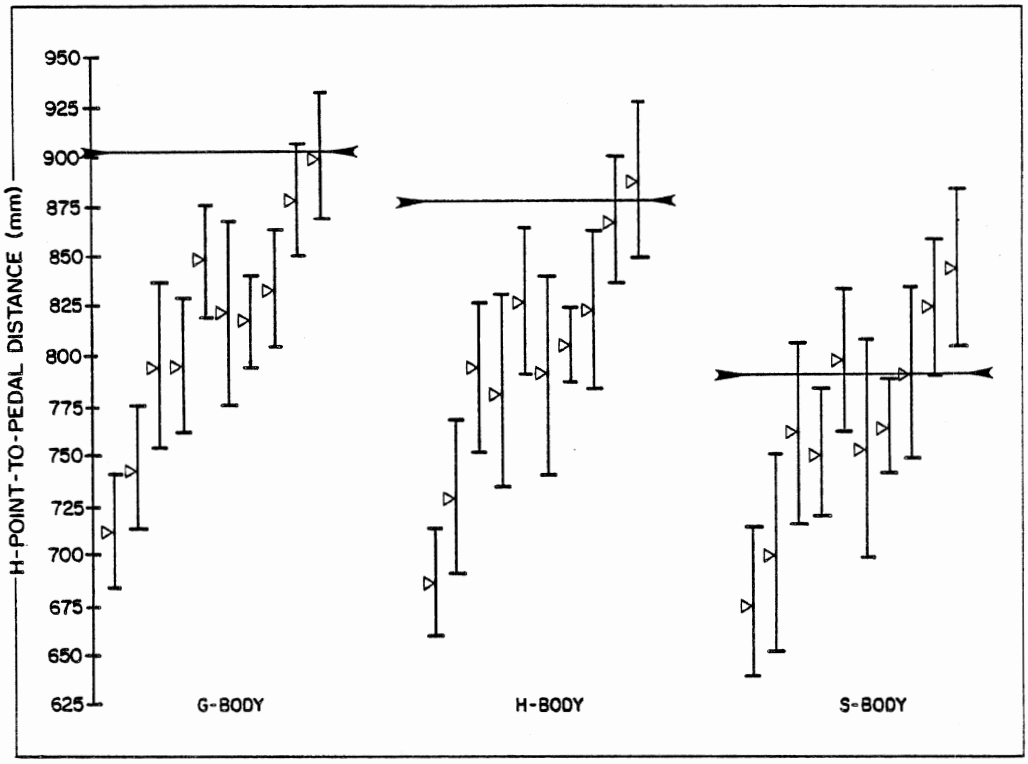


Figure 33. Group mean translated seat H-point-to-pedal distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

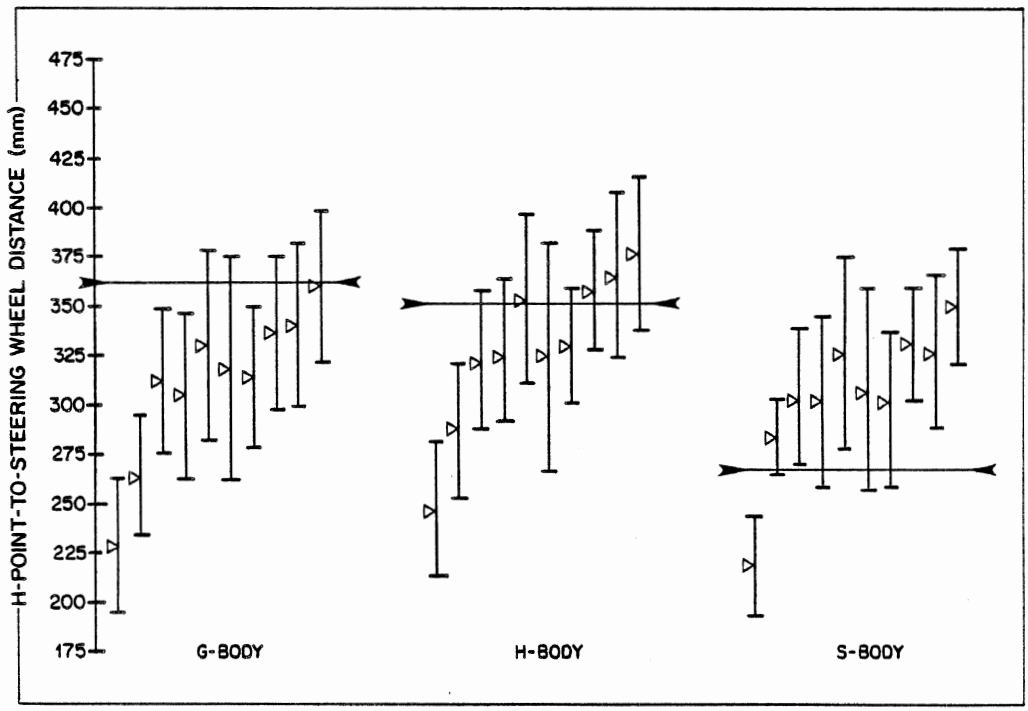


Figure 34. Group mean translated seat H-point-to-steering wheel distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

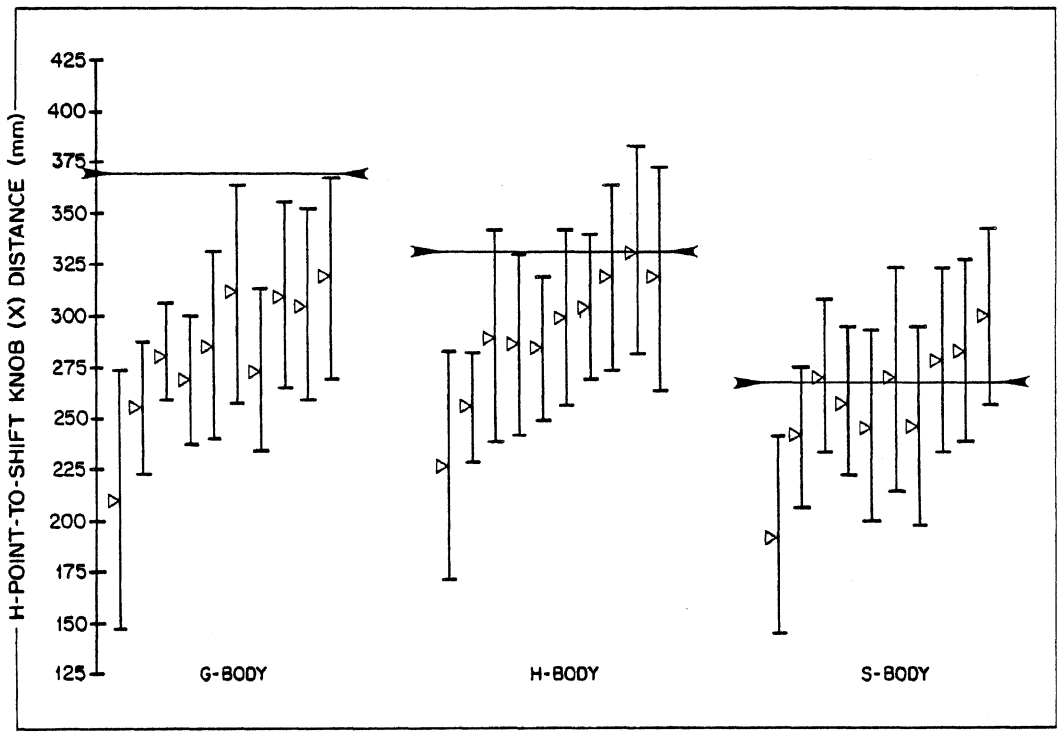


Figure 35. Group mean translated seat H-point-to-shift knob (X) distances +/- one standard deviation. Lines with arrows indicate current distances in vehicles.

G. INFLUENCE OF CLUTCH ON PEDAL POSITIONS PLUS SHIFT KNOB/CONSOLE ARMREST INTERACTIONS

It will be recalled that the test protocol required subjects to initially select a preferred position for the pedals without consideration of the clutch pedal, and subsequently to select a preferred position with the clutch pedal. Also, the console armrest and shift knob were located independently first and then in conjunction with each other. While the data used to determine the optimal positions described previously were for the conditions which included the clutch pedal, and for the shift knob and console armrest together, it is useful to examine the differences between these results and the initial or independent locations.

As indicated in Table 26, there were many instances when subjects chose not to make any changes in their initial or independent selections. Of those who chose to adjust the pedals, however, the large majority chose to move them rearward (i.e., positive direction in X) when the clutch was considered. Also, when the shift knob and console armrest were considered together, the majority of subjects who made adjustments from the independent locations did so by moving the shift knob up (positive Z), the console rearward (positive X), and/or the shift knob forward (negative X).

Group mean differences for initial and final preferred locations of the controls are tabulated in Appendix H. Table 27 summarizes the differences in overall mean preferred locations for the pedals, the shift knob, and the console armrest locations for the different conditions. As indicated in the top line, the overall change in mean pedal position was quite small but consistently rearward, across all vehicles, when the clutch was involved. With the shift knob and console armrest considered together, subjects tended to move the shift knob up about 3/4 inch and the console armrest back about 2 inches from their independently preferred locations.

Table 26.
Percentages of Selected Control Positions

NOTE: The following references indicate directional changes

1. Pedals - + values represent a rearward change
2. Shift X - + values represent a rearward change
3. Shift Y - + values represent a change to the right
4. Shift Z - + values represent an upward change
5. Console/Armrest X - + values represent a rearward change
6. Console/Armrest Z - + values represent an upward change

	% Positive Change	% No Change	% Negative Change
Pedals			
G	42	49	9
H	48	44	8
S	31	51	18
SHIFT X:			
G	5	65	30
H	8	56	36
S	20	52	28
SHIFT Y:			
G	3	85	12
H	6	68	26
S	16	66	18
SHIFT Z:			
G	38	49	13
H	54	42	4
S	54	43	3
CONSOLE X:			
G	66	31	3
H	74	25	1
S	58	38	3
CONSOLE Z:			
G	14	58	28
H	7	46	47
S	8	60	32

Table 27.
Mean Differences in Control/Armrest
Locations for Different Test Conditions

Compared Test Conditions	Mean Difference (mm) G	H	S
Brake & Clutch - Brake Alone	5	8	2
Shift X with Console - Shift X alone	-9	-12	-9
Shift Z with Console - Shift Z alone	18	20	23
Console X with Shift - Console alone	47	62	42
Console Z with Shift - Console Z alone	-4	-6	-5

+ X indicates that first condition is more rearward
+ Z indicates that first condition is higher

H. STEERING WHEEL CANT ANGLE LIMITS

As indicated in the procedures, the lateral movement of the steering wheel center by eleven degrees (i.e., approximately 5 inches) to the left or right of the seat centerline was designed by following an arc with a radius equal to the steering column length. This mechanism was used to estimate driver tolerance for steering wheel cant angle. The cant angle limits for each subject are those positions of the wheel where the offset was considered significantly noticeable to the point of being unaccecptable and/or unsuitable for operation of the steering wheel.

Figures 36 and 37 show the distributions for cant angle limits for all subjects and demonstrate fairly normal distributions in both the left- and right-of-centerline directions. Each histogram displays the distribution for all 100 subjects. Table 28 shows the group mean cant angle limits which are displayed graphically in Figures 38 and 39 along with standard deviations. As indicated, the mean acceptable offset limits are similar for all vehicles and in the range of 5.9 degrees or 2.8 inches of steering wheel offset from the seat centerline. There is also a slight indication that drivers are willing to tolerate somewhat more offset to the right than to the left. This may be attributed to interference with the door for cant angles to the left. There is also a slight suggestion in these data that taller drivers have less tolerance for steering wheel offset than shorter drivers. This may also be an influence of interference of longer and larger bodies with vehicle components.

ACCEPTABLE RIGHT CANT ANGLE (DEGREES)

0.	0	+	
1.	1	+X	
2.	1	+X	
3.	14	+XXXXXXXXXXXXXX	
4.	6	+XXXXXX	
5.	25	+XXXXXXXXXXXXXXXXXXXXXXXXX	
6.	25	+XXXXXXXXXXXXXXXXXXXXXXXXX	**G-BODY**
7.	2	+XX	
8.	16	+XXXXXXXXXXXXXXXX	
9.	3	+XXX	
10.	2	+XX	
11.	5	+XXXXX	
TOTAL	100		

0.	0	+	
1.	0	+	
2.	1	+X	
3.	9	+XXXXXXXXX	
4.	10	+XXXXXXXXXX	
5.	25	+XXXXXXXXXXXXXXXXXXXXXXXXX	
6.	26	+XXXXXXXXXXXXXXXXXXXXXXXXXX	**H-BODY**
7.	7	+XXXXXXX	
8.	10	+XXXXXXXXXX	
9.	7	+XXXXXXX	
10.	3	+XXX	
11.	2	+XX	
TOTAL	100		

0.	0	+	
1.	1	+X	
2.	2	+XX	
3.	14	+XXXXXXXXXXXXXX	
4.	10	+XXXXXXXXXX	
5.	20	+XXXXXXXXXXXXXXXXXXX	
6.	21	+XXXXXXXXXXXXXXXXXXXX	**S-BODY**
7.	12	+XXXXXXXXXXXX	
8.	12	+XXXXXXXXXXXX	
9.	1	+X	
10.	3	+XXX	
11.	4	+XXXX	
TOTAL	100		

Figure 36. Frequency histograms for RIGHT CANT ANGLE of steering wheel.

ACCEPTABLE LEFT CANT ANGLE (DEGREES)

0.	0	+	
1.	3	+XXX	
2.	4	+XXXX	
3.	19	+XXXXXXXXXXXXXXXXXX	
4.	9	+XXXXXXXXX	
5.	31	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	
6.	9	+XXXXXXXXX	**G-BODY**
7.	9	+XXXXXXXXX	
8.	6	+XXXXXX	
9.	5	+XXXXX	
10.	2	+XX	
11.	3	+XXX	
TOTAL	100		

0.	2	+XX	
1.	3	+XXX	
2.	1	+X	
3.	22	+XXXXXXXXXXXXXXXXXXXXXX	
4.	20	+XXXXXXXXXXXXXXXXXXXX	
5.	12	+XXXXXXXXXXXX	
6.	17	+XXXXXXXXXXXXXXXXX	**H-BODY**
7.	8	+XXXXXXXX	
8.	9	+XXXXXXXXX	
9.	3	+XXX	
10.	0	+	
11.	3	+XXX	
TOTAL	100		

0.	2	+XX	
1.	3	+XXX	
2.	3	+XXX	
3.	16	+XXXXXXXXXXXXXXXX	
4.	13	+XXXXXXXXXXXXX	
5.	25	+XXXXXXXXXXXXXXXXXXXXXXXXX	
6.	13	+XXXXXXXXXXXXX	**S-BODY**
7.	8	+XXXXXXXX	
8.	9	+XXXXXXXXX	
9.	4	+XXXX	
10.	1	+X	
11.	3	+XXX	
TOTAL	100		

Figure 37. Frequency histograms for LEFT CANT ANGLE of steering wheel.

Table 28.
Left and Right Cant Angles of Steering Wheel
(in degrees)

		Mean Acceptable Cant Angle					
		G		H		S	
Group	N	Left	Right	Left	Right	Left	Right
1	10	6.9	6.4	5.7	5.8	6.7	6.8
2	10	5.7	6.3	5.7	6.7	5.6	5.9
3	10	5.2	6.3	5.4	6.4	5.0	5.0
4	10	5.6	6.3	4.9	6.1	5.6	7.1
5	10	5.5	6.2	5.4	5.3	4.6	5.4
6	10	5.2	6.2	5.7	6.0	6.0	6.3
7	10	5.6	6.1	5.6	6.8	5.3	6.1
8	10	3.4	4.5	3.6	5.3	3.7	4.7
9	10	3.9	5.0	3.6	4.9	3.8	4.7
10	10	4.7	5.4	4.7	6.1	5.0	5.6
ALL	100	5.2	5.9	5.0	5.9	5.1	5.8

Note: All values are in DEGREES with respect to rotation of the steering column (radius) in the left-to-right or Y-direction.

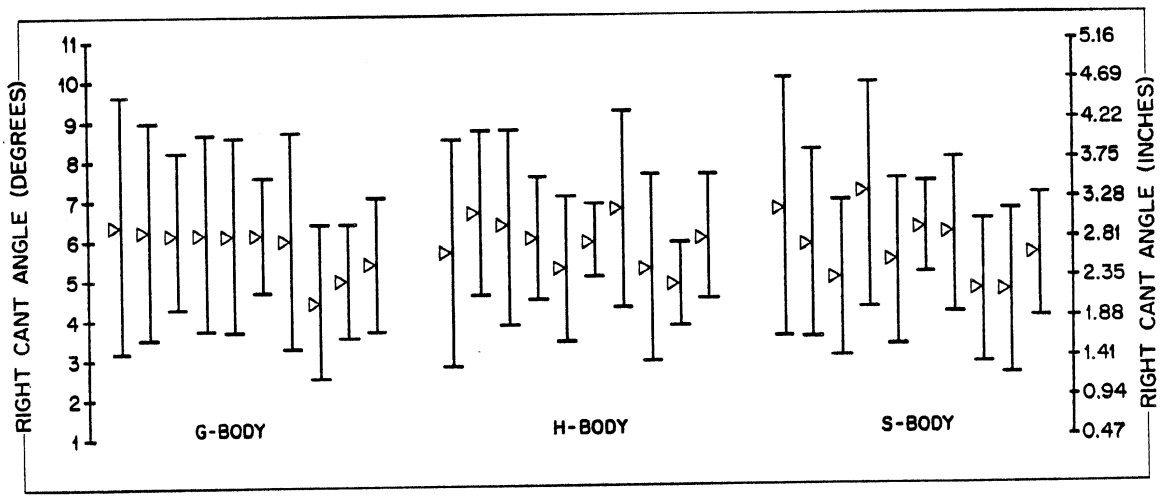


Figure 38. Group mean right cant angles +/- one standard deviation

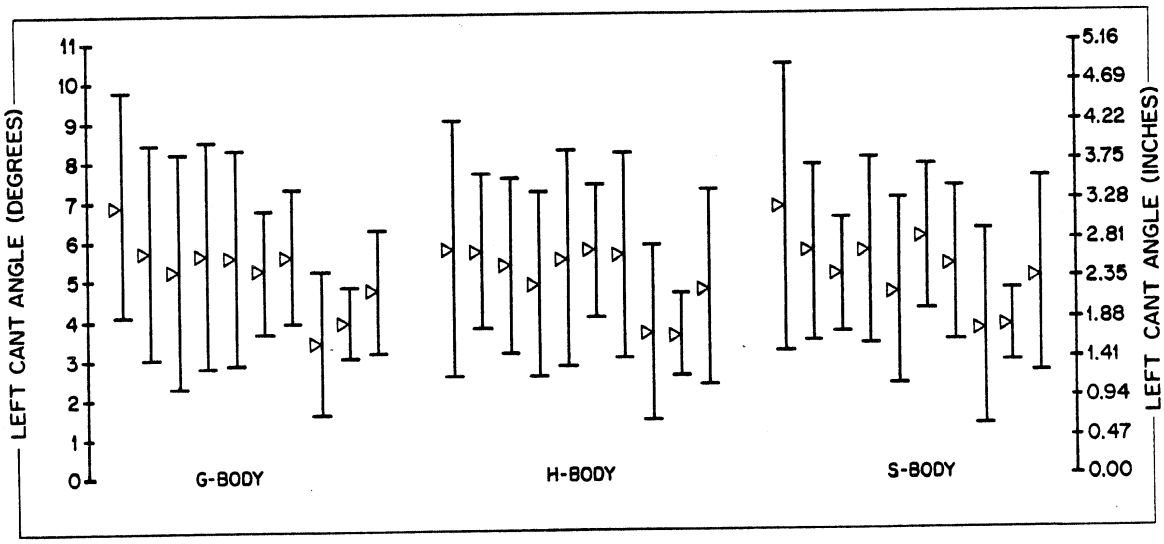


Figure 39. Group mean left cant angles +/- one standard deviation.

I. PREFERRED ARMREST AND ELBOW LOCATIONS AND COMPARISON WITH RESULTS FROM ARMREST POSITION STUDY

While the inclusion of preferred armrest height in the test protocol was somewhat secondary to the primary study goals, the results are surprising in light of the results from the armrest study. Group mean values for the two studies are compared in Appendix I. As has been indicated previously, the overall mean of preferred location for controls and armrests (see Schneider, 1987) for all subjects is generally quite similar to the optimal location determined by the peak in the acceptable-location function and can therefore be used as a good estimate of the optimal location. Using this assumption, Table 29 gives the optimal armrest heights for the three vehicles determined in the Control Position Study. Tables 30 and 31 compare these optimal armrest heights with the locations in current vehicles and with the optimal, overall mean of preferred, and overall mean of the lower acceptable limit locations from the armrest study. Table 32 summarizes the door and console height differences in overall preferred means from the two studies.

Table 29.
Optimal* Armrest Heights for the
Control Position Study

	G	H	S
Door Armrest Height	472	501	705
Console Armrest Height	448	475	690

* based on overall mean preferred locations

It is immediately apparent from these comparisons that the two studies have produced significantly different results for optimal armrest heights. It will be recalled that the optimal heights determined in the armrest study were significantly higher than current armrest heights in all cases except the center armrest for the S-body vehicle. In the control study, the optimal door armrest heights (indicated by the mean of preferred heights) are between 41 mm (1-1/2") and 49 mm (2") lower than the mean preferred heights from the armrest study and are quite close to both the current design heights and the means of the lower limits from the Armrest Position Study. For the console armrest, the differences vary across vehicles but are consistently lower in the Control Position Study than in the

Table 30.
Comparison of DOOR ARMREST HEIGHT Results
from ARMREST and CONTROL Studies

	G	H	S
Optimal Height re Armrest Study	530	549	749
Mean Preferred Height re Armrest Study	521	542	746
Mean Preferred Height re Control Study	472	501	705
Mean Lower Limit re Armrest Study	469	495	700
Design Height	480	507	715

Table 31.
Comparison of CONSOLE ARMREST HEIGHT Results
from ARMREST and CONTROL Studies

	G	H	S
Optimal Height re Armrest Study	500	510	712
Mean Preferred Height re Armrest Study	479	498	698
Mean Preferred Height re Control Study	448	475	690
Mean Lower Limit re Armrest Study	443	464	667
Design Height	410	477	728

Table 32.
Comparison of Differences between
Mean Preferred Door and Armrest Heights for
Armrest and Control Studies

	Differences (mm)		
	G	H	S
Armrest Study Differences	42	44	48
Control Study Differences	24	26	15

Armrest Position Study. It is interesting to note that the mean preferred heights for the two studies are most similar for the S-body center armrest, which is the only armrest whose current height is close to the optimal height determined in the Armrest Position Study.

While these differences in armrest heights between the two studies were unexpected and initially somewhat disturbing, upon further consideration of the differences in test protocol, a rational and meaningful explanation can be found. In the first study, the emphasis was on finding the optimal armrest heights for highway driving, which was determined by the armrest survey to be the type of driving for which most drivers would tend to use, and want to use, the armrests. Thus, the emphasis was on the armrests and subjects were instructed to place their hands on the steering wheel and position the armrests for highway cruising. In the second study, positioning of the armrests was a secondary issue, with the primary emphasis on positioning of the steering wheel, pedals, and shift knob. Subjects were instructed to pay attention to the need to turn the wheel and operate the pedals and shift knob when making their determinations of preferred positions for these controls. The armrests were positioned only after the subject had located his/her preferred pedal and steering wheel positions and no instructions were given to the subjects about what type of driving they should consider.

Given these differences in emphasis in the two studies, it can be concluded that the results of both studies are valid and must be interpreted together to determine how armrests should be designed and positioned for future vehicles. The results from the first study provide information on how to position the armrests for the situation in which they are most commonly used -- highway driving -- and indicate that the door armrests and consoles are generally too low in today's vehicles. The results of the second study suggest that, when a driver is not using the armrest for highway driving, he/she would prefer not to have the armrest quite so high (as would be selected for highway driving) since it can interfere with operation of the vehicle (i.e., steering wheel) for around-town driving situations.

The obvious, but perhaps unrealistic solution, is an adjustable or removable armrest. The flip-up type armrest in the minivan is a good example of the kind of armrest needed for highway-type driving, although the driver is left without any armrest on the console side when it is flipped up.

Tables 33 and 34 summarize the preferred elbow location results from the two studies. An approximate required armrest length can be determined by encompassing the range for all preferred elbow locations. The required armrest lengths are slightly greater for the Control Position Study.

Table 33.
Reslts for Preferred Locations
of RIGHT ELBOW
(Vehicle Coordinates, all Subjects)

	G	H	S
CONTROL POSITION STUDY:			
Mean Preferred Positions	1376	1363	1347
Range of Preferred Positions	1162 - 1533	1190 - 1535	1148 - 1495
Length of Preferred Range	371	345	347
ARMREST LOCATION STUDY:			
Mean Preferred Positions	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

Table 34.
Results for Preferred Locations
of LEFT ELBOW
(Vehicle Coordinates, all Subjects)

	G	H	S
CONTROL POSITION STUDY:			
Mean Preferred Position	1308	1297	1303
Range of Preferred Positions	1126 - 1451	1148 - 1438	1122 - 1434
Length of Preferred Range	325	290	312
ARMREST LOCATION STUDY:			
Mean Prerred Position	1384	1377	1338
Range of Preferred Positions	1253 - 1541	1181 - 1529	1210 - 1509
Length of Preferred Range	288	348	299

Note: All dimensions in millimeters

J. SUBJECT COMMENTS DURING TESTING

Subjects were encouraged at the beginning of each test sessions to verbalize their thoughts and opinions about the positioning of controls as they experienced them. These verbal comments were recorded by the investigators within each subject's file and are listed in Appendix J. The number of subjects expressing the same idea while in the same seating package are tabulated below each comment. It is important to note, however, that these totals represent only those subjects who made spontaneous comments and do not represent the percentage of subjects that might have had the same opinion or experience.

With respect to the seat itself, comments about the seat-back angle were most frequent. Many felt that there was not enough upright adjustment provided, especially for the S-body. Another common remark was that the seat cushion was too long and quite uncomfortable in that it interfered with the back of the knees while operating the pedals.

Driver opinions about the pedals were varied. Many subjects expressed difficulties in locating a single pedal position which would be optimal with respect to the accelerator pedal while still feeling comfortable for operating the clutch through its full travel. Only a few comments were made in reference to the accelerator pedal. Comments about the steering wheel and shift knob were infrequent and are tabulated in Appendix J. Among the comments regarding the armrests, one of the more common was a desire to have the armrests closer to the seat. When testing for acceptable control locations, verbal comments mostly reflected the factors that influenced the decisions about the acceptable limits.

K. QUESTIONNAIRE RESULTS

At the time of scheduling, a questionnaire (see Appendix B) was mailed to each subject to be completed prior to his test appointment. Results are tabulated in Appendix K. Questions referred to primary controls such as the steering wheel, pedals, and shift knob in the subject's own vehicle and any problems experienced with regard to the locations of these controls. Instructions were given to drive with these questions in mind for a few days before completing the survey. In addition, information on the make and model of the subject's vehicle was obtained and is tabulated in Table K-1.

While a full and meaningful interpretation of the results from this survey would require correlating individual driver responses with vehicle geometry and subject anthropometry, such an exercise is beyond the scope of the present study. A brief review of the simplified tabulation of results from the questionnaire given in Table K-2 of Appendix K will, however, offer some insight into potential problem areas being experienced by the driving population.

The first three questions related to the comfort of vehicle seats. This included front-to-back adjustment, seat height, and seat-back angle adjustment. Of the 96 subjects who returned their questionnaires, 81 felt that their front-to-back adjustment was adequate. Four responded that there was not enough forward adjustment and 11 noted they would prefer more rearward adjustment. As would be expected, the former were mostly from the shorter subject groups and the latter from the taller groups.

Sixty-eight of the subjects indicated that they were satisfied with the seat height in their vehicle, while 17 thought the seat was too low. Half of those who felt the seat was too low were short females. Five subjects mentioned that the seat was higher than they would like and seven had adjustable seat heights in their vehicle. When asked about the seat-back angle adjustment, 63 subjects checked that they had an adequate amount of adjustment in their vehicle. Thirteen responded that they would prefer to sit in a more upright position than allowable, and four suggested that a greater seat-back angle would be more comfortable. Nineteen subjects owned vehicles that did not provide any adjustment. Although only thirteen subjects said that they would like a more erect seat in their own vehicle, 33 subjects made this same comment during test sessions on the Chrysler buck.

Five questions of the Control Position Survey dealt with the accelerator, brake, and clutch pedals both individually and with respect to each other. From the subject population, 85 people responded that the height of the brake pedal from the floor was fine in their

vehicle. Five suggested that the brake pedal was too high while four subjects felt it was too low. These responses were evenly distributed throughout the subject groups. With regard to the distance of the brake pedal from the accelerator in the lateral direction, 89 subjects were satisfied, five replied they were too close together, and only one subject indicated that the brake and accelerator were too far apart.

Considering the front/back brake-to-accelerator pedal distance produced similar results. Five subjects said they were too close and four replied that the pedals were too far away from each other. It was interesting to find that 16 people noted that their shoe sometimes catches on the back side of the brake. The remaining subjects did not, however, experience any problems in operating the brake and accelerator pedal with respect to each other. Similarly, five subjects said their left foot sometimes catches on the clutch pedal while 60 had no problems in operating the clutch pedal in their vehicle. Nineteen subjects noted that they needed to sit closer to the steering wheel than they would like to operate the clutch pedal. Of these 19 subjects, 16 were females and nine were short females.

One question each was asked about the steering wheel and shift knob locations. Responses were quite varied for both of these controls. Regarding the steering wheel, 18 subjects commented that it interfered with their view of the instrument panel. Others replied that the wheel was either too high (9 subjects) or too low (6), that the steering column (4) and/or the wheel rim (5) interfered with their knees, that the wheel was too far off-center from the seat (3), that the wheel interfered with the view out the front windshield (2), or that the wheel was too close (8) or too far away (2) when the seat was adjusted to the pedals. Only 47 subjects were completely satisfied with the location of their steering wheel.

Shift knob location also ranked in importance among the subject drivers. Again, only 47 subjects were pleased with their currently owned vehicle with respect to shift knob location. Twenty subjects thought that the shift knob was too far forward. It was specified by 11 subjects that the shift knob was too difficult to operate, particularly in reverse and fifth gear. Eleven subjects also felt that the shift knob was too far to the right and, in some cases, interfered with the passenger's knee when shifting. Three others thought the shift knob was too low and only one subject noted that the shift knob was too high in his vehicle.

IV. DISCUSSION AND RECOMMENDATION FOR FOLLOW-ON WORK

Because of the large variability in driver sizes and personal preferences for driving postures, the ranges of preferred and acceptable locations for primary controls and armrests for the driving population are also relatively large. As a consequence, conducting an experimental study such as this in actual vehicles is impractical if not impossible. However, before applying the results of a study conducted in a laboratory seating buck, it is important to consider what differences might exist between the results obtained in the static buck situation and in the real driving situation.

For example, the results of this study suggest that the brake pedals should be located further forward and closer to the accelerator pedal than in current vehicle models. This finding is based on the subject's judgement of his/her desired physical relationship of the brake to accelerator pedal in the limited simulation conditions of the laboratory buck. The key elements in the final preferred position are the desire to move the foot easily back and forth between the brake and accelerator pedal and the ability to easily operate the clutch pedal through its full travel. In the actual vehicle and under actual driving conditions, however, other dynamic factors may be operating which could modify the drivers' preference.

It has been noted by Chrysler engineers (personal communication), for example, that when the brake pedal is positioned lower (i.e., further forward), drivers experience the feeling that the brakes are not working correctly (i.e., an increase in warranty complaints) even though the absolute distance of brake travel and the pedal actuation force is unchanged. In addition, one must consider the safety implications of having the brake and accelerator in nearly the same plane, since pedal actuation errors, whereby the accelerator could inadvertently be depressed during or instead of braking, may increase.

In light of the need to consider these other real-world factors that may modify or influence the decisions about optimal control and armrest placements, it is recommended that the results from the Armrest and Control Position Studies be used to establish the optimal control configurations, along with some smaller amount of variability, in actual vehicles, and that road testing be conducted to further evaluate these positions under actual and different driving conditions.

V. REFERENCES

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.

Schneider, L.W. Ergonomic Investigation of Armrest Locations in G-, H-, and S-Body Vehicles Using a Computer-Controlled Universal Seating Buck. Final Report UMTRI-87-29. July 15, 1987.

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

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 H-Body

DOOR ARMREST:

Armrest is level and approximately 65 mm wide.

		mm	in
Z-coordinate (at design H-point)		507	
Height from AHP (at design H-point)		452	17.8
Height from Design H-point		188	7.4
Front edge of useable armrest:	X	1150	
	Z	507	
Back edge of useable armrest:	X	1500	
	Z	507	
Effective length of armrest		350	13.8
Effective width of armrest		65	2.6
Seat centerline to edge of armrest		311	12.2
Seat centerline to center of armrest		344	13.5

CONSOLE ARMREST:

Dimensions below are estimates based on measurements from an H-body vehicle

Z-coordinate (at design H-point)		477	
Height from AHP (at design H-point)		392	15.4
Height from Design H-point		128	5.0
Front edge of useable armrest:	X	1289	
	Z	477	
Back edge of useable armrest:	X	1609	
	Z	477	
Effective Console Length		320	12.6
Effective console width		90	3.5
Seat centerline to edge of console		295	11.6
Seat centerline to center of console		340	13.4

AHP: X = 577, Z = 55 DESIGN H-POINT: X = 1405, Z = 3.9

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	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

APPENDIX B
QUESTIONNAIRE

Name: _____ Subject No.: _____

UMTRI
Control Position Survey

==========

Vehicle Information Section

Vehicle Make _____ Model_____ Year _____

Check one: 2-door _____ 4-door _____ Wagon/Van _____

Check one: Transmission 4-speed _____ 5-speed _____ Automatic _____

Tilt wheel: Yes _____ No _____

Seat adjustment: manual _____ power _____

==========

For each of the following, please check all the statements that apply under each item.

1. With regard to the front to back seat adjustment provided in my vehicle:

   _____ It is adequate
   _____ There's not enough forward adjustment
   _____ There's not enough rearward adjustment
   _____ Other comments _____

2. With regard to the seat height in my vehicle:

   _____ The seat height is fine
   _____ The seat is too low
   _____ The seat is too high
   _____ The seat height is adjustable
   _____ Other comments _____

3. With regard to the seat back angle adjustment in my car:

   _____ It doesn't adjust
   _____ The adjustment is adequate
   _____ I would like to sit more upright than it allows
   _____ I would like to lean further back than it allows
   _____ Other comments _____

4. With regard to the height of the brake pedal from the floor:

   _____ It is too high
   _____ It is too low
   _____ It is fine
   _____ Other comments _____

5. With regard to the distance of the brake pedal from the accelerator pedal sideways:

_____ It is too close
_____ It is too far
_____ It is fine
_____ Other comments _____

6. With regard to the distance of the brake pedal from the accelerator pedal toward the driver:

_____ It is fine
_____ It is too close
_____ It is too far
_____ Other comments _____

7. In operating the brake and accelerator pedal in my car:

_____ I have no problems
_____ My shoe sometimes catches on the brake pedal
_____ Other comments _____

8. With regard to operating the clutch pedal in my car:

_____ I have no problems
_____ I need to sit closer to the steering wheel than I would like to operate the clutch pedal easily through its full range
_____ My left foot sometimes catches on the clutch pedal
_____ Other comments _____

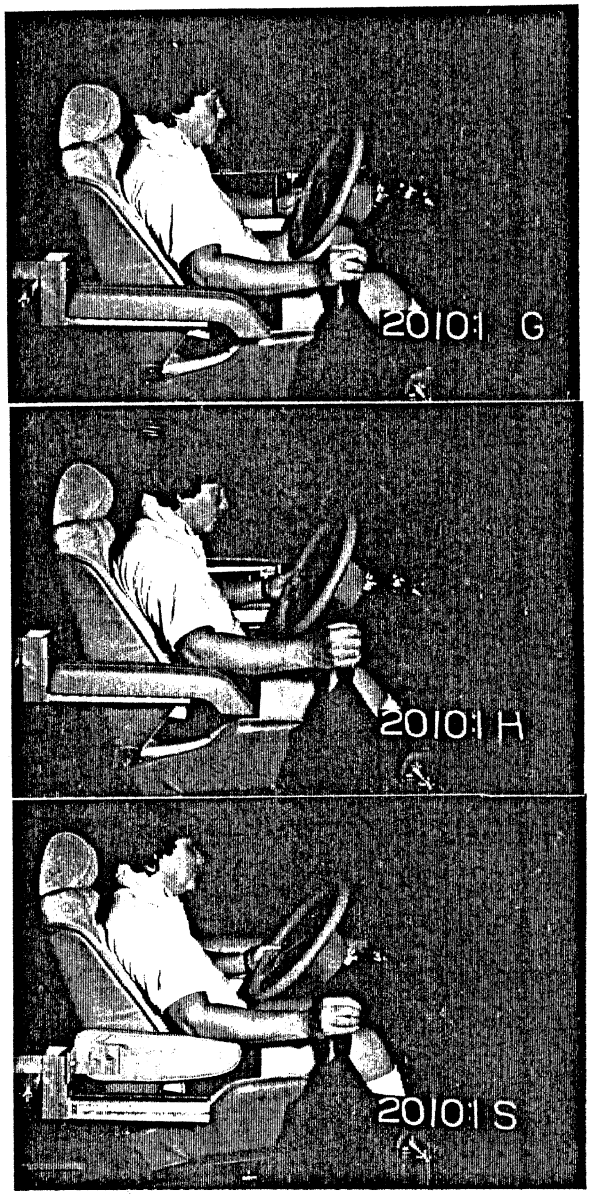
9. With regard to the steering wheel location in my car:

_____ It is too high
_____ It is too low
_____ The column interferes with my knees
_____ The steering wheel rim interferes with my knees
_____ The steering wheel is too close when I sit so I can operate the pedals
_____ The steering wheel is too far away when I sit so I can operate the pedals
_____ It interferes with my view of the instrument panel
_____ It is too far off center from the seat
_____ It interferes with my view out the front window
_____ It is fine
_____ Other comments _____

10. With regard to the shift knob in my car

_____ It's too far forward
_____ It's too far back
_____ It's too high
_____ It's too low
_____ It's too hard to operate
_____ It's too close to the seat
_____ It's too far to the right
_____ It is fine
_____ Other comments _____

APPENDIX C
SIDEVIEW PHOTOGRAPHS OF SUBJECTS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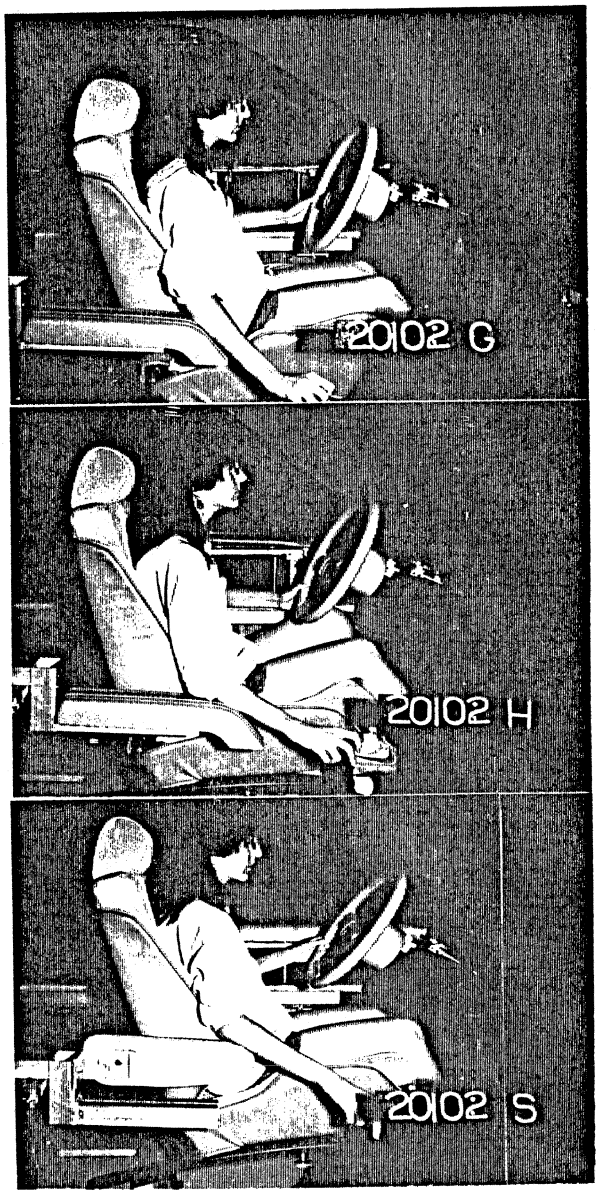
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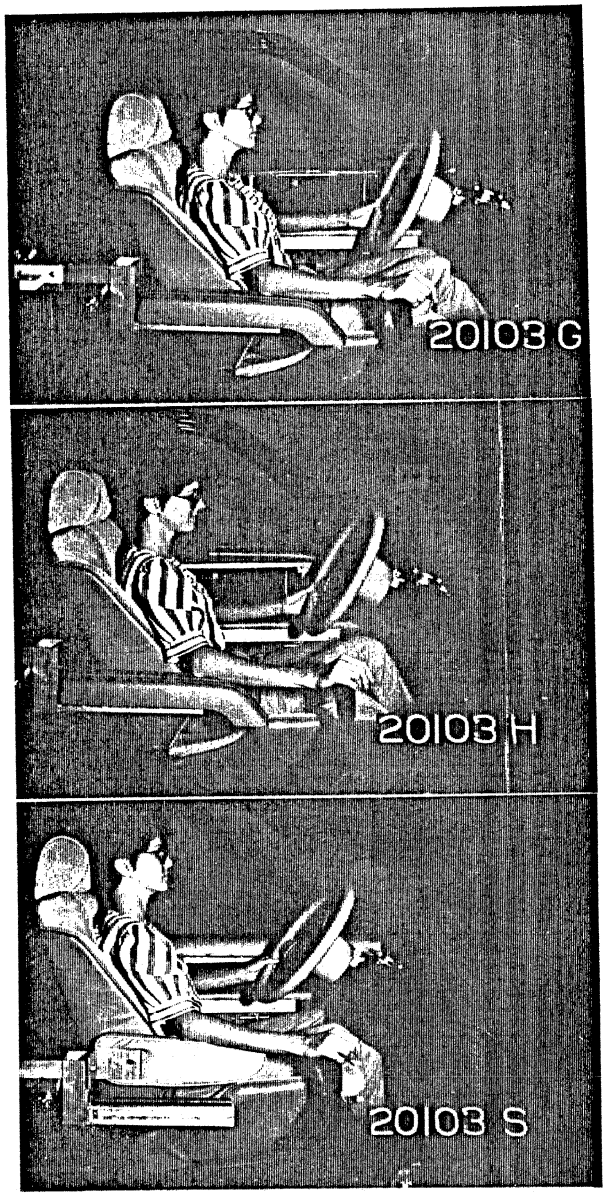
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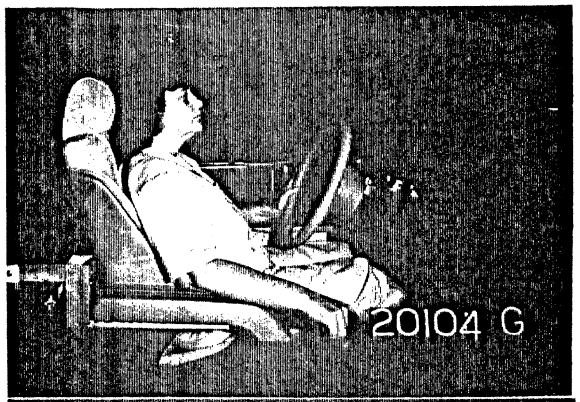
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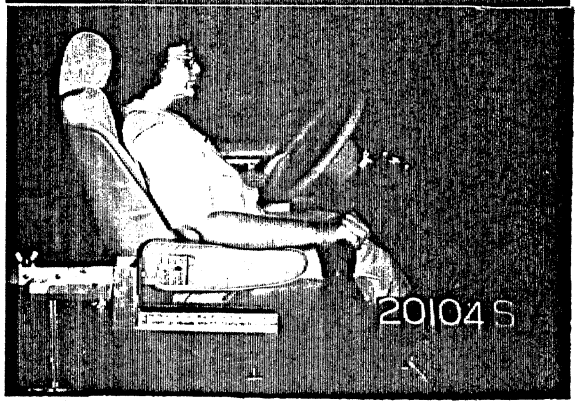
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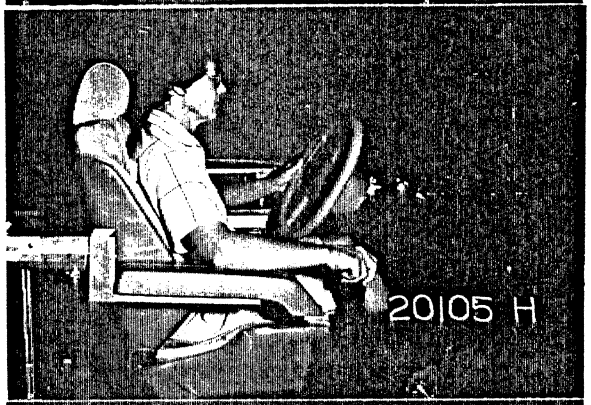
20105 G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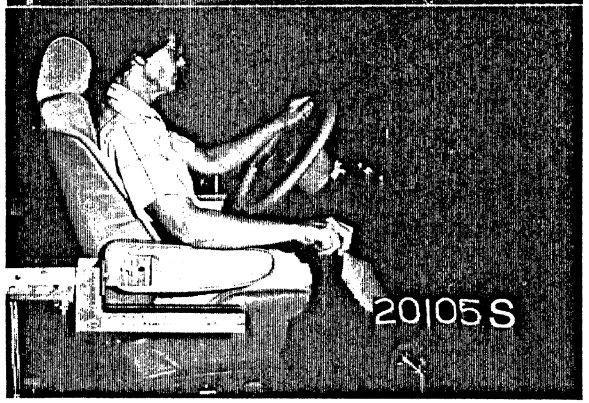
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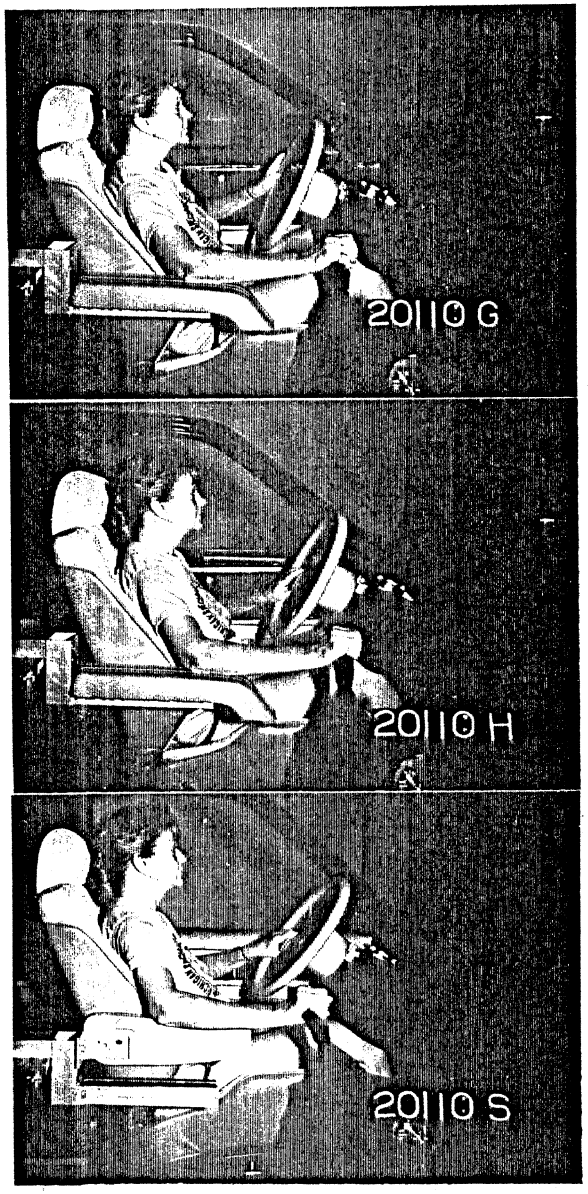
20106 G


20106 H


20106 S

20109 G
20109 H
20109 S
20108 G
20108 H
20108 S
20107 G
20107 H
20107 S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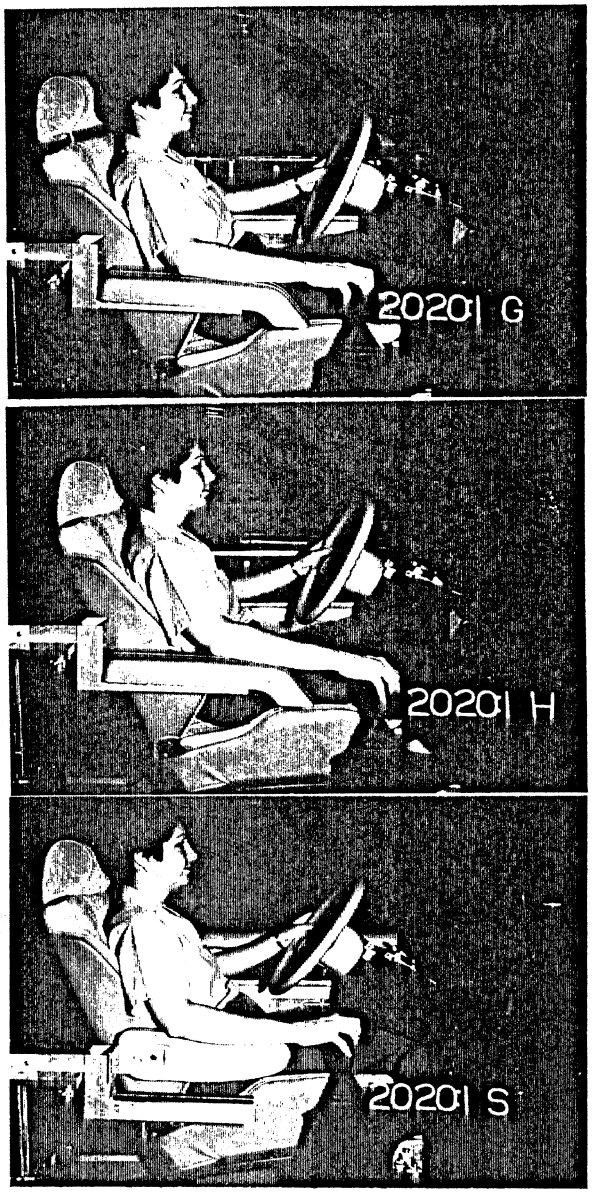
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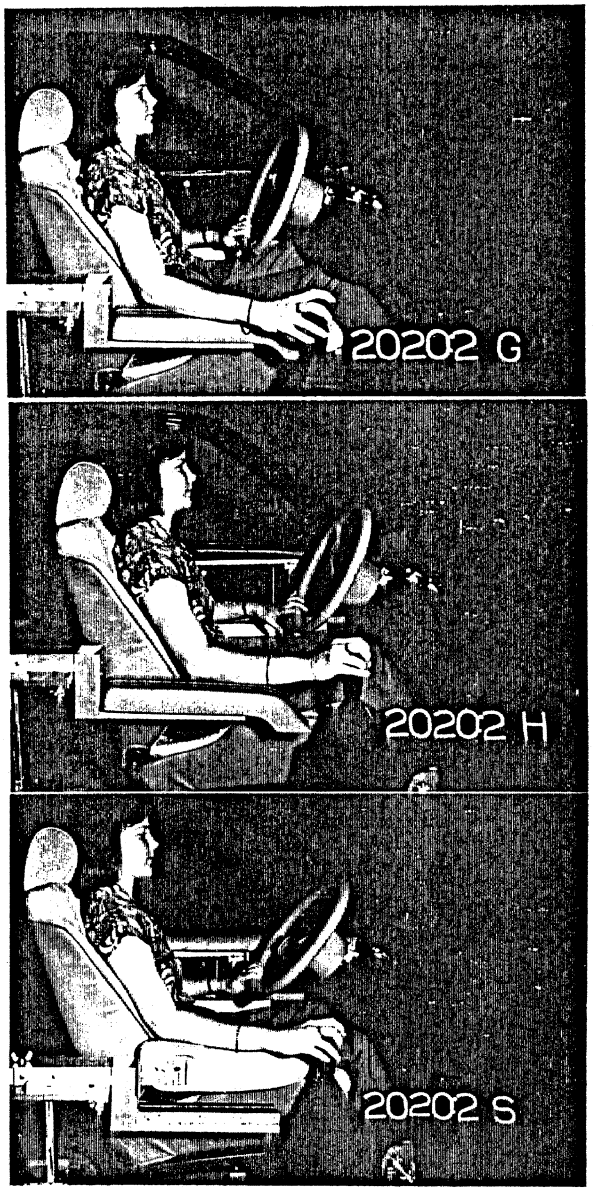
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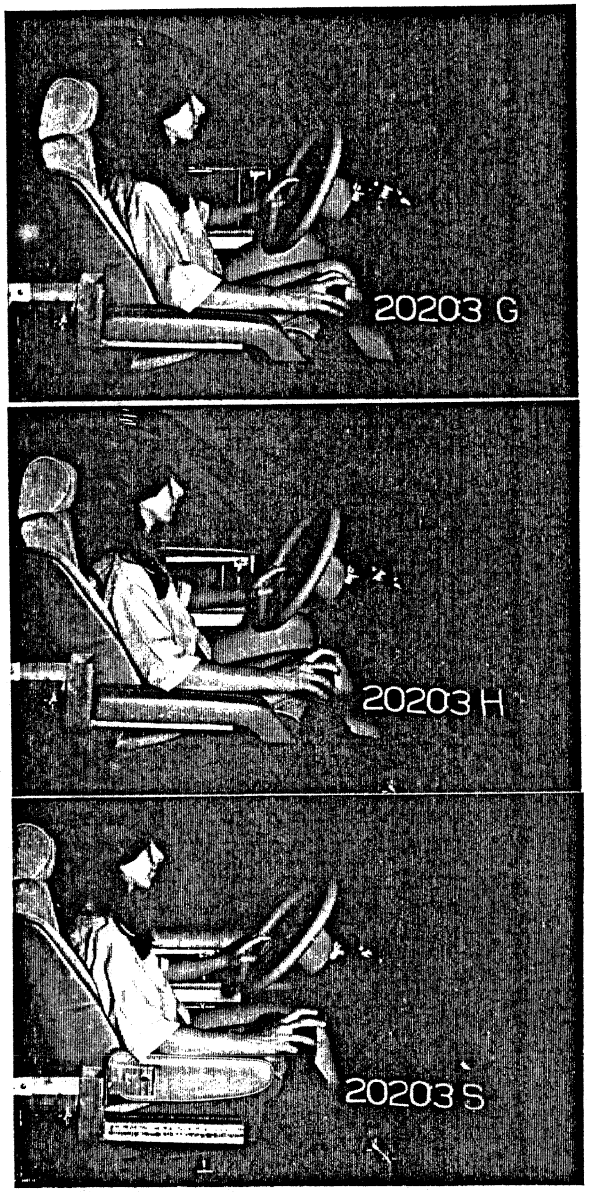
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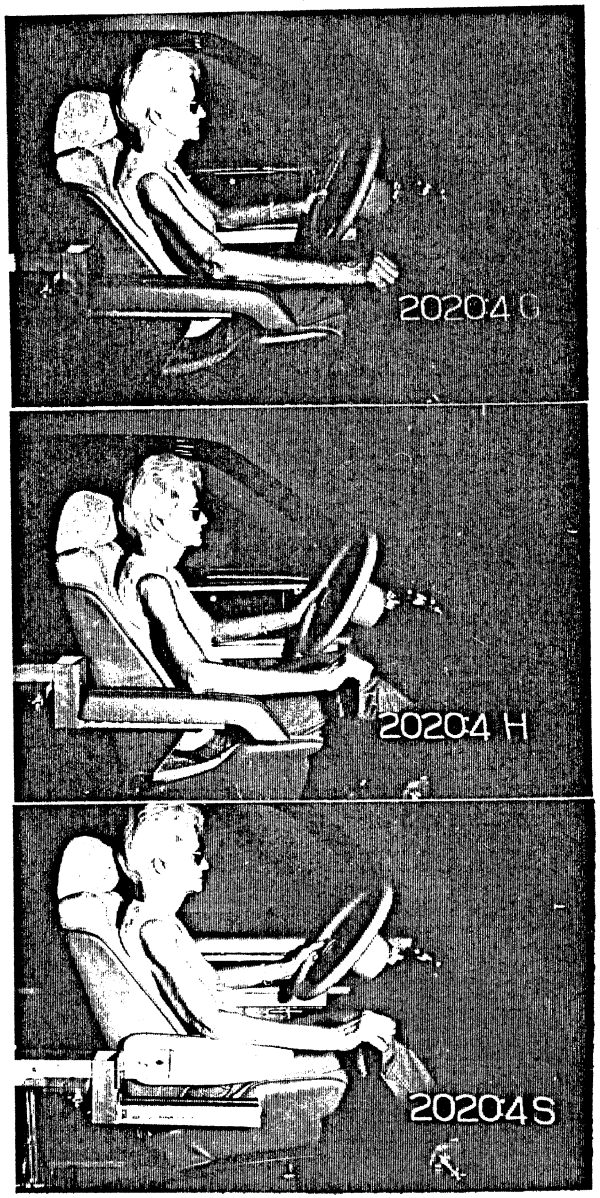
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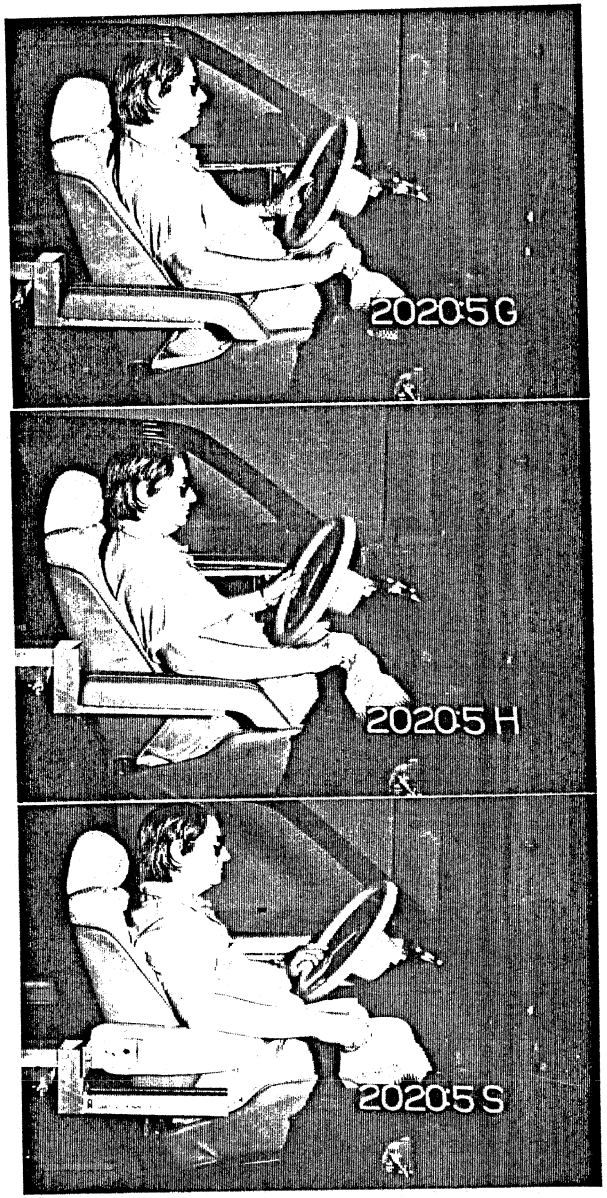
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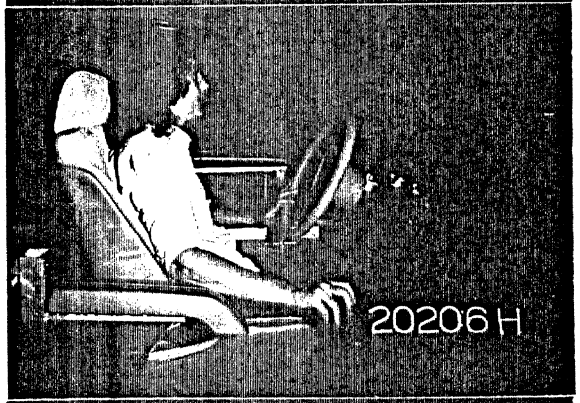
20205 H
20205 S


20206 G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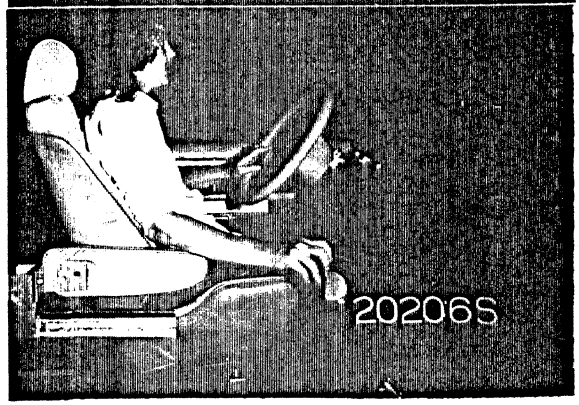

20206S


20207 G

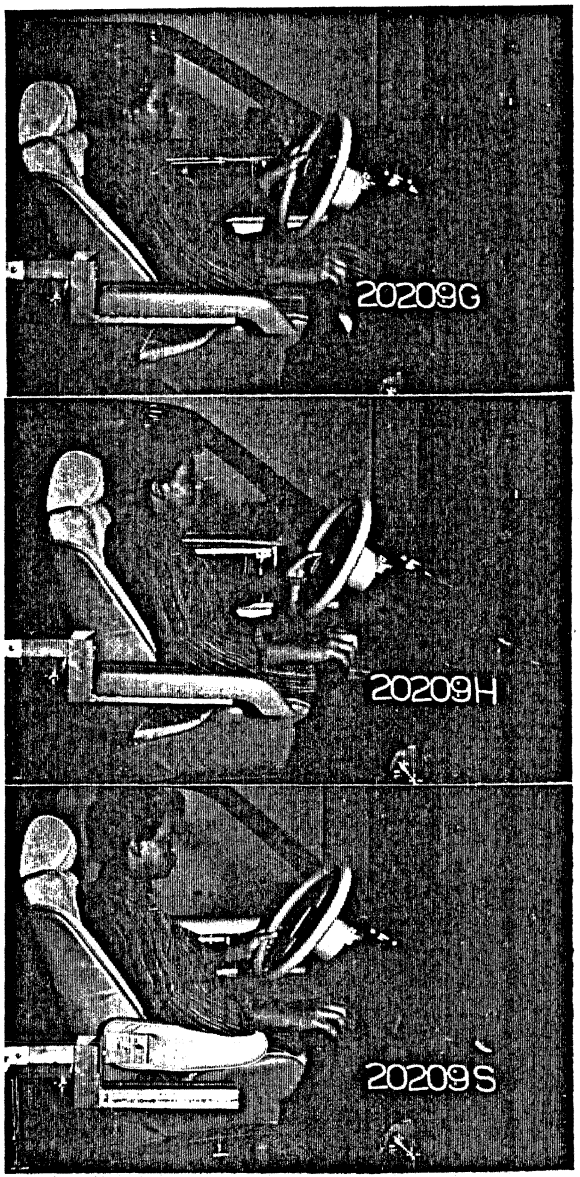

20207 H


20207 S


20208 G


20208 H


20208 S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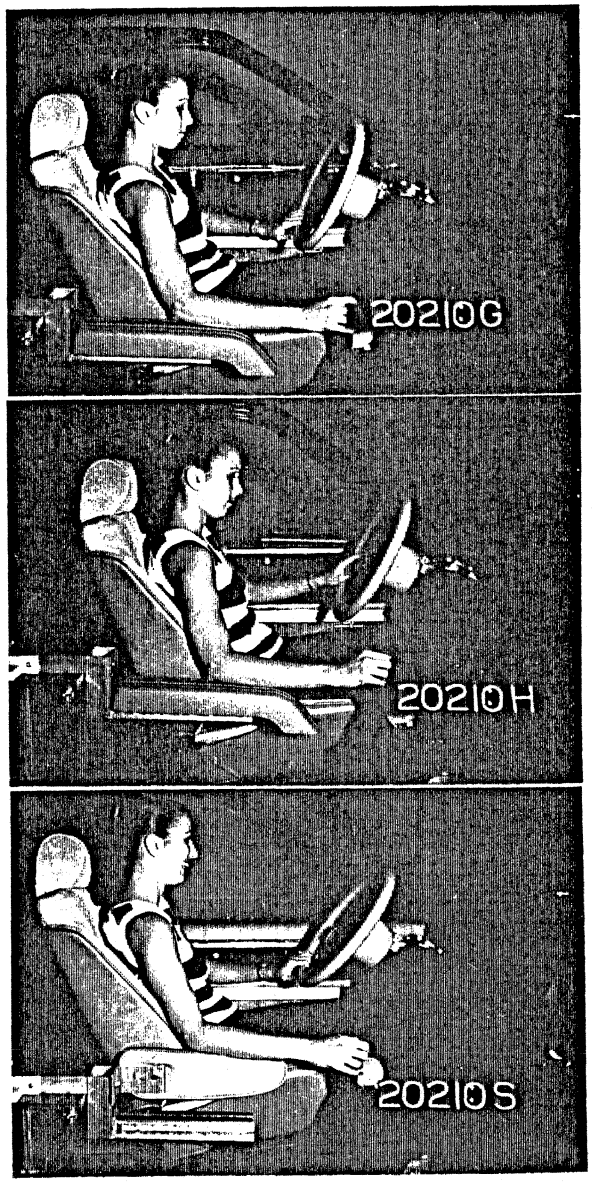
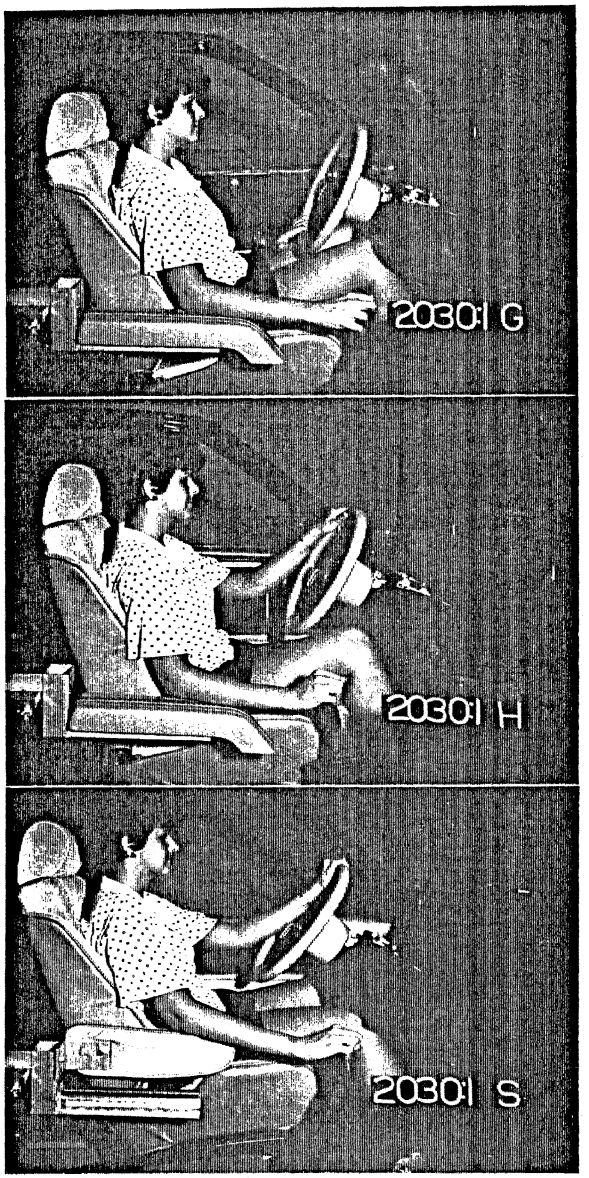
20209H
20209S


20210G
20210H
20210S


20301G
20301H
20301S


20302 G


20302 H


20302 S


20303 G

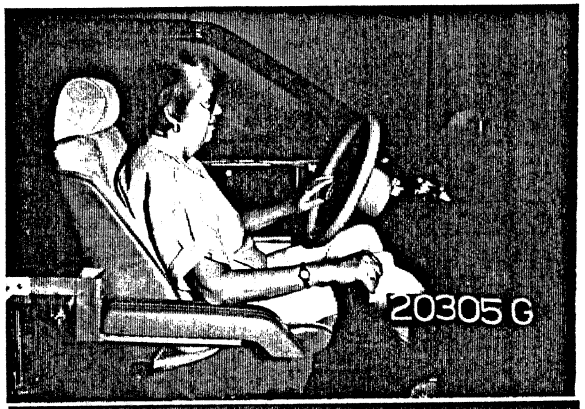

20303H


20303 S

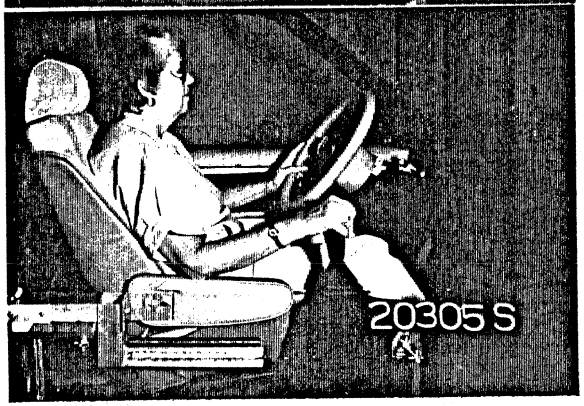

20304 G

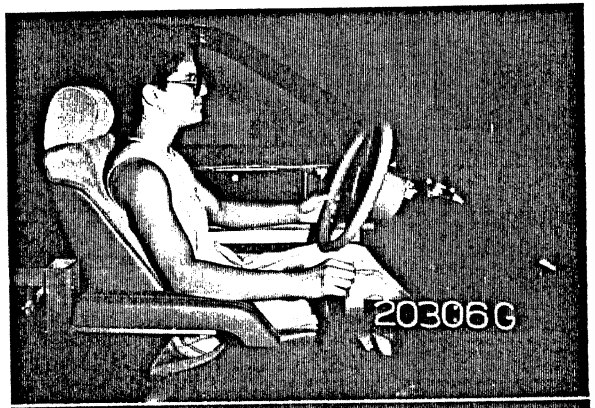

20304 H


20304 S

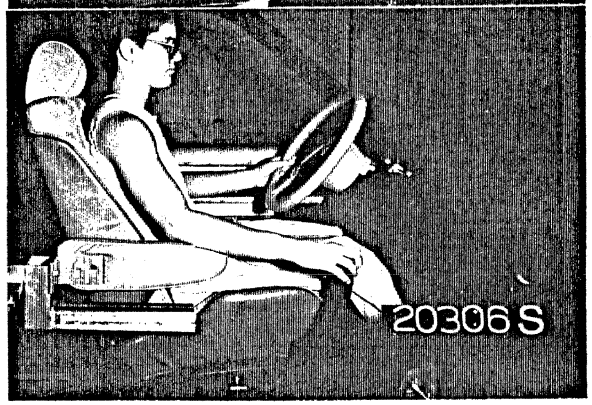

20305 G


20305 H


20305 S


20306 G


20306H


20306 S

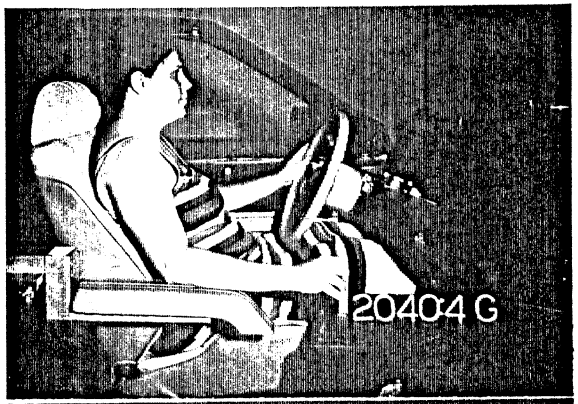

20307 G


20307 H


20307 S

20310 G
20310 H
20310 S
20309 G
20309 H
20309 S
20308 G
20308 H
20308 S

20401 G
20401 H
20401 S
20402 G
20402 H
20402 S
20403 G
20403 H
20403 S

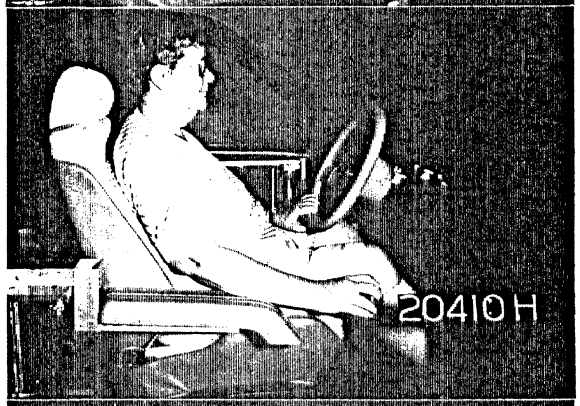


MISSING
20406 G

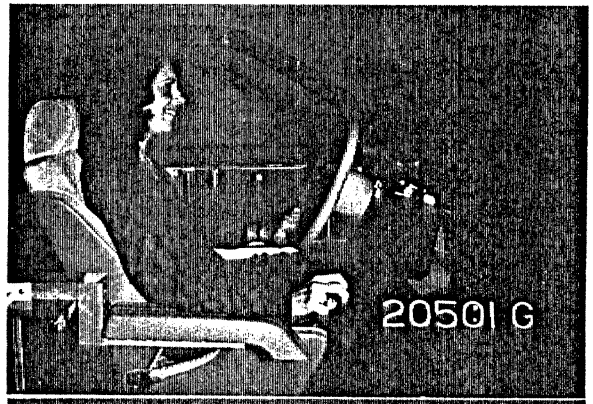
MISSING
20406 H

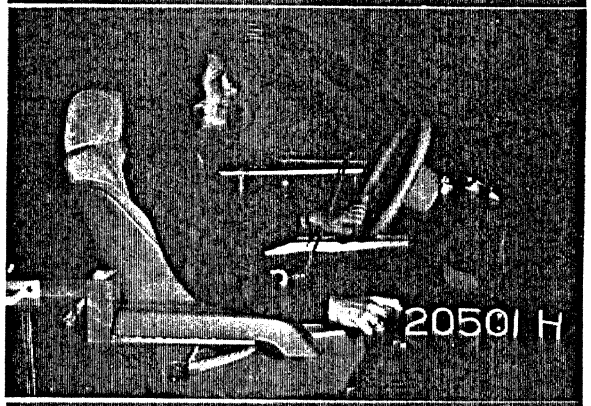
20409G
20409H
20409S
20408G
20408H
20408S
20407G
20407H
20407S

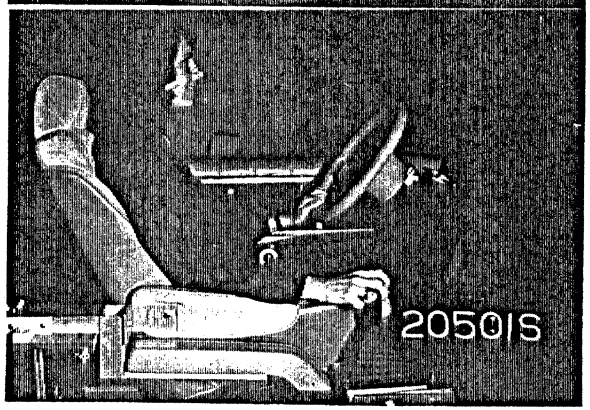

20410 G

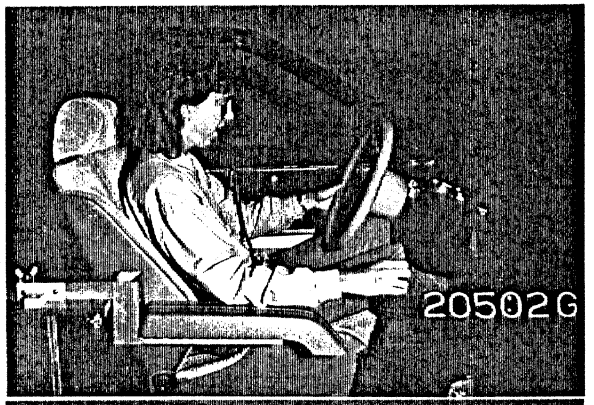

20410H

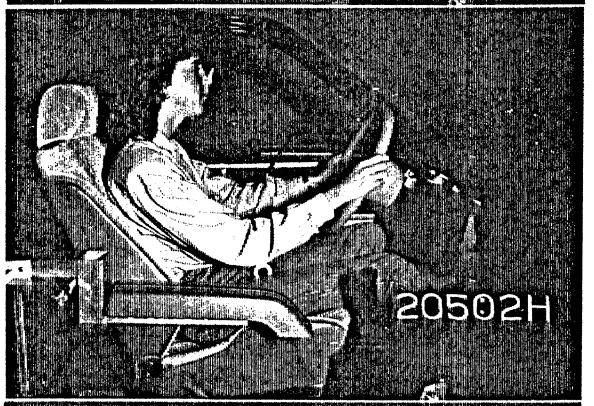

20410S

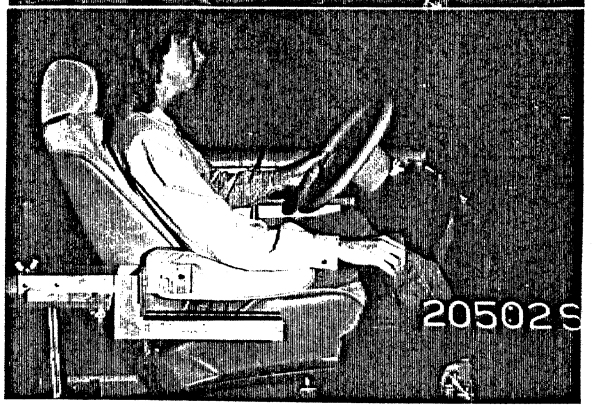

20501 G


20501 H


20501S


20502G


20502H


20502S

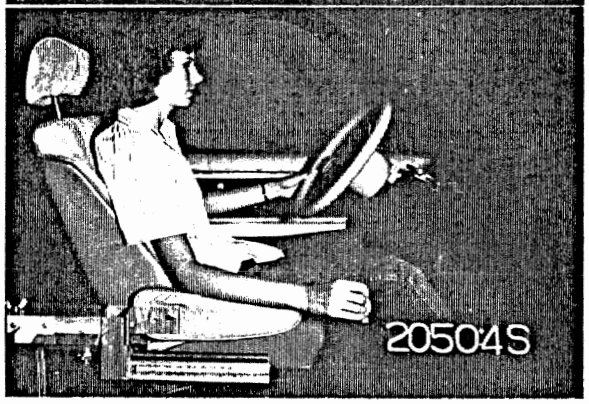

20503 G

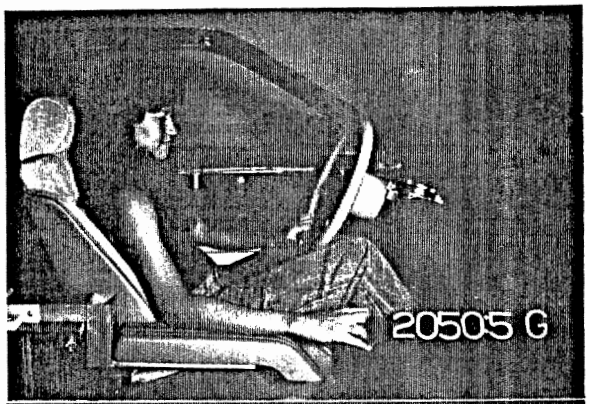

20503 H

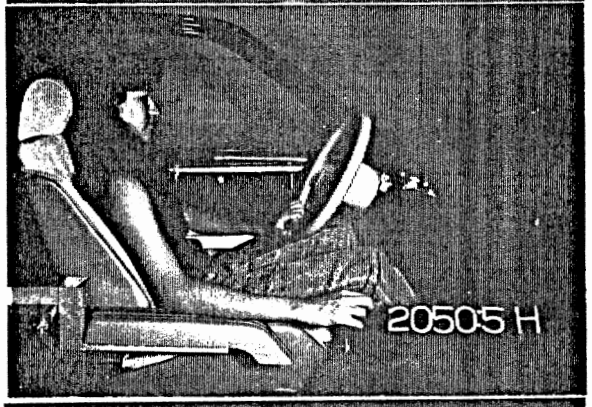

20503 S

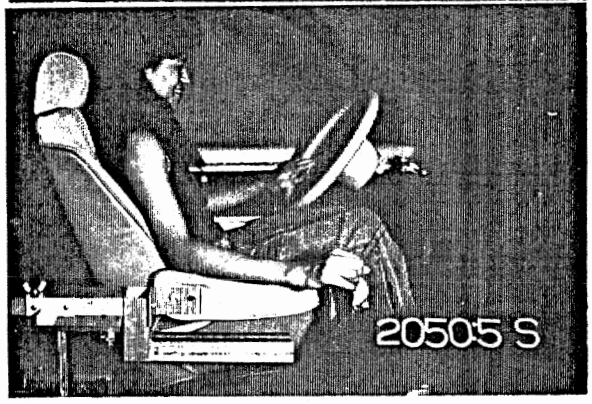

20504 G

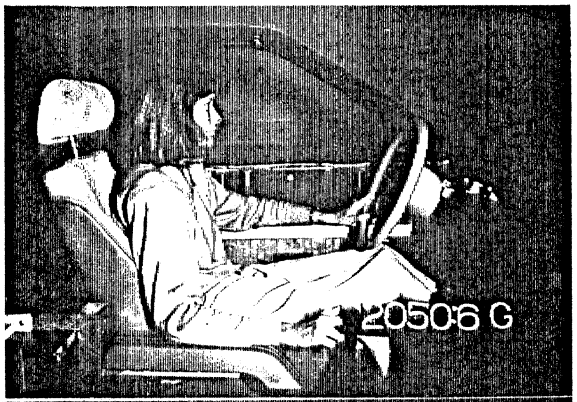

20504 H


20504S

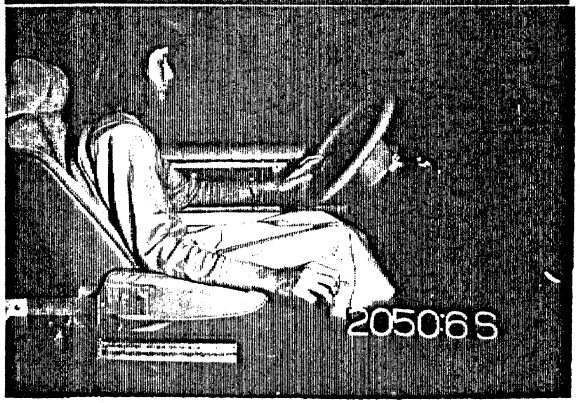

20505 G

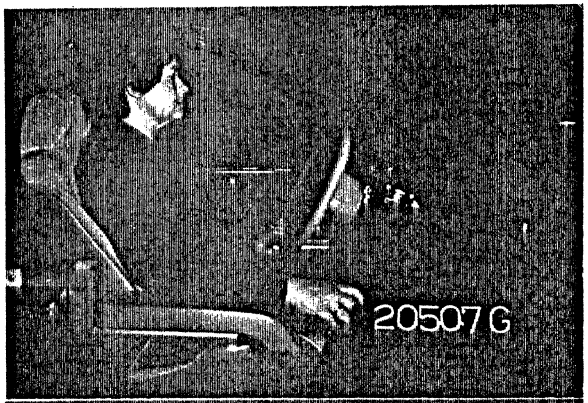

20505 H

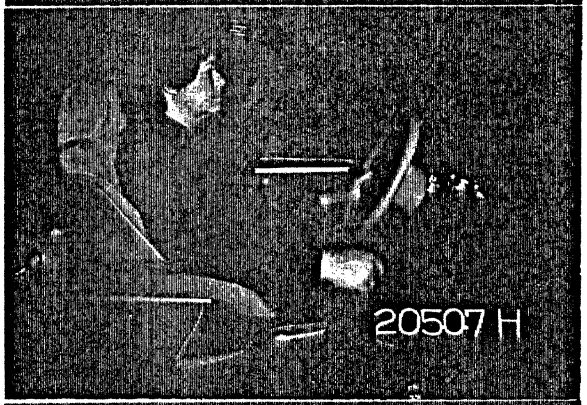

20505 S

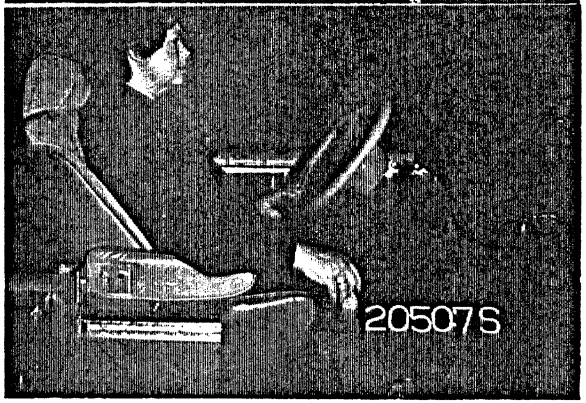

20506 G


20506 H

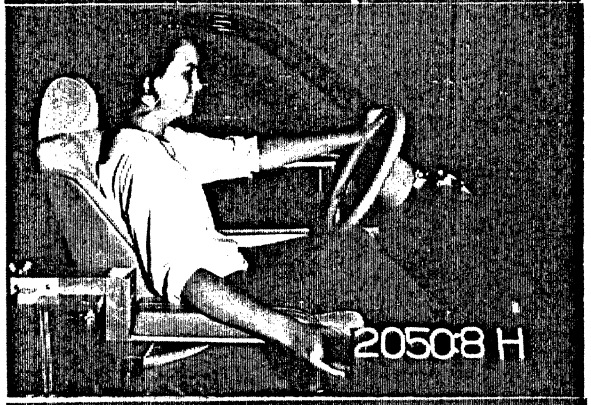

20506 S


20507 G

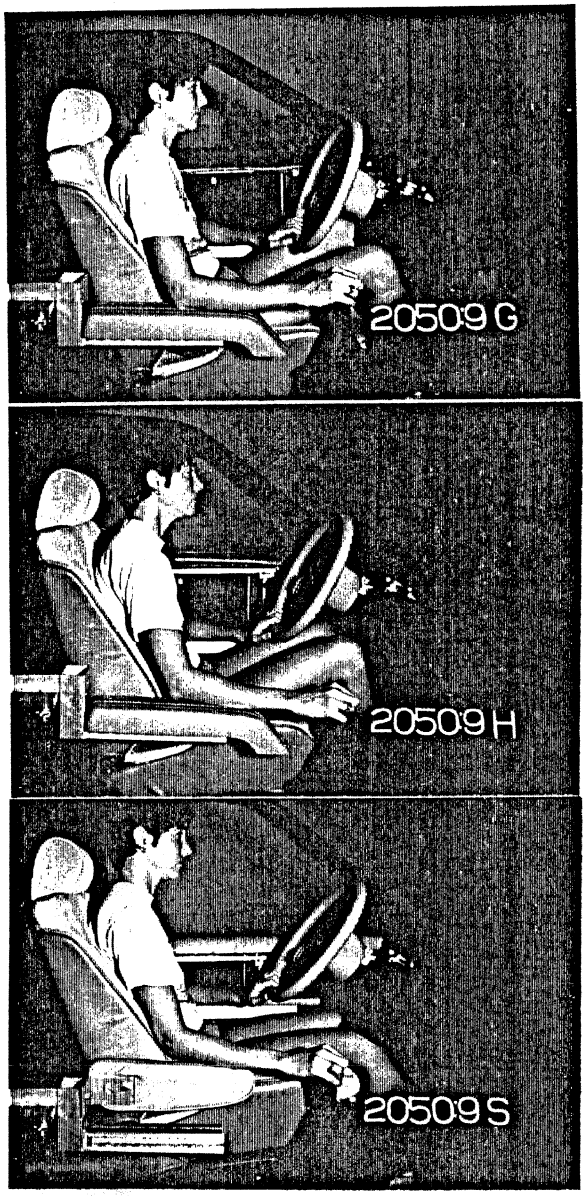

20507 H

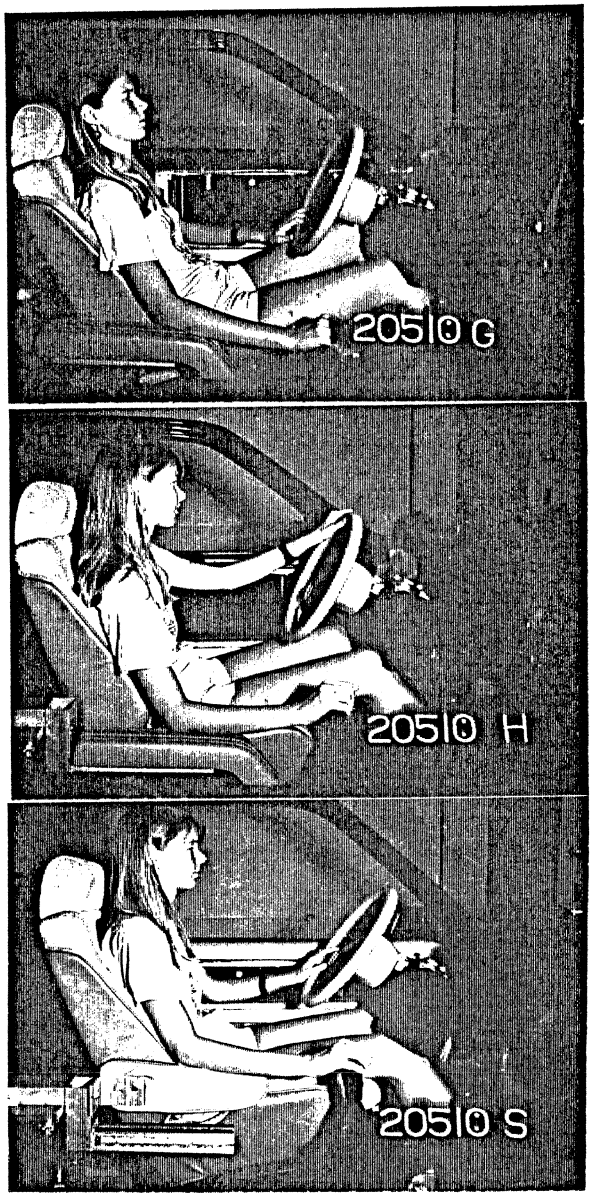

20507 S

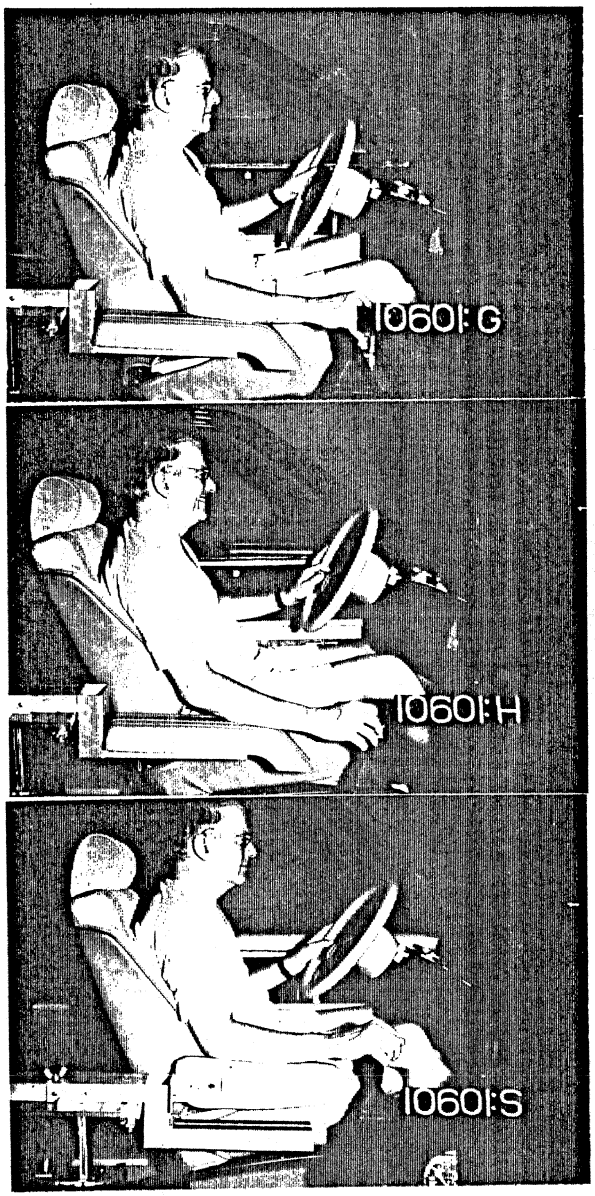

20508 G

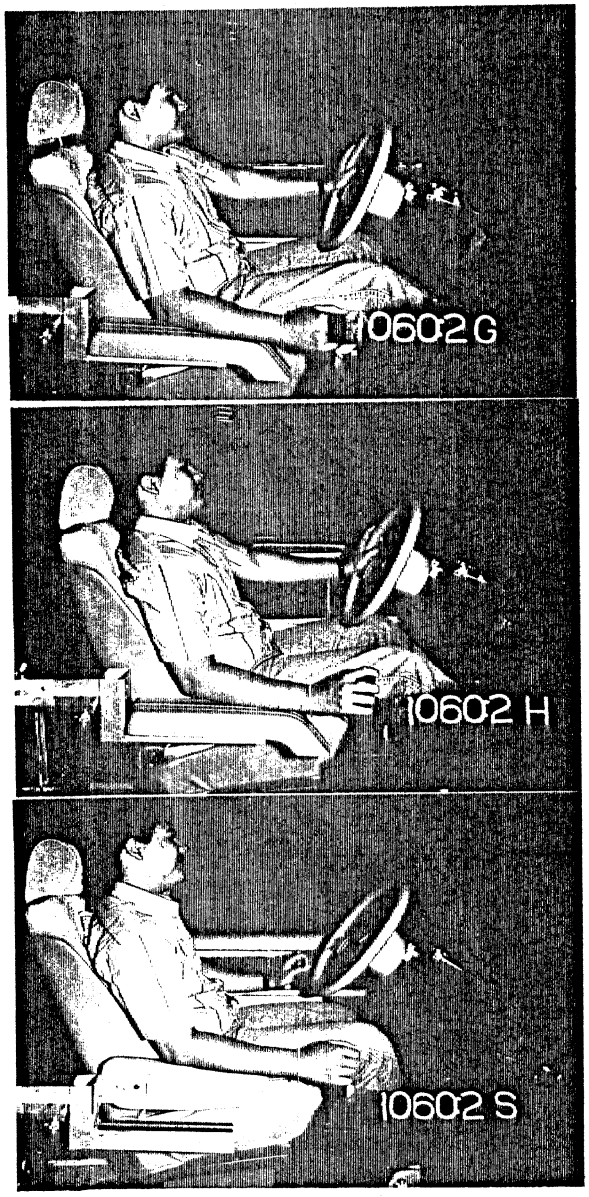

20508 H

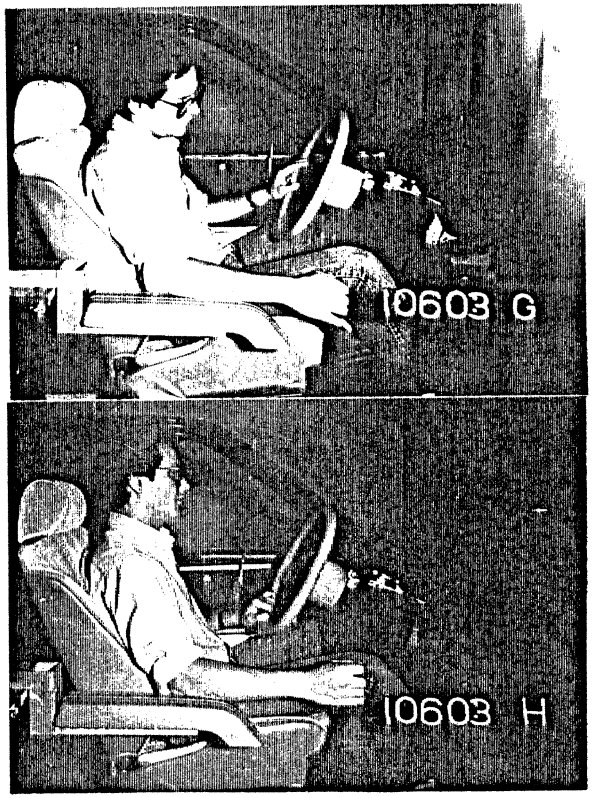

20508 S


20509 G
20509 H
20509 S

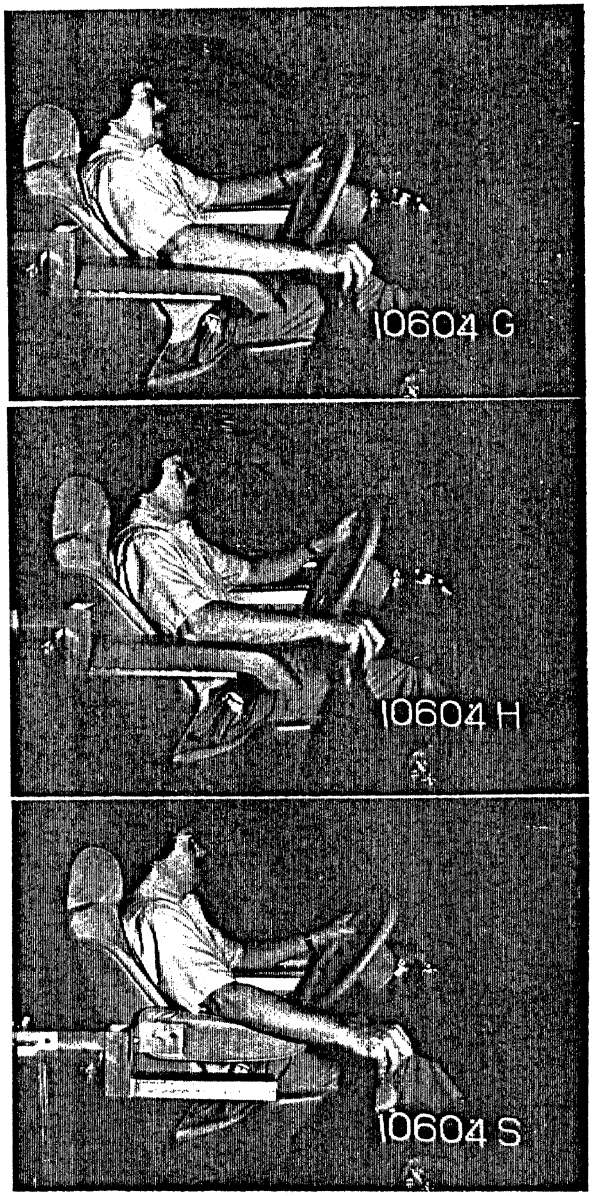

20510 G
20510 H
20510 S

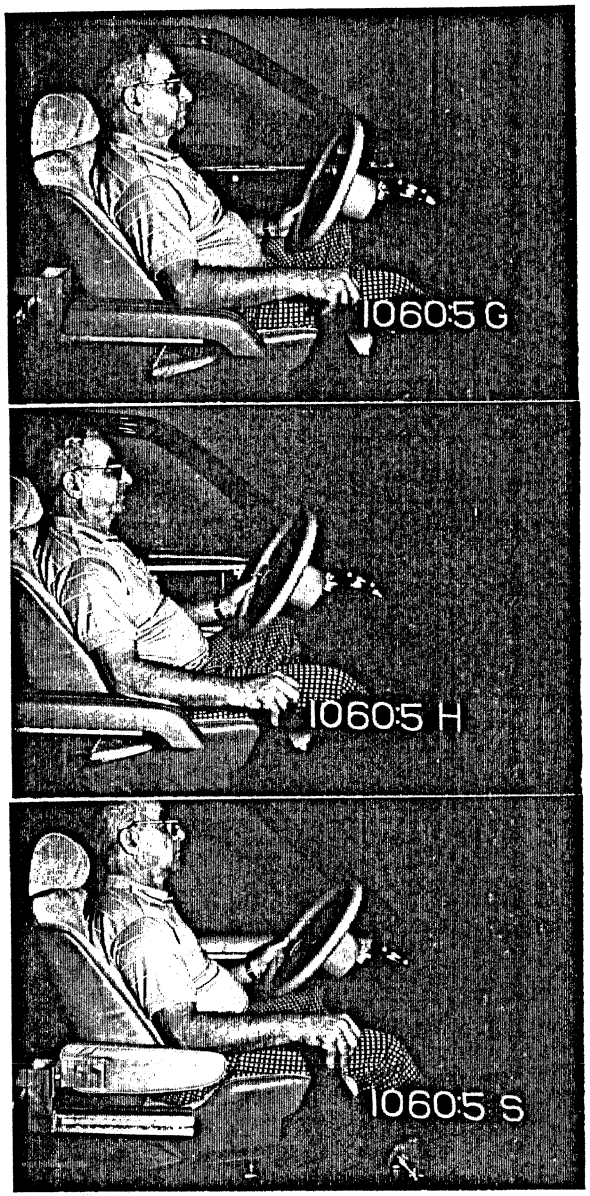

10601: G
10601: H
10601: S

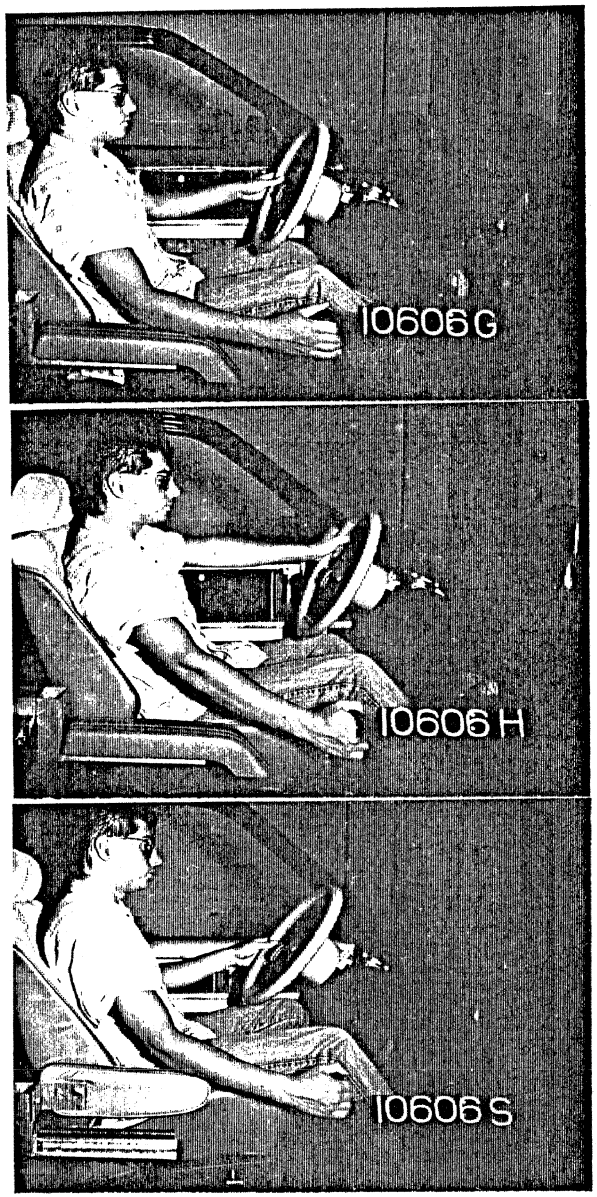


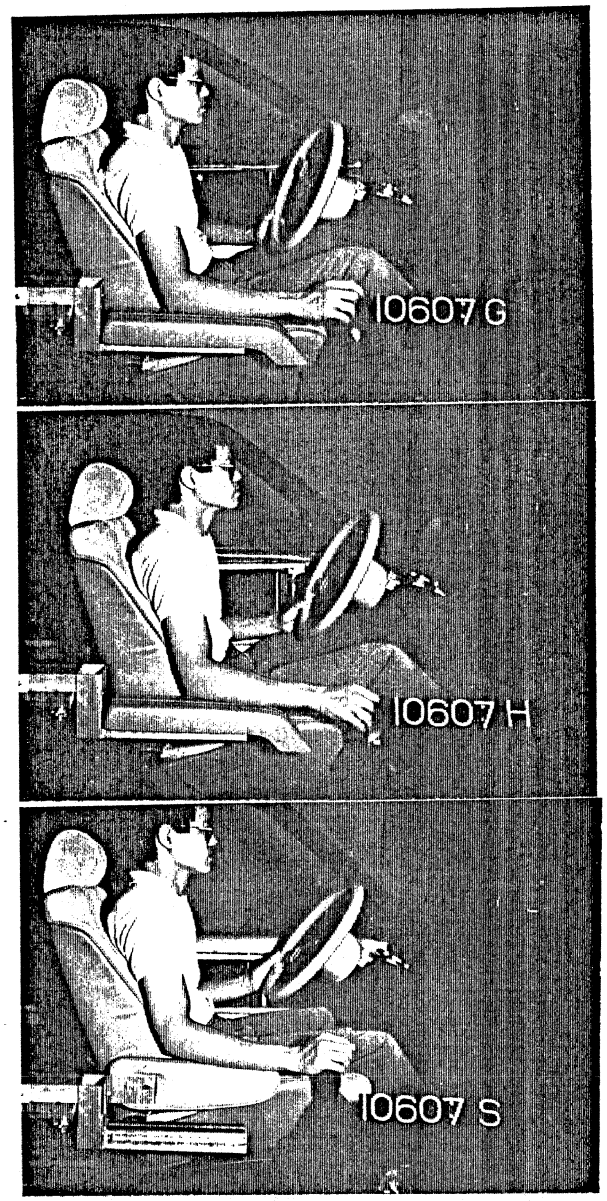


MISSING
10603 S

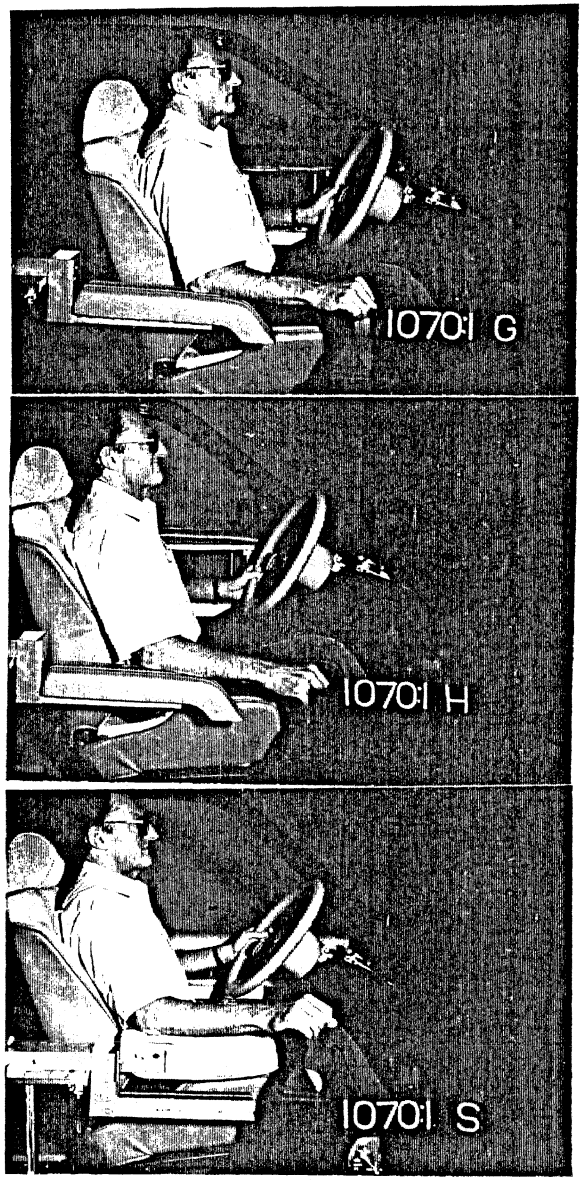


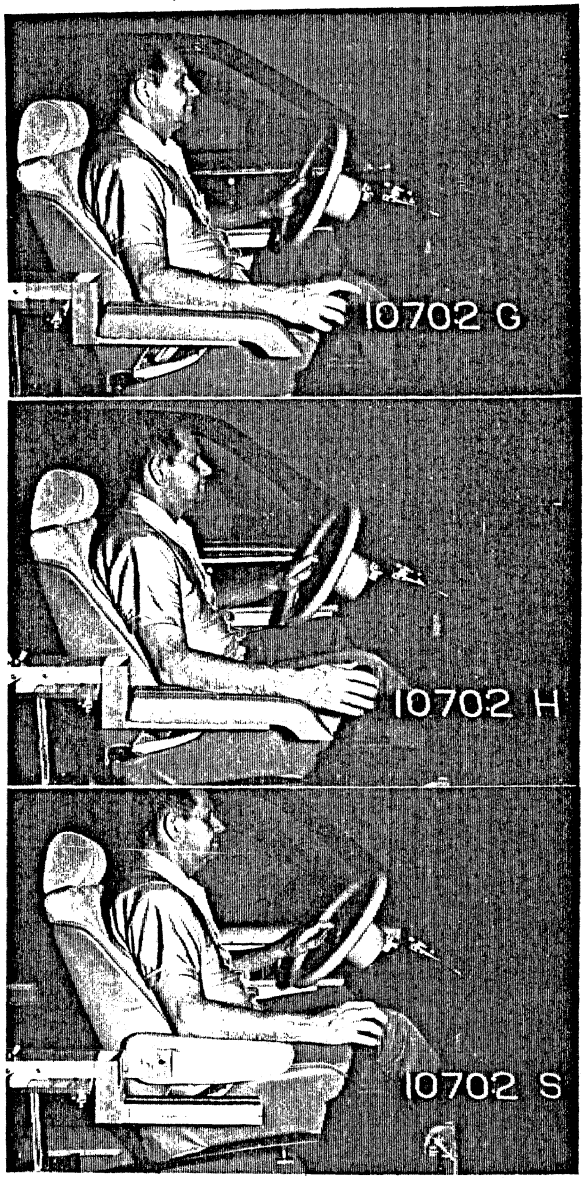

10605 G
10605 H
10605 S

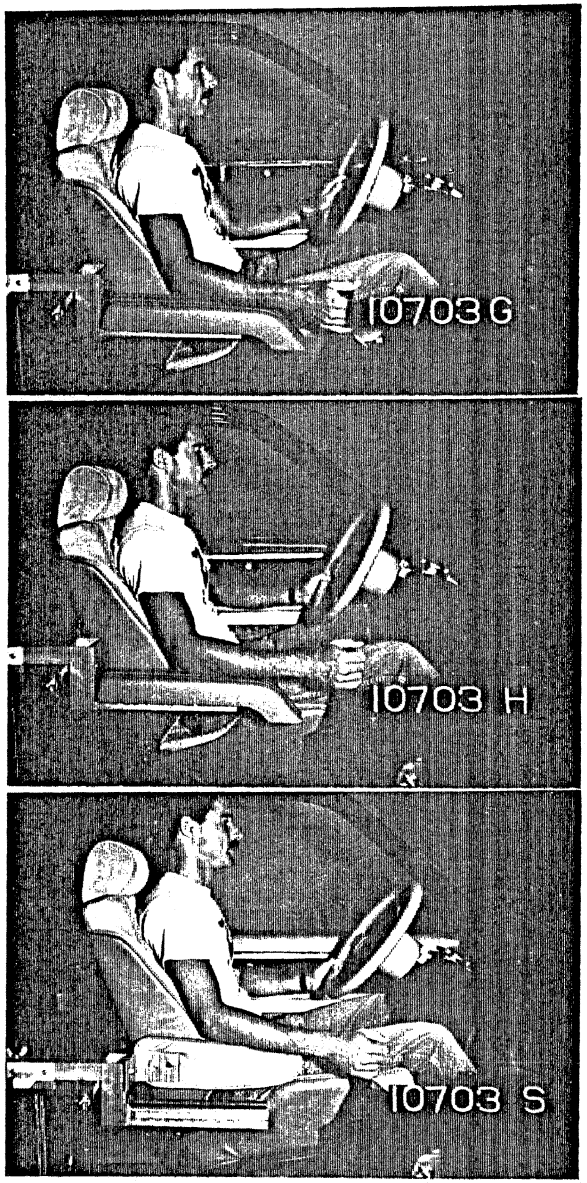

10606 G
10606 H
10606 S

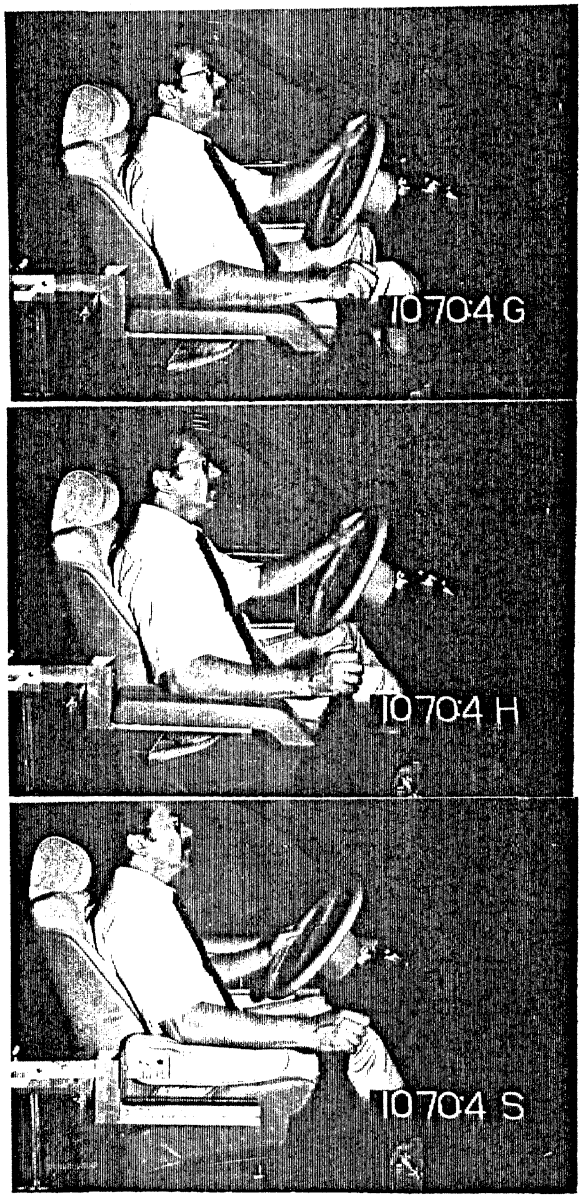

10607 G
10607 H
10607 S

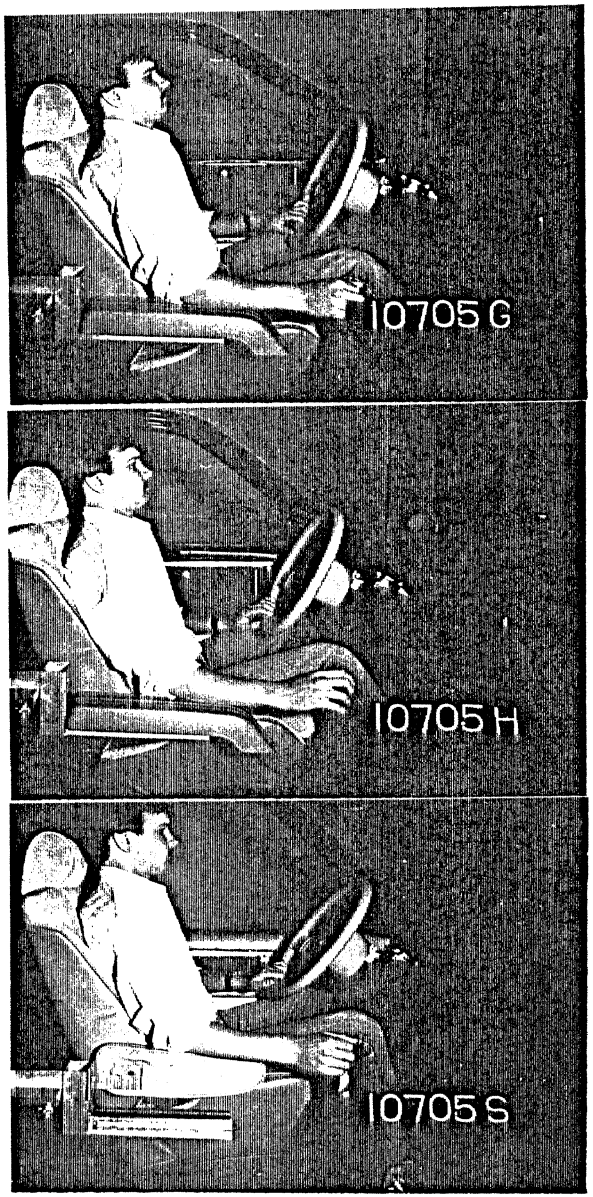
G 01901
H 01901
S 01901
G 06901
H 06901
S 06901
G 08901
H 08901
S 08901

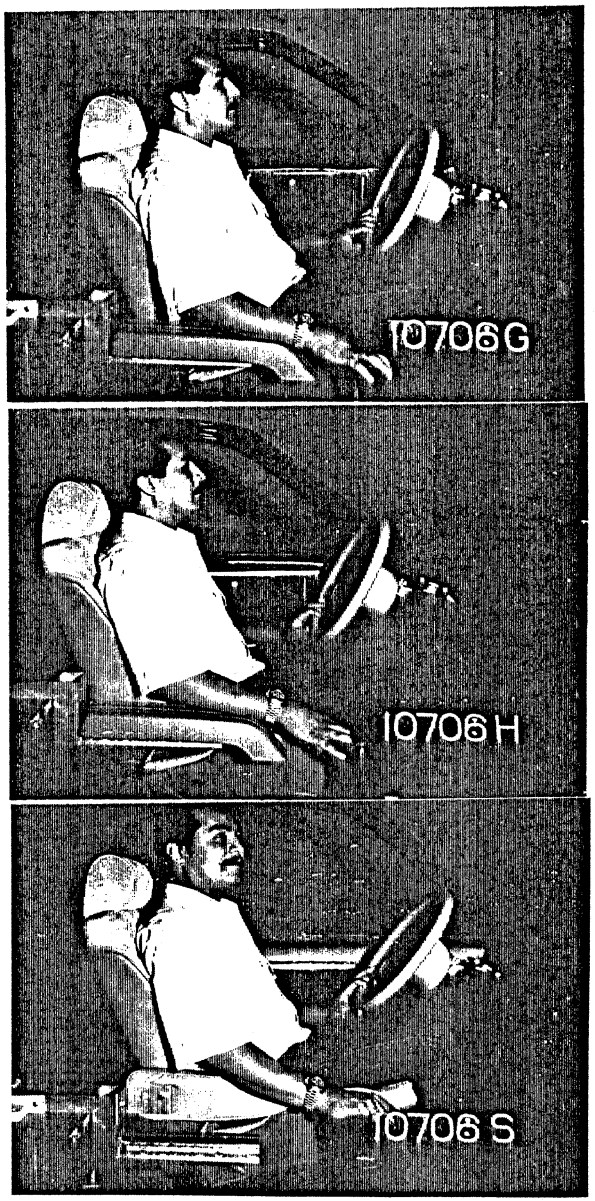

10701 G
10701 H
10701 S


10702 G
10702 H
10702 S


10703 G
10703 H
10703 S


10704 G
10704 H
10704 S

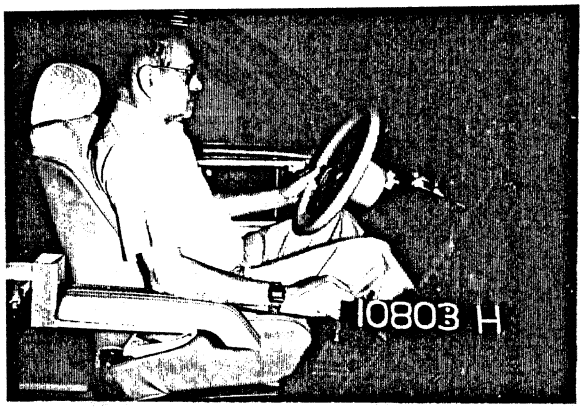

10705 G
10705 H
10705 S


10706 G
10706 H
10706 S

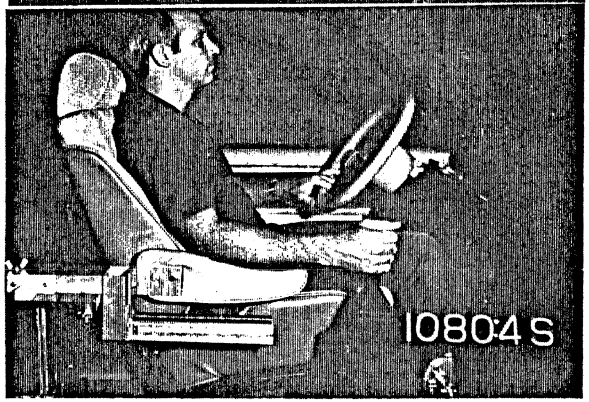
10707G
10707H
10707S
10708G
10708H
10708S
10709G
10709H
10709S

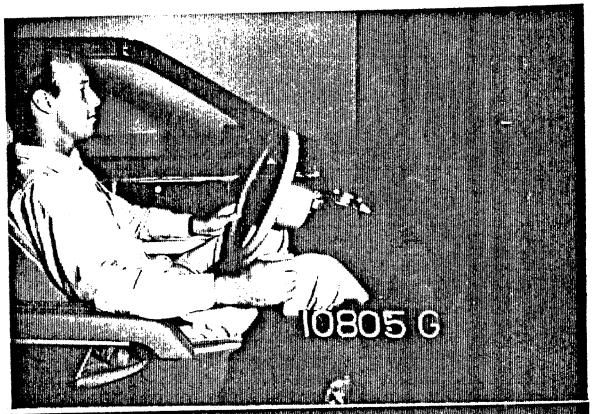
10802 G
10802 H
10802 S
10801 G
10801 H
10801 S
10710 G
10710 H
10710 S

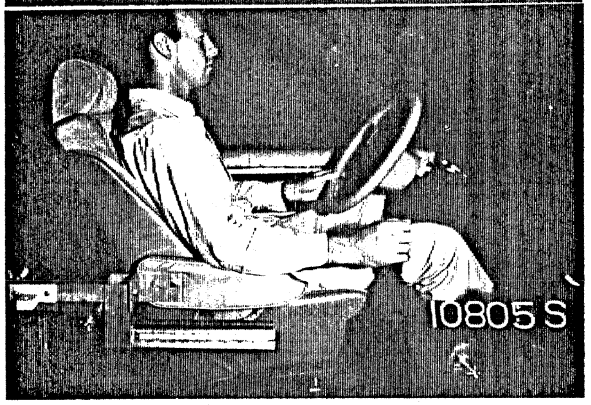
MISSING
10803 G



MISSING
10803 S








10806 G


10806 H

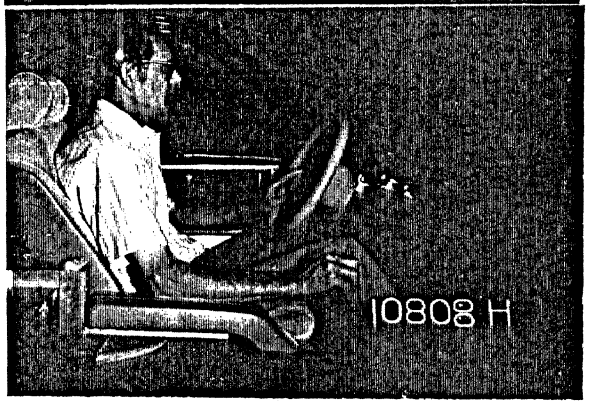

10806 S

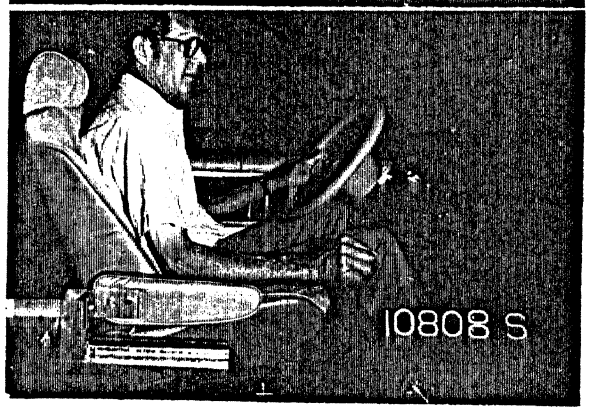

10807 G


10807 H


10807 S

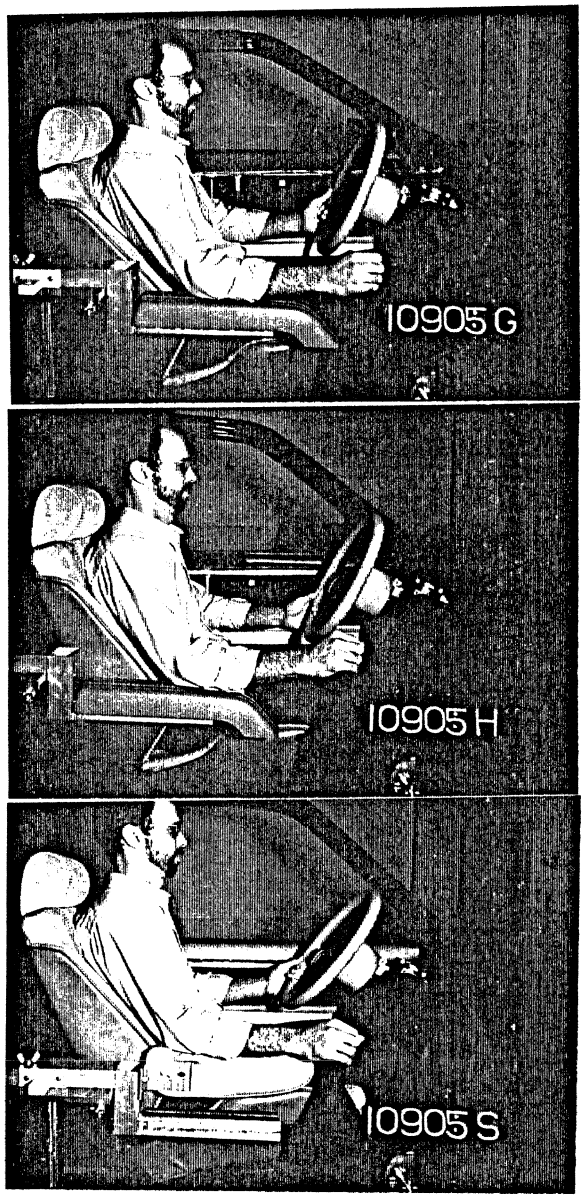

10808 G

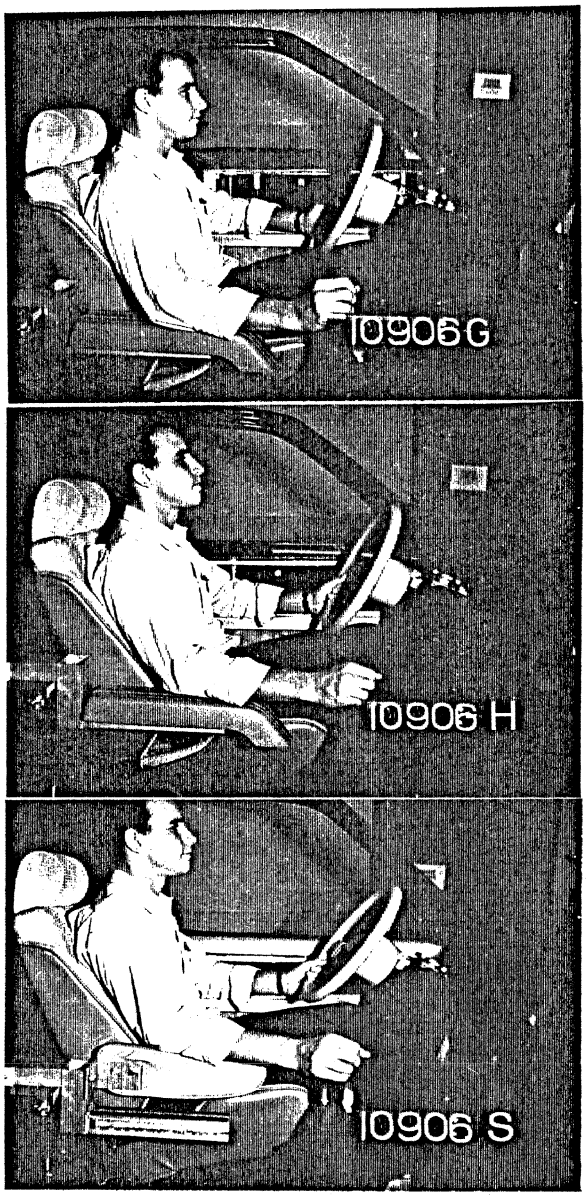

10808 H

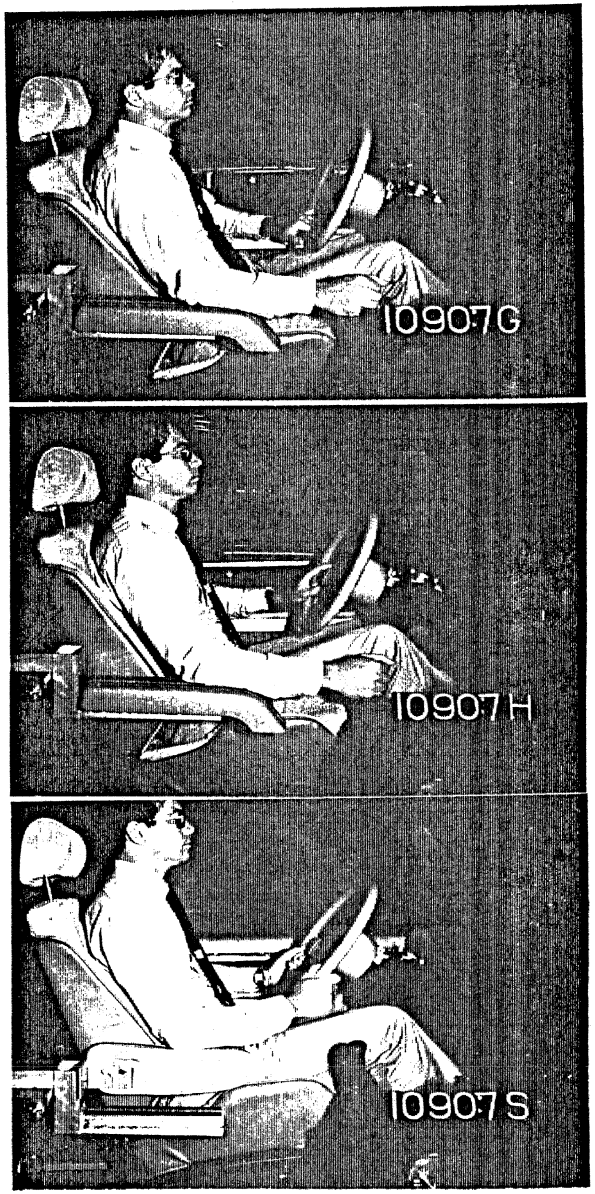

10808 S

10809 G
10809 H
10809 S
10810 G
10810 H
10810 S
10901 G
10901 H
10901 S

10902 G
10902 H
10902 S
10903 G
10903 H
10903 S
10904 G
10904 H
10904 S


10905 G
10905 H
10905 S

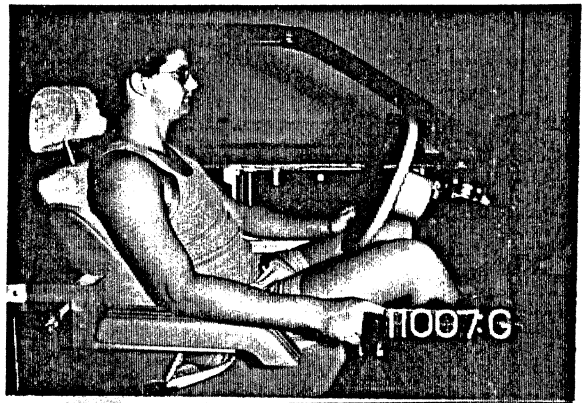

10906 G
10906 H
10906 S

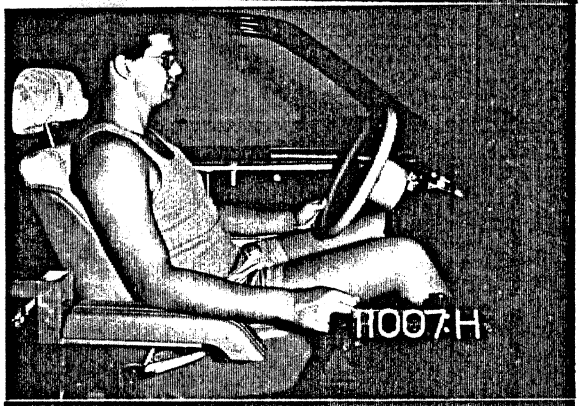

10907 G
10907 H
10907 S

G 1010
H 1010
S 1010
G 1009
H 1009
S 1009
G 1008
H 1008
S 1008

110G1: G
110G1: H
110G1: S
110G2 G
110G2 H
110G2 S
110G3 G
110G3 H
110G3 S

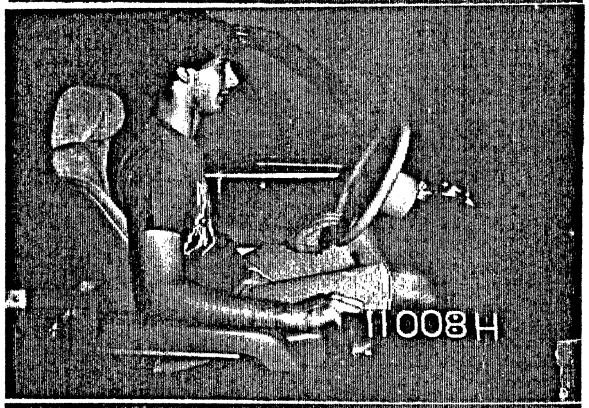
11006 G
11006 H
11006 S
11005G
11005 H
11005 S
11004 G
11004H
11004S

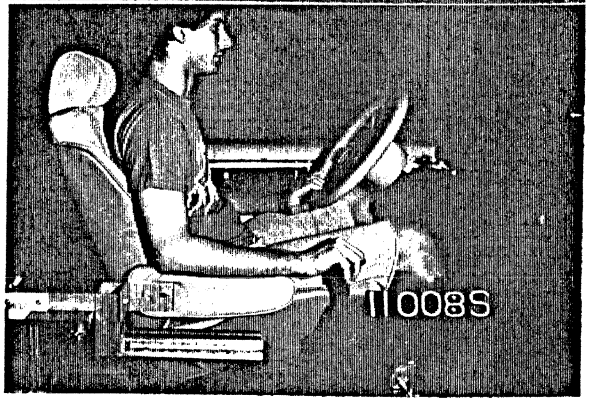

11007G


11007H

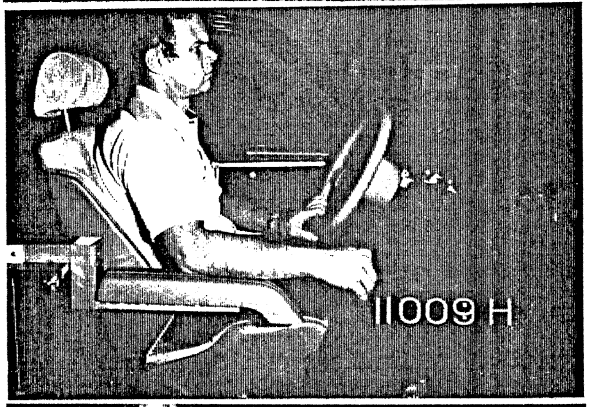

11007S

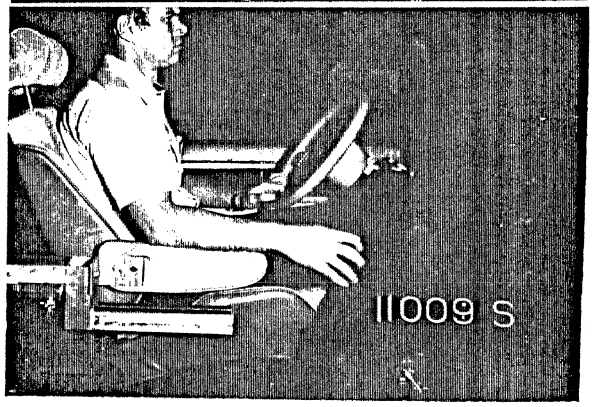

11008G


11008H


11008S


11009G


11009H


11009S

G:0101
H :0101
S:0101

APPENDIX D
SEAT POSITION RESULTS

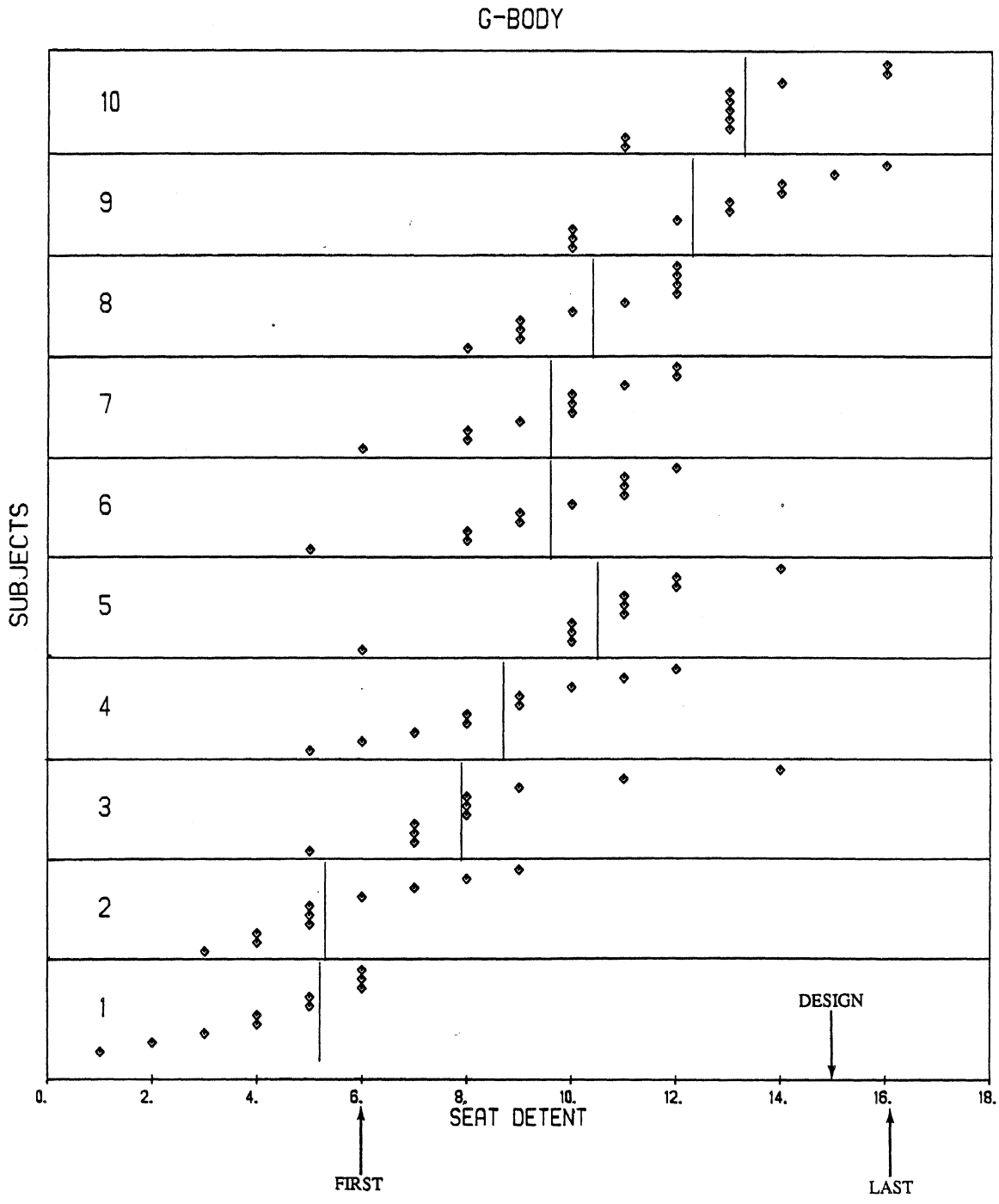

G-BODY
10
9
8
7
6
5
4
3
2
1
SUBJECTS
DESIGN
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SEAT DETENT
FIRST
LAST

Figure D-1

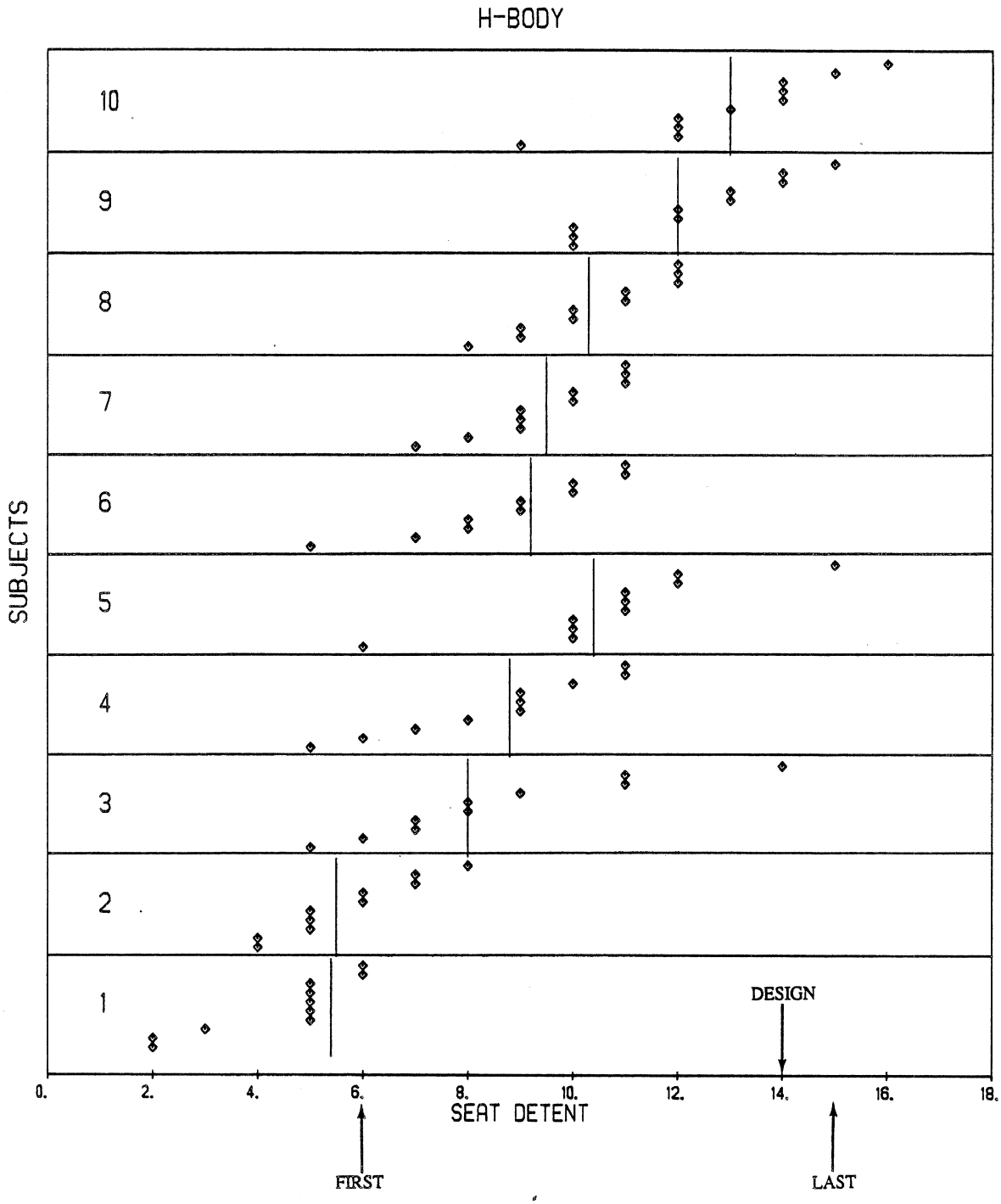

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SEAT DETENT
DESIGN
FIRST
LAST

Figure D-2

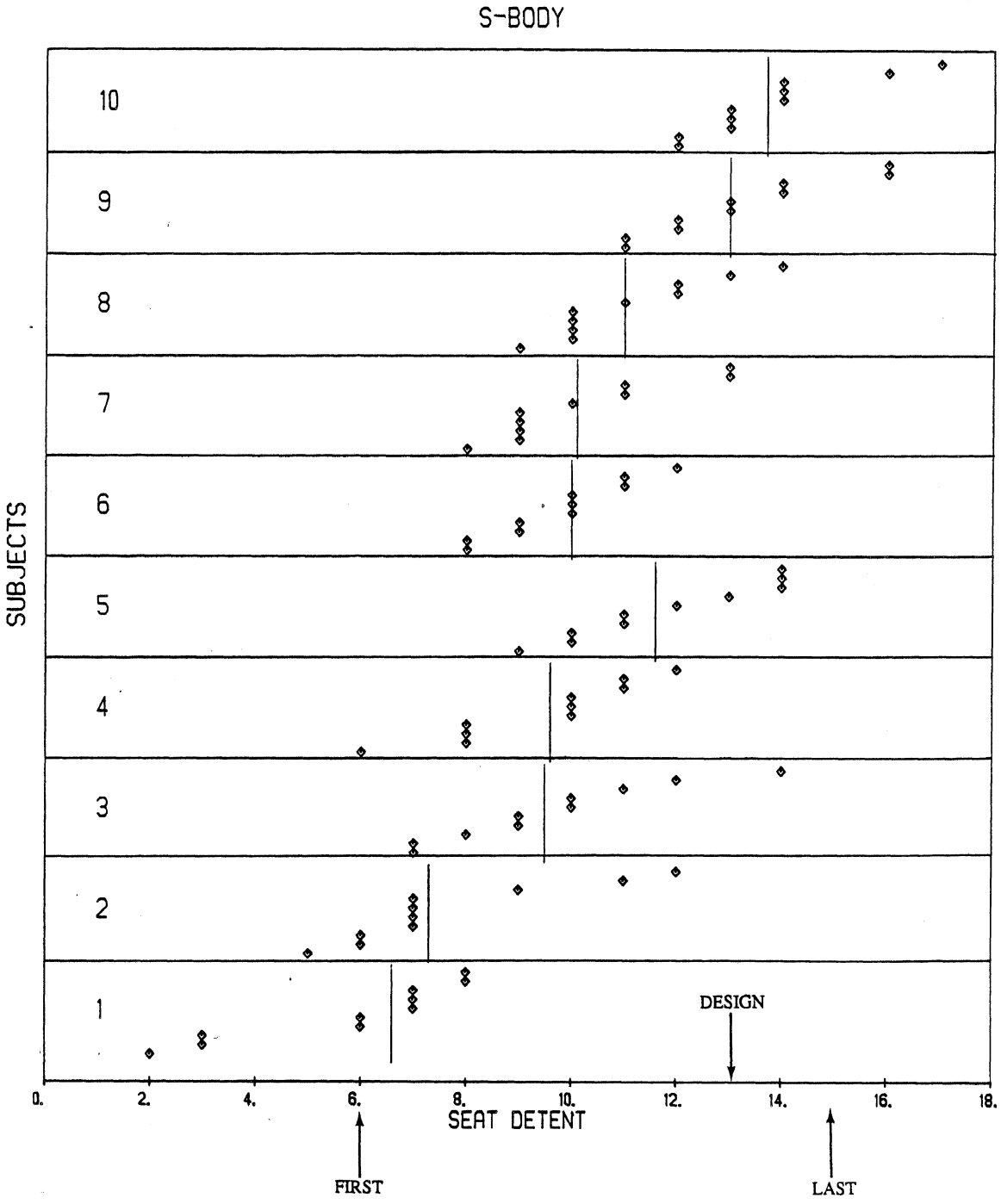

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
DESIGN
0.
2.
4.
6.
8.
10.
12.
14.
16.
18.
SEAT DETENT
FIRST
LAST

Figure D-3

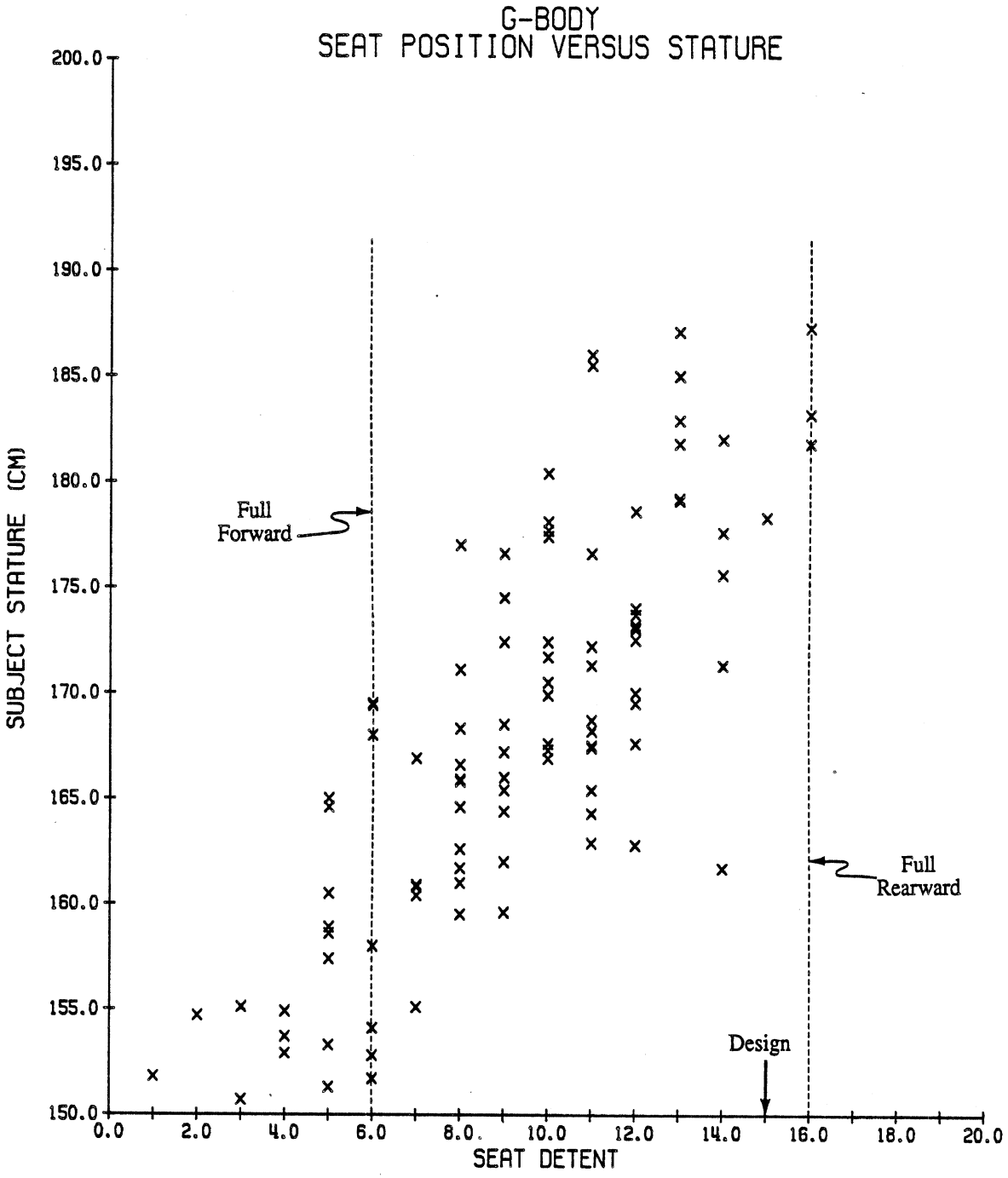

G-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
Full
Forward
Full
Rearward
Design
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SEAT DETENT

Figure D-4

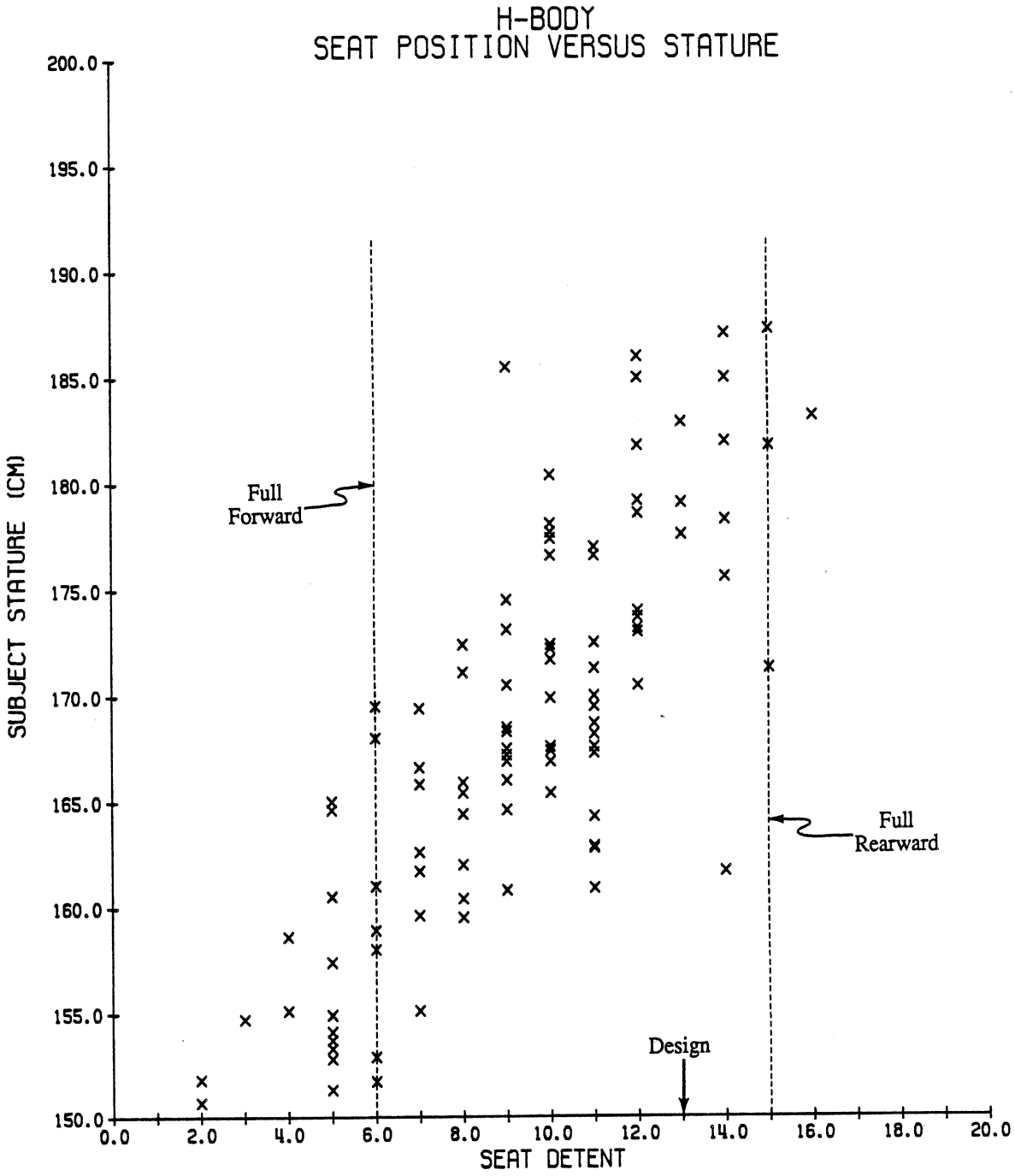

H-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SEAT DETENT
Full Forward
Full Rearward
Design

Figure D-5

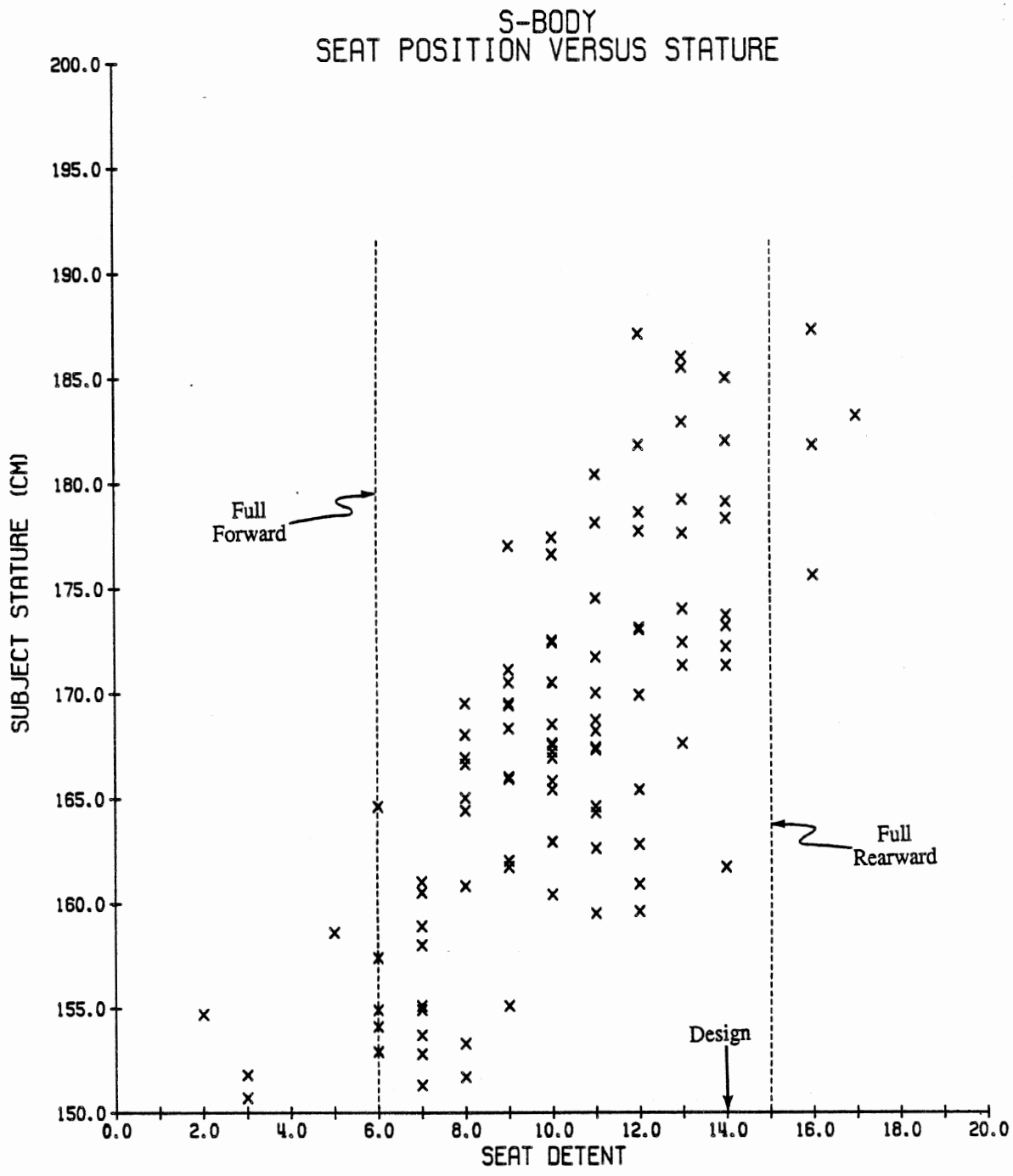

S-BODY
SEAT POSITION VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
SEAT DETENT
Full Forward
Full Rearward
Design

Figure D-6

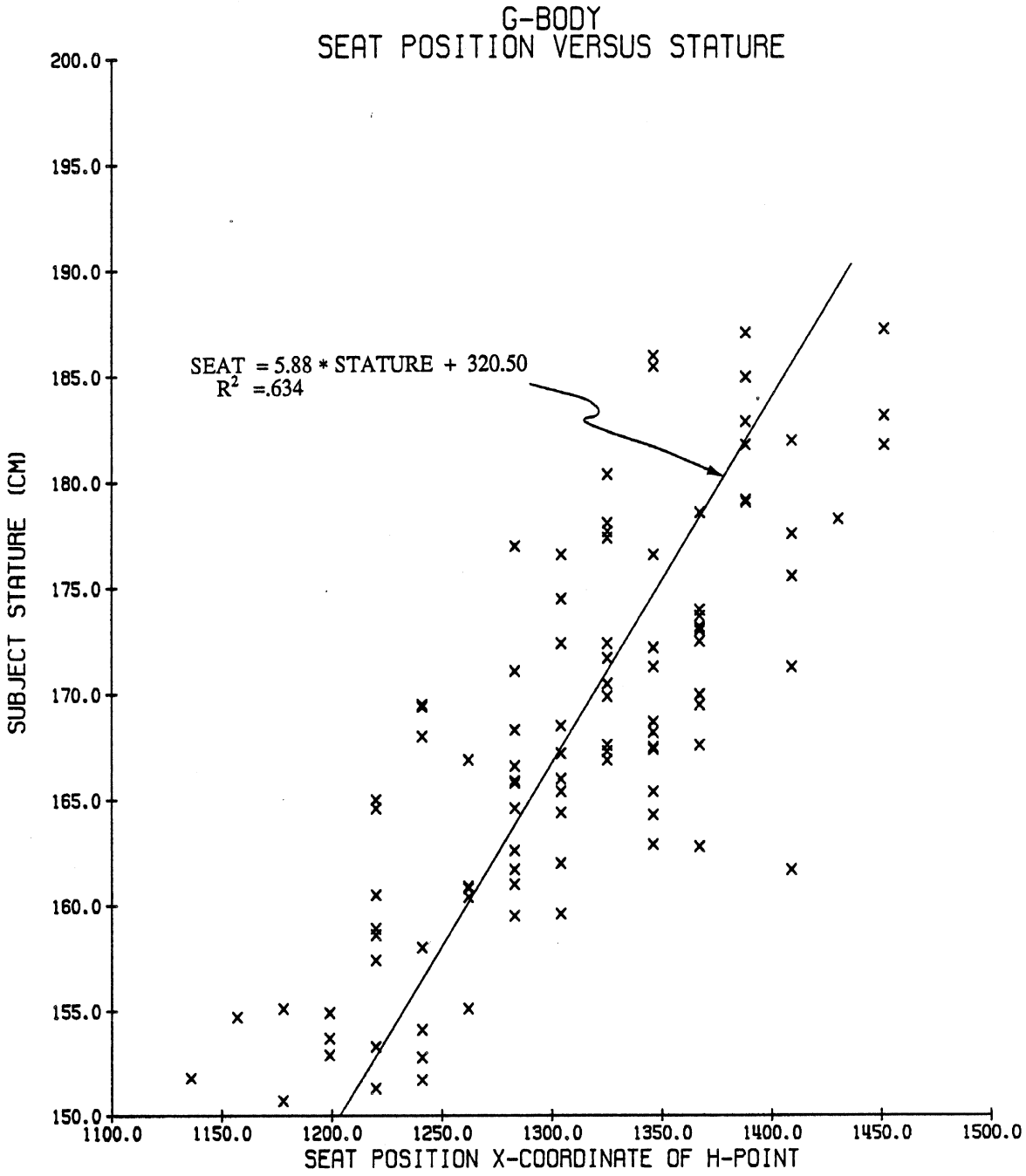

G-BODY
SEAT POSITION VERSUS STATURE
SEAT = 5.88 * STATURE + 320.50
R² =.634
SUBJECT STATURE (CM)
SEAT POSITION X-COORDINATE OF H-POINT
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0

Figure D-7

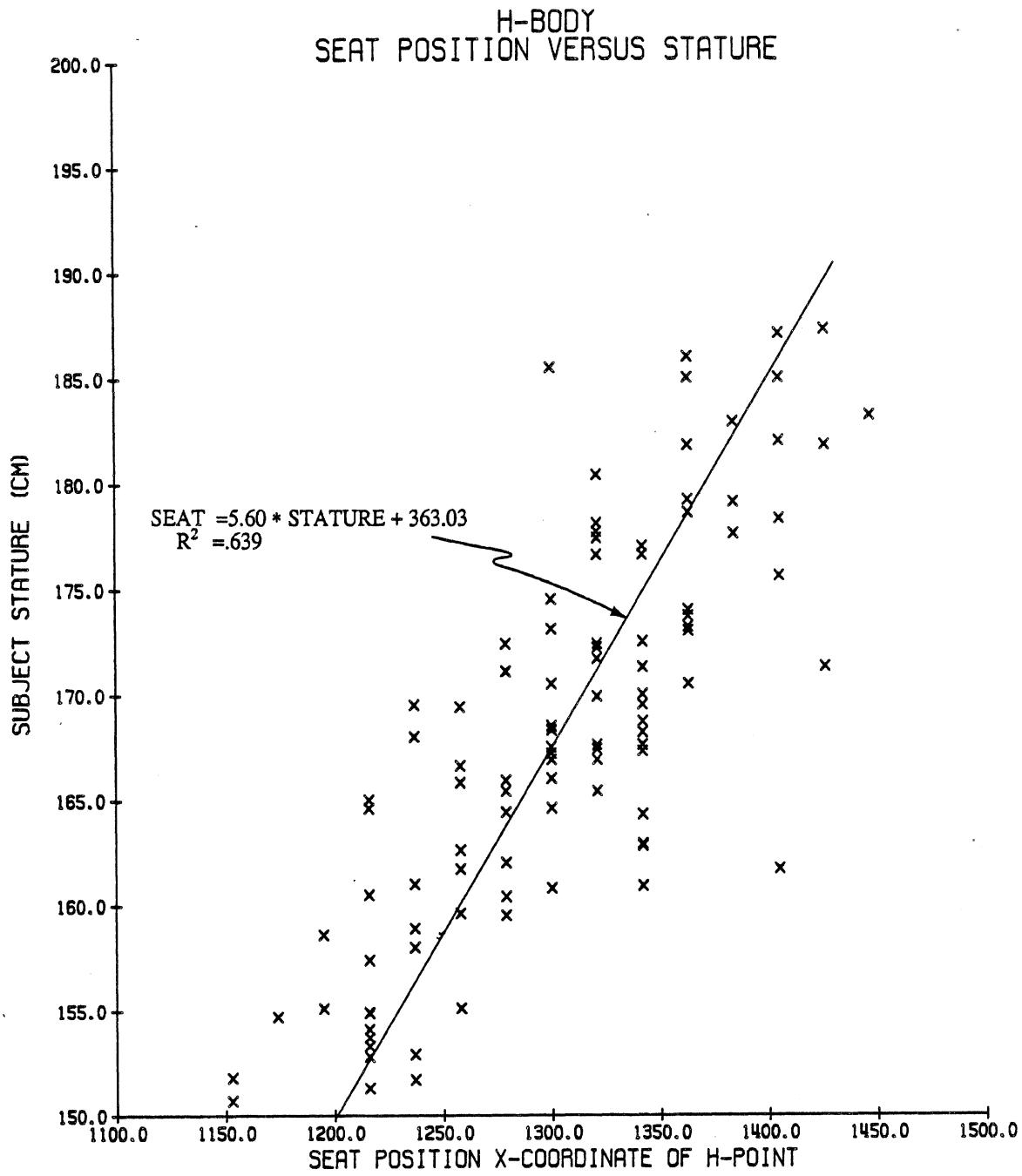

H-BODY
SEAT POSITION VERSUS STATURE
SEAT =5.60 * STATURE + 363.03
R² =.639
SUBJECT STATURE (CM)
SEAT POSITION X-COORDINATE OF H-POINT
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0

Figure D-8

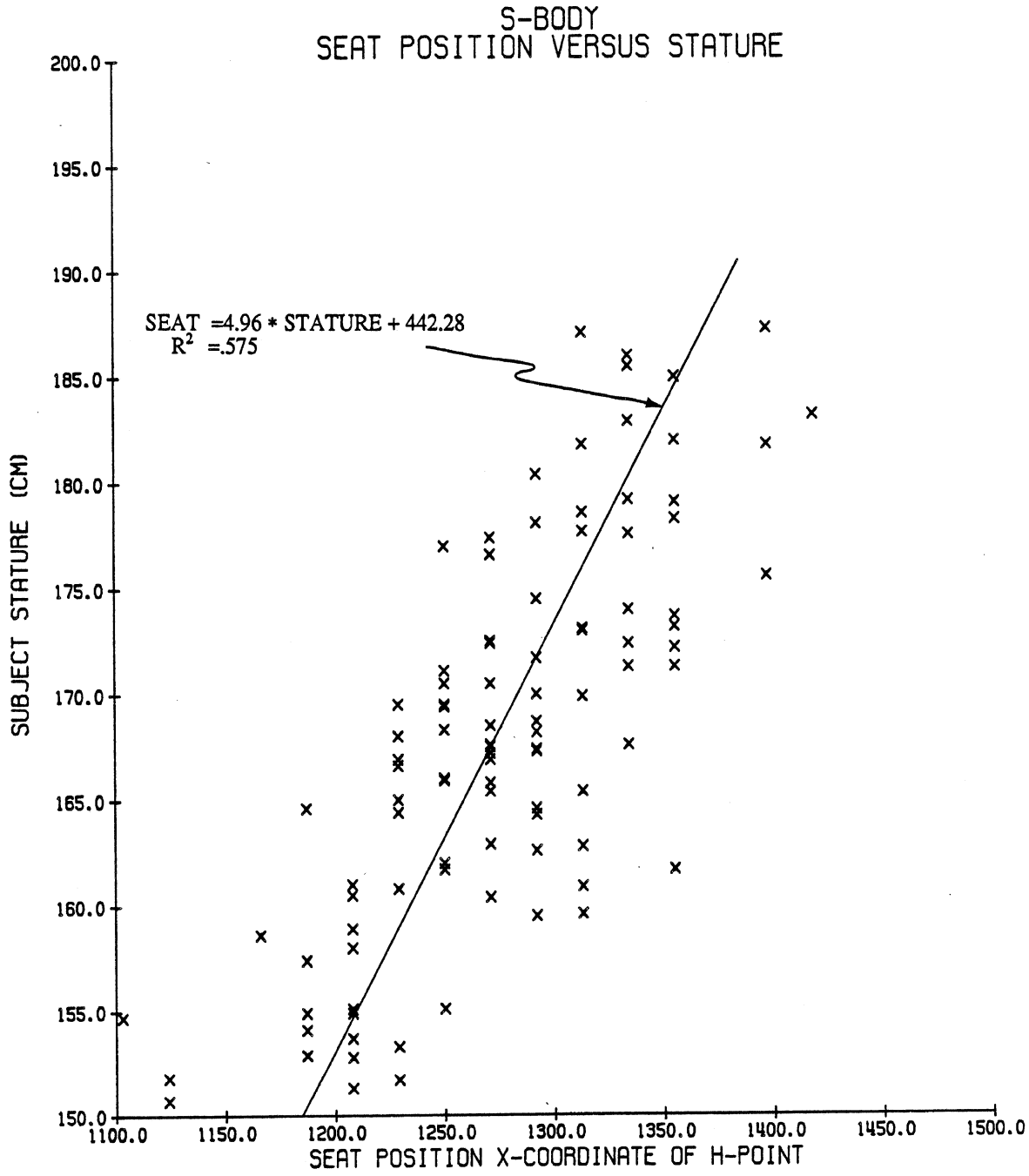

S-BODY
SEAT POSITION VERSUS STATURE
SEAT =4.96 * STATURE + 442.28
R² =.575
SUBJECT STATURE (CM)
SEAT POSITION X-COORDINATE OF H-POINT
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
1100.0
1150.0
1200.0
1250.0
1300.0
1350.0
1400.0
1450.0
1500.0

Figure D-9

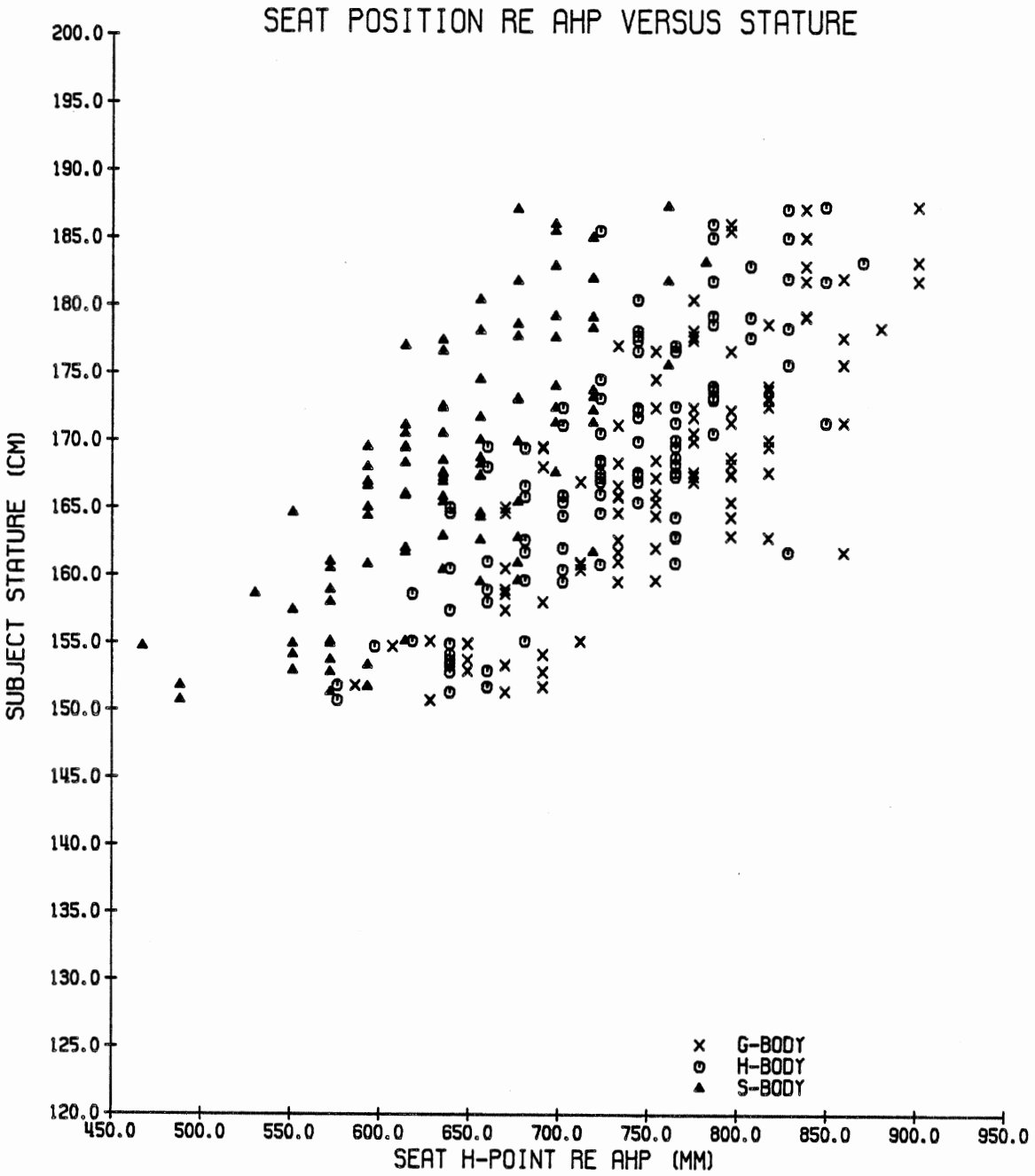
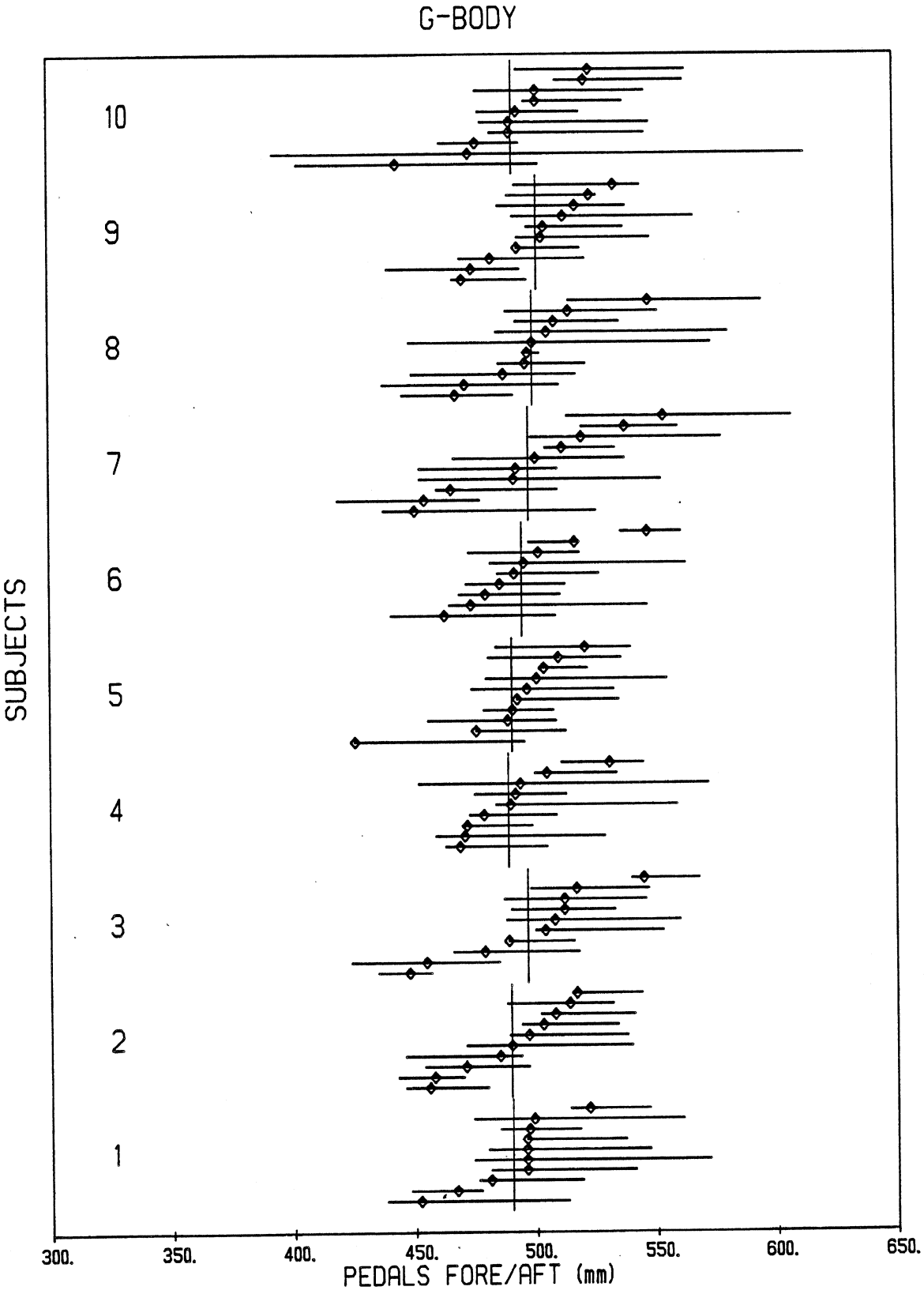
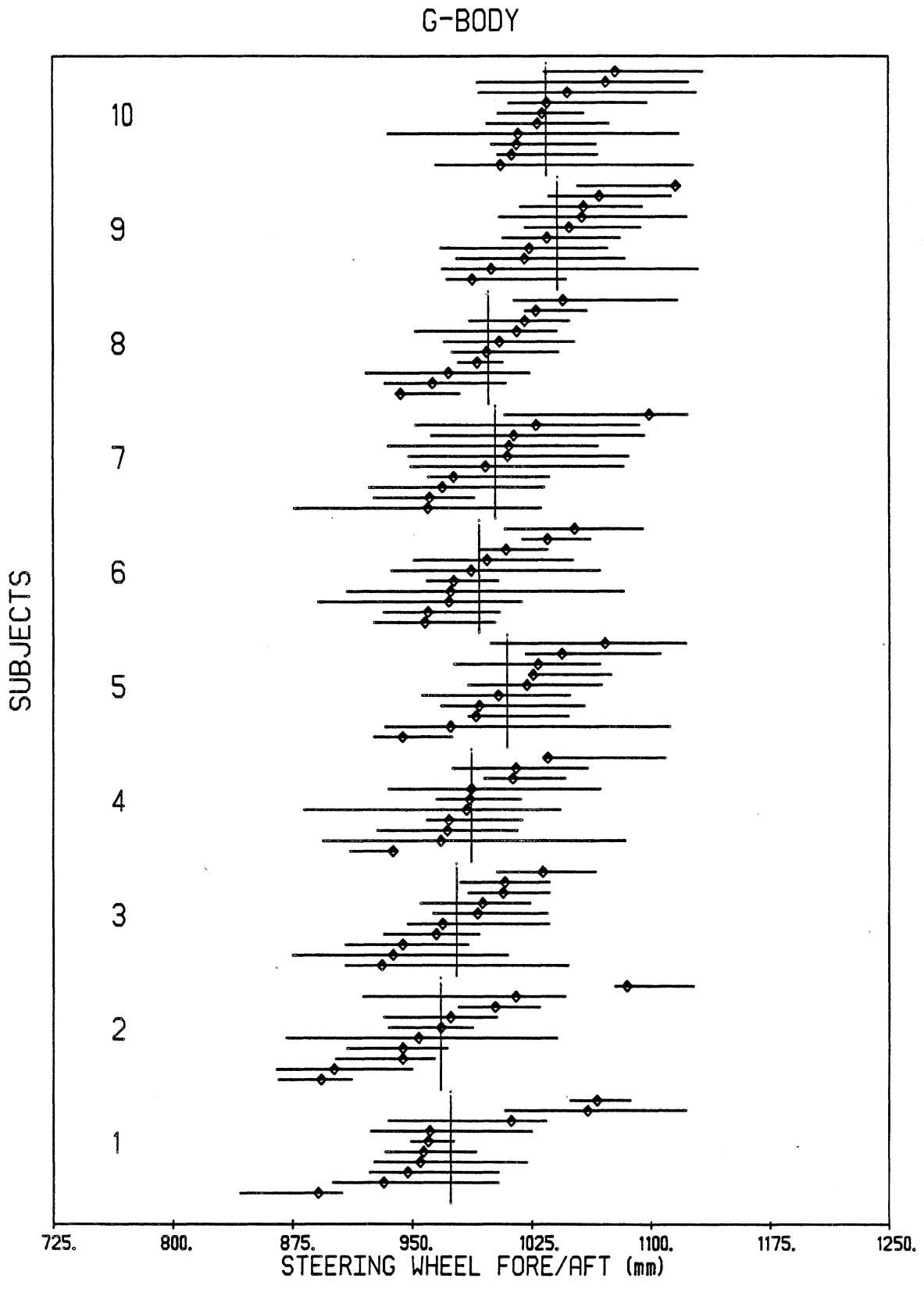
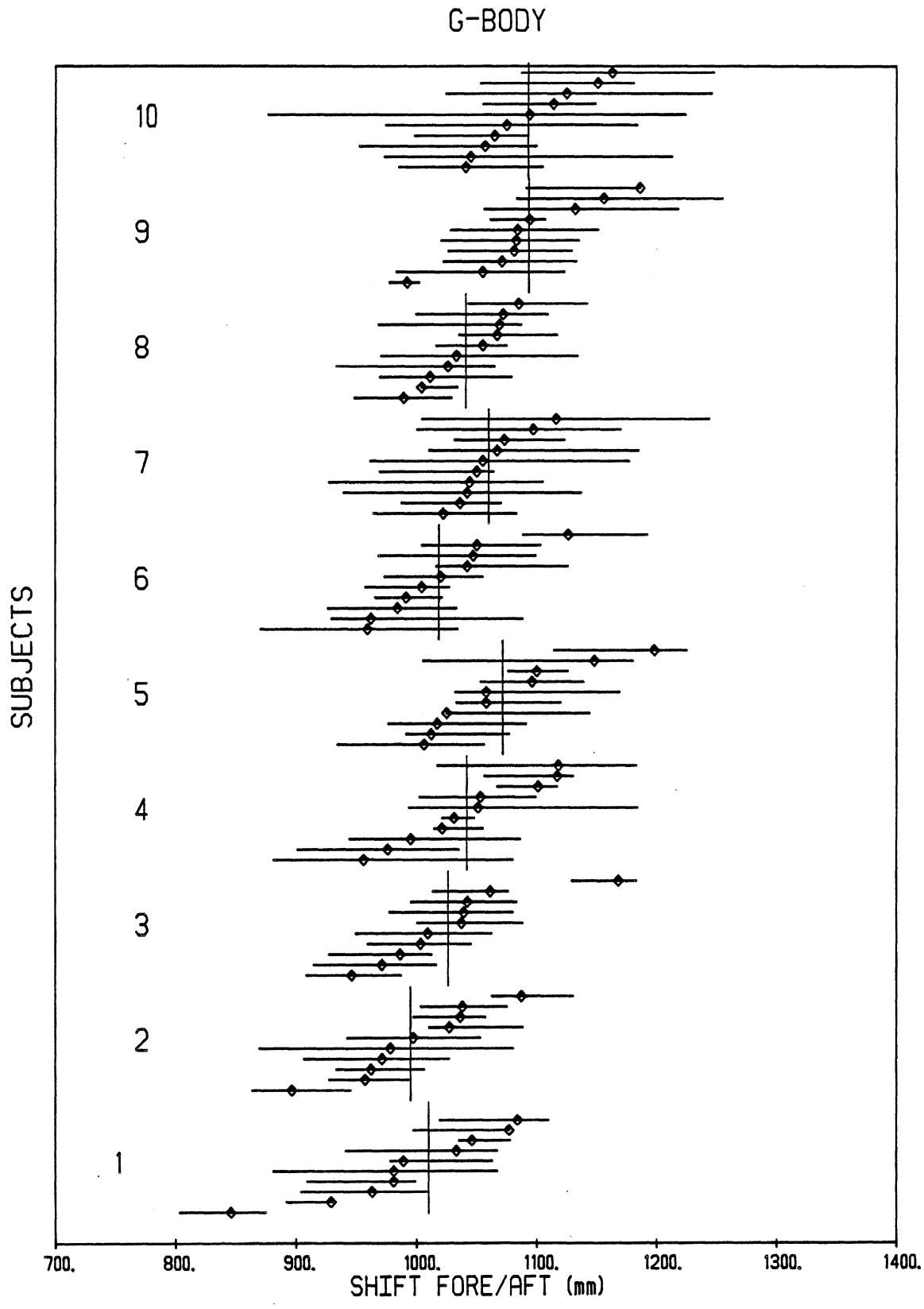

SEAT POSITION RE AHP VERSUS STATURE
SUBJECT STATURE (CM)
200.0
195.0
190.0
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
120.0
450.0
500.0
550.0
600.0
650.0
700.0
750.0
800.0
850.0
900.0
950.0
SEAT H-POINT RE AHP (MM)
G-BODY
H-BODY
S-BODY

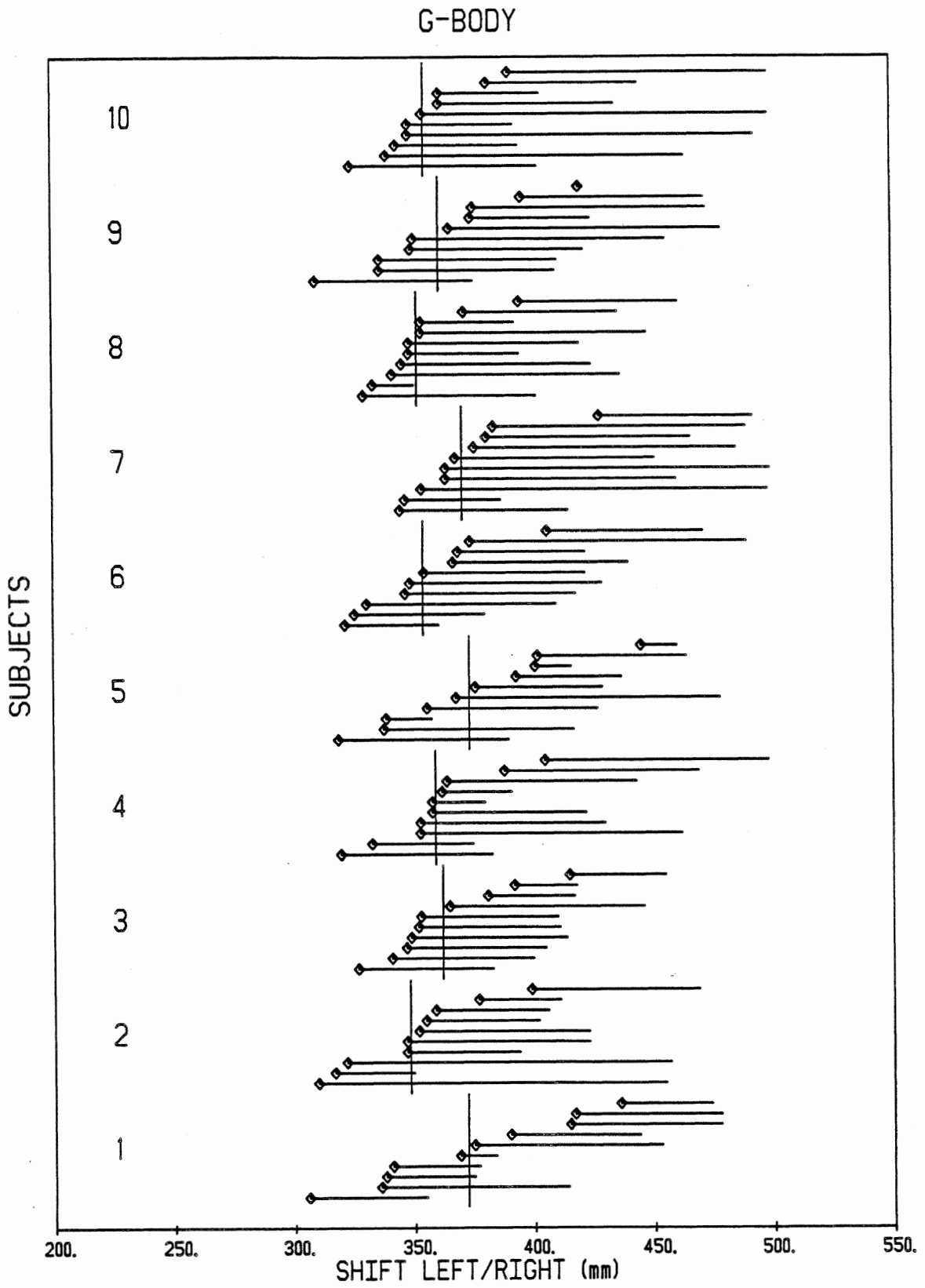
Figure D-10

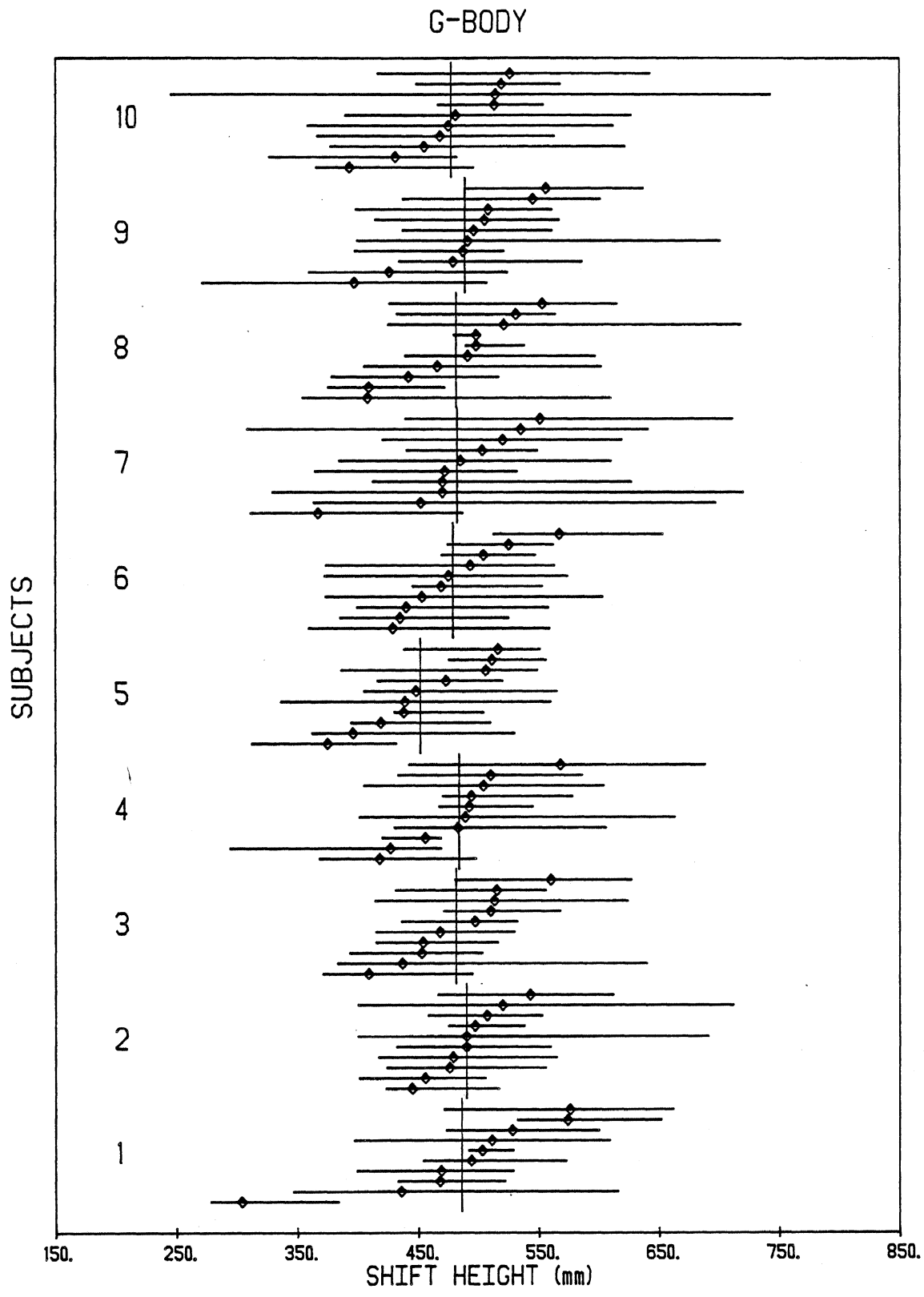
APPENDIX E
PREFERRED AND ACCEPTABLE LIMITS
CONTROL POSITION RESULTS BY SUBJECT

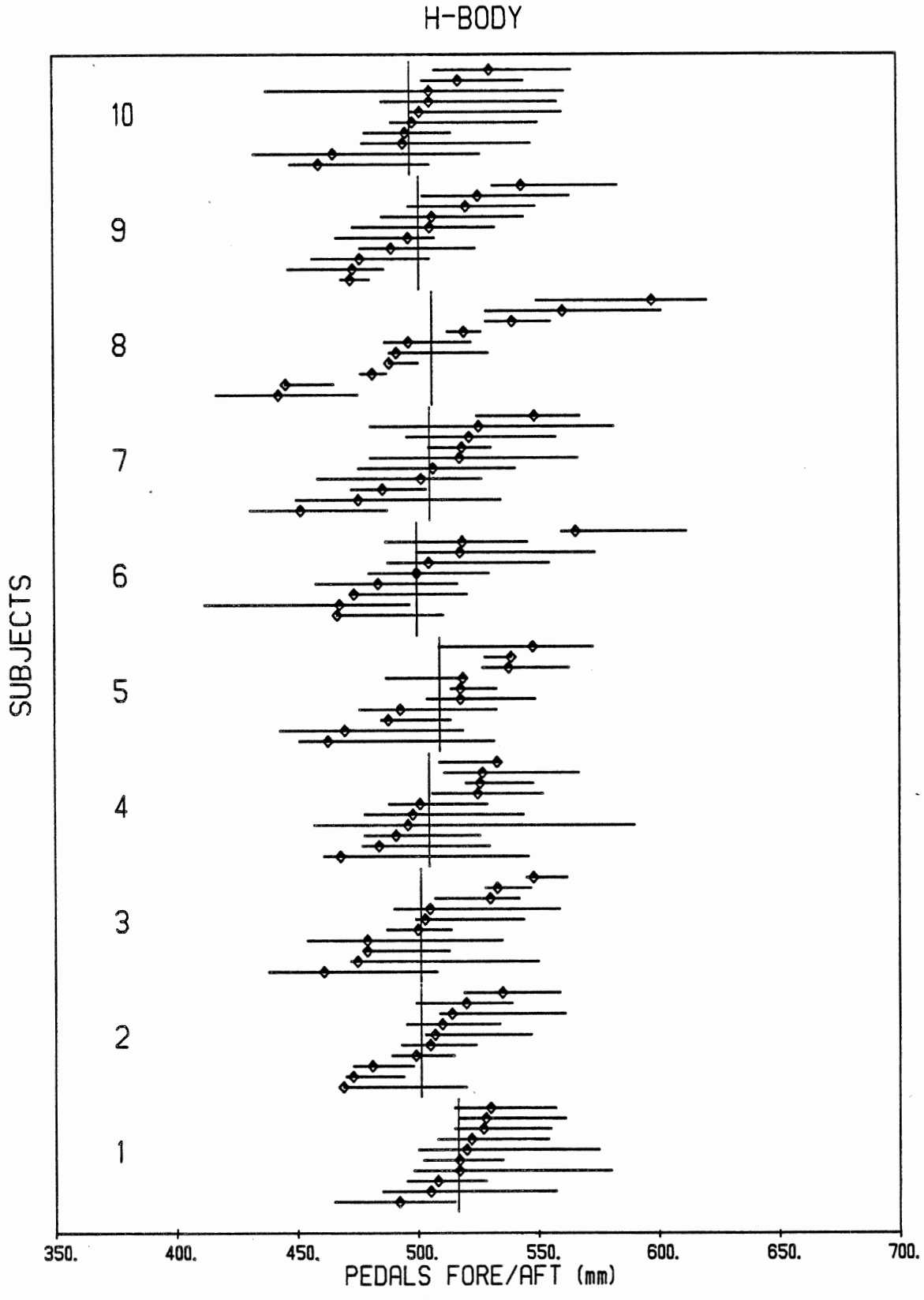

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
PEDALS FORE/AFT (mm)

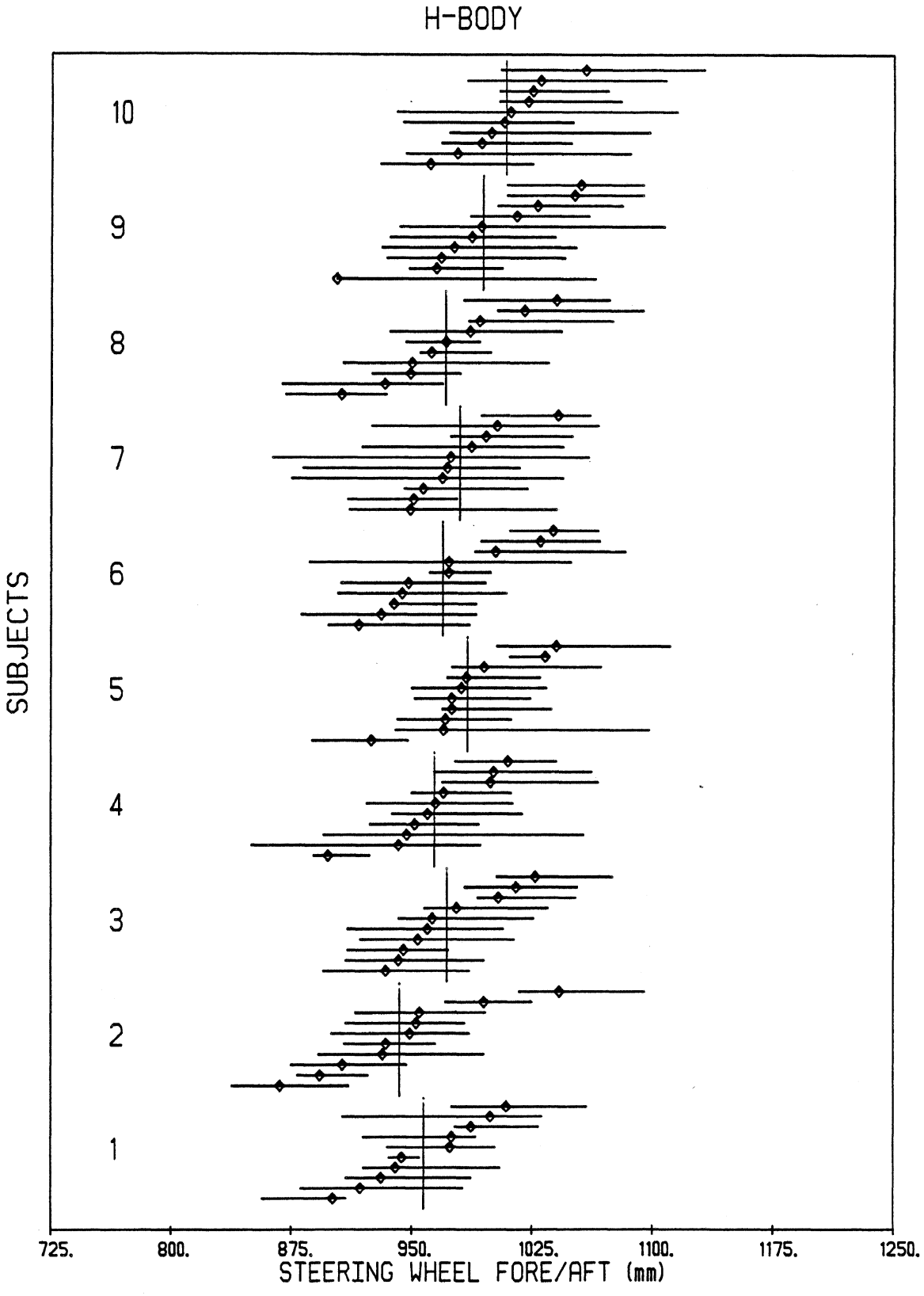

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)

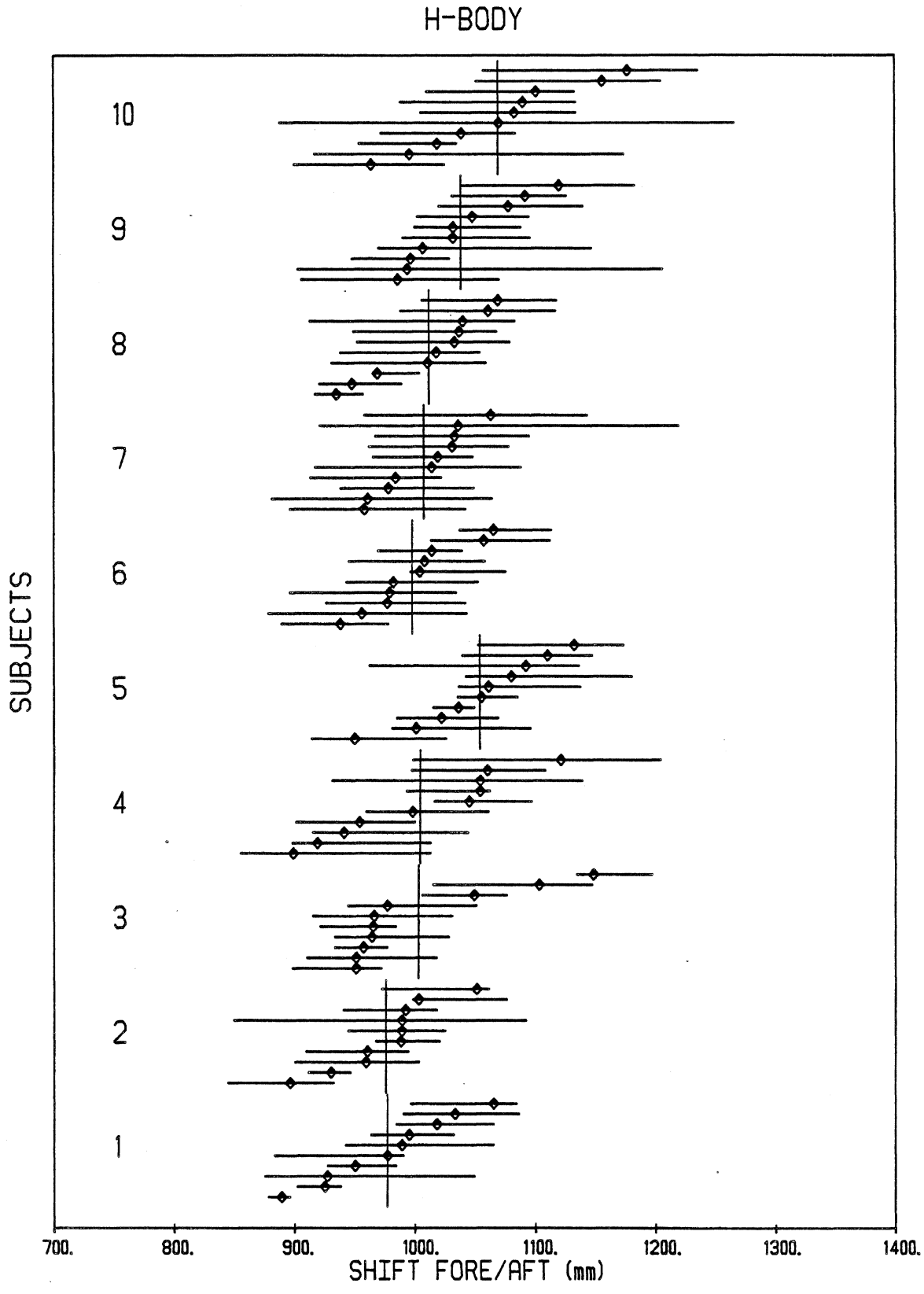

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)

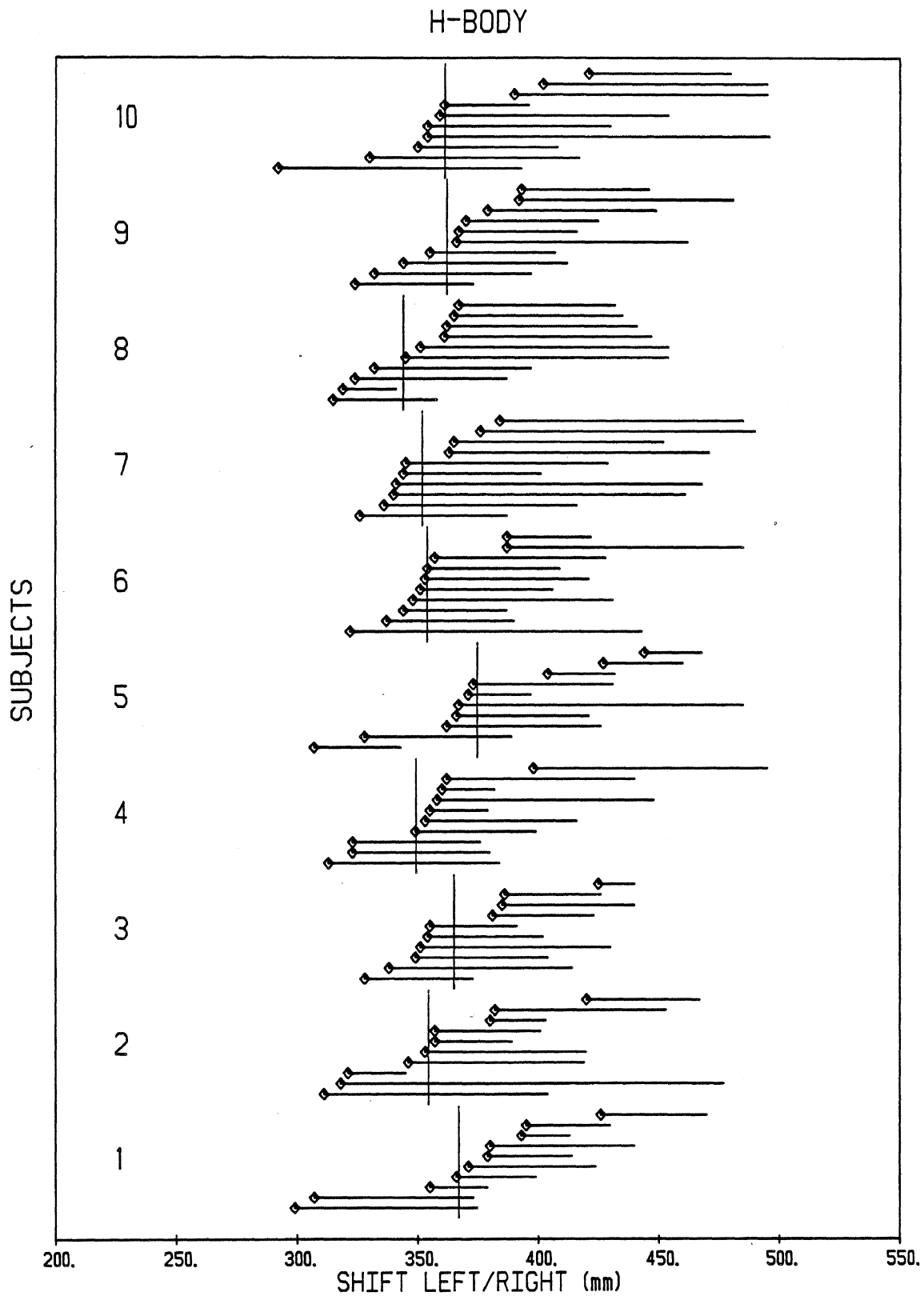

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
200.
250.
300.
350.
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)

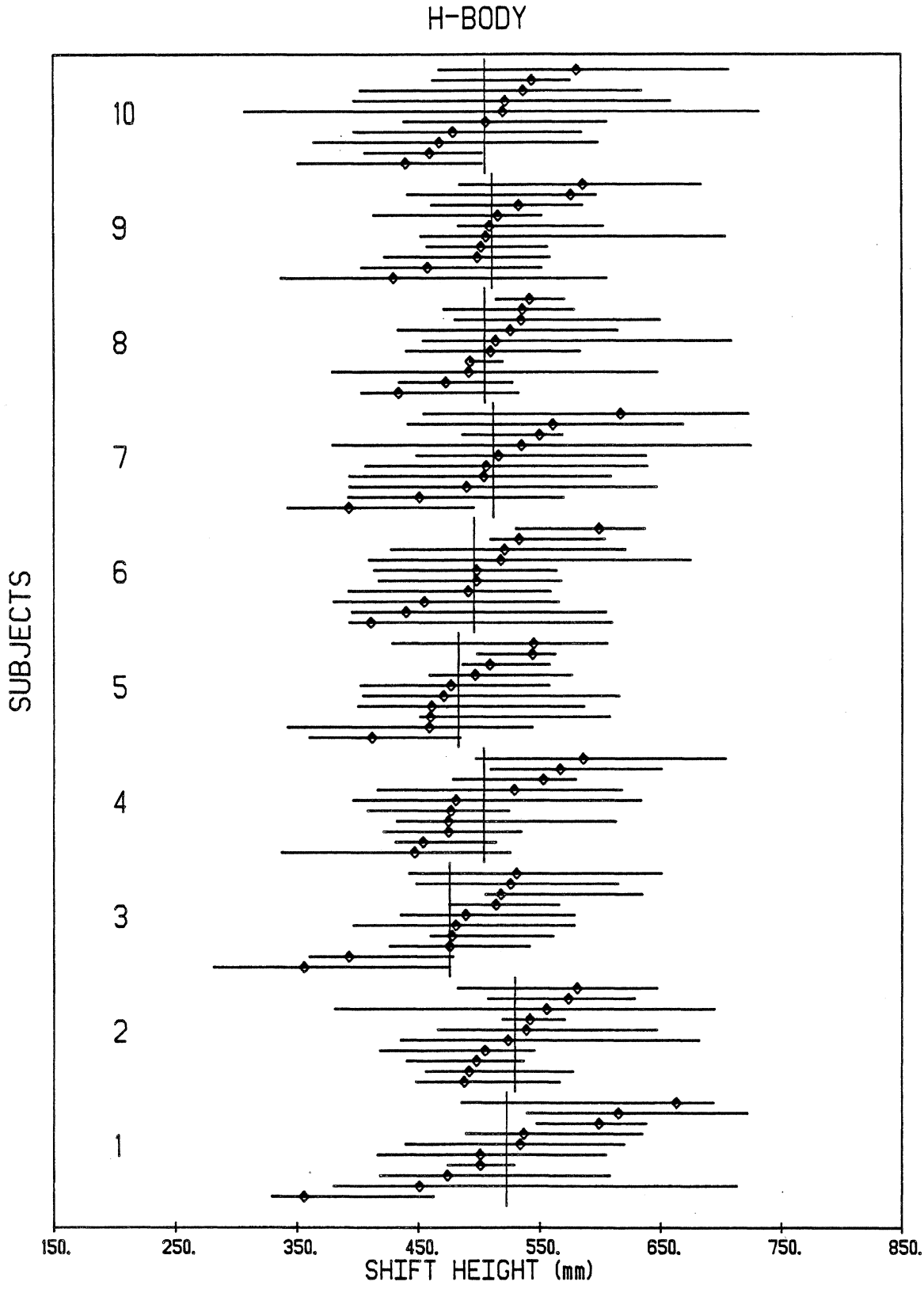

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
150.
250.
350.
450.
550.
650.
750.
850.
SHIFT HEIGHT (mm)

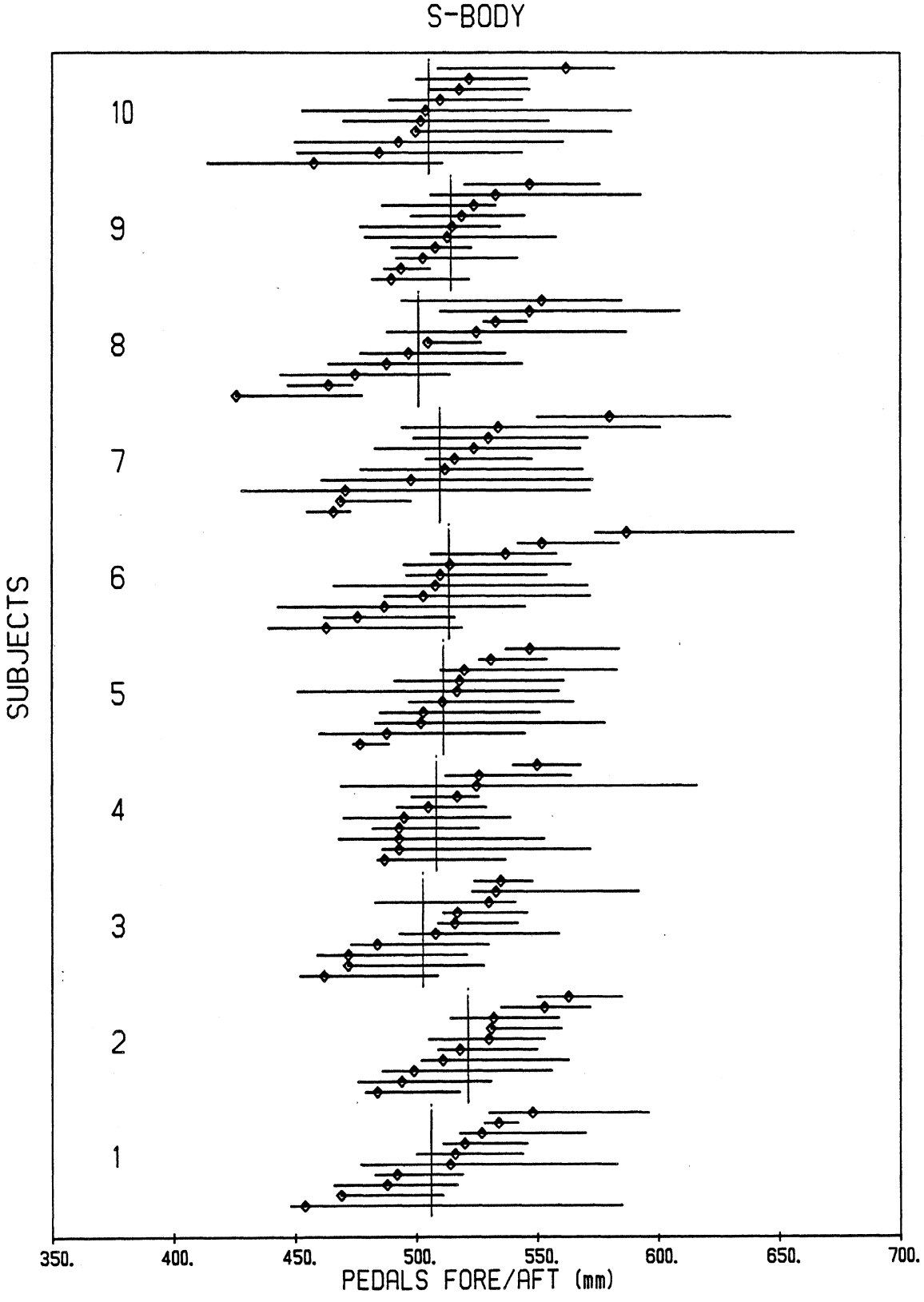

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
PEDALS FORE/AFT (mm)

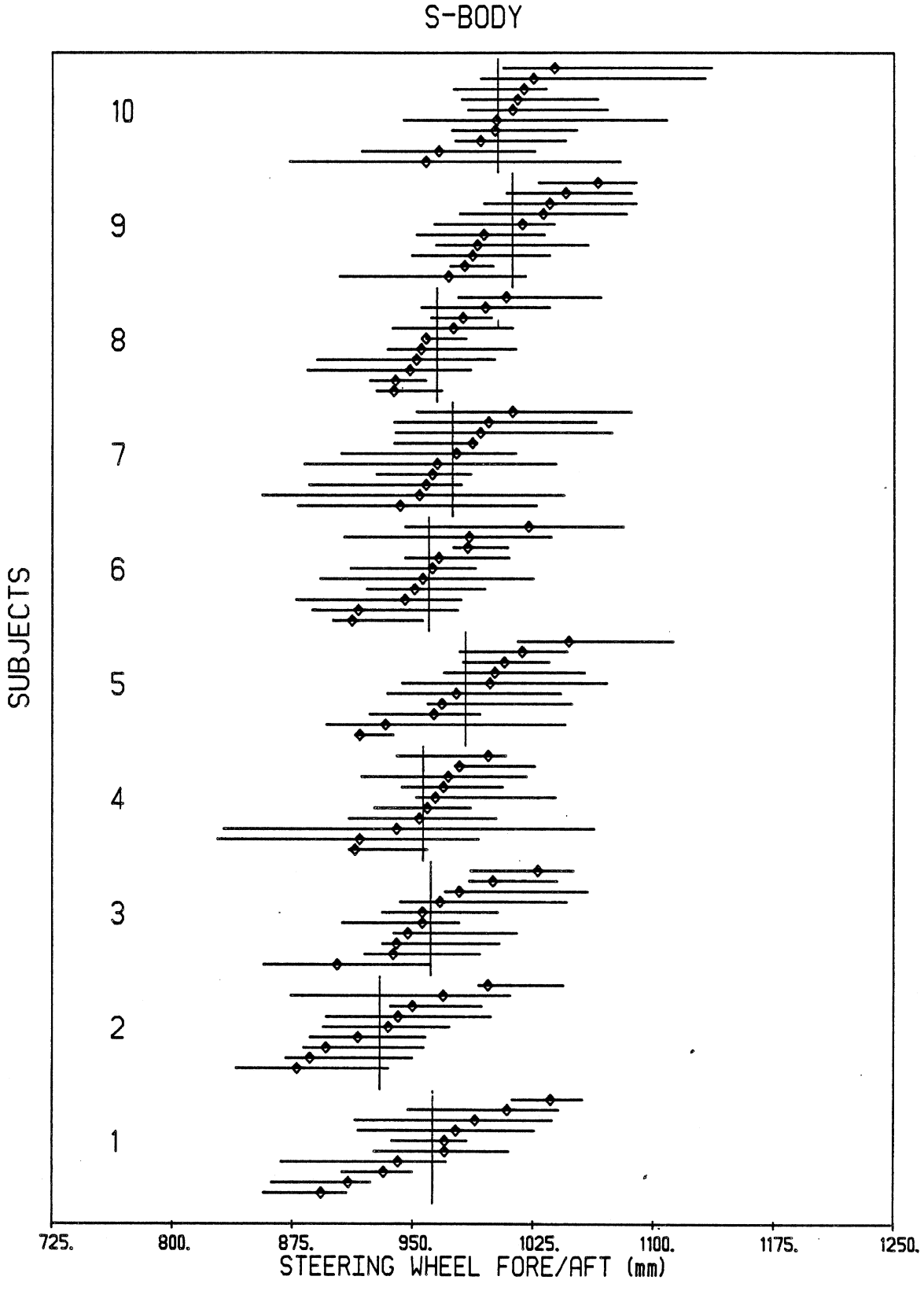

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)

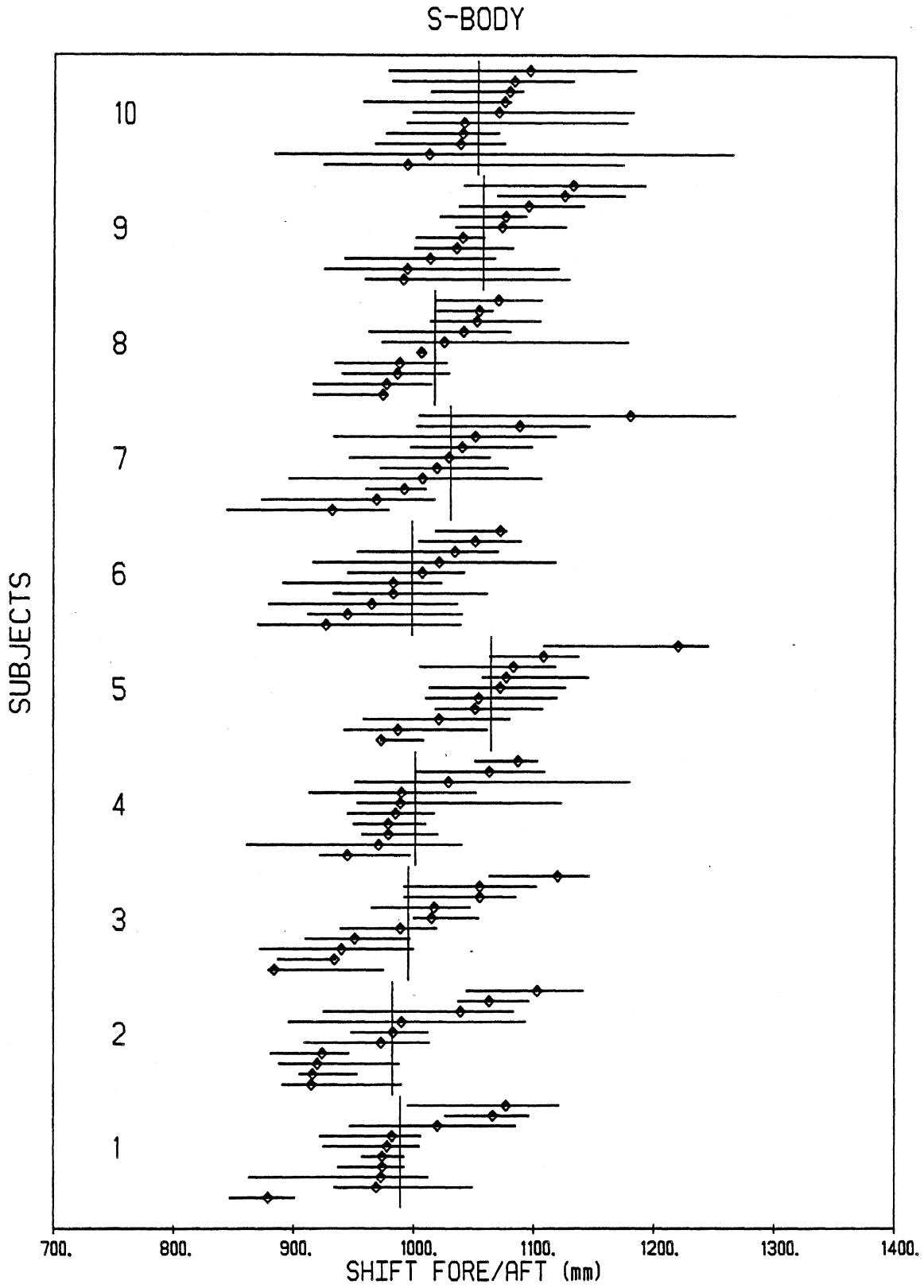

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)

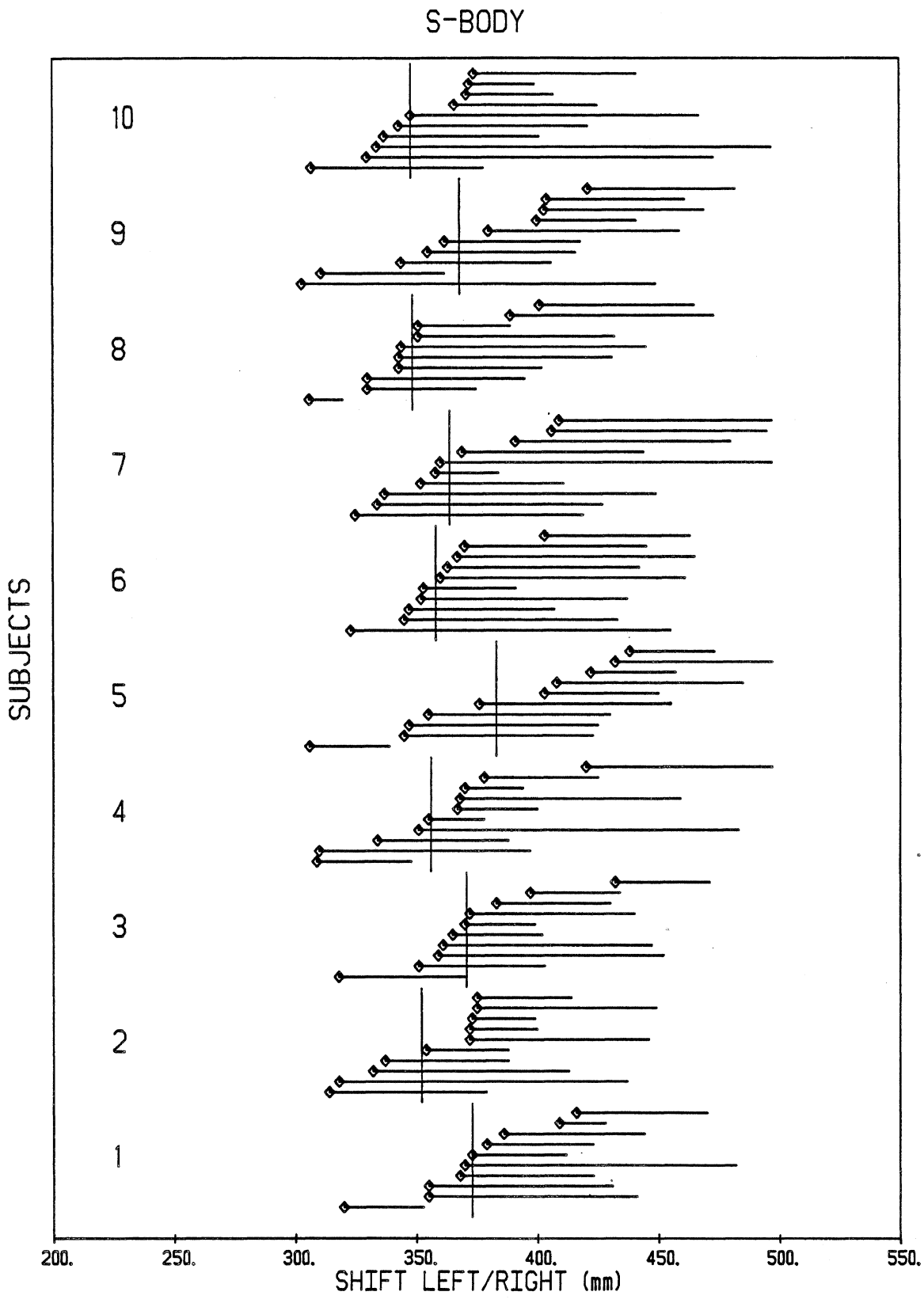

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
200.
250.
300.
350.
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)

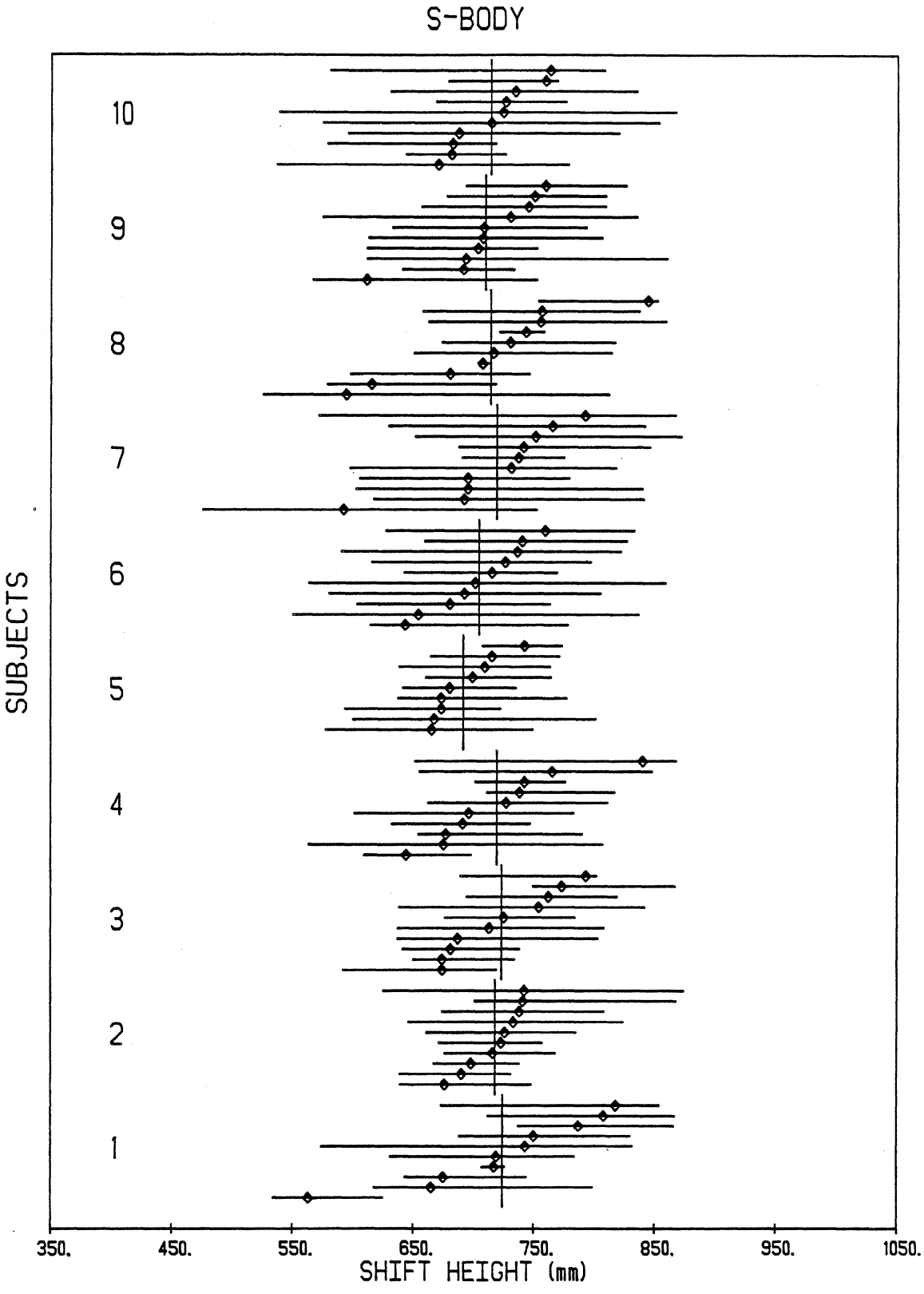

H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
150.
250.
350.
450.
550.
650.
750.
850.
SHIFT HEIGHT (mm)

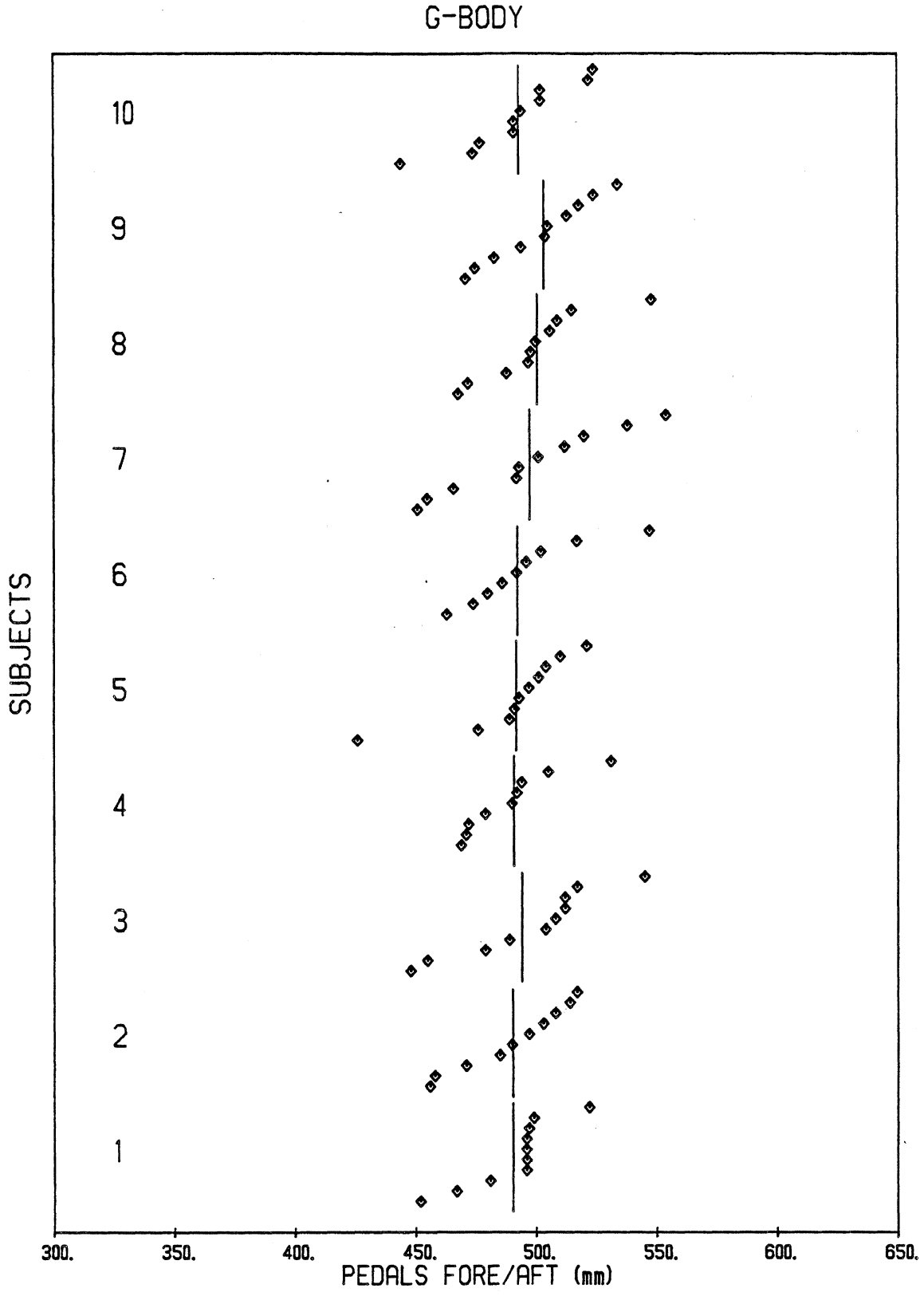

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
PEDALS FORE/AFT (mm)

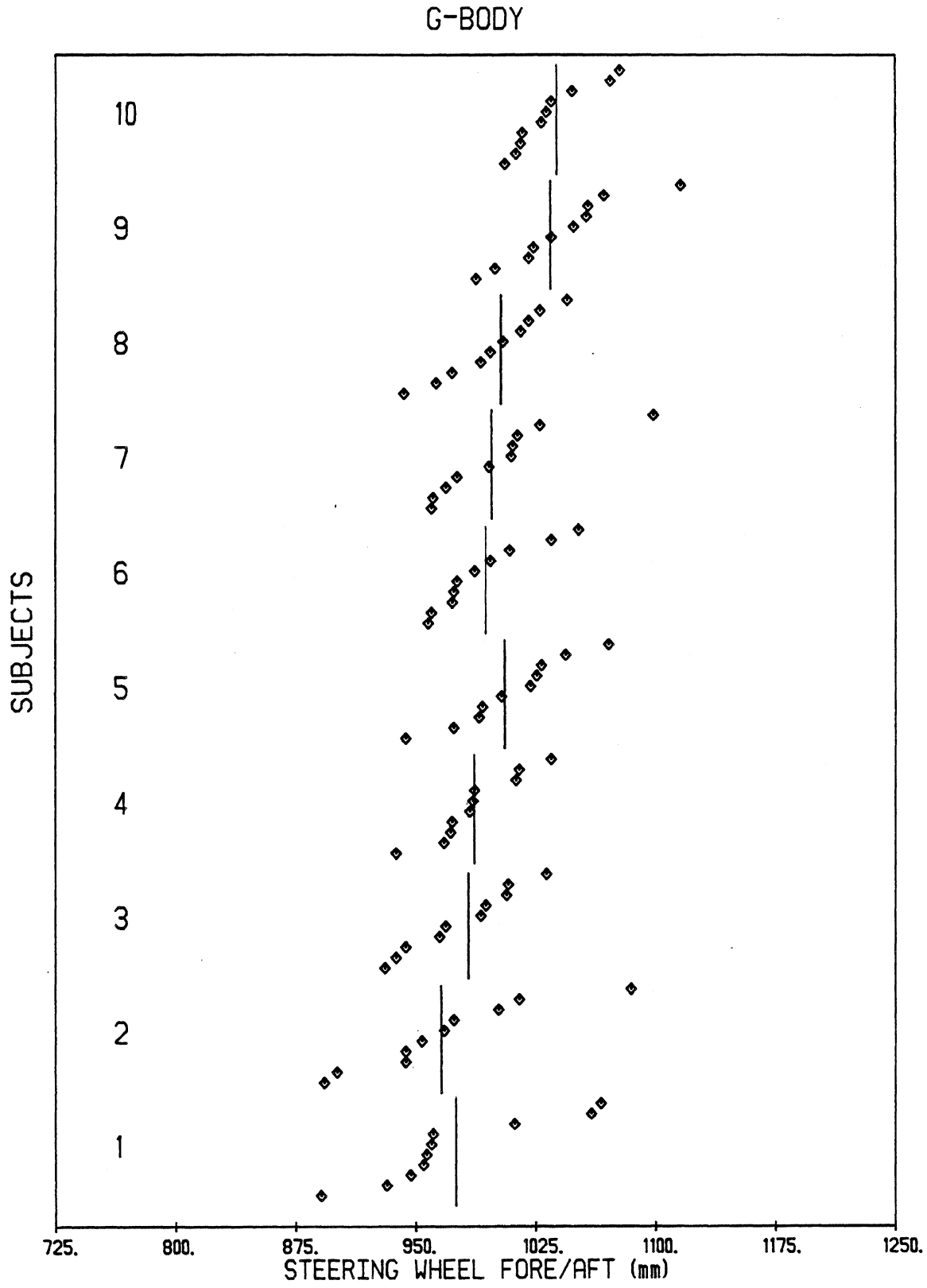

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)

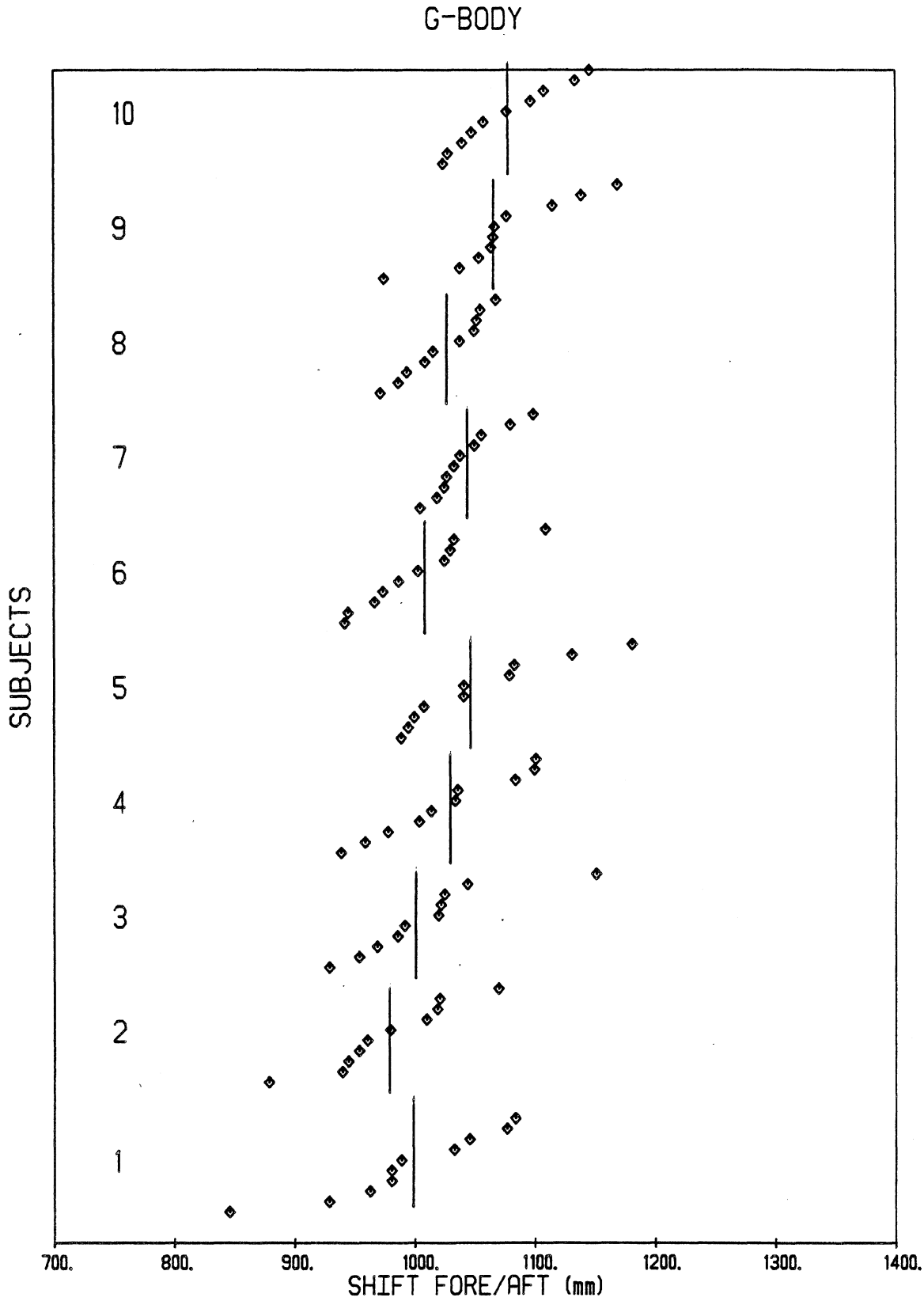

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)

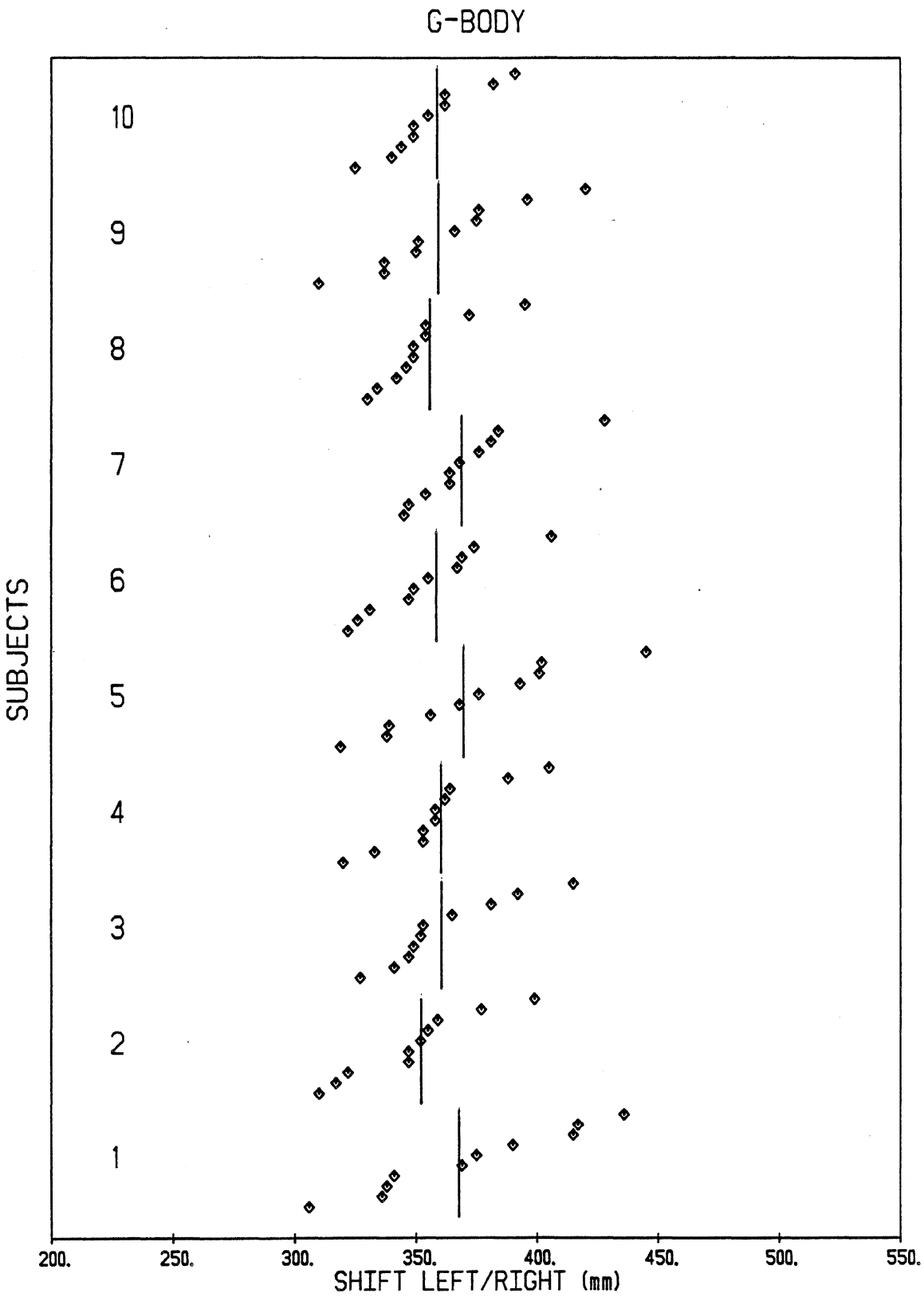

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
200.
250.
300.
350.
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)

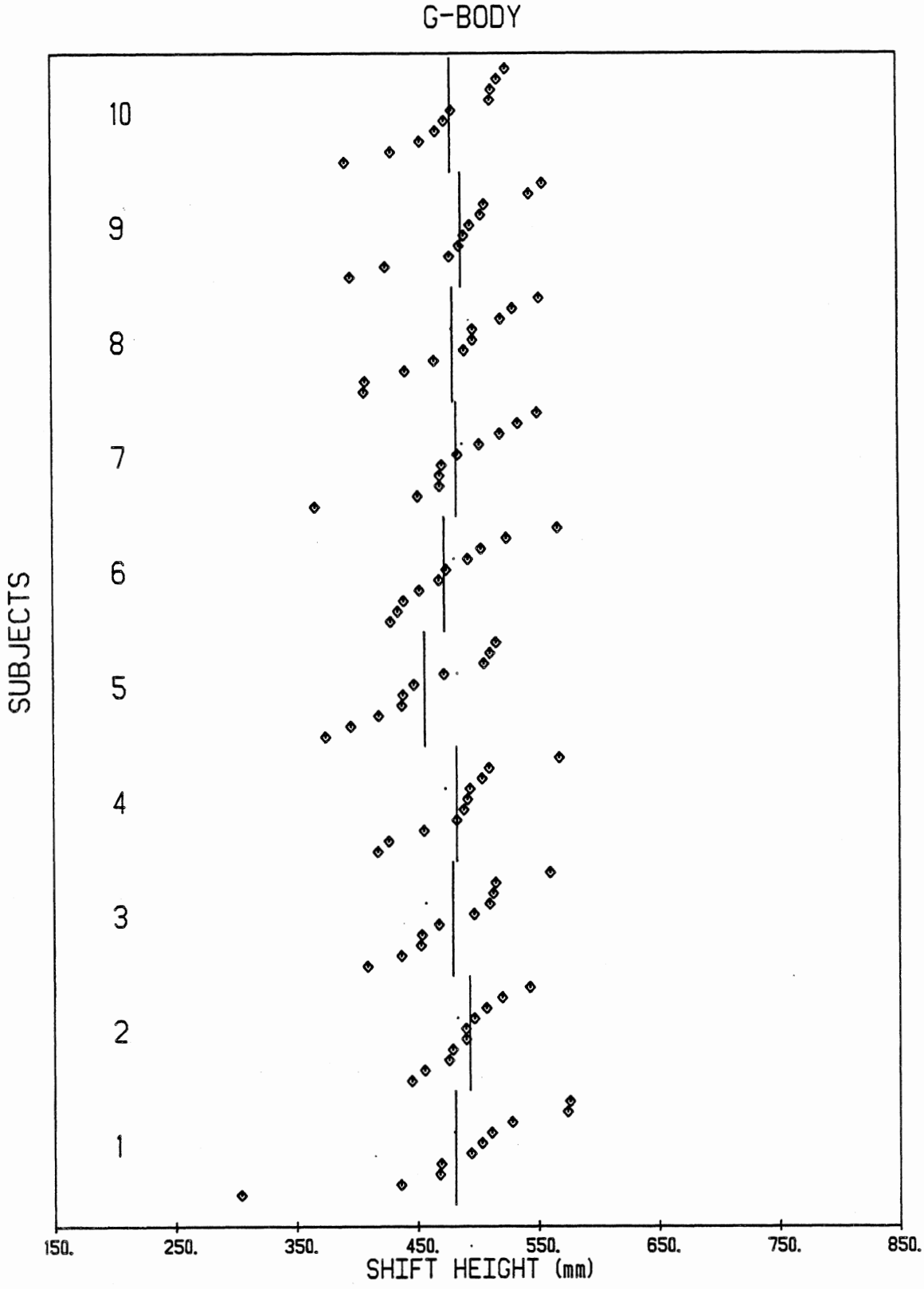

S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
450.
550.
650.
750.
850.
950.
1050.
SHIFT HEIGHT (mm)

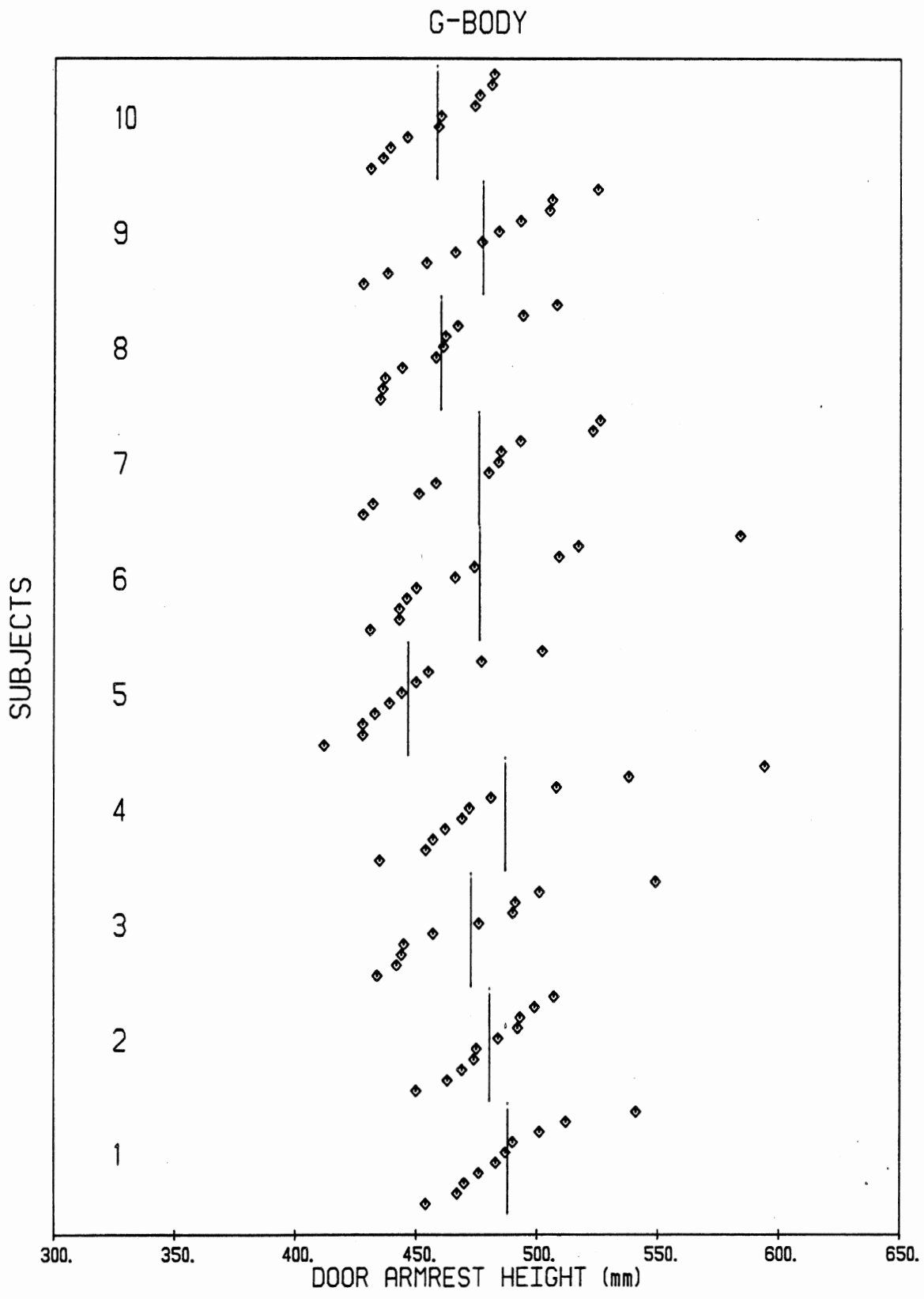

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
PEDALS FORE/AFT (mm)

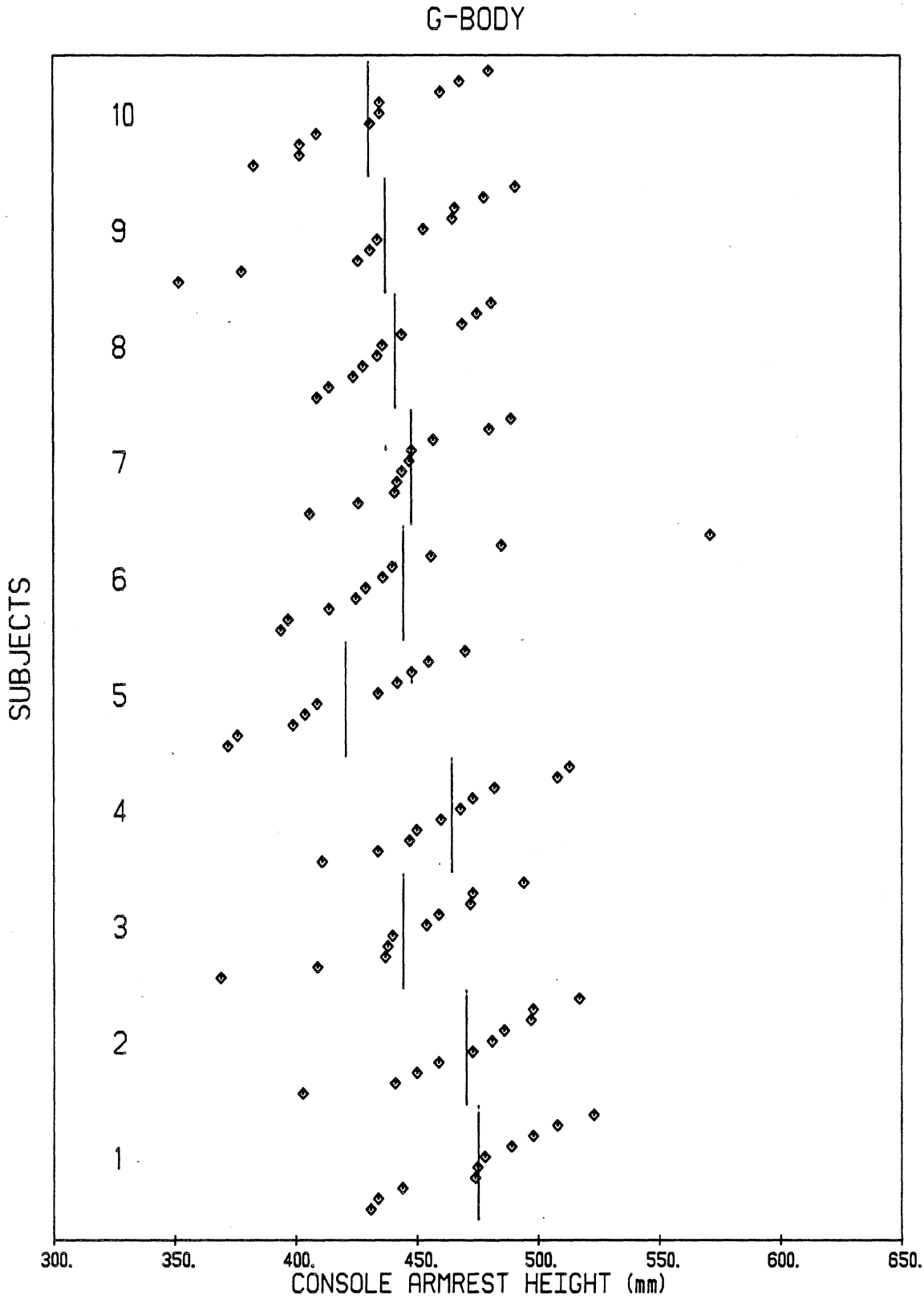

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)

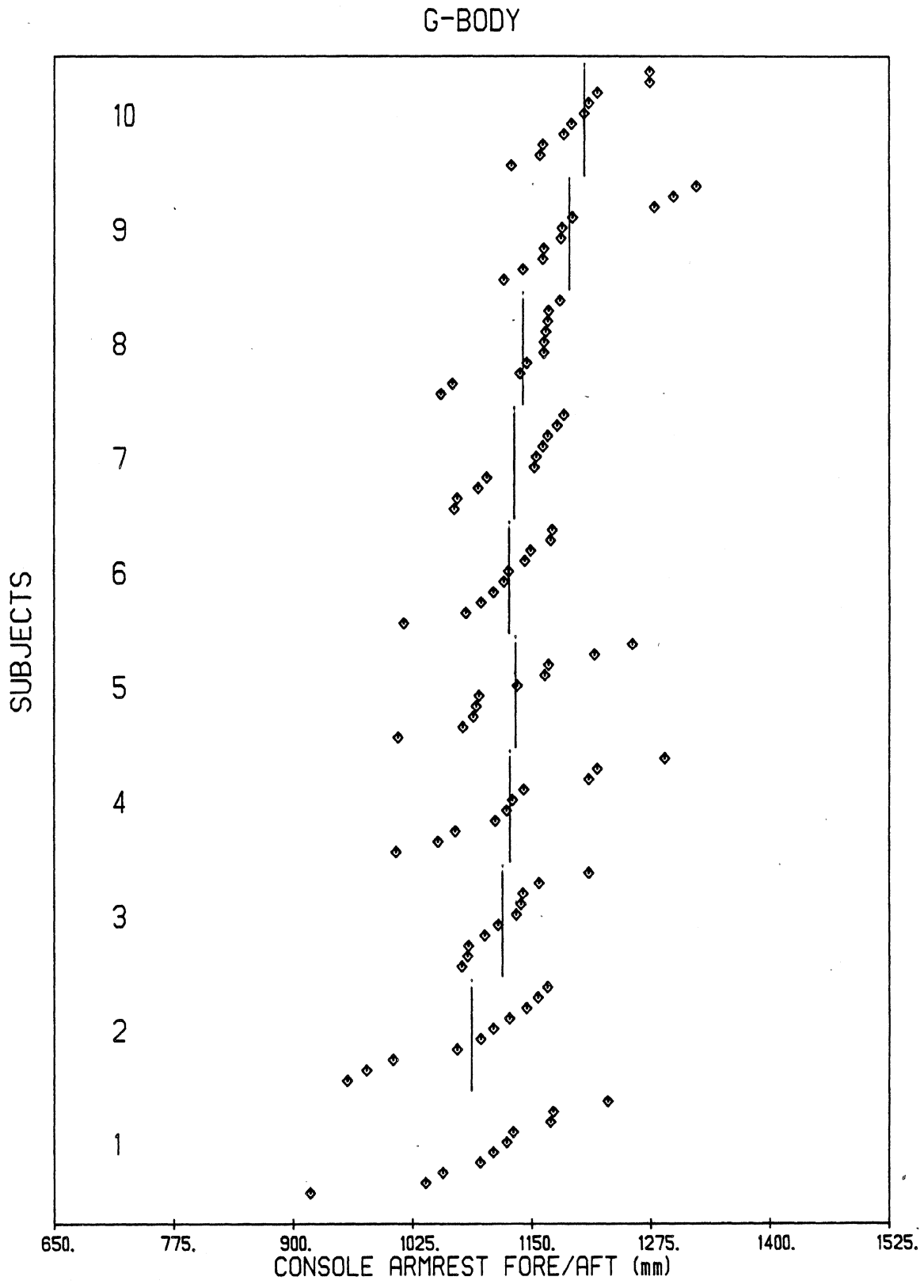

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)

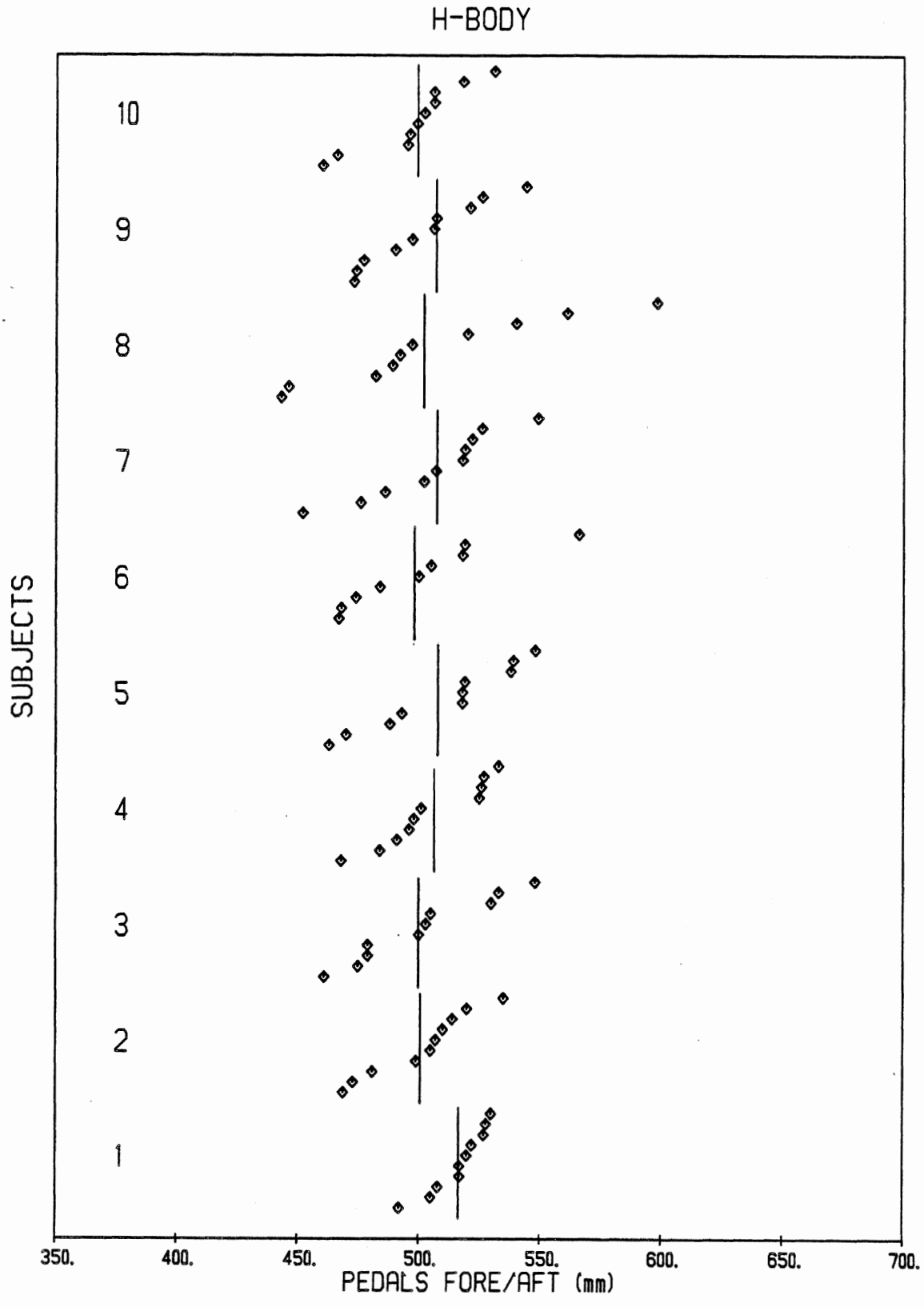

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
200.
250.
300.
350.
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)

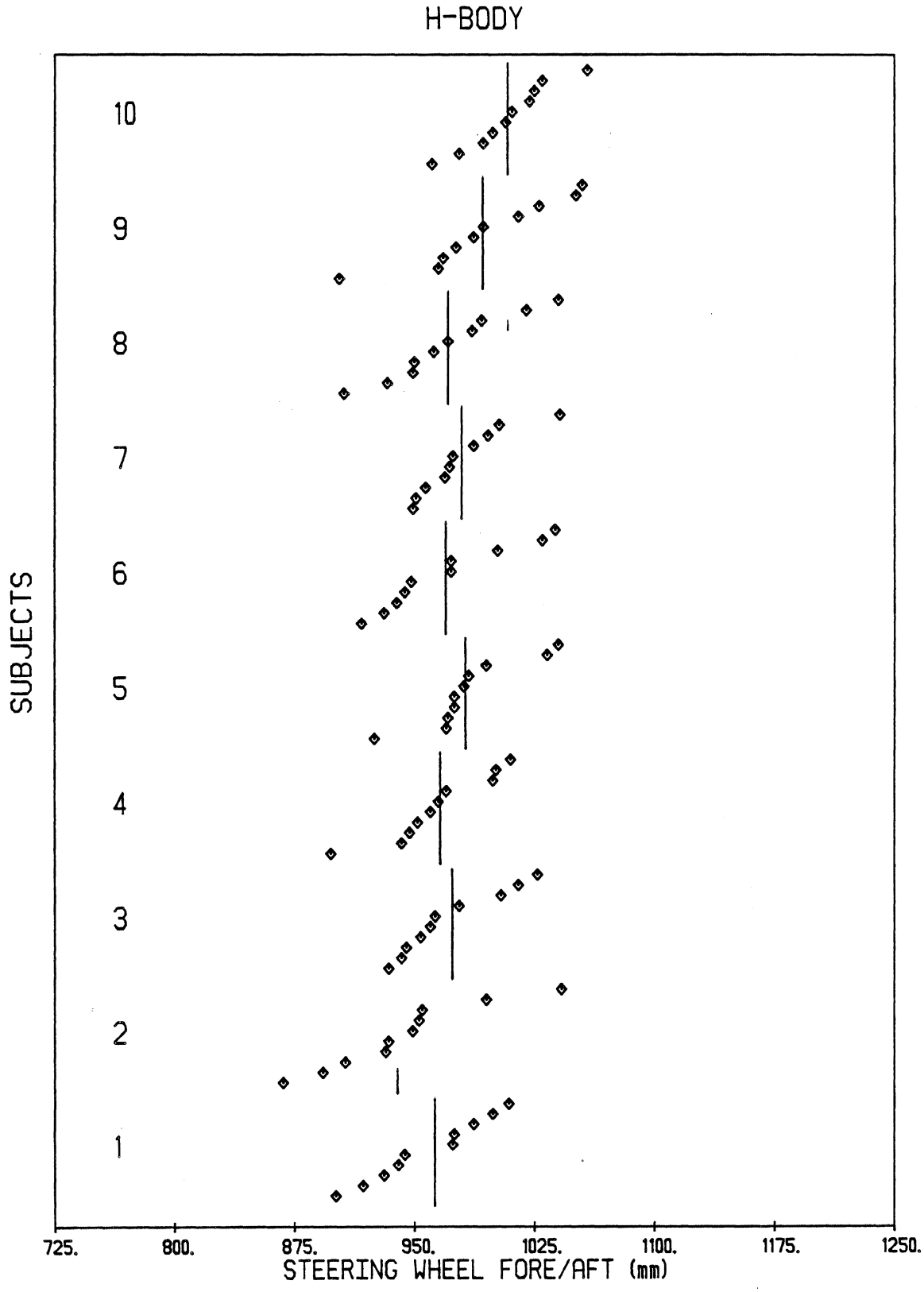

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
150.
250.
350.
450.
550.
650.
750.
850.
SHIFT HEIGHT (mm)

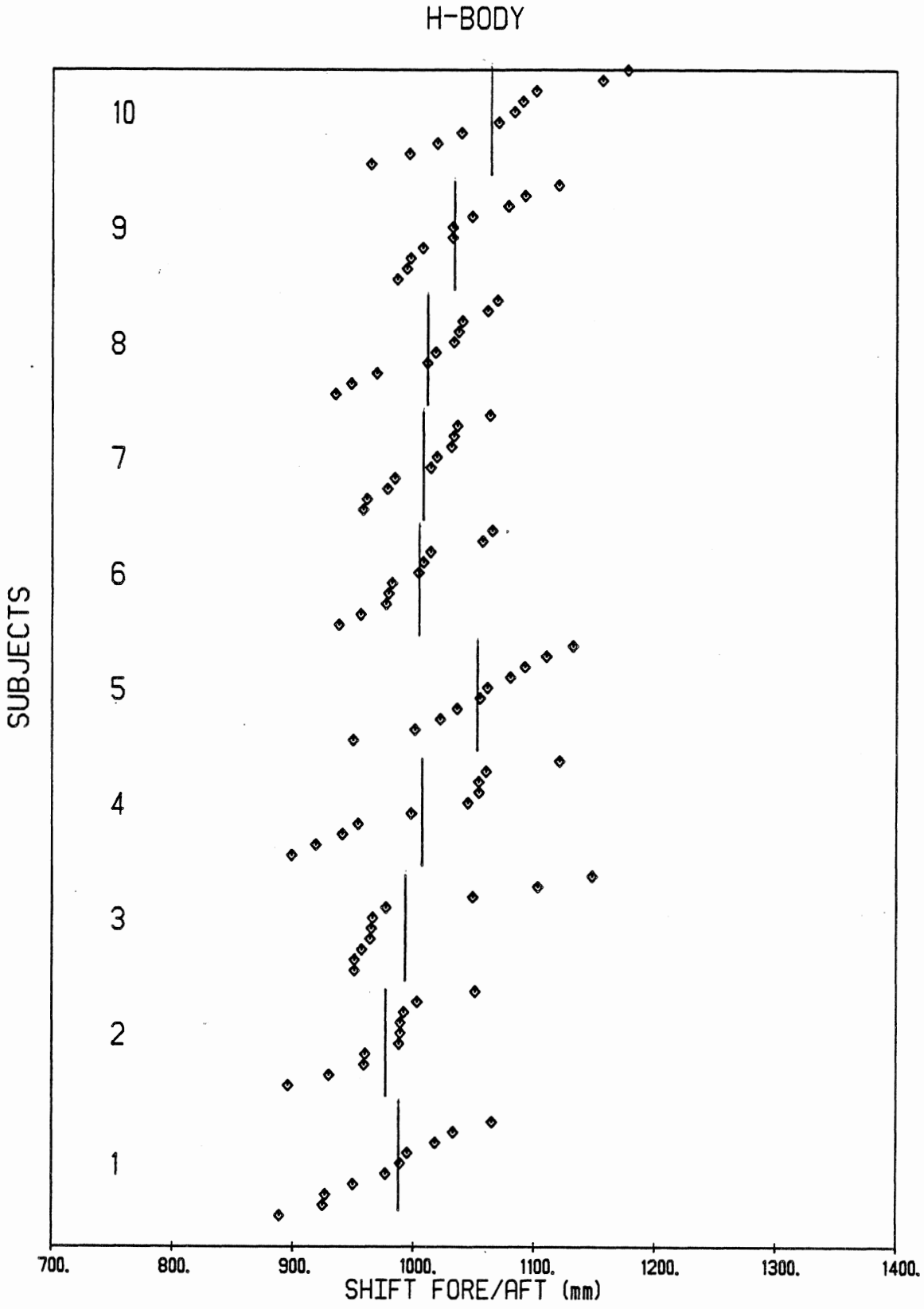

G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
DOOR ARMREST HEIGHT (mm)


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)


G-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
650.
775.
900.
1025.
1150.
1275.
1400.
1525.
CONSOLE ARMREST FORE/AFT (mm)


H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
PEDALS FORE/AFT (mm)


H-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)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7
6
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3
2
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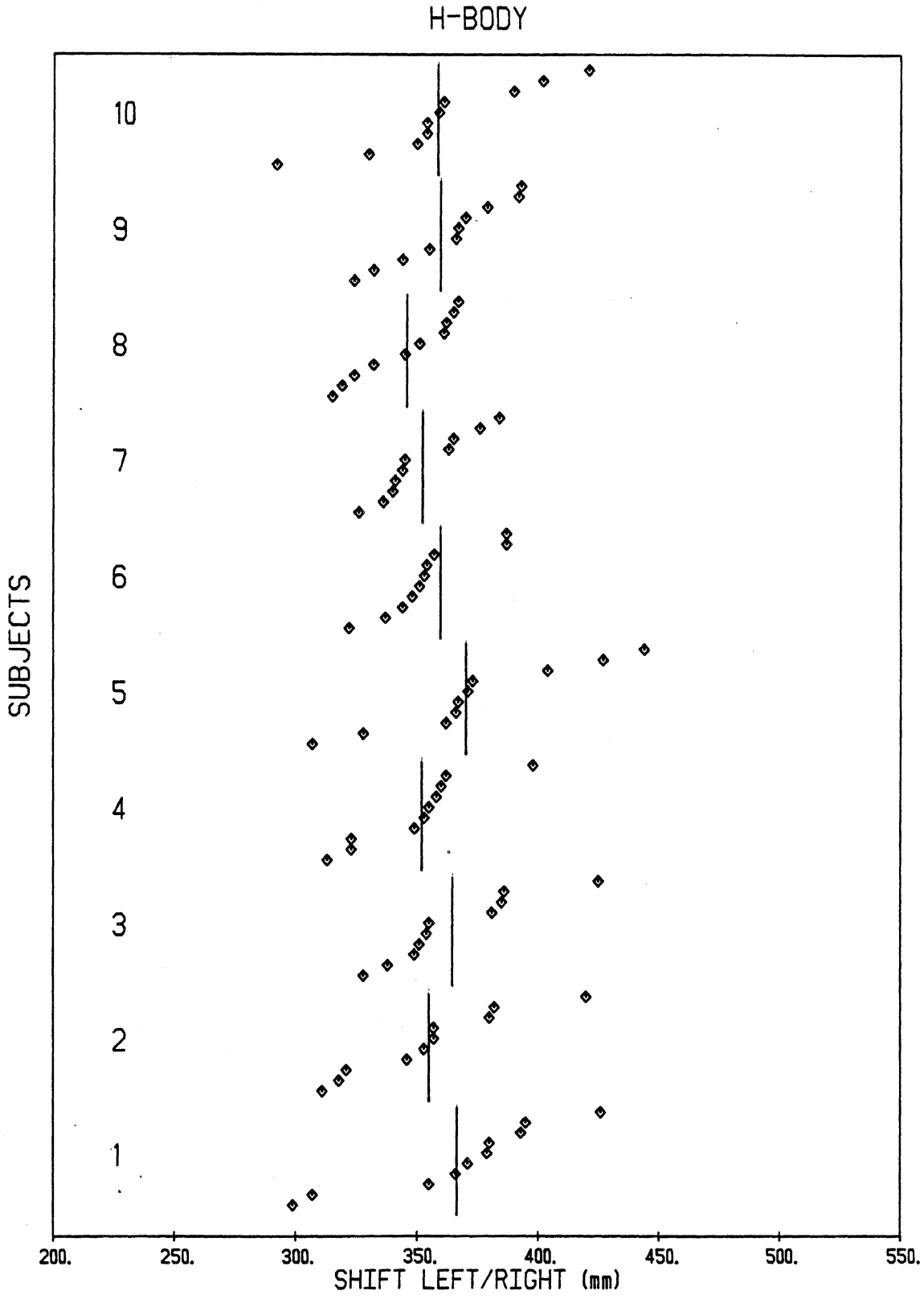
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)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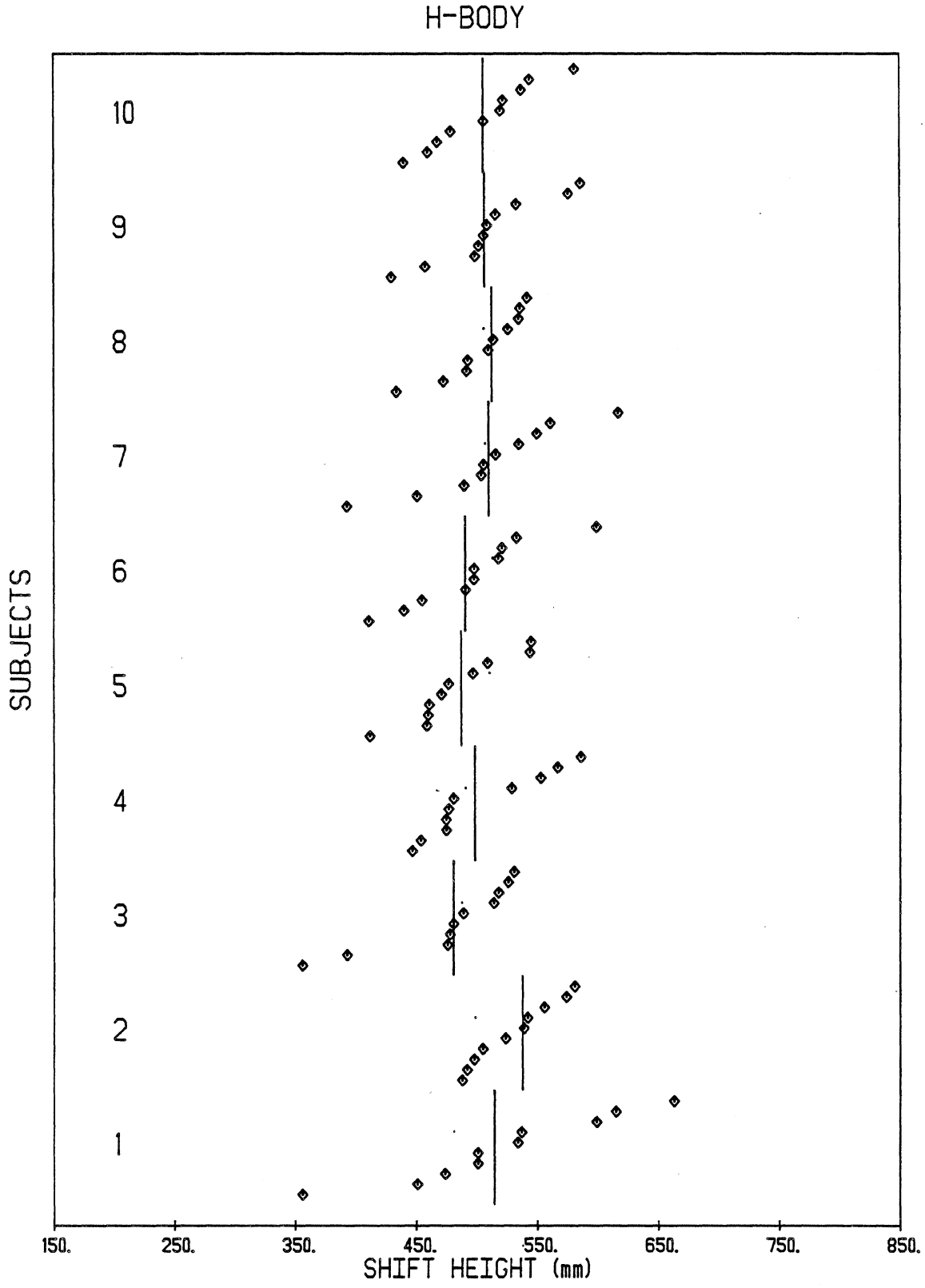
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)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SUBJECTS
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3
2
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250.
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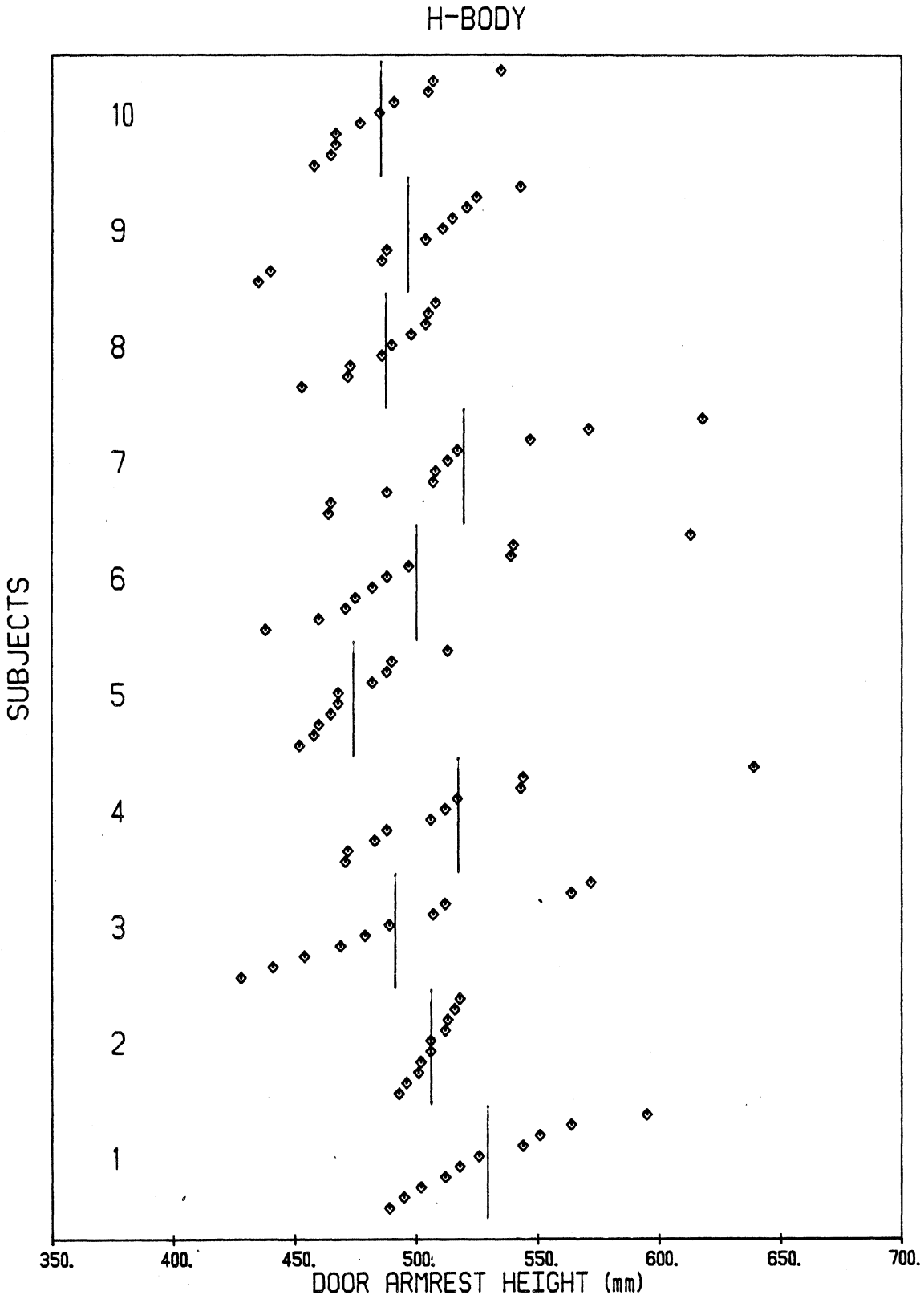
450.
550.
650.
750.
850.
SHIFT HEIGHT (mm)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SUBJECTS
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9
8
7
6
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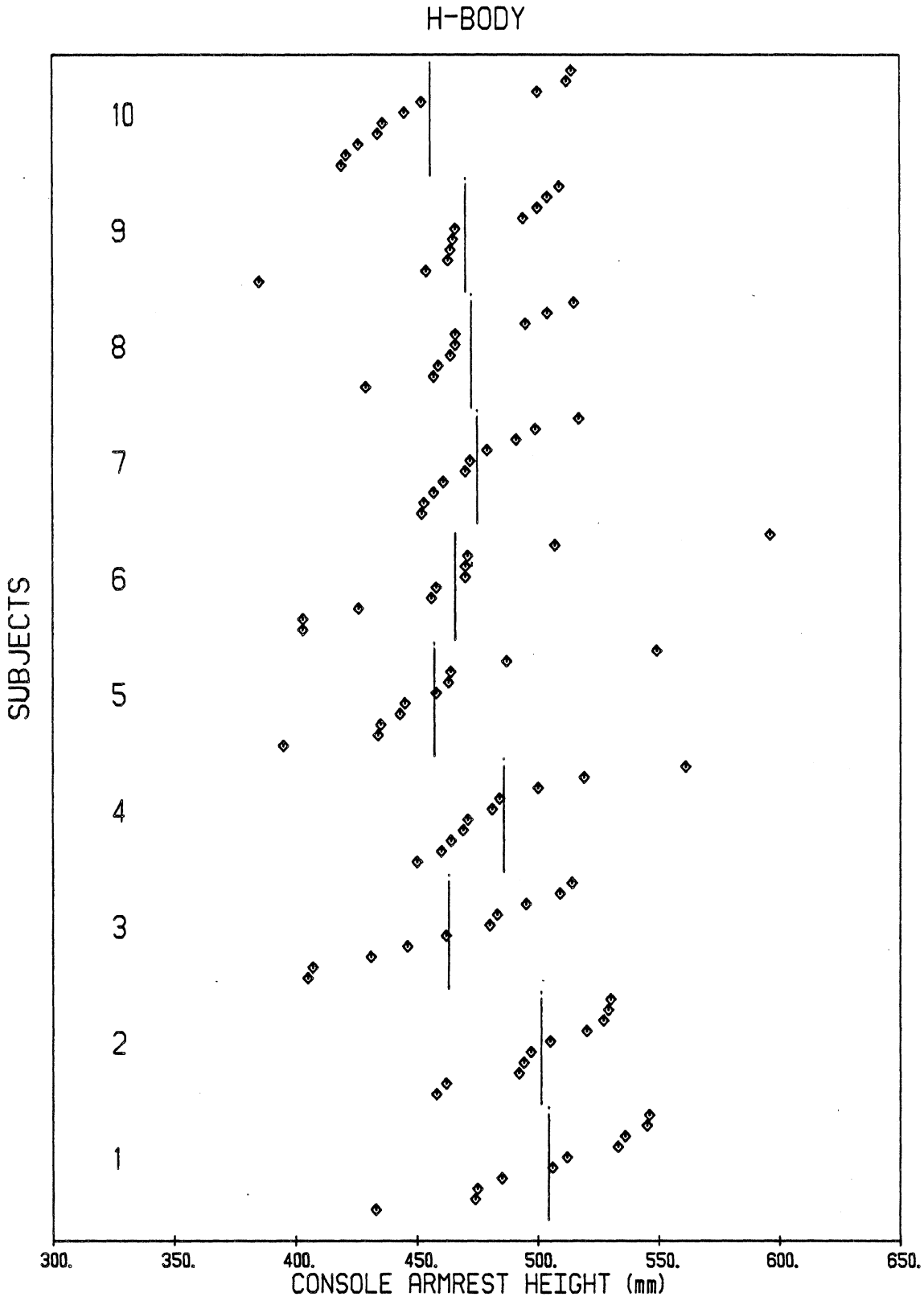
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
DOOR ARMREST HEIGHT (mm)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SUBJECTS
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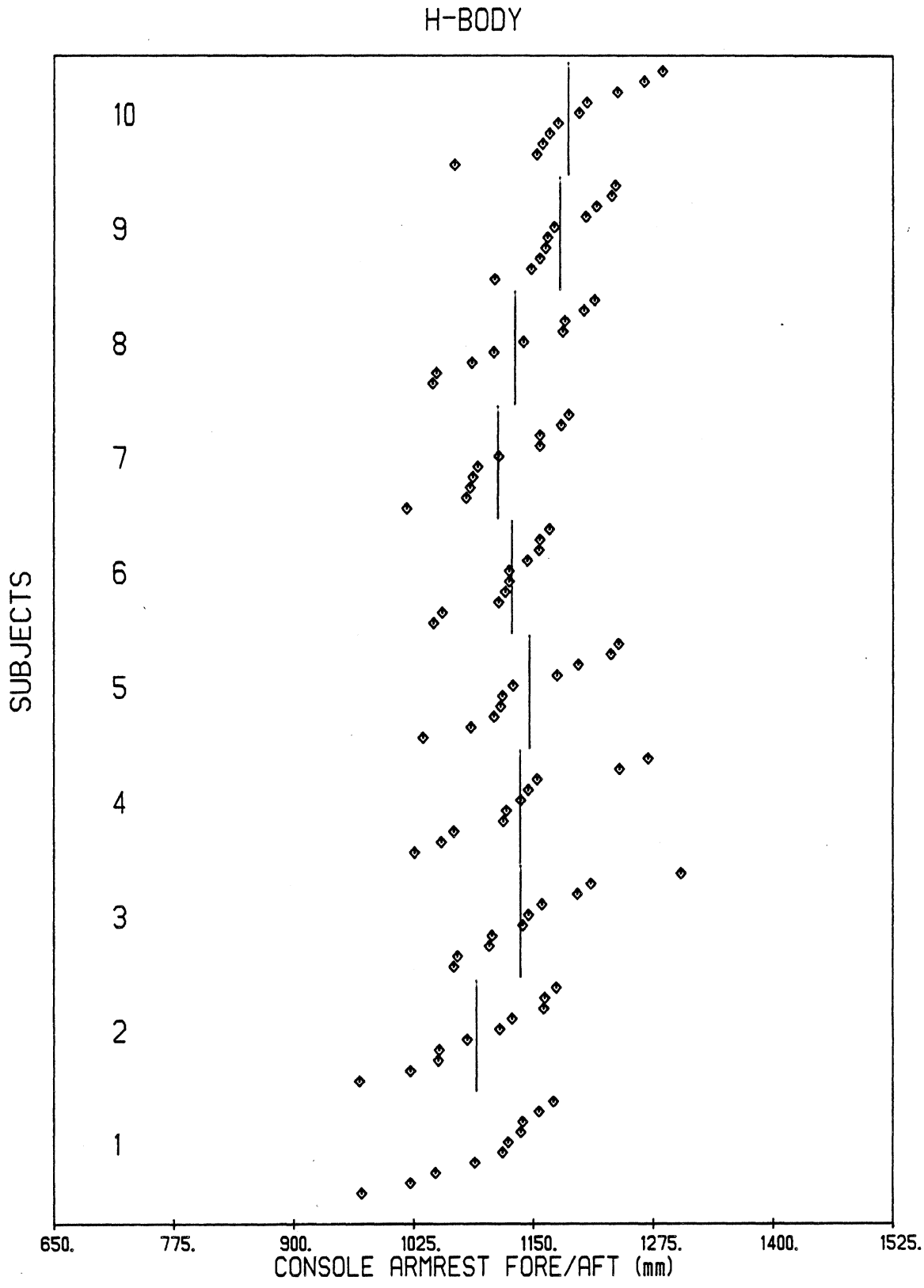
9
8
7
6
5
4
3
2
1
300.
350.
400.
450.
500.
550.
600.
650.
CONSOLE ARMREST HEIGHT (mm)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SUBJECTS
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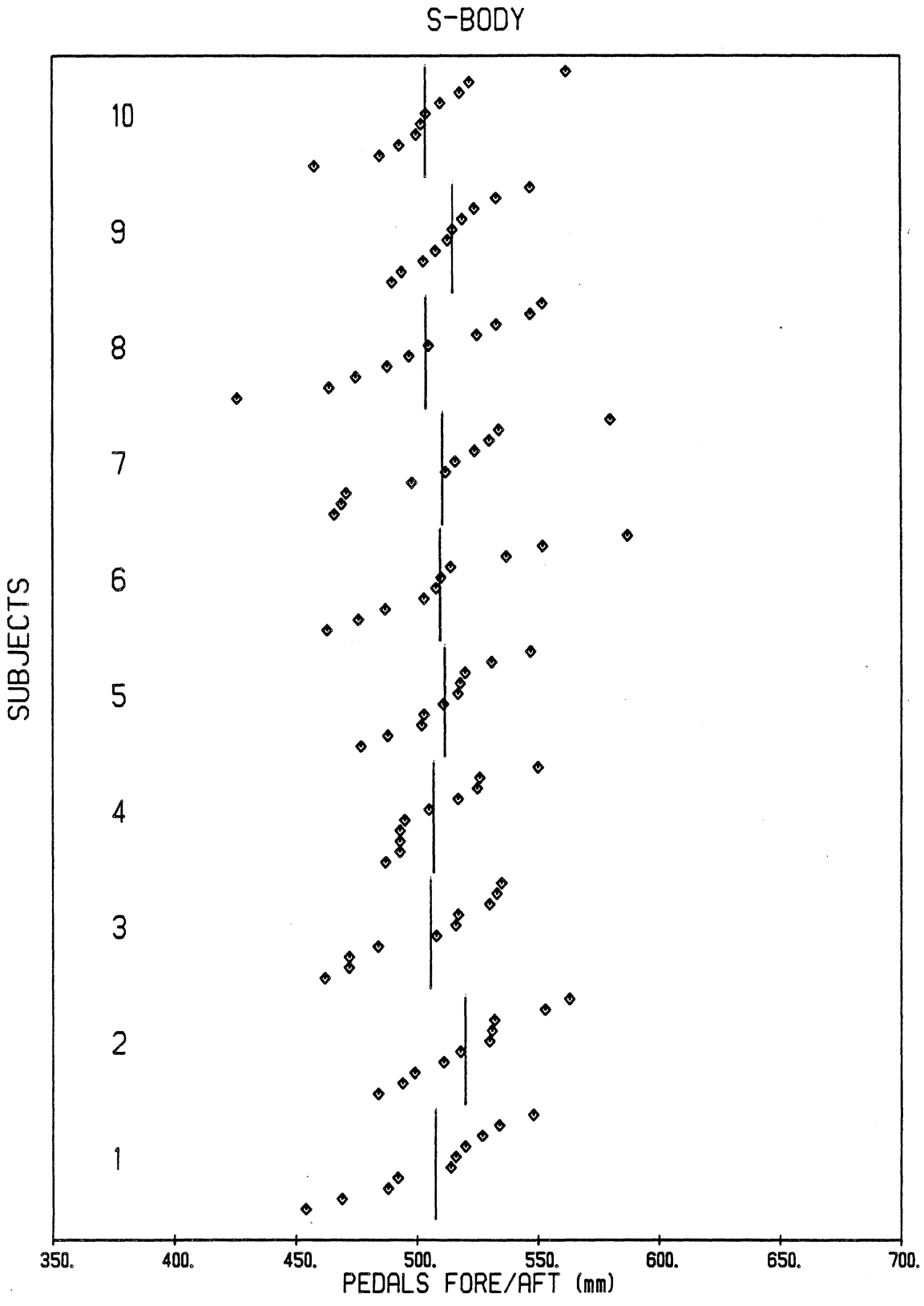
9
8
7
6
5
4
3
2
1
650.
775.
900.
1025.
1150.
1275.
1400.
1525.
CONSOLE ARMREST FORE/AFT (mm)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SUBJECTS
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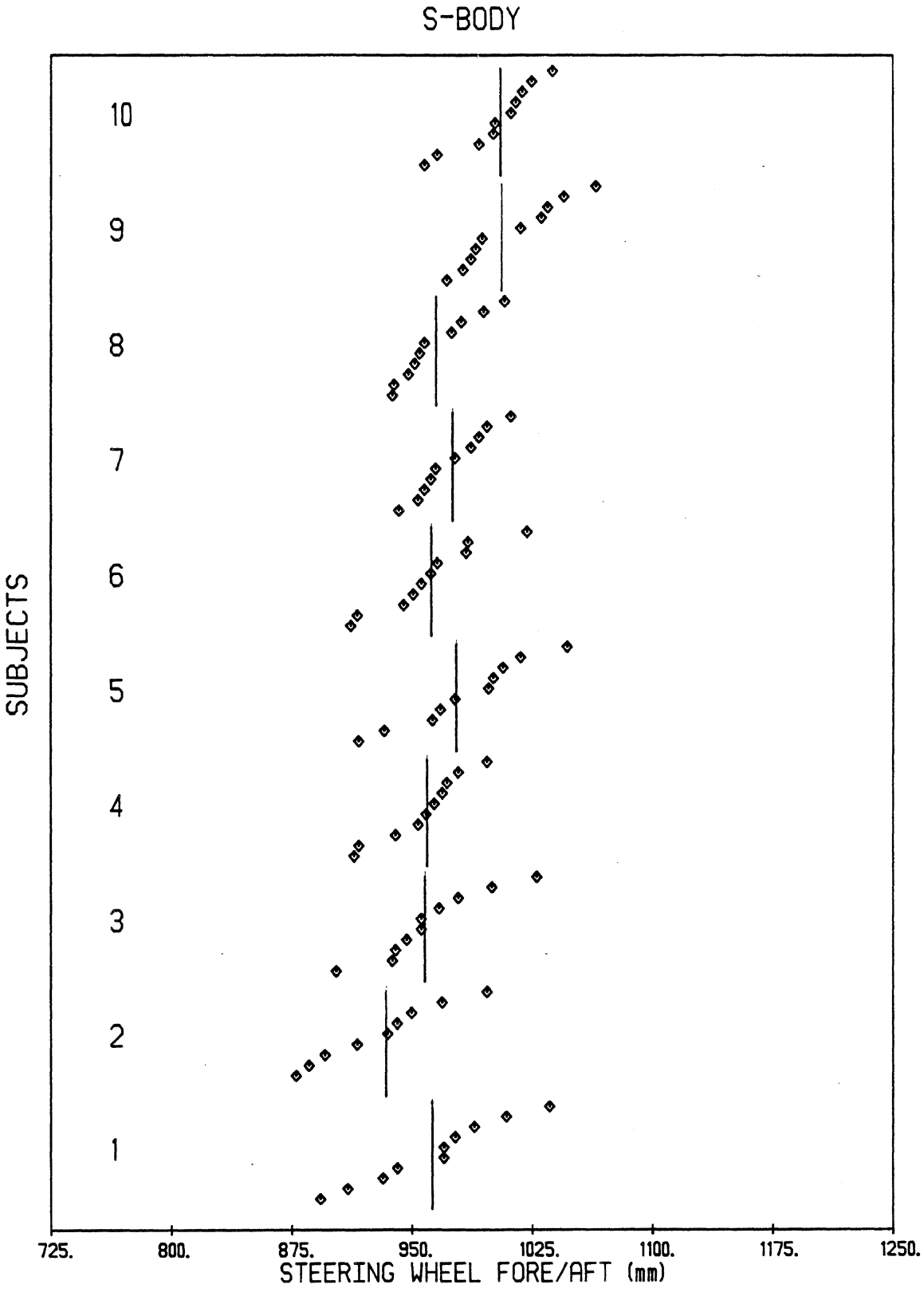
9
8
7
6
5
4
3
2
1
350.
400.
450.
500.
550.
600.
650.
700.
PEDALS FORE/AFT (mm)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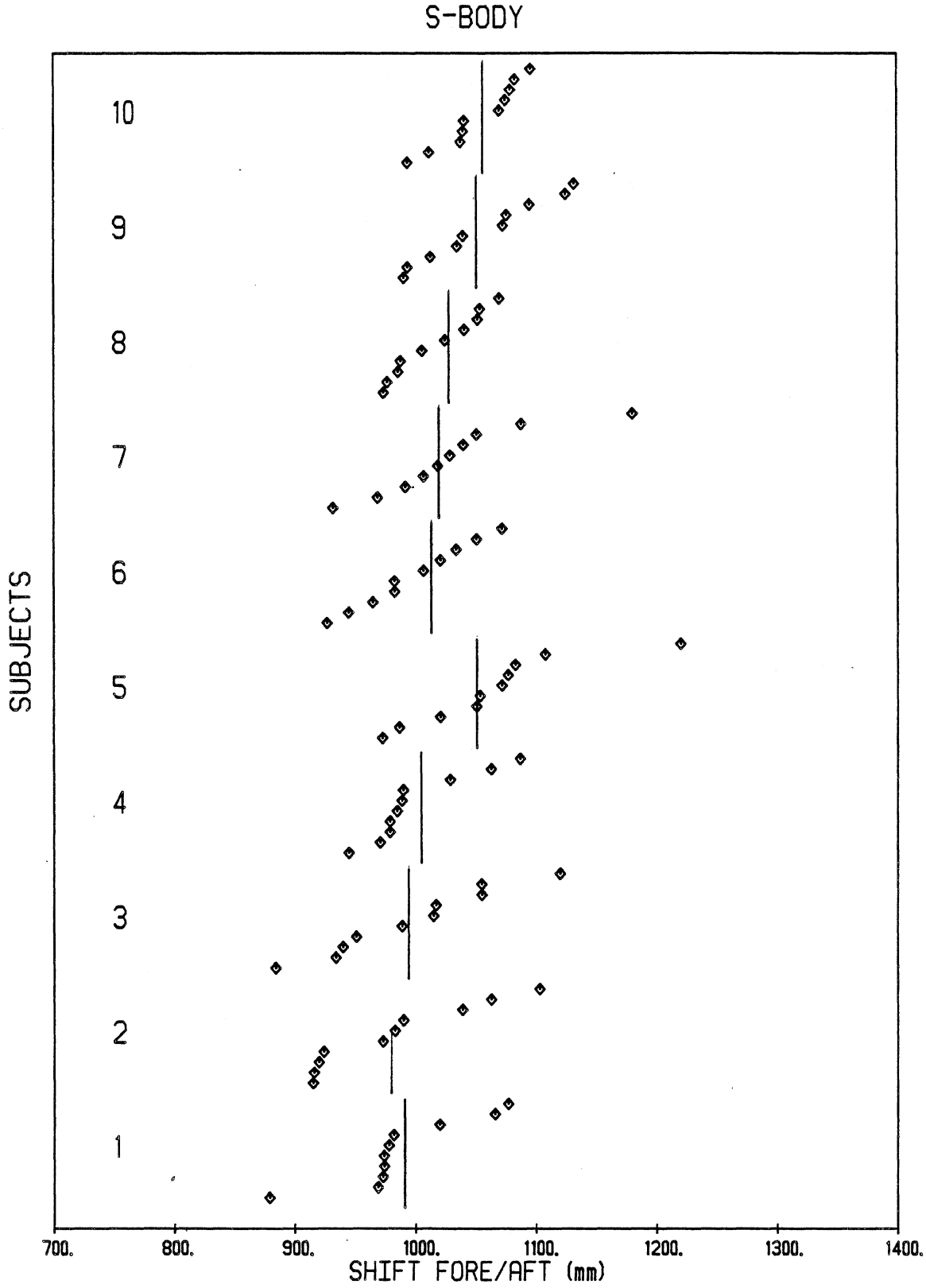
SUBJECTS
10
9
8
7
6
5
4
3
2
1
725.
800.
875.
950.
1025.
1100.
1175.
1250.
STEERING WHEEL FORE/AFT (mm)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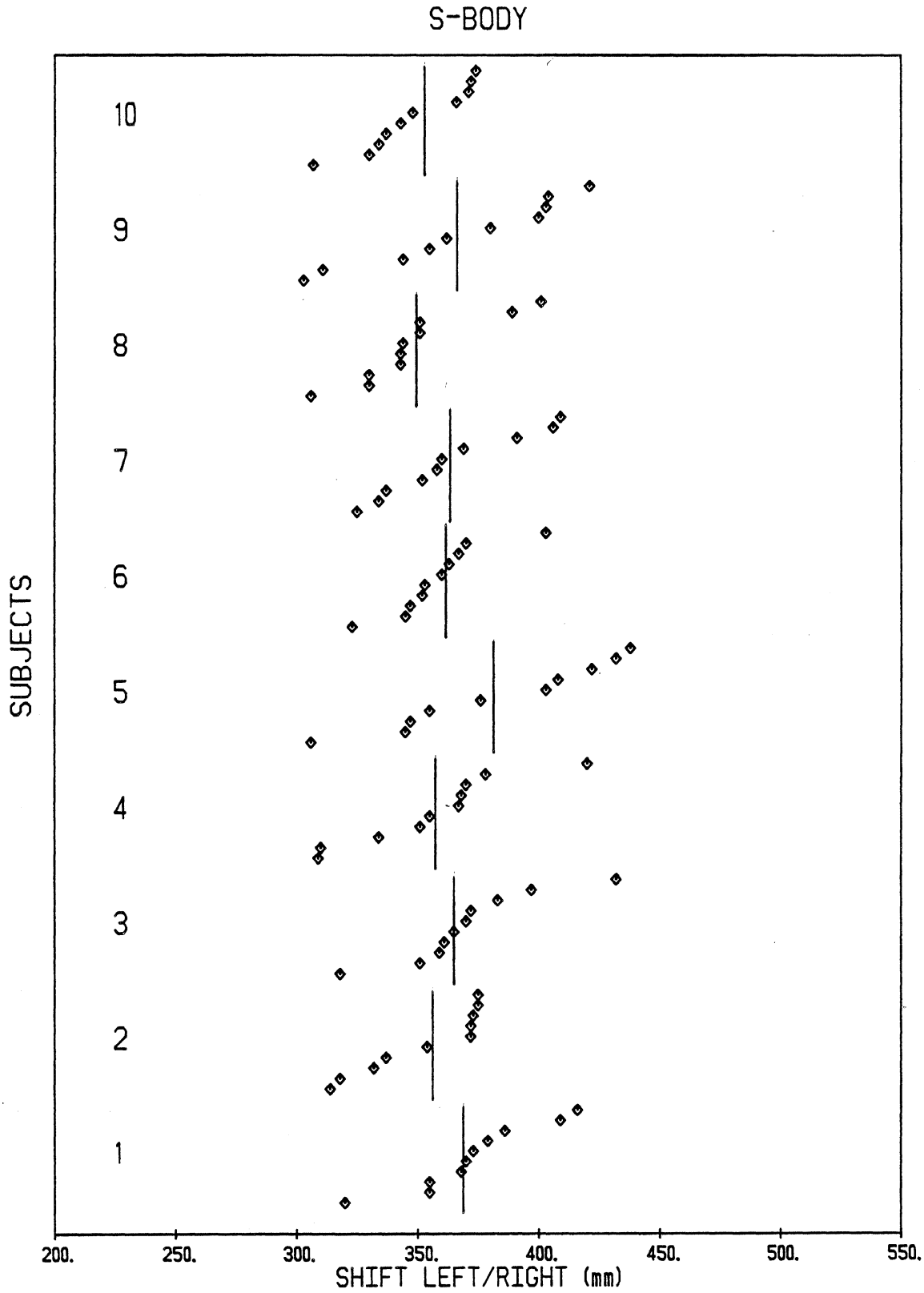
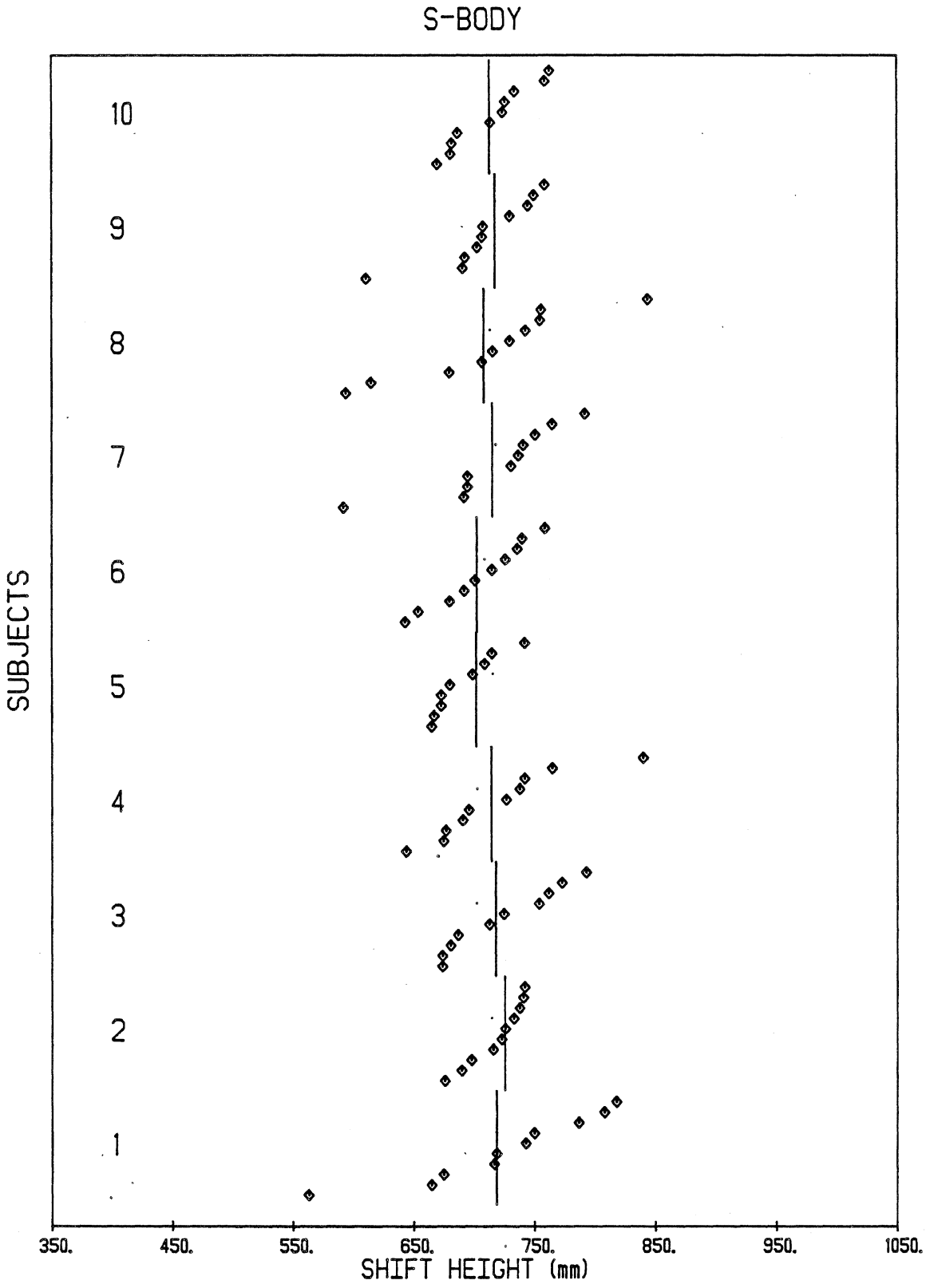
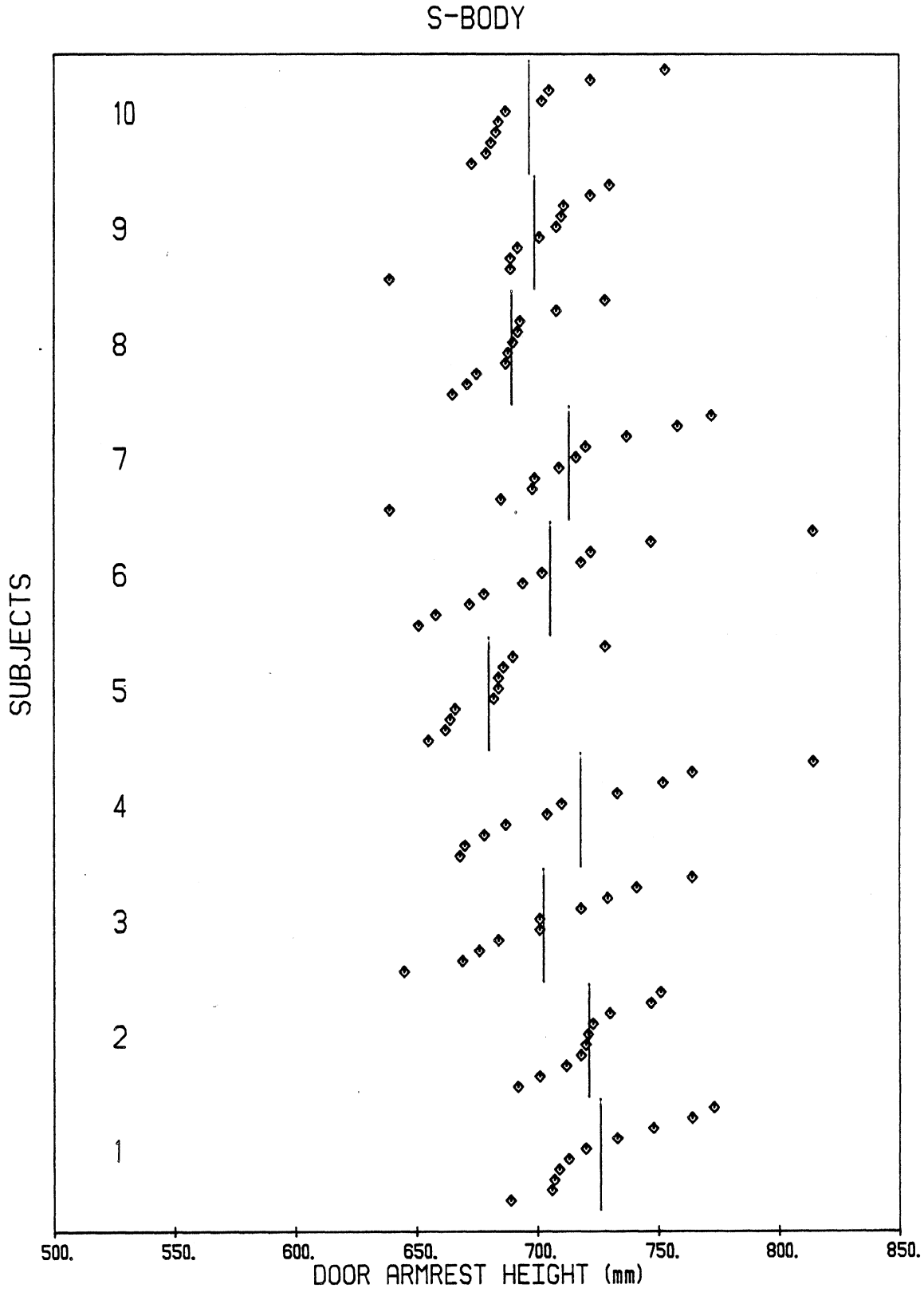
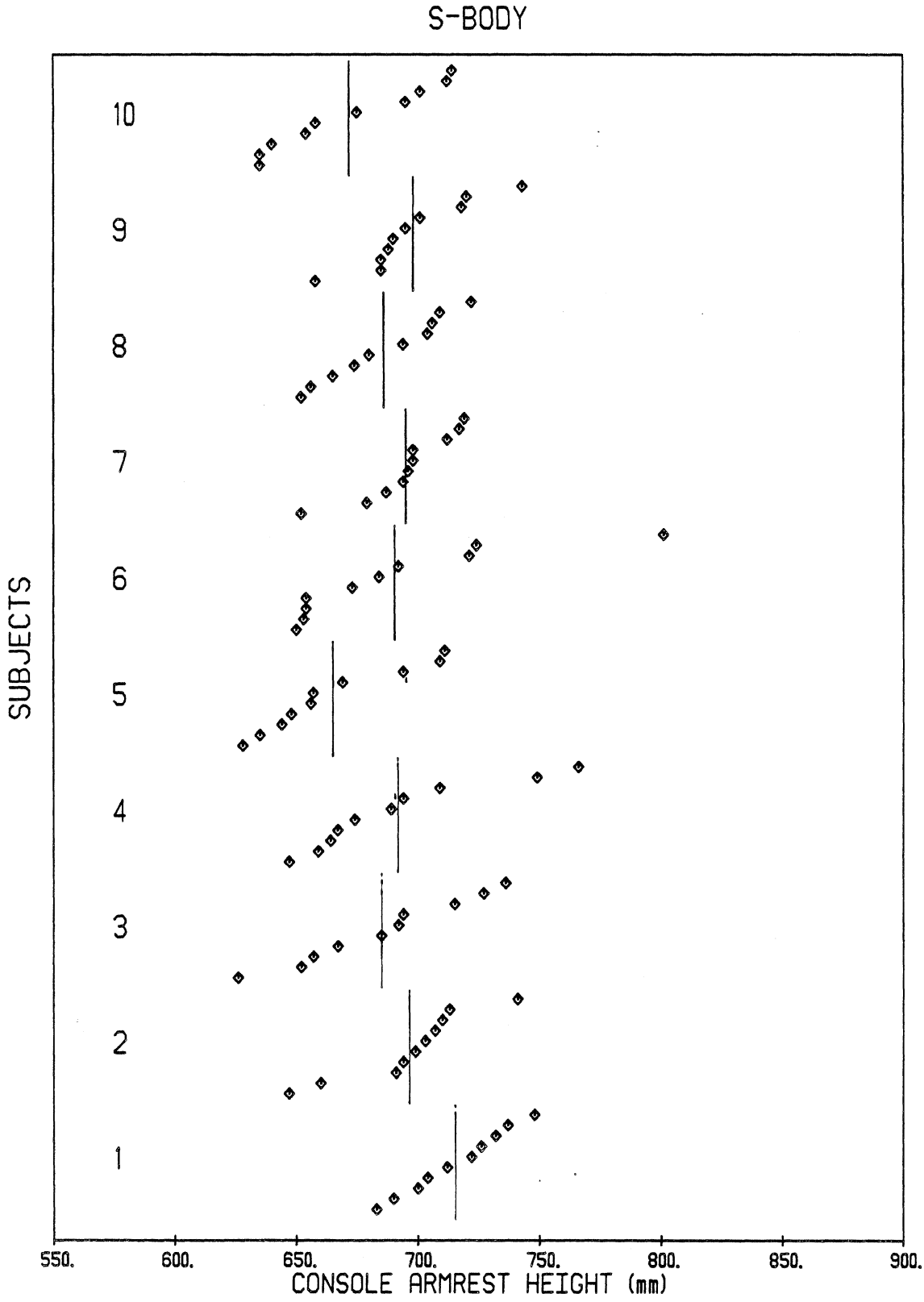
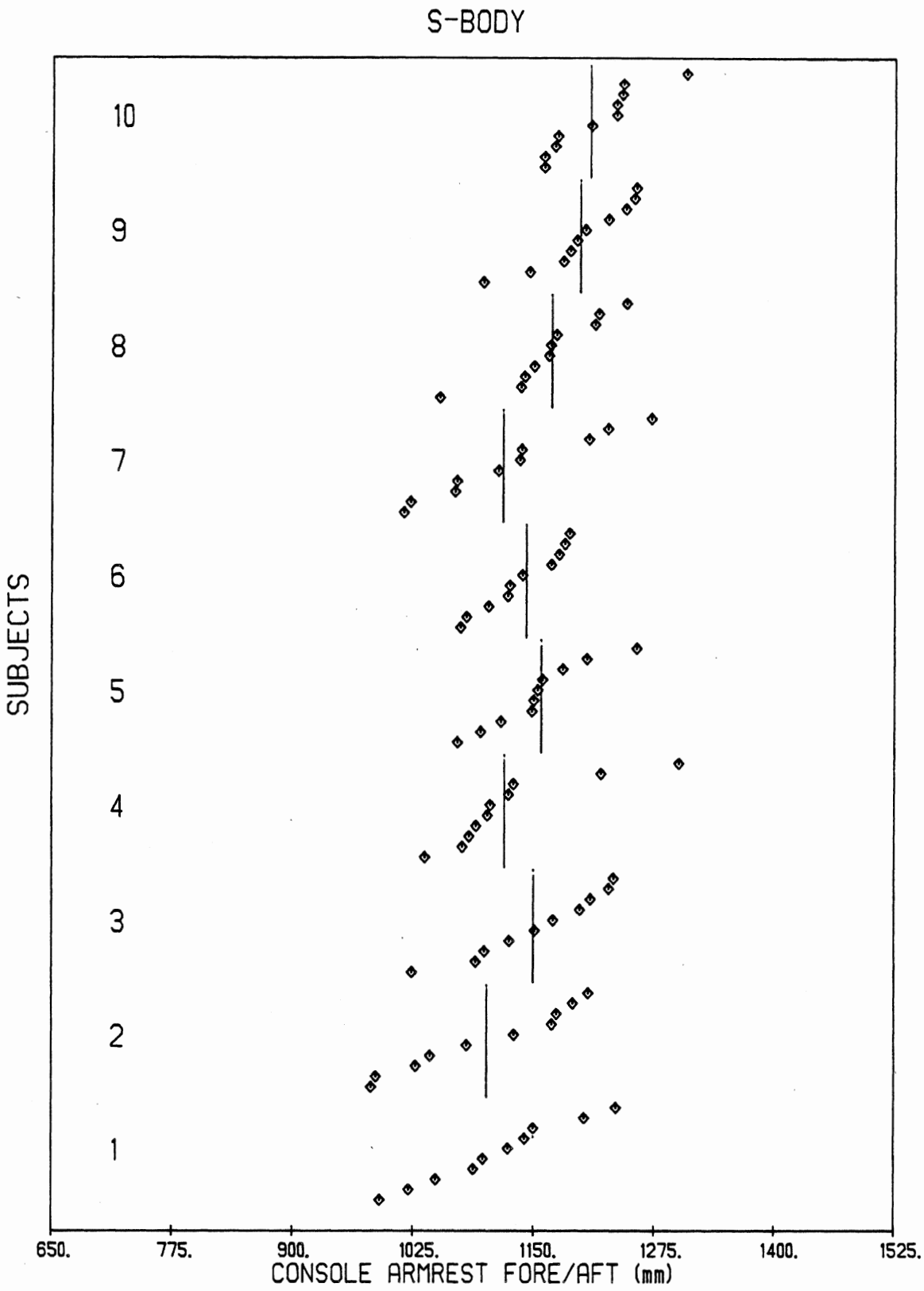
SUBJECTS
10
9
8
7
6
5
4
3
2
1
700.
800.
900.
1000.
1100.
1200.
1300.
1400.
SHIFT FORE/AFT (mm)


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
200.
250.
300.
350.
400.
450.
500.
550.
SHIFT LEFT/RIGHT (mm)


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
350.
450.
550.
650.
750.
850.
950.
1050.
SHIFT HEIGHT (mm)


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
500.
550.
600.
650.
700.
750.
800.
850.
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.
CONSOLE ARMREST HEIGHT (mm)


S-BODY
SUBJECTS
10
9
8
7
6
5
4
3
2
1
650.
775.
900.
1025.
1150.
1275.
1400.
1525.
CONSOLE ARMREST FORE/AFT (mm)

APPENDIX F
GROUP MEAN PREFERRED AND ACCEPTABLE LIMITS RESULTS

Table F-1
Preferred Position and Acceptable Limit Results for
PEDALS FORE/AFT in Vehicle Coordinates (mm)

Group	N	Preferred mean	(sd)	Back Limit mean	(sd)	Front Limit mean	(sd)	Mean Acceptable Range
G-BODY:								
1	10	491	(20)	533	(27)	477	(22)	56
2	10	490	(22)	517	(28)	475	(26)	42
3	10	497	(30)	528	(35)	482	(33)	46
4	10	493	(18)	529	(25)	476	(19)	53
5	10	491	(27)	525	(18)	475	(21)	50
6	10	501	(25)	530	(22)	480	(26)	50
7	10	498	(34)	539	(37)	473	(35)	66
8	10	499	(23)	538	(36)	475	(27)	63
9	10	502	(21)	530	(22)	482	(18)	48
10	10	494	(24)	544	(34)	468	(39)	76
H-BODY:								
1	10	518	(10)	552	(20)	500	(16)	52
2	10	501	(21)	529	(23)	492	(17)	37
3	10	502	(30)	537	(19)	490	(32)	47
4	10	507	(22)	547	(20)	489	(22)	58
5	10	509	(30)	538	(19)	492	(30)	46
6	10	500	(32)	540	(36)	481	(39)	59
7	10	505	(27)	540	(30)	478	(27)	62
8	10	507	(49)	529	(51)	493	(40)	36
9	10	502	(24)	528	(33)	481	(25)	47
10	10	498	(21)	544	(21)	476	(27)	68
S-BODY:								
1	10	506	(30)	551	(31)	493	(28)	58
2	10	522	(25)	555	(19)	509	(25)	46
3	10	503	(28)	542	(23)	490	(26)	52
4	10	508	(20)	553	(28)	490	(22)	63
5	10	512	(19)	557	(27)	491	(27)	66
6	10	514	(37)	564	(39)	491	(42)	73
7	10	510	(36)	560	(46)	482	(33)	78
8	10	503	(36)	540	(45)	479	(31)	61
9	10	515	(17)	543	(26)	492	(13)	51
10	10	508	(29)	556	(23)	474	(32)	82

Table F-2
Preferred Position and Acceptable Limit Results for
STEERING WHEEL FORE/AFT in Vehicle Coordinates (mm)

Group	N	Preferred mean	(sd)	Back Limit mean	(sd)	Front Limit mean	(sd)	Mean Acceptable Range
G-BODY:								
1	10	974	(56)	1017	(59)	939	(56)	78
2	10	968	(57)	1003	(61)	926	(64)	77
3	10	980	(32)	1027	(25)	946	(40)	81
4	10	988	(27)	1040	(46)	948	(47)	92
5	10	1010	(36)	1068	(42)	977	(33)	91
6	10	995	(31)	1042	(34)	952	(42)	90
7	10	1003	(42)	1064	(40)	944	(34)	120
8	10	998	(31)	1038	(37)	969	(33)	69
9	10	1042	(37)	1096	(26)	1003	(30)	93
10	10	1035	(25)	1099	(30)	993	(27)	106
H-BODY:								
1	10	958	(36)	995	(42)	922	(37)	73
2	10	944	(50)	983	(53)	910	(51)	73
3	10	971	(31)	1022	(33)	942	(39)	80
4	10	964	(33)	1018	(43)	928	(40)	90
5	10	985	(33)	1040	(46)	960	(35)	80
6	10	971	(40)	1024	(38)	937	(49)	87
7	10	981	(28)	1038	(26)	920	(42)	118
8	10	971	(40)	1019	(53)	938	(46)	81
9	10	1004	(33)	1064	(31)	964	(33)	100
10	10	1010	(27)	1082	(33)	970	(29)	112
S-BODY:								
1	10	963	(44)	991	(51)	915	(47)	76
2	10	930	(40)	980	(35)	897	(44)	83
3	10	962	(34)	1015	(33)	937	(39)	78
4	10	957	(27)	1010	(29)	914	(39)	96
5	10	983	(39)	1039	(46)	951	(36)	88
6	10	960	(33)	1006	(35)	916	(31)	90
7	10	975	(22)	1030	(38)	910	(33)	120
8	10	964	(23)	1002	(32)	935	(30)	67
9	10	1012	(31)	1053	(32)	971	(34)	82
10	10	1010	(26)	1075	(39)	962	(40)	113

Table F-3
Preferred Position and Acceptable Limit Results for
SHIFT KNOB FORE/AFT in Vehicle Coordinates (mm)

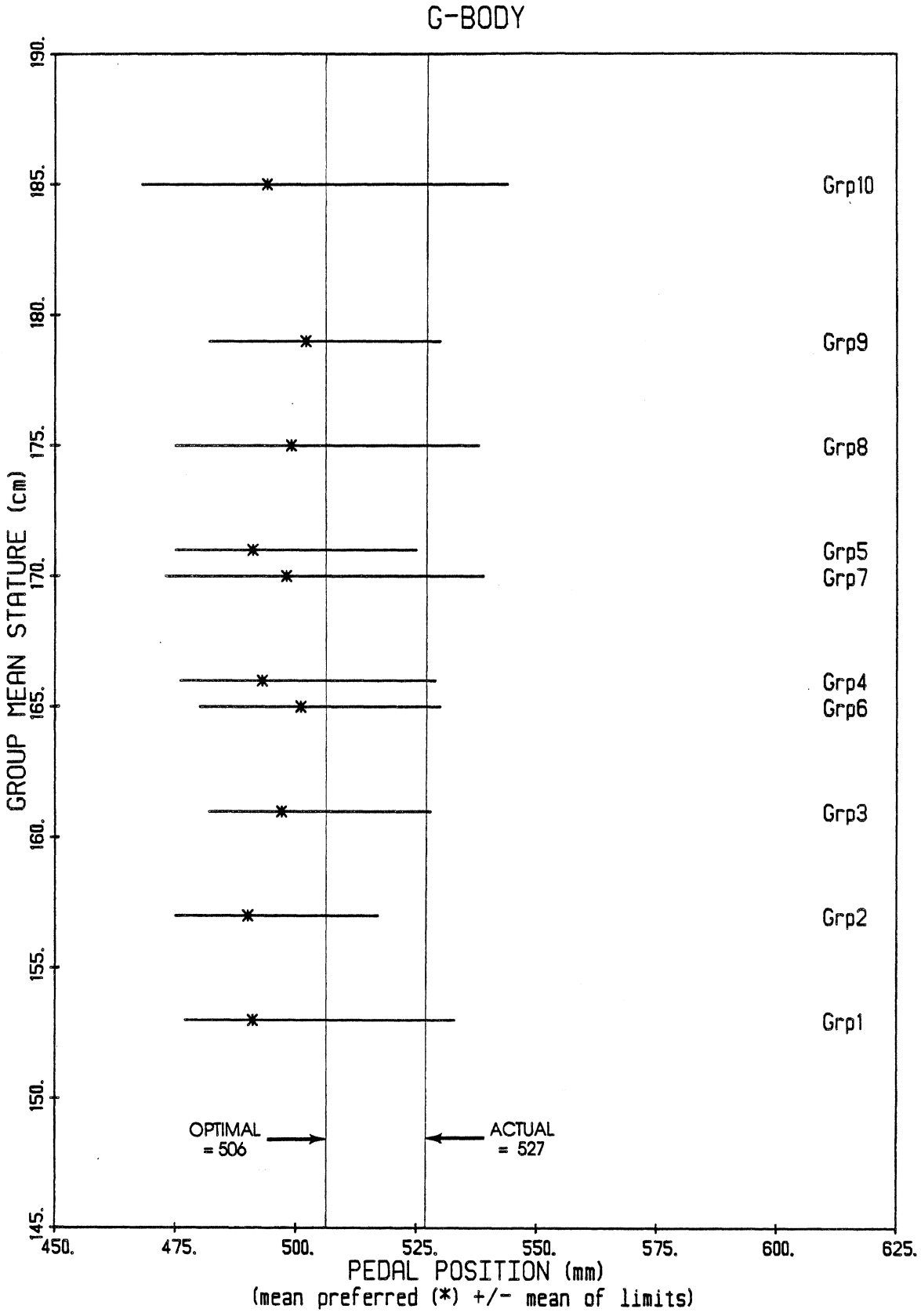
Group	N	Preferred mean	(sd)	Back Limit mean	(sd)	Front Limit mean	(sd)	Mean Acceptable Range
G-BODY:								
1	10	993	(72)	1027	(75)	936	(72)	91
2	10	978	(54)	1028	(54)	934	(65)	94
3	10	1009	(61)	1009	(61)	960	(65)	49
4	10	1025	(57)	1085	(52)	973	(62)	112
5	10	1055	(64)	1116	(51)	1007	(51)	109
6	10	1002	(50)	1061	(55)	953	(59)	108
7	10	1043	(29)	1119	(58)	962	(33)	157
8	10	1024	(33)	1070	(39)	972	(37)	98
9	10	1076	(54)	1127	(68)	1018	(38)	109
10	10	1076	(44)	1157	(60)	981	(61)	176
H-BODY:								
1	10	977	(54)	1019	(65)	934	(48)	85
2	10	976	(42)	1017	(52)	923	(51)	94
3	10	1003	(71)	1048	(74)	961	(72)	87
4	10	1005	(73)	1074	(64)	946	(54)	128
5	10	1054	(54)	1110	(53)	1006	(44)	104
6	10	998	(41)	1055	(39)	949	(54)	106
7	10	1008	(35)	1085	(58)	932	(31)	153
8	10	1012	(46)	1053	(54)	948	(31)	105
9	10	1039	(46)	1118	(53)	981	(49)	137
10	10	1070	(67)	1143	(80)	974	(59)	169
S-BODY:								
1	10	989	(56)	1026	(64)	935	(53)	91
2	10	983	(67)	1032	(67)	932	(60)	100
3	10	996	(71)	1036	(64)	950	(63)	86
4	10	1002	(44)	1065	(60)	951	(51)	114
5	10	1065	(69)	1115	(62)	1015	(51)	100
6	10	999	(47)	1060	(29)	932	(50)	128
7	10	1031	(68)	1088	(82)	943	(56)	145
8	10	1017	(36)	1059	(60)	969	(42)	90
9	10	1057	(51)	1118	(44)	1003	(47)	115
10	10	1053	(33)	1143	(64)	967	(38)	176

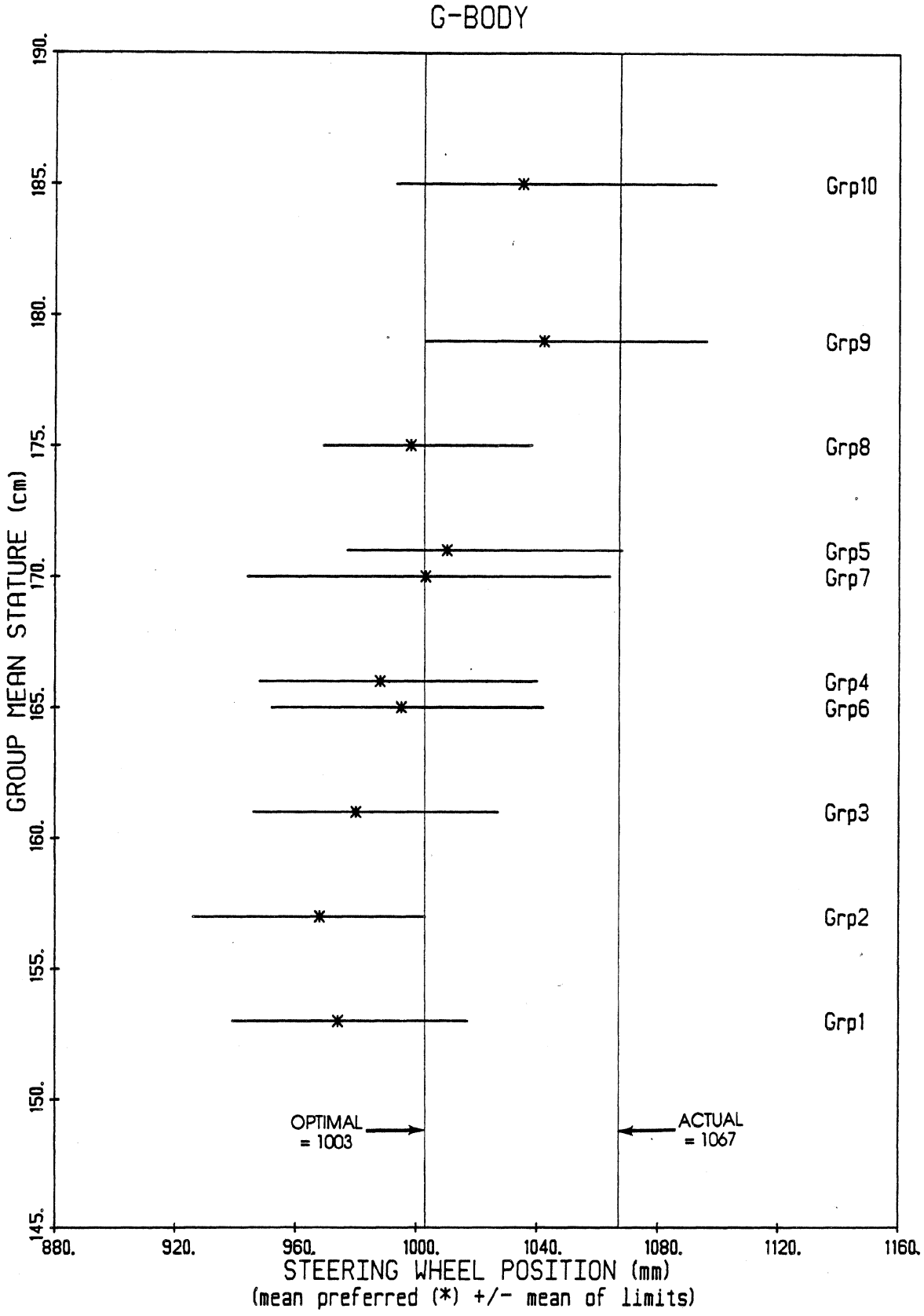
Table F-4
Preferred Position and Acceptable Limit Results for
SHIFT KNOB LEFT/RIGHT in Vehicle Coordinates (mm)

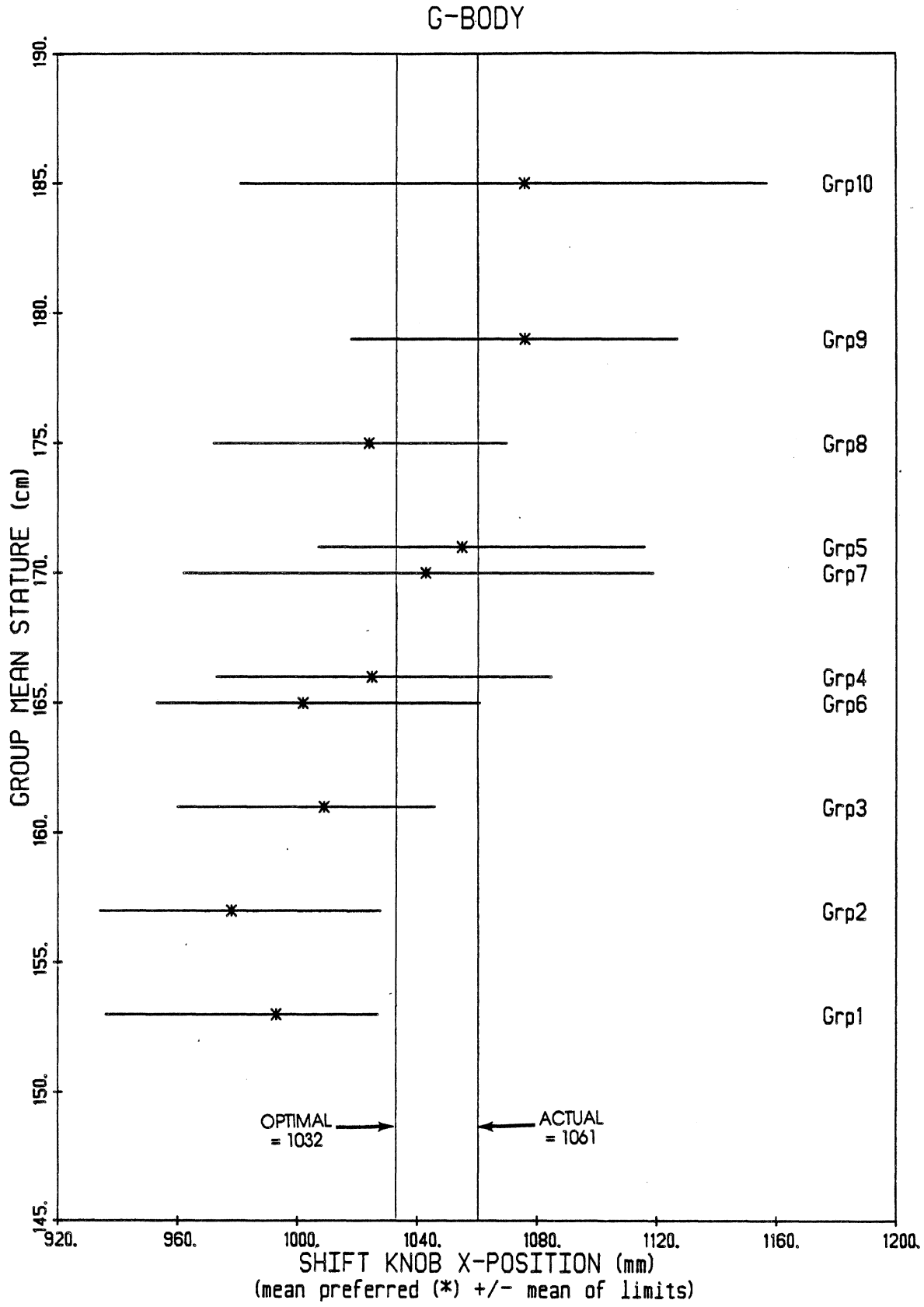
Group	N	Preferred mean	(sd)	Right Limit mean	(sd)	Mean Acceptable Range
G-BODY:						
1	10	372	(42)	423	(48)	51
2	10	349	(27)	419	(35)	70
3	10	362	(26)	416	(21)	54
4	10	359	(24)	425	(43)	66
5	10	374	(38)	428	(36)	54
6	10	355	(26)	424	(38)	69
7	10	371	(24)	464	(38)	93
8	10	353	(19)	417	(32)	64
9	10	362	(32)	435	(34)	73
10	10	356	(20)	443	(44)	87
H-BODY:						
1	10	367	(39)	412	(31)	45
2	10	355	(34)	418	(39)	63
3	10	365	(29)	414	(22)	49
4	10	349	(25)	410	(40)	61
5	10	375	(41)	425	(42)	50
6	10	354	(20)	422	(28)	68
7	10	352	(19)	446	(36)	94
8	10	344	(20)	415	(41)	71
9	10	362	(24)	427	(33)	65
10	10	361	(37)	447	(43)	86
S-BODY:						
1	10	373	(28)	431	(35)	58
2	10	352	(25)	411	(25)	59
3	10	371	(30)	425	(31)	54
4	10	356	(33)	417	(48)	61
5	10	383	(44)	443	(44)	60
6	10	358	(21)	440	(24)	82
7	10	364	(30)	450	(40)	86
8	10	349	(28)	413	(46)	64
9	10	368	(40)	446	(43)	78
10	10	348	(22)	431	(38)	83

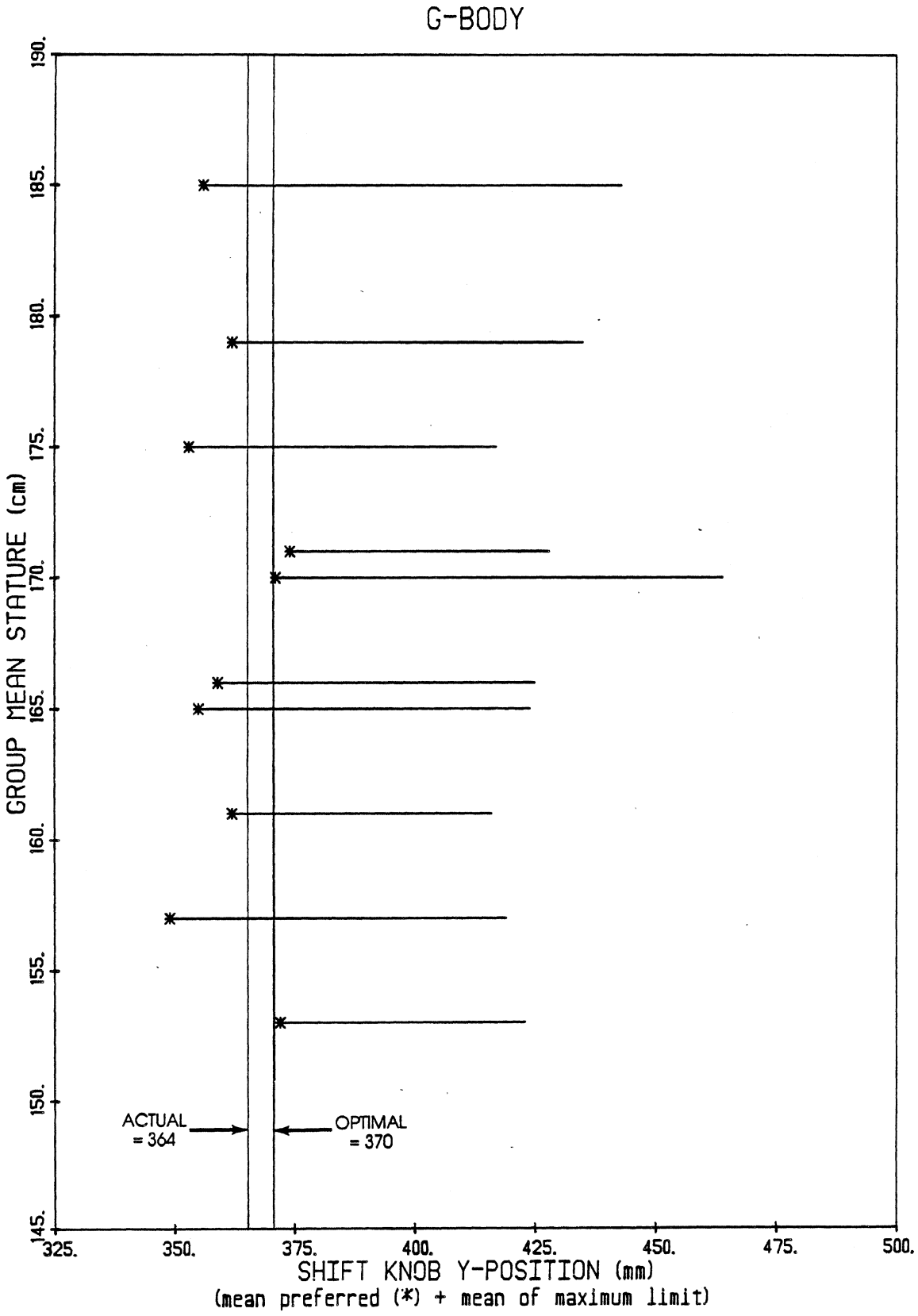
Table F-5
Preferred Position and Acceptable Limit Results for
SHIFT KNOB HEIGHT in Vehicle Coordinates (mm)

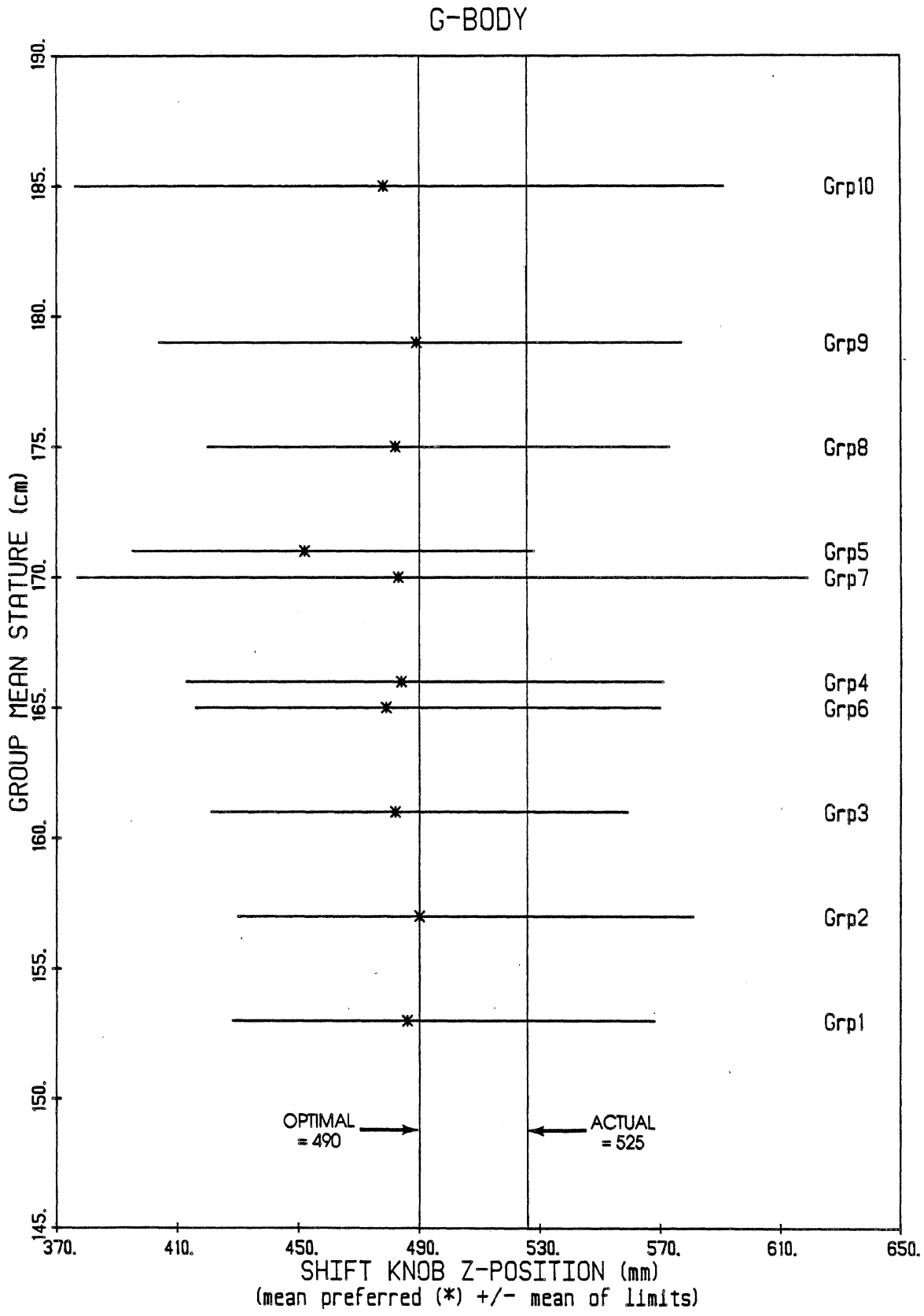
Group	N	Preferred mean	(sd)	Upper Limit mean	(sd)	Lower Limit mean	(sd)	Mean Acceptable Range
G-BODY:								
1	10	486	(78)	568	(82)	428	(75)	140
2	10	490	(29)	581	(70)	430	(28)	151
3	10	482	(45)	559	(54)	421	(35)	138
4	10	484	(43)	571	(76)	413	(52)	158
5	10	452	(49)	528	(40)	395	(49)	133
6	10	479	(44)	570	(35)	416	(54)	154
7	10	483	(52)	619	(78)	377	(50)	242
8	10	482	(50)	573	(71)	420	(44)	153
9	10	489	(48)	577	(59)	404	(58)	173
10	10	478	(43)	591	(76)	376	(63)	215
H-BODY:								
1	10	523	(89)	623	(80)	452	(69)	171
2	10	530	(34)	610	(57)	455	(41)	155
3	10	476	(58)	568	(59)	423	(64)	145
4	10	504	(50)	590	(64)	433	(51)	157
5	10	484	(41)	570	(39)	423	(51)	147
6	10	496	(53)	601	(38)	427	(51)	174
7	10	512	(61)	629	(71)	413	(43)	216
8	10	506	(34)	594	(62)	450	(41)	144
9	10	512	(47)	600	(54)	435	(44)	165
10	10	506	(44)	611	(76)	399	(50)	212
S-BODY:								
1	10	725	(77)	793	(76)	652	(64)	141
2	10	718	(23)	790	(52)	660	(23)	130
3	10	724	(45)	792	(48)	660	(43)	132
4	10	720	(56)	795	(49)	644	(45)	151
5	10	691	(26)	762	(24)	635	(40)	127
6	10	705	(38)	809	(32)	604	(34)	205
7	10	719	(55)	823	(41)	612	(62)	211
8	10	714	(72)	793	(55)	652	(69)	141
9	10	710	(42)	798	(41)	627	(41)	171
10	10	714	(33)	795	(51)	602	(50)	193

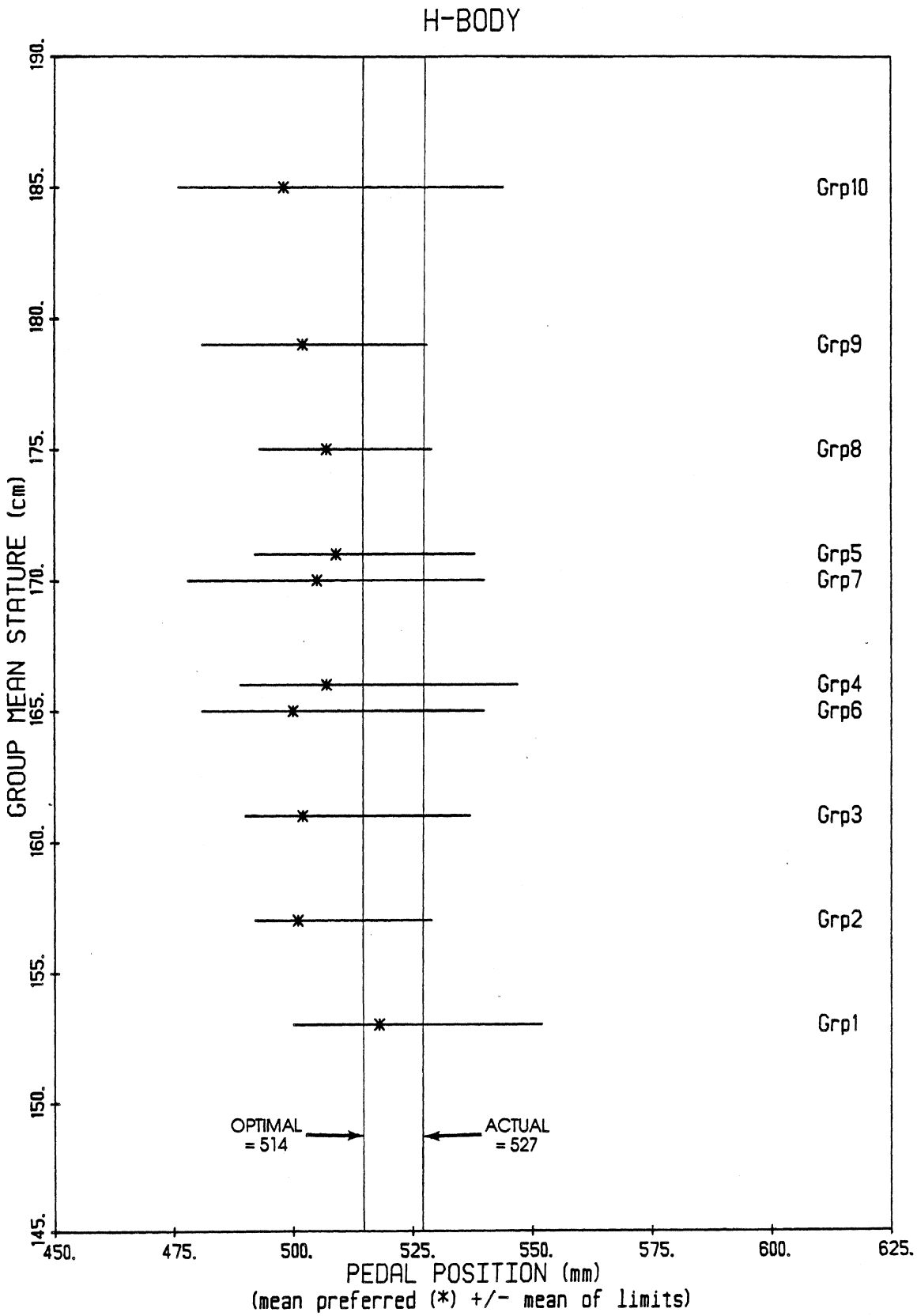

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 506
ACTUAL
= 527
450.
475.
500.
525.
550.
575.
600.
625.
PEDAL POSITION (mm)
(mean preferred (*) +/- mean of limits)

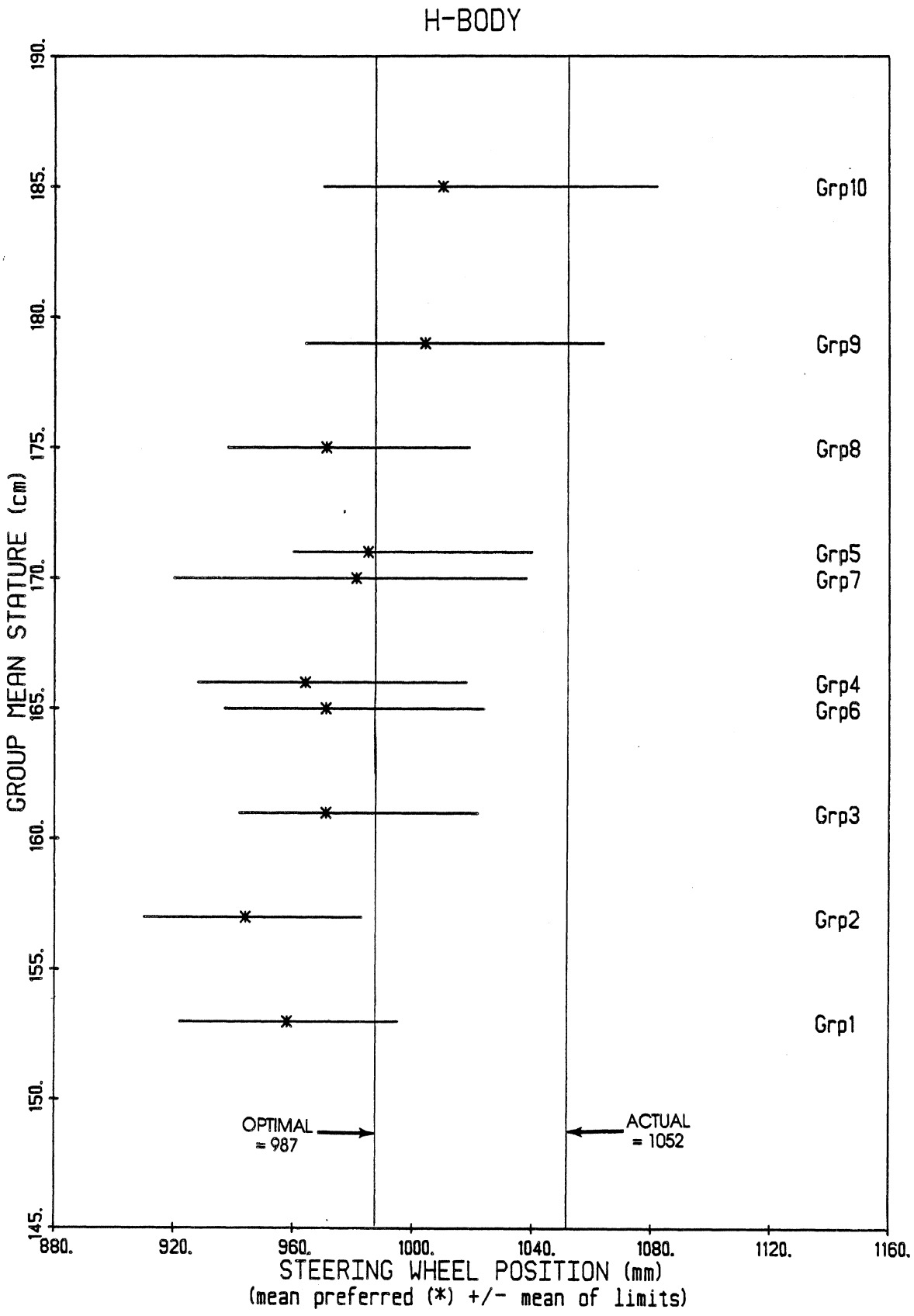

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 1003
ACTUAL
= 1067
880.
920.
960.
1000.
1040.
1080.
1120.
1160.
STEERING WHEEL POSITION (mm)
(mean preferred (*) +/- mean of limits)

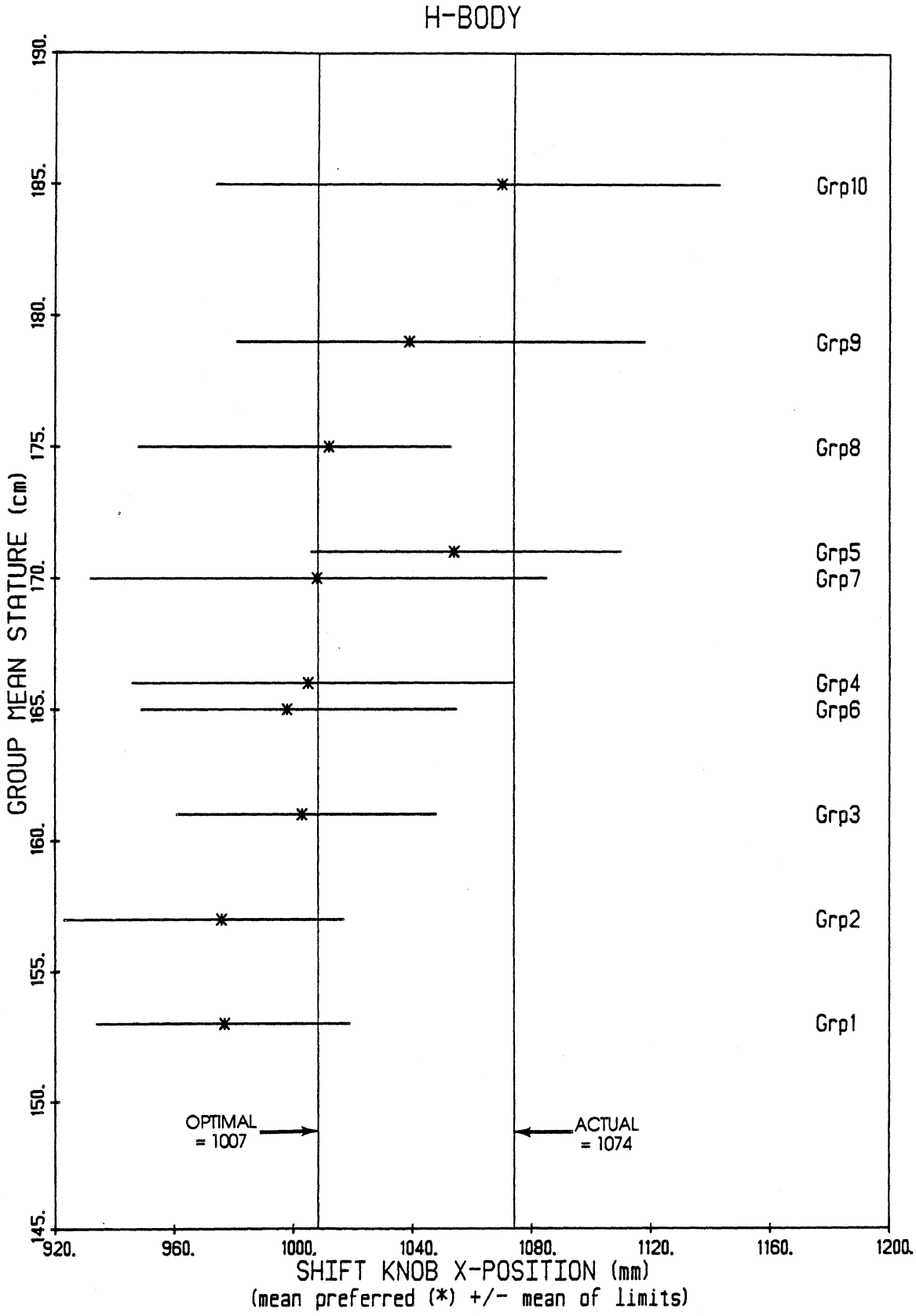

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 1032
ACTUAL
= 1061
920.
960.
1000.
1040.
1080.
1120.
1160.
1200.
SHIFT KNOB X-POSITION (mm)
(mean preferred (*) +/- mean of limits)

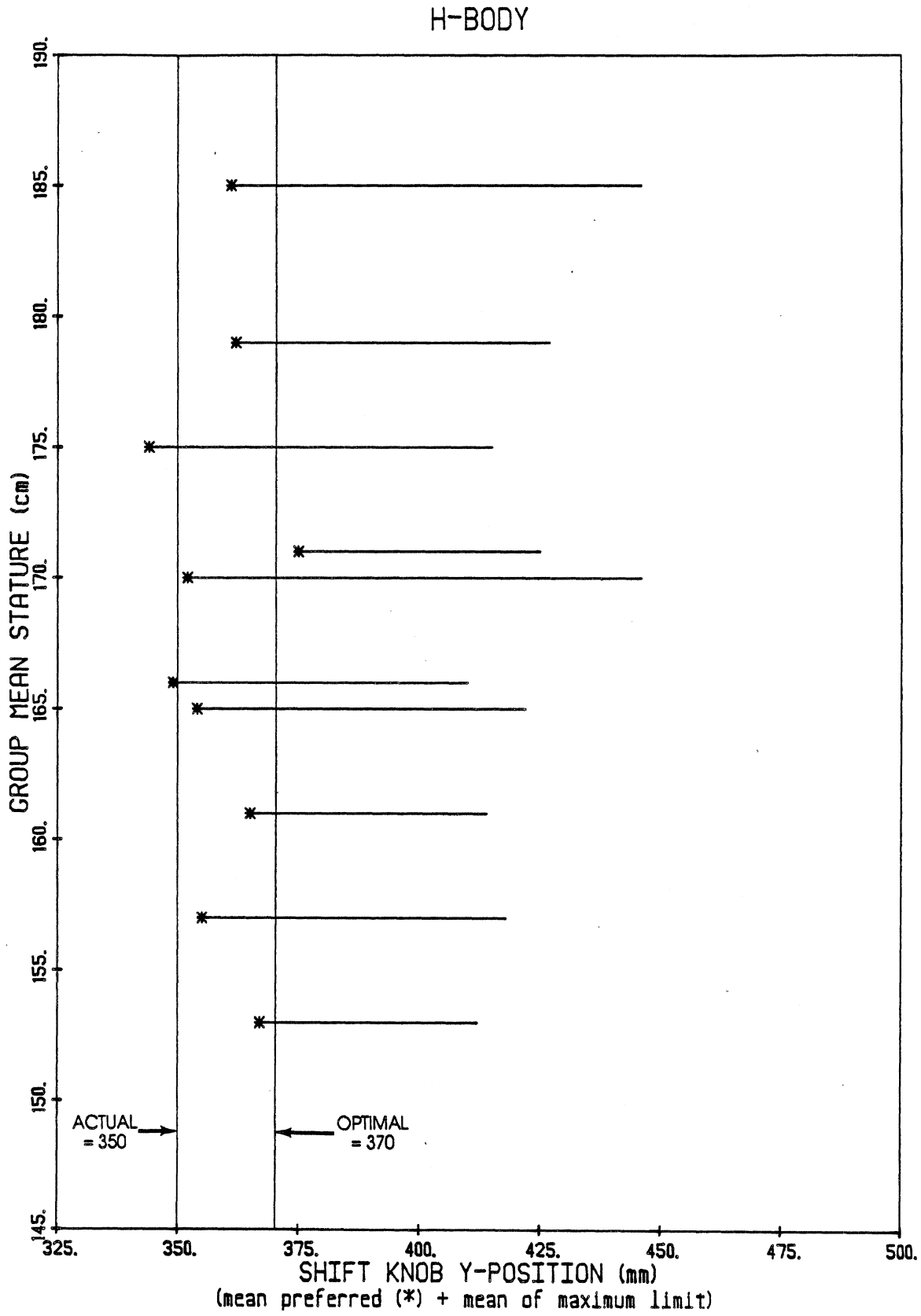

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
ACTUAL
= 364
OPTIMAL
= 370
325.
350.
375.
400.
425.
450.
475.
500.
SHIFT KNOB Y-POSITION (mm)
(mean preferred (*) + mean of maximum limit)

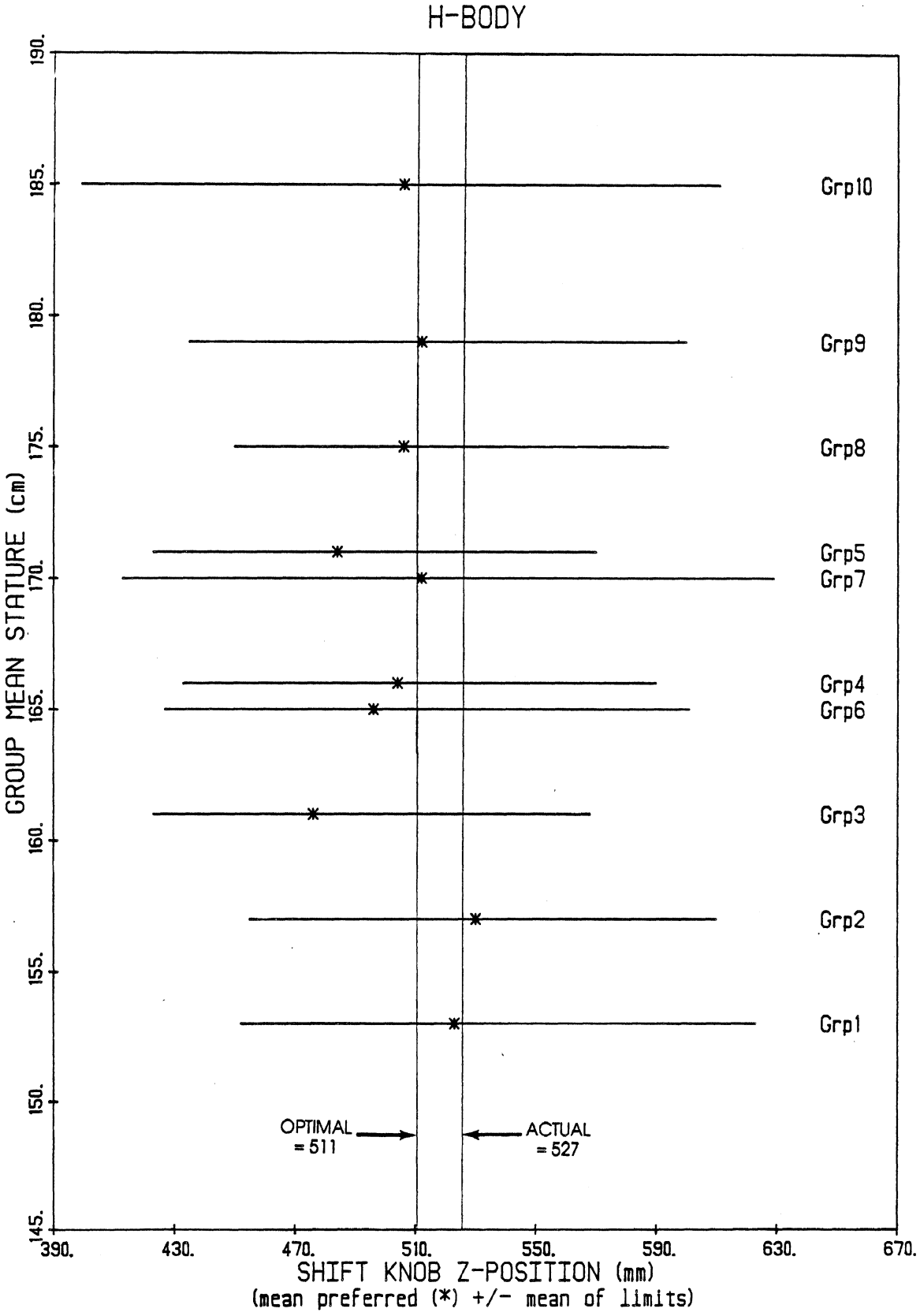

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 490
ACTUAL
= 525
370.
410.
450.
490.
530.
570.
610.
650.
SHIFT KNOB Z-POSITION (mm)
(mean preferred (*) +/- mean of limits)

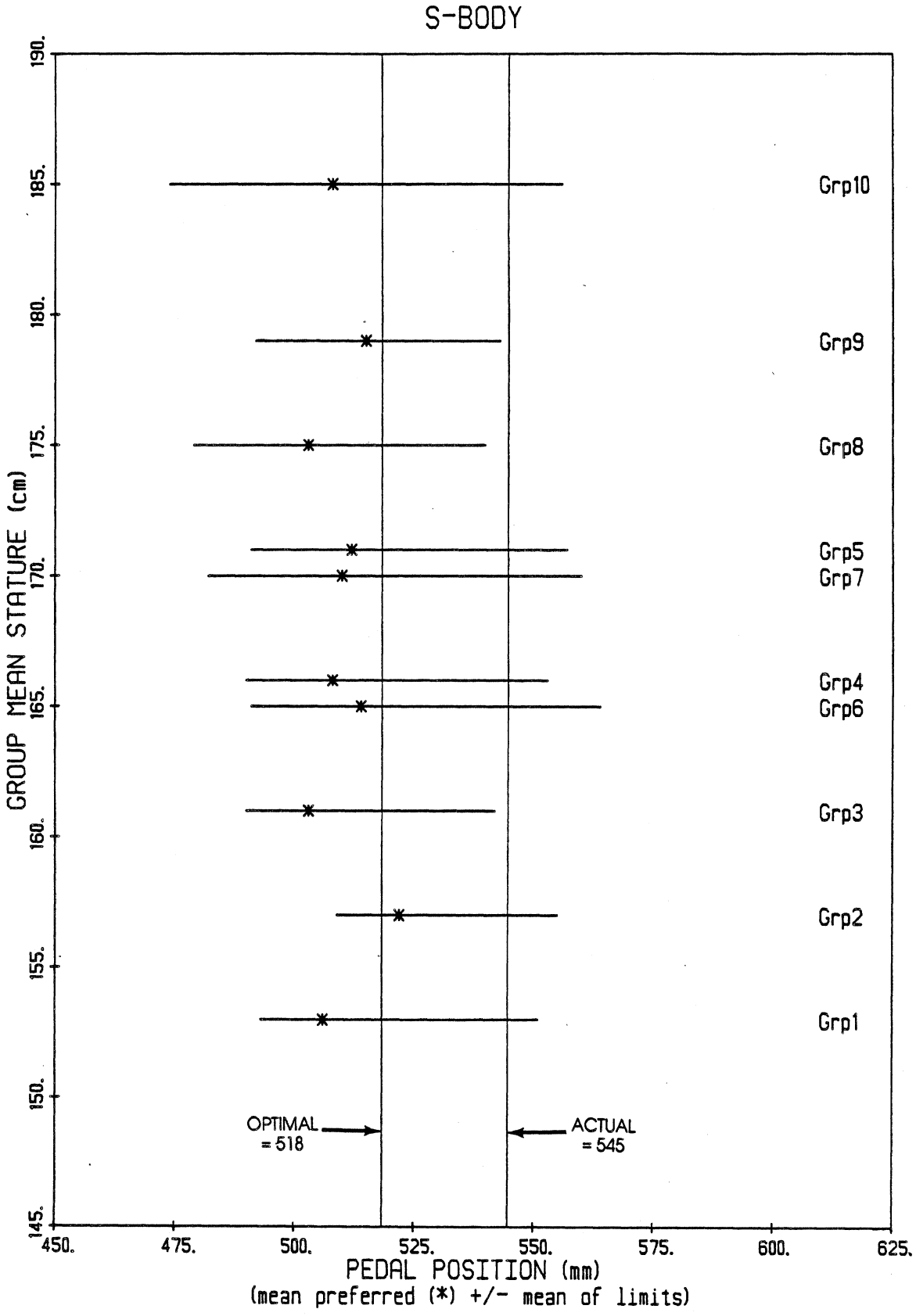

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 514
ACTUAL
= 527
450.
475.
500.
525.
550.
575.
600.
625.
PEDAL POSITION (mm)
(mean preferred (*) +/- mean of limits)

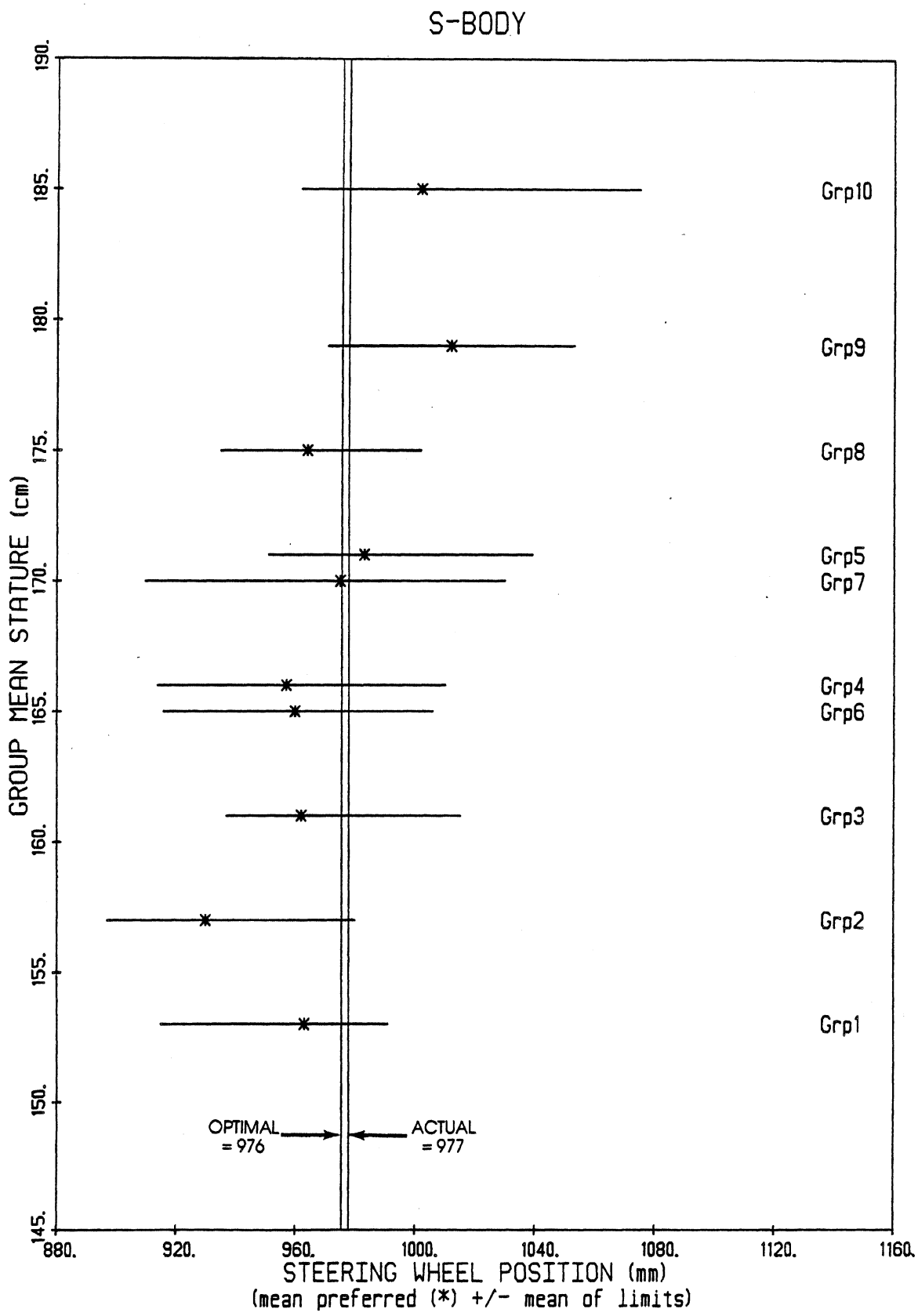

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 987
ACTUAL
= 1052
880.
920.
960.
1000.
1040.
1080.
1120.
1160.
STEERING WHEEL POSITION (mm)
(mean preferred (*) +/- mean of limits)

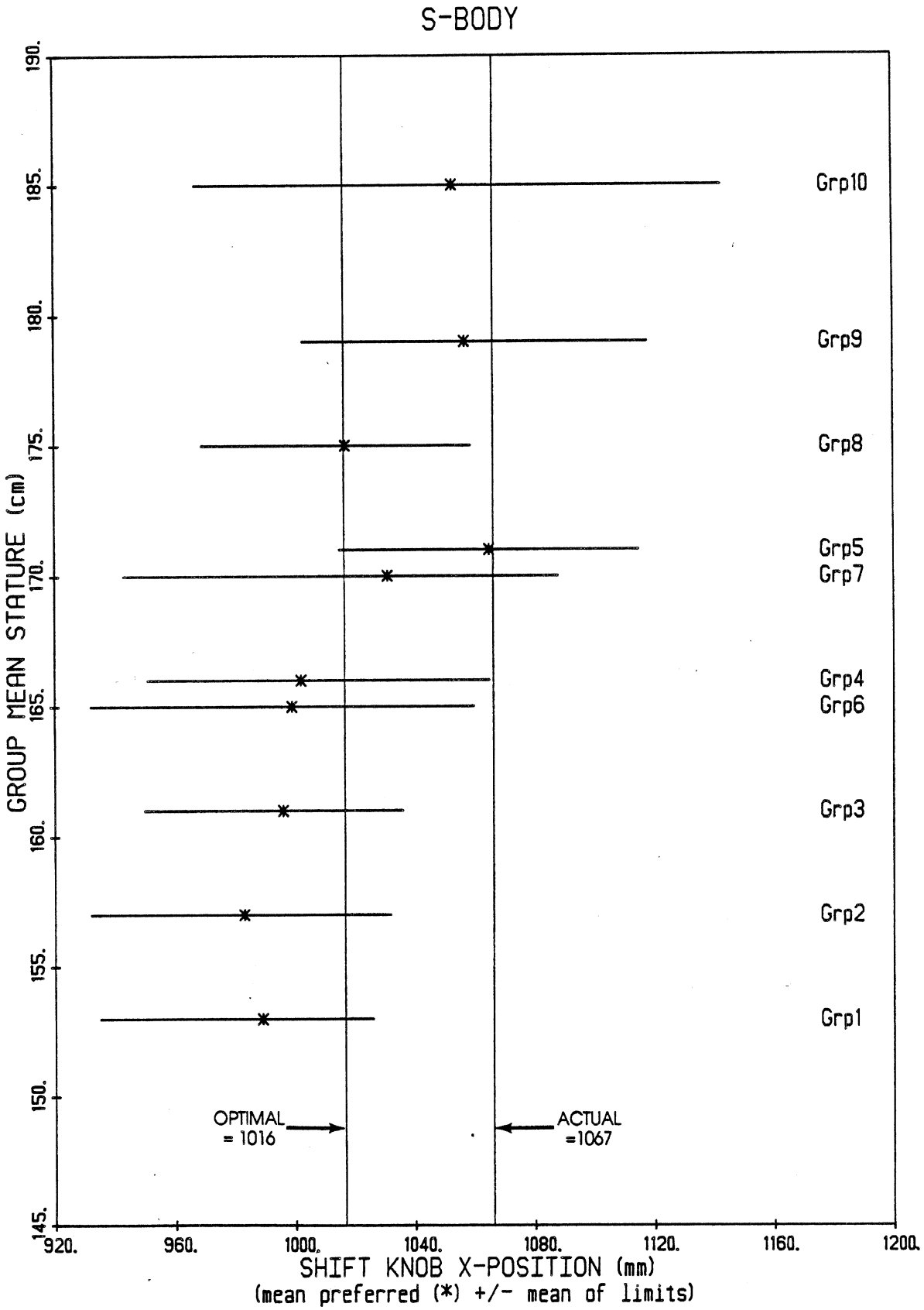

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 1007
ACTUAL
= 1074
920.
960.
1000.
1040.
1080.
1120.
1160.
1200.
SHIFT KNOB X-POSITION (mm)
(mean preferred (*) +/- mean of limits)

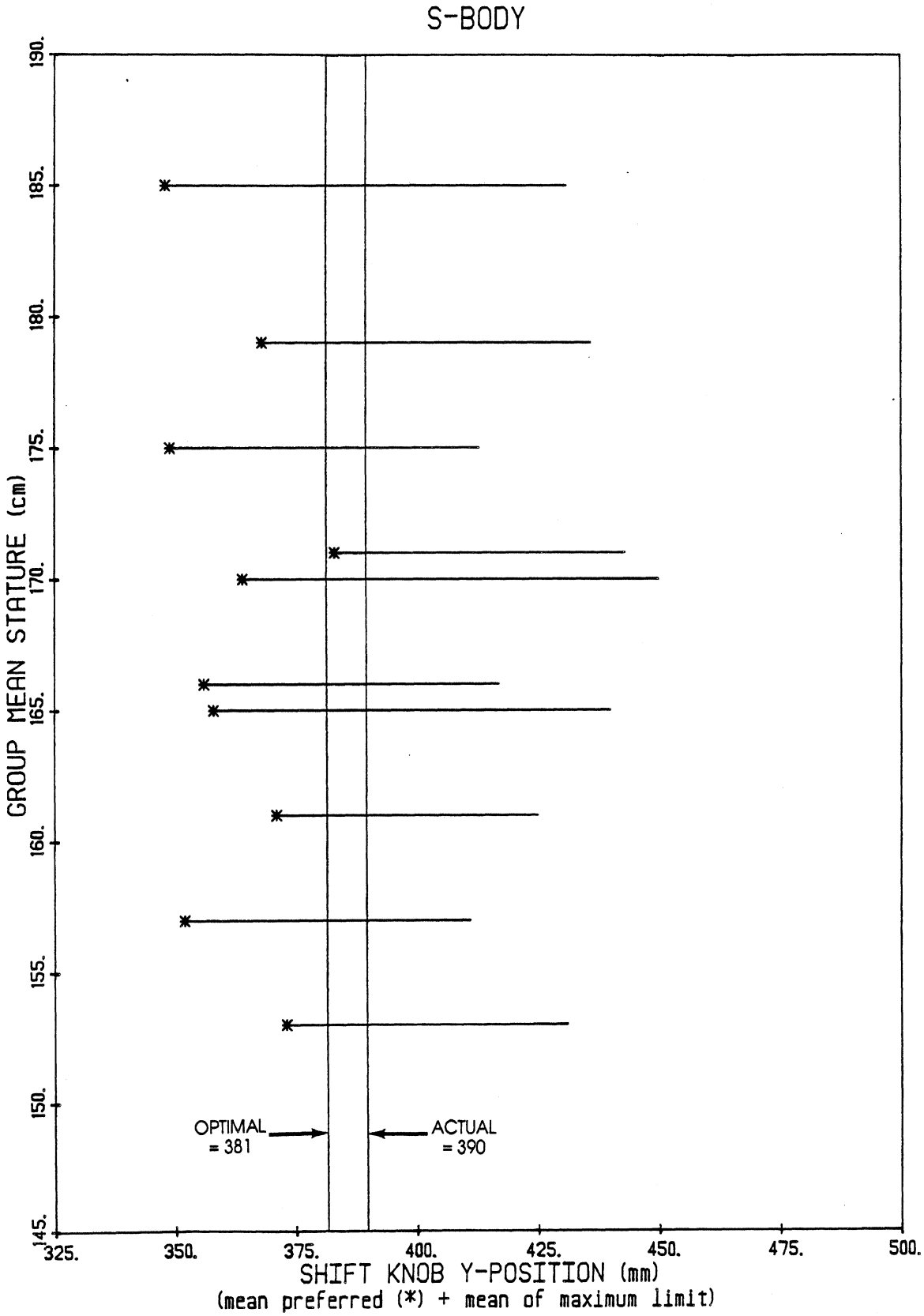

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
ACTUAL
= 350
OPTIMAL
= 370
325.
350.
375.
400.
425.
450.
475.
500.
SHIFT KNOB Y-POSITION (mm)
(mean preferred (*) + mean of maximum limit)

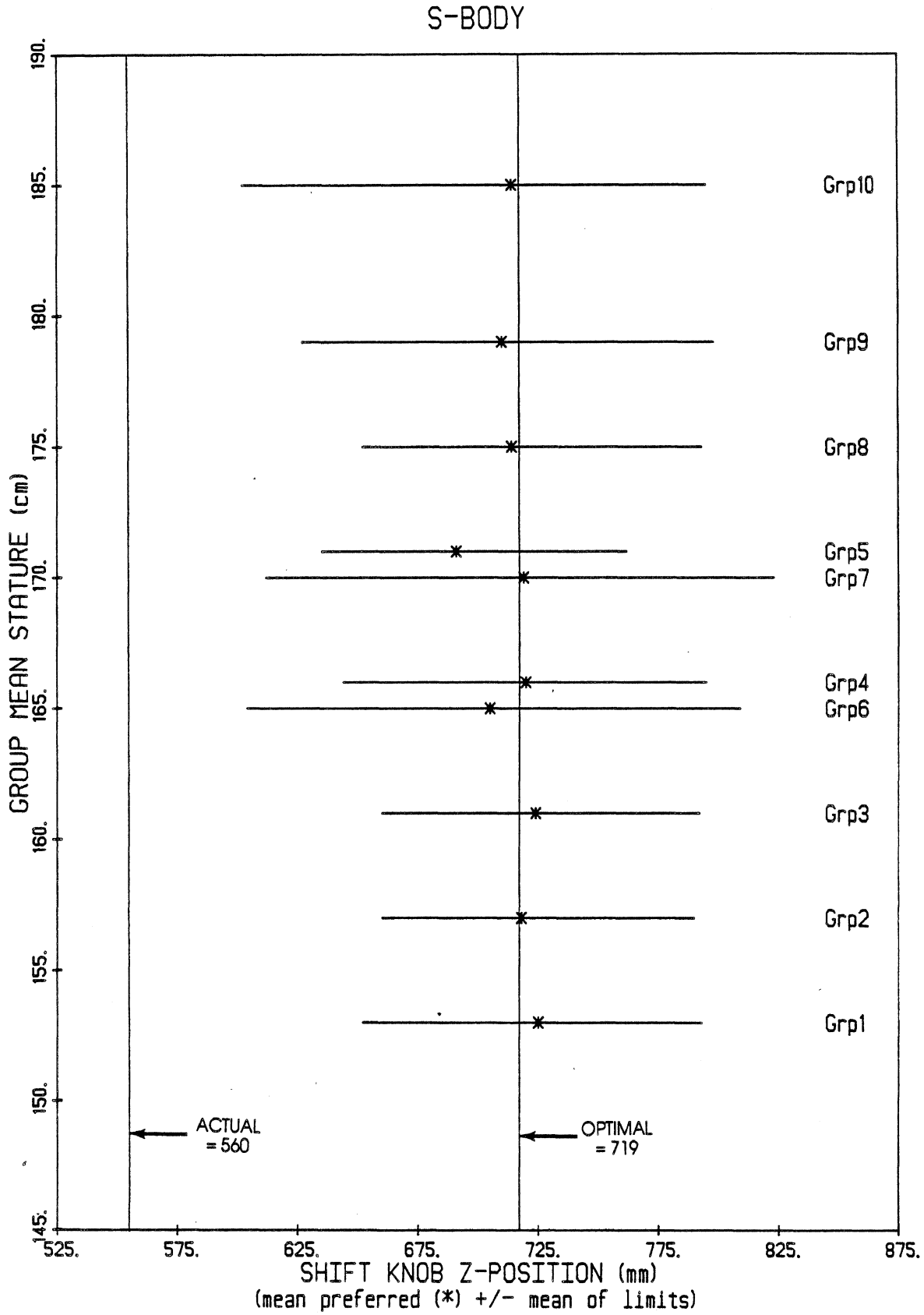

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 511
ACTUAL
= 527
390.
430.
470.
510.
550.
590.
630.
670.
SHIFT KNOB Z-POSITION (mm)
(mean preferred (*) +/- mean of limits)

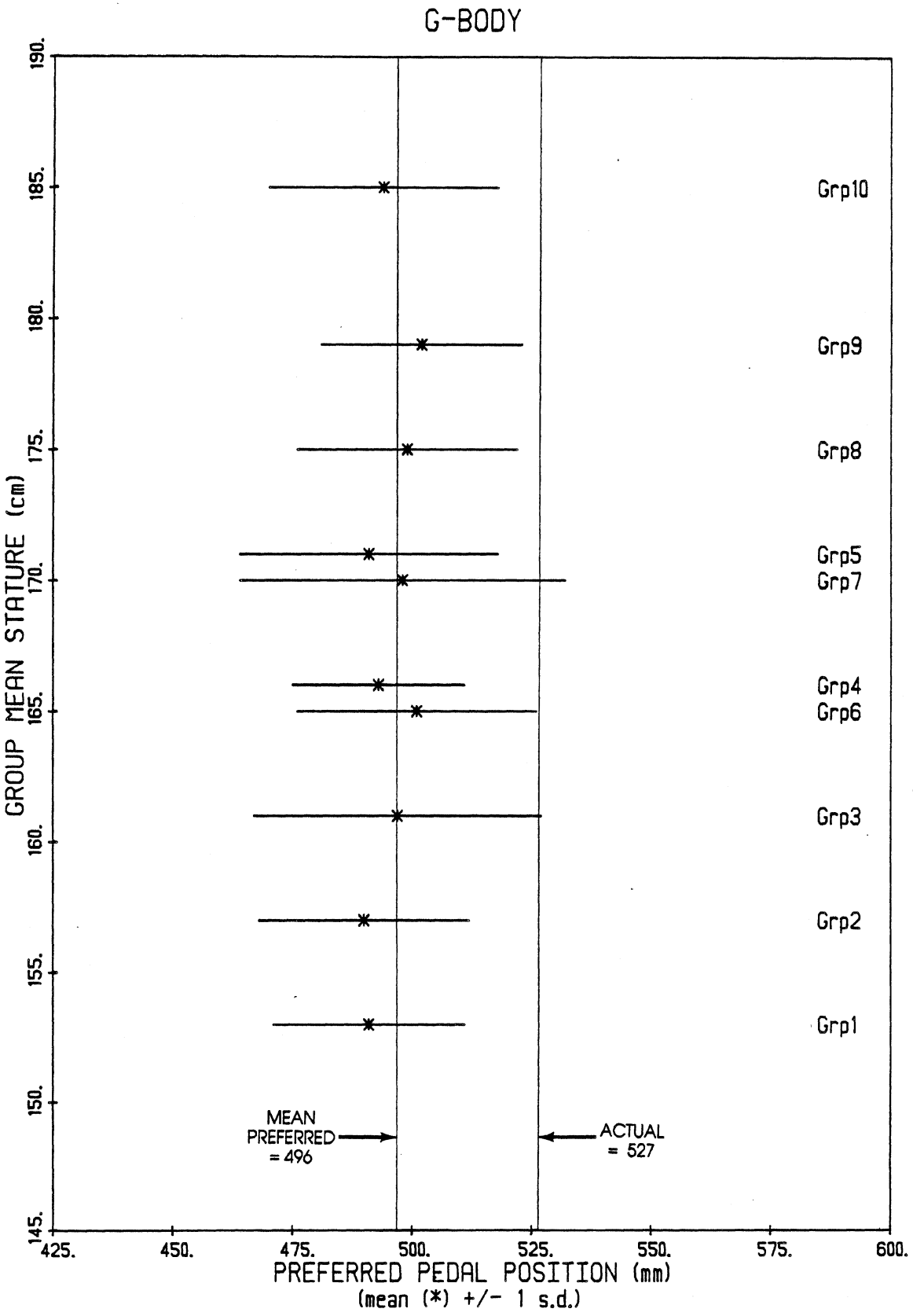

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 518
ACTUAL
= 545
450.
475.
500.
525.
550.
575.
600.
625.
PEDAL POSITION (mm)
(mean preferred (*) +/- mean of limits)

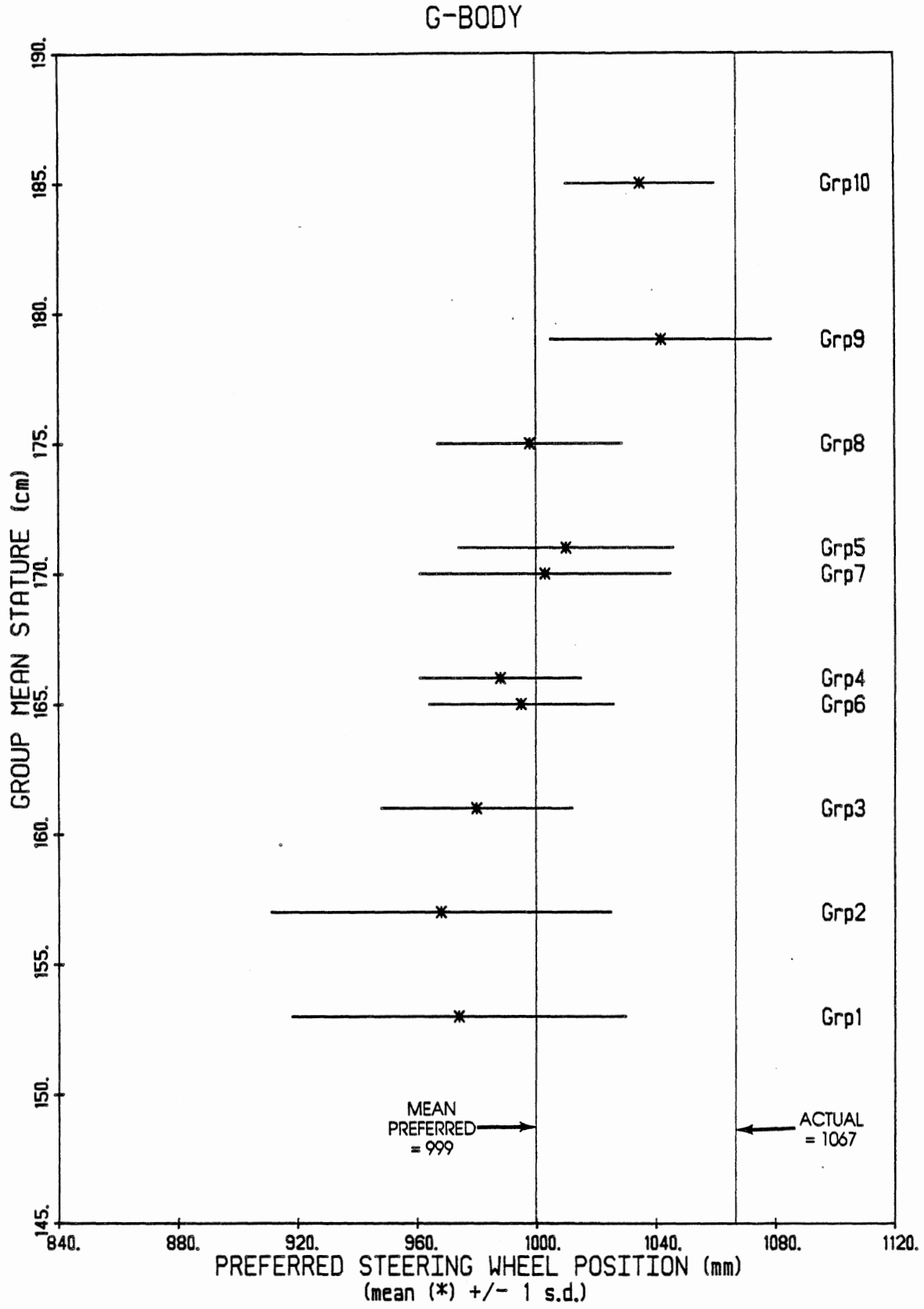

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 976
ACTUAL
= 977
880.
920.
960.
1000.
1040.
1080.
1120.
1160.
STEERING WHEEL POSITION (mm)
(mean preferred (*) +/- mean of limits)

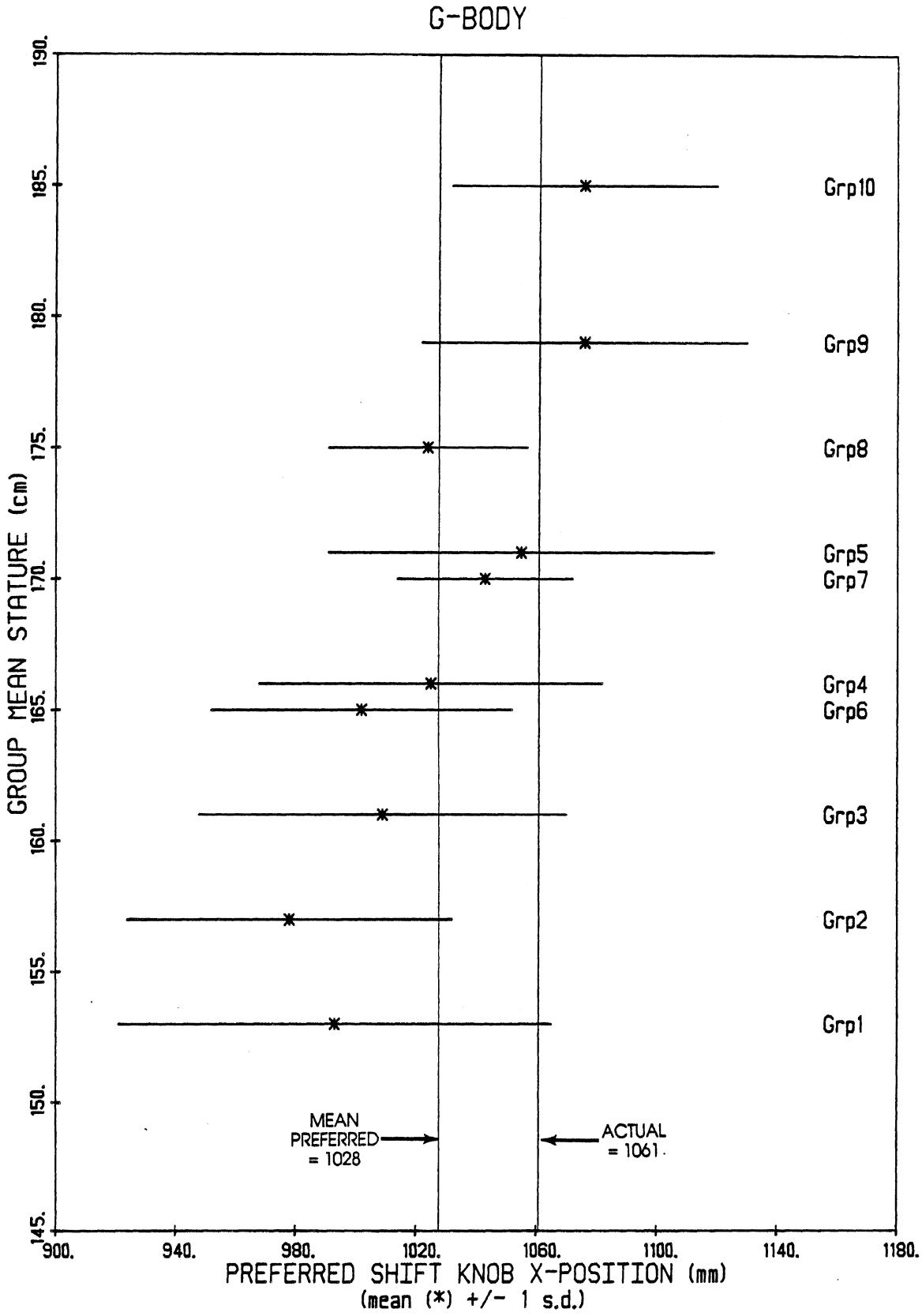

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
OPTIMAL
= 1016
ACTUAL
=1067
920.
960.
1000.
1040.
1080.
1120.
1160.
1200.
SHIFT KNOB X-POSITION (mm)
(mean preferred (*) +/- mean of limits)

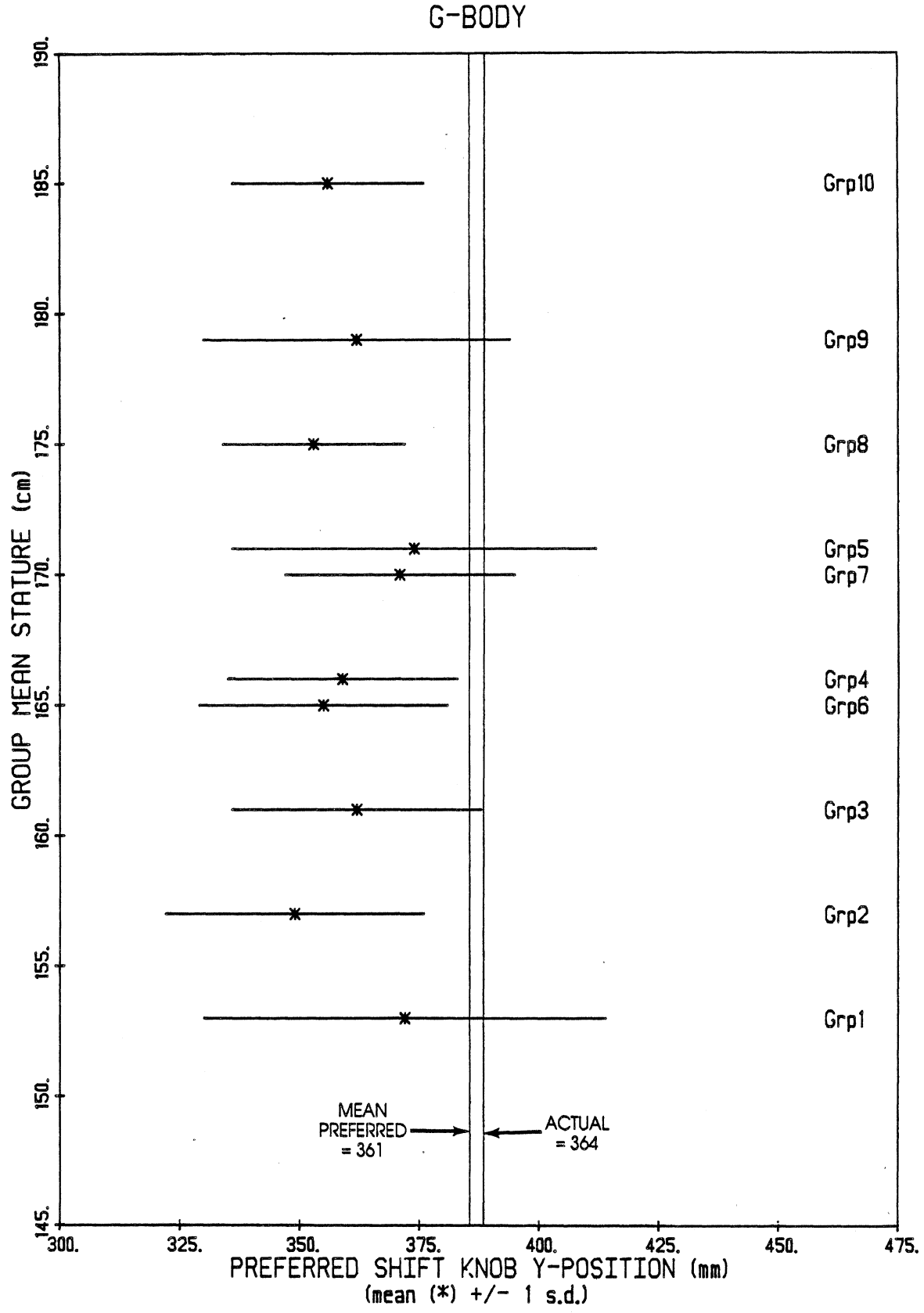

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
OPTIMAL
= 381
ACTUAL
= 390
325.
350.
375.
400.
425.
450.
475.
500.
SHIFT KNOB Y-POSITION (mm)
(mean preferred (*) + mean of maximum limit)

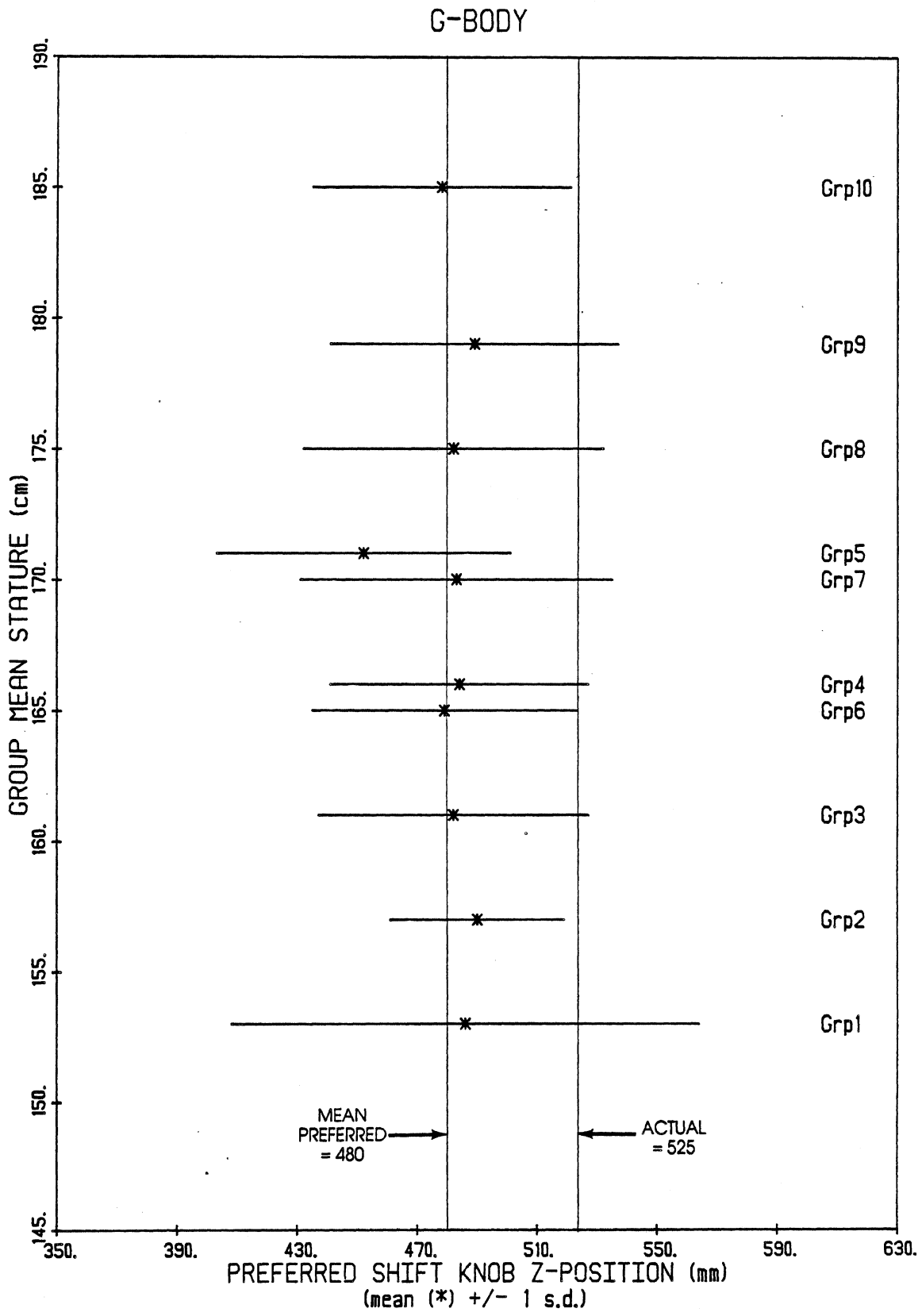

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
ACTUAL
= 560
OPTIMAL
= 719
525.
575.
625.
675.
725.
775.
825.
875.
SHIFT KNOB Z-POSITION (mm)
(mean preferred (*) +/- mean of limits)

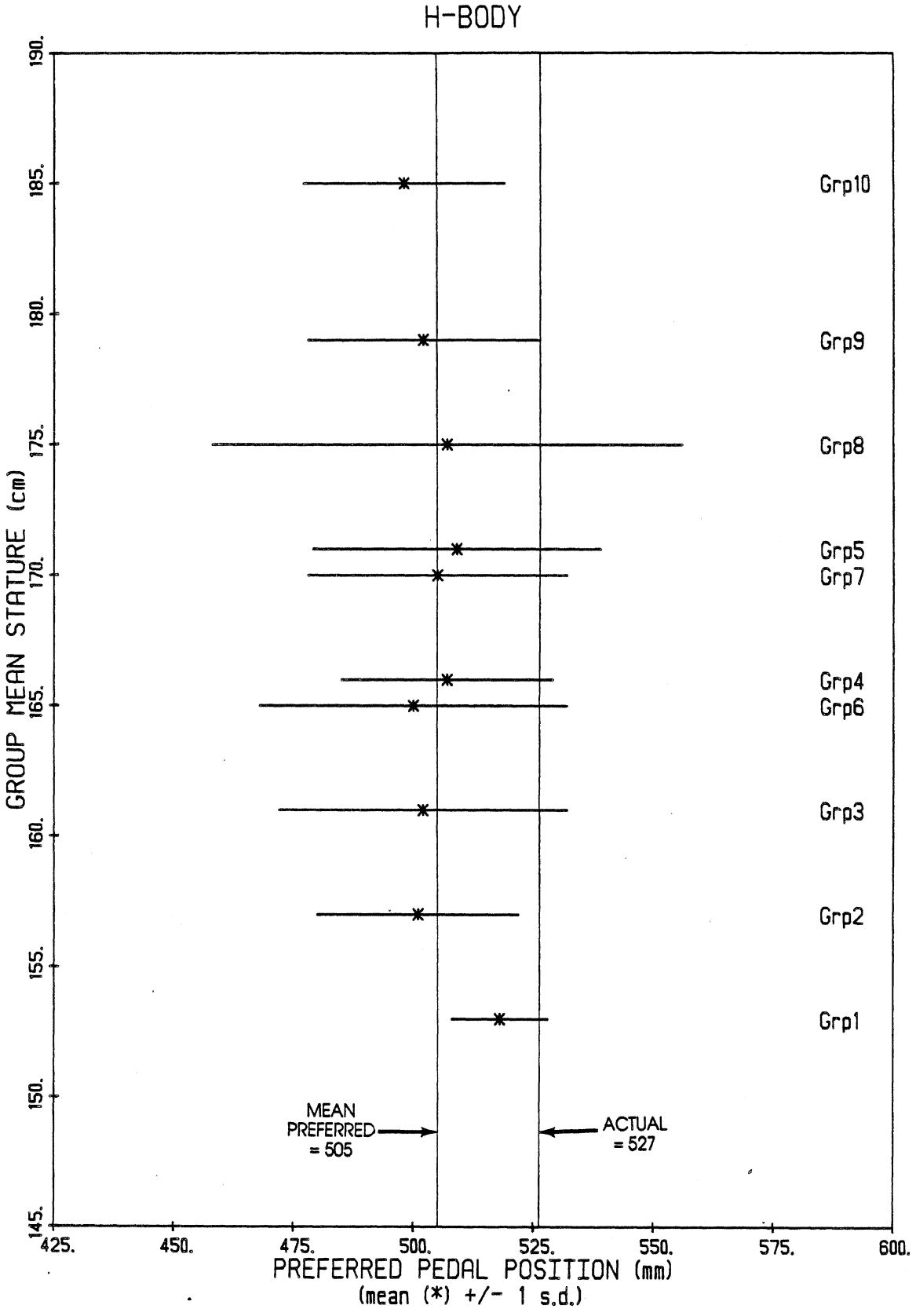

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 496
ACTUAL = 527
425.
450.
475.
500.
525.
550.
575.
600.
PREFERRED PEDAL POSITION (mm)
(mean (*) +/- 1 s.d.)

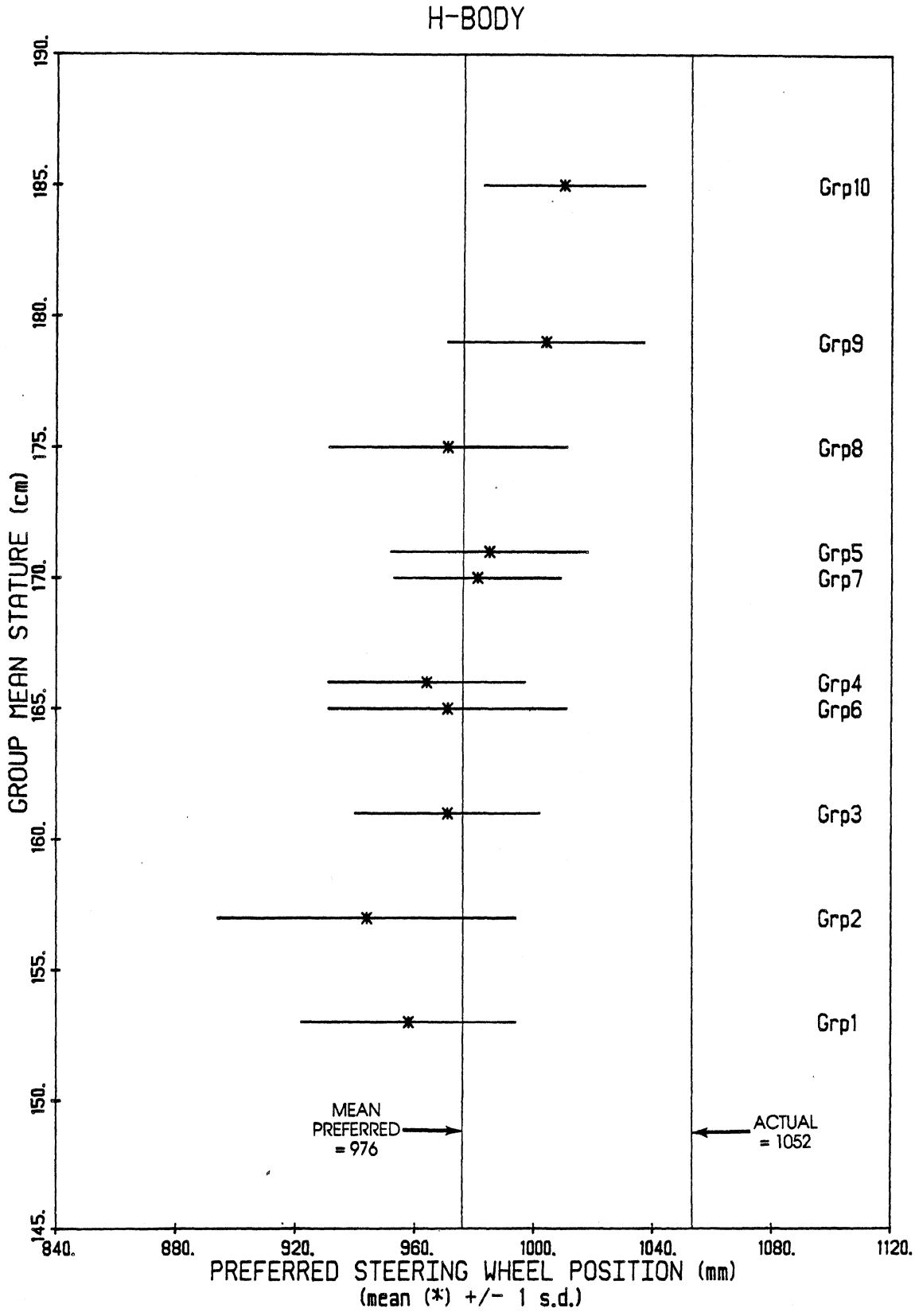

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 999
ACTUAL = 1067
840.
880.
920.
960.
1000.
1040.
1080.
1120.
PREFERRED STEERING WHEEL POSITION (mm)
(mean (*) +/- 1 s.d.)

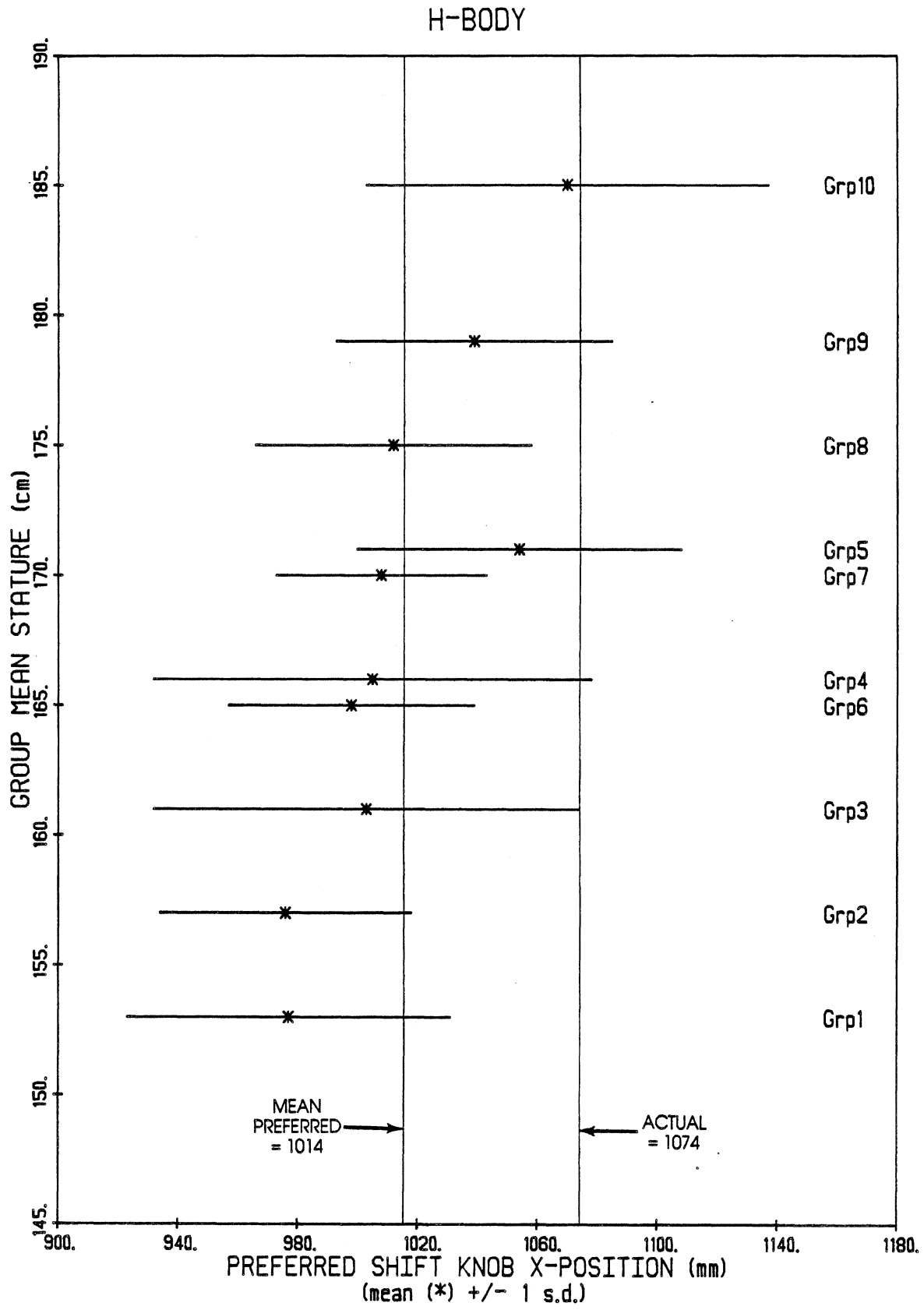

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 1028
ACTUAL = 1061.
900.
940.
980.
1020.
1060.
1100.
1140.
1180.
PREFERRED SHIFT KNOB X-POSITION (mm)
(mean (*) +/- 1 s.d.)

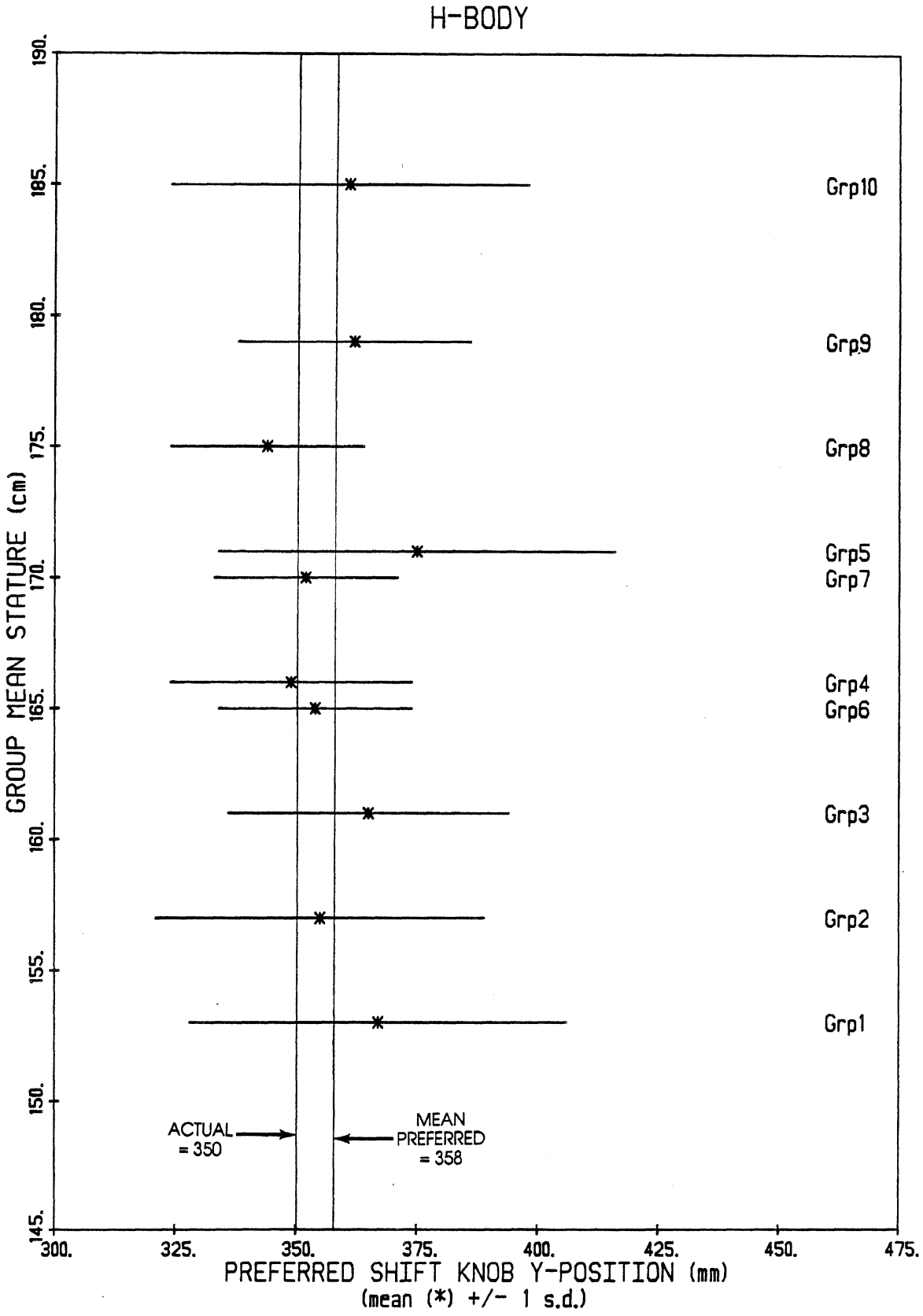

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 361
ACTUAL = 364
300.
325.
350.
375.
400.
425.
450.
475.
PREFERRED SHIFT KNOB Y-POSITION (mm)
(mean (*) +/- 1 s.d.)

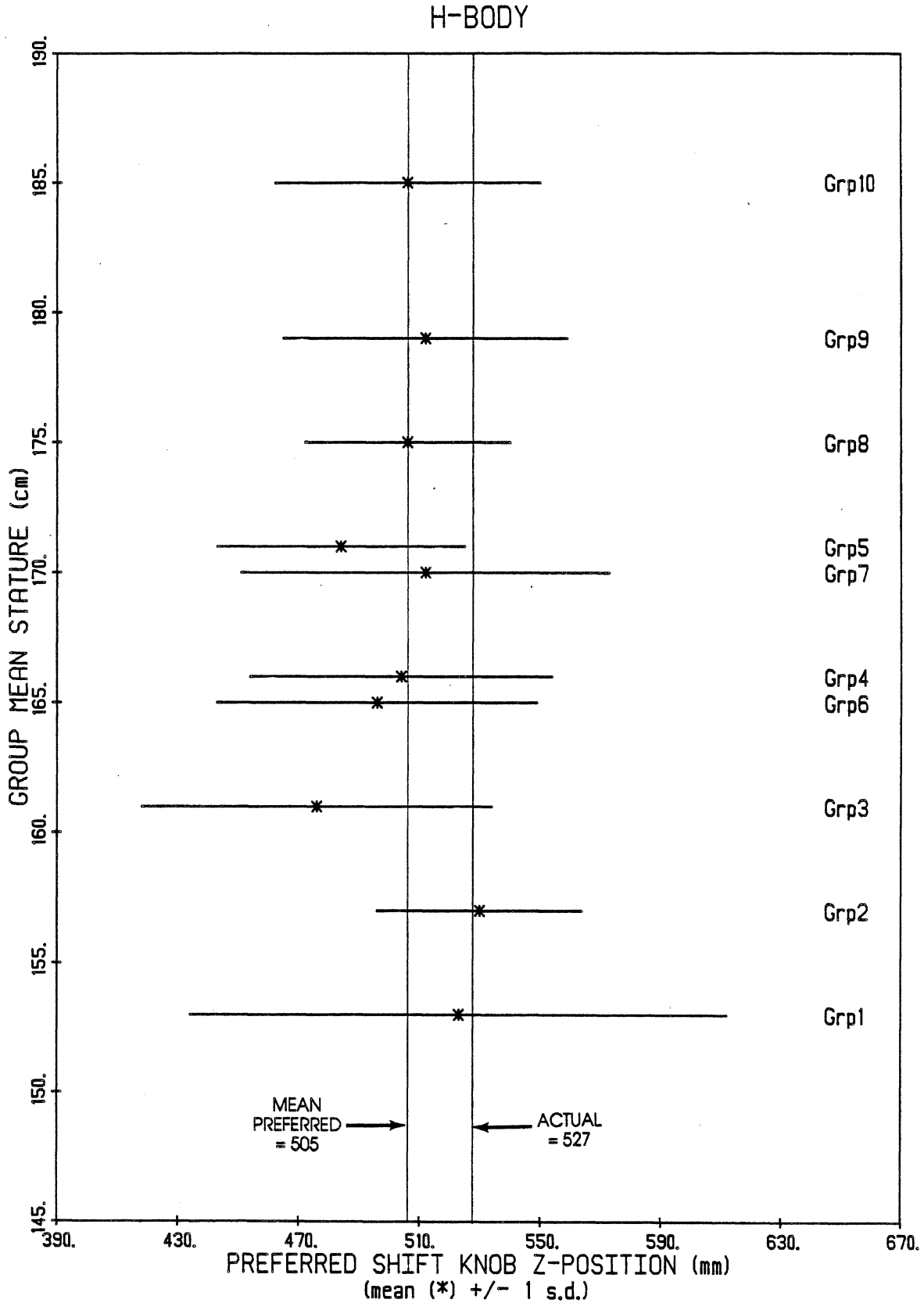

G-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN
PREFERRED
= 480
ACTUAL
= 525
350.
390.
430.
470.
510.
550.
590.
630.
PREFERRED SHIFT KNOB Z-POSITION (mm)
(mean (*) +/- 1 s.d.)

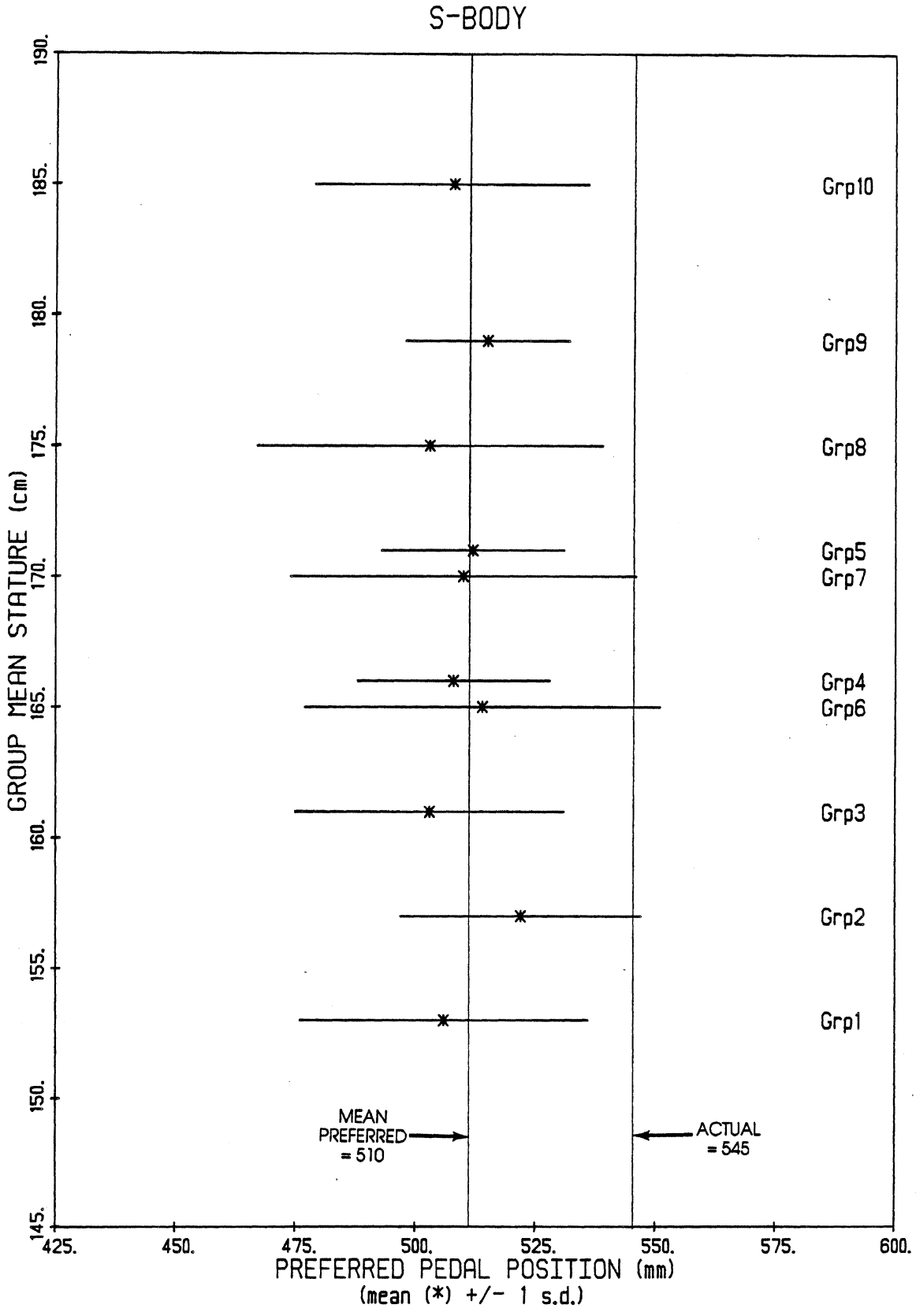

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 505
ACTUAL = 527
425.
450.
475.
500.
525.
550.
575.
600.
PREFERRED PEDAL POSITION (mm)
(mean (*) +/- 1 s.d.)

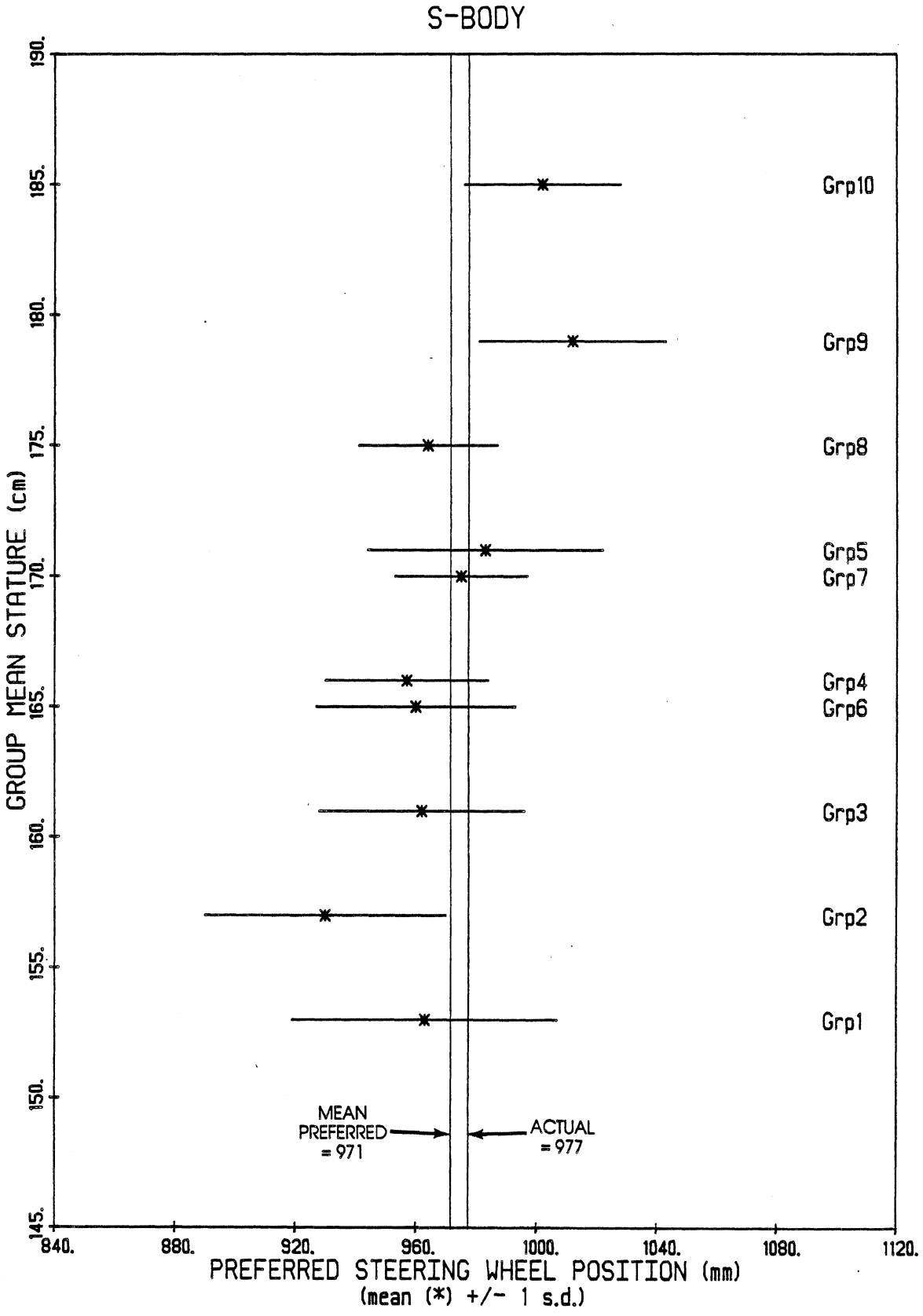

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN
PREFERRED
= 976
ACTUAL
= 1052
840.
880.
920.
960.
1000.
1040.
1080.
1120.
PREFERRED STEERING WHEEL POSITION (mm)
(mean (*) +/- 1 s.d.)

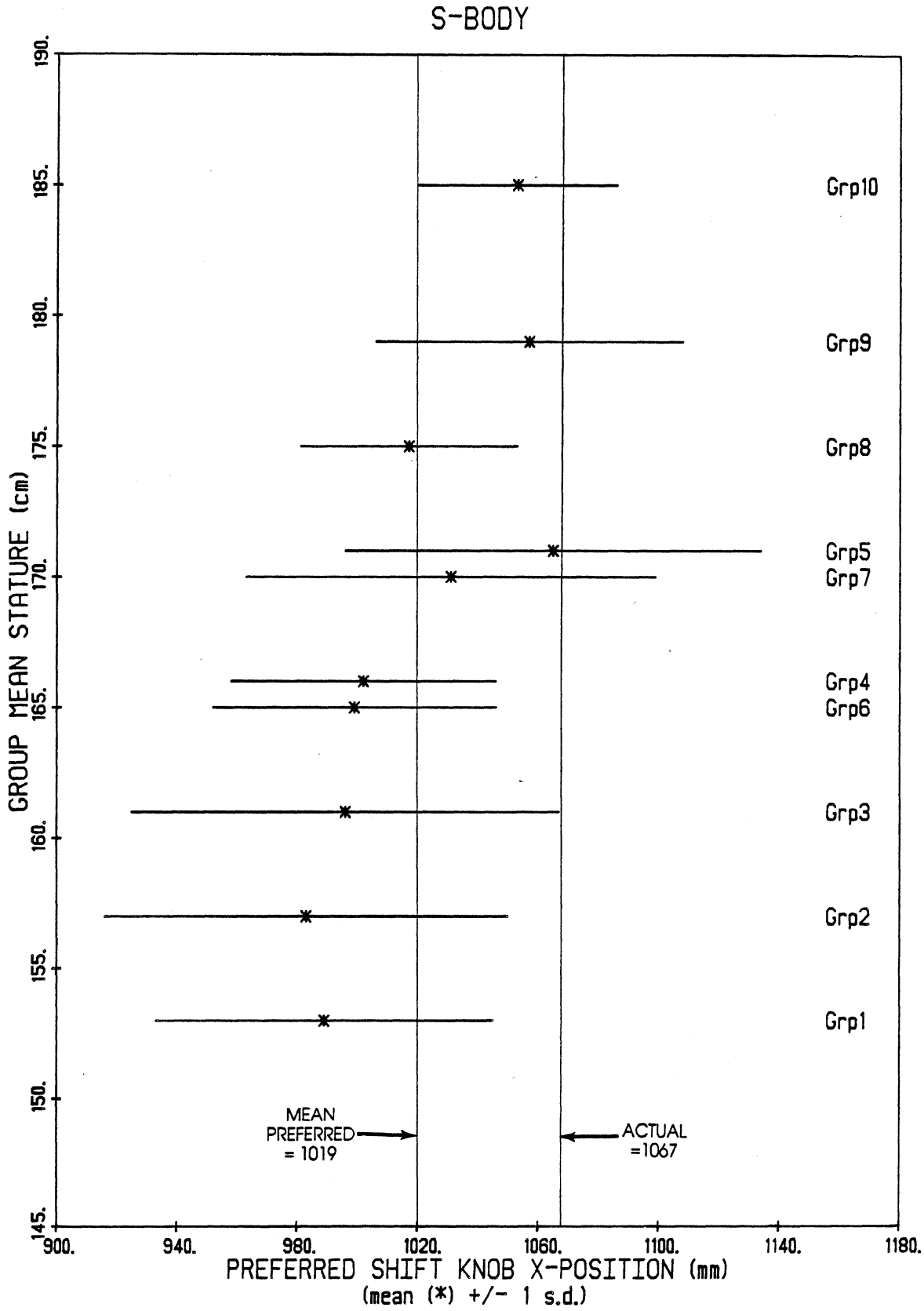

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 1014
ACTUAL = 1074
900.
940.
980.
1020.
1060.
1100.
1140.
1180.
PREFERRED SHIFT KNOB X-POSITION (mm)
(mean (*) +/- 1 s.d.)

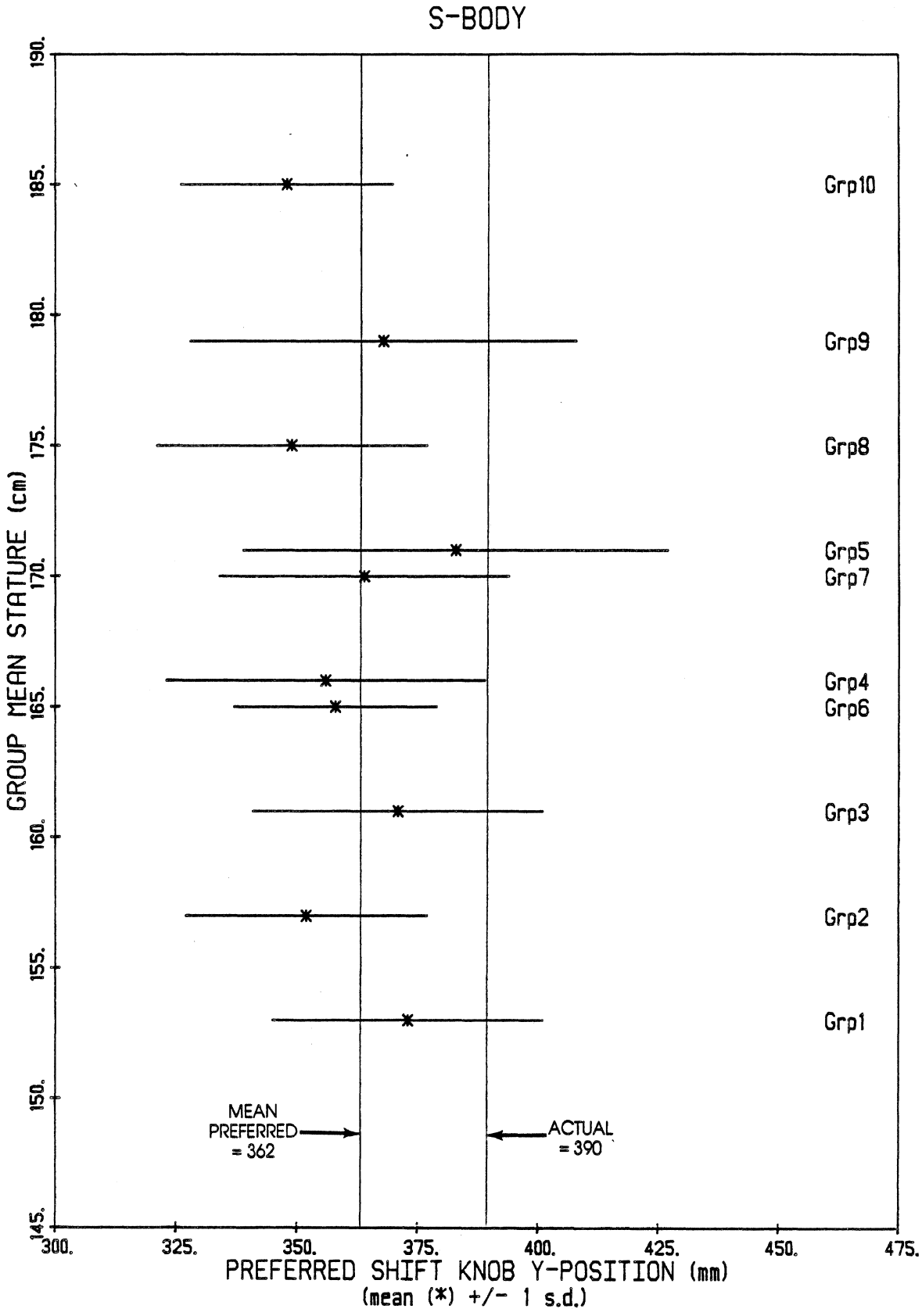

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
ACTUAL
= 350
MEAN
PREFERRED
= 358
300.
325.
350.
375.
400.
425.
450.
475.
PREFERRED SHIFT KNOB Y-POSITION (mm)
(mean (*) +/- 1 s.d.)

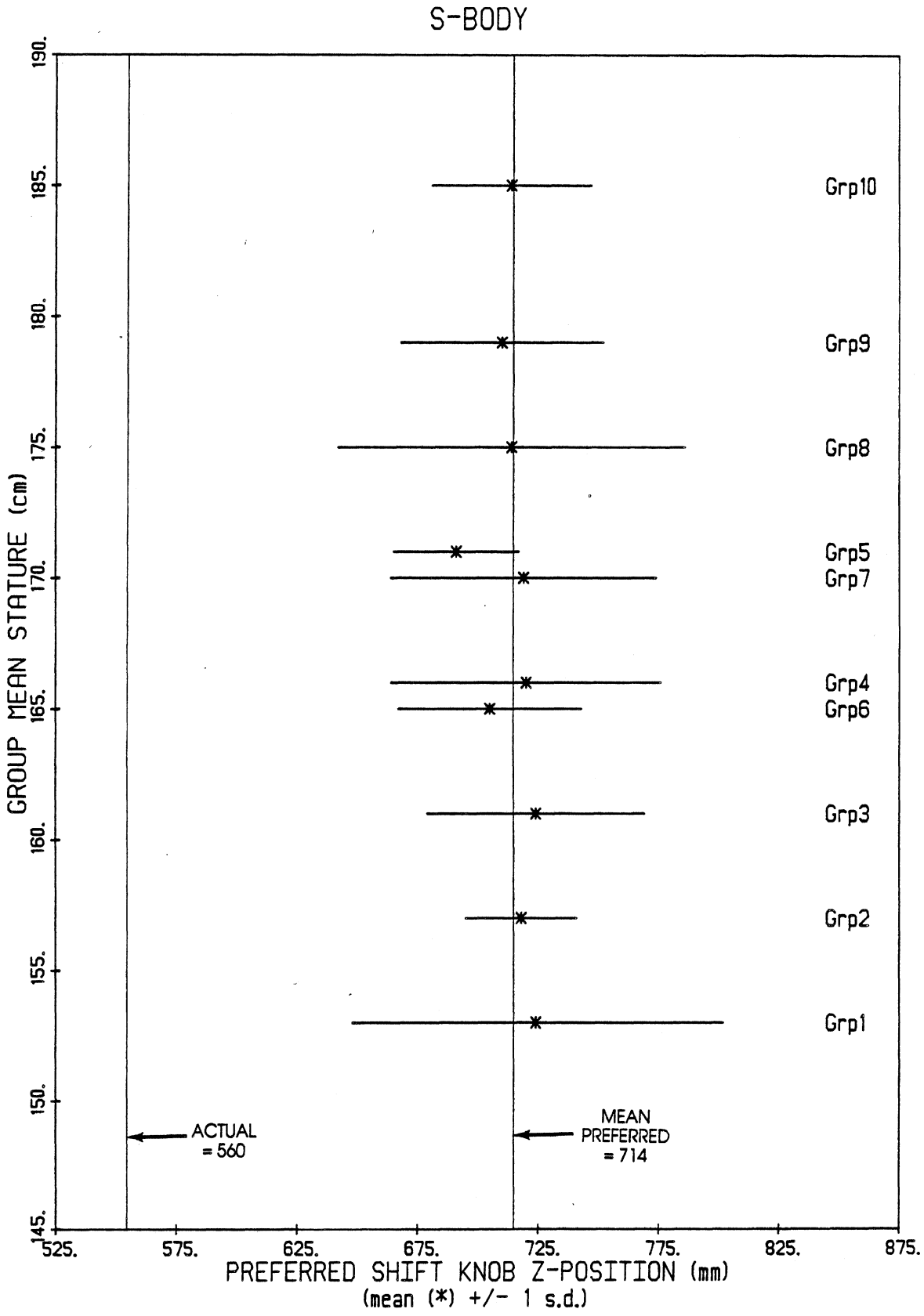

H-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 505
ACTUAL = 527
390.
430.
470.
510.
550.
590.
630.
670.
PREFERRED SHIFT KNOB Z-POSITION (mm)
(mean (*) +/- 1 s.d.)


S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 510
ACTUAL = 545
425.
450.
475.
500.
525.
550.
575.
600.
PREFERRED PEDAL POSITION (mm)
(mean (*) +/- 1 s.d.)

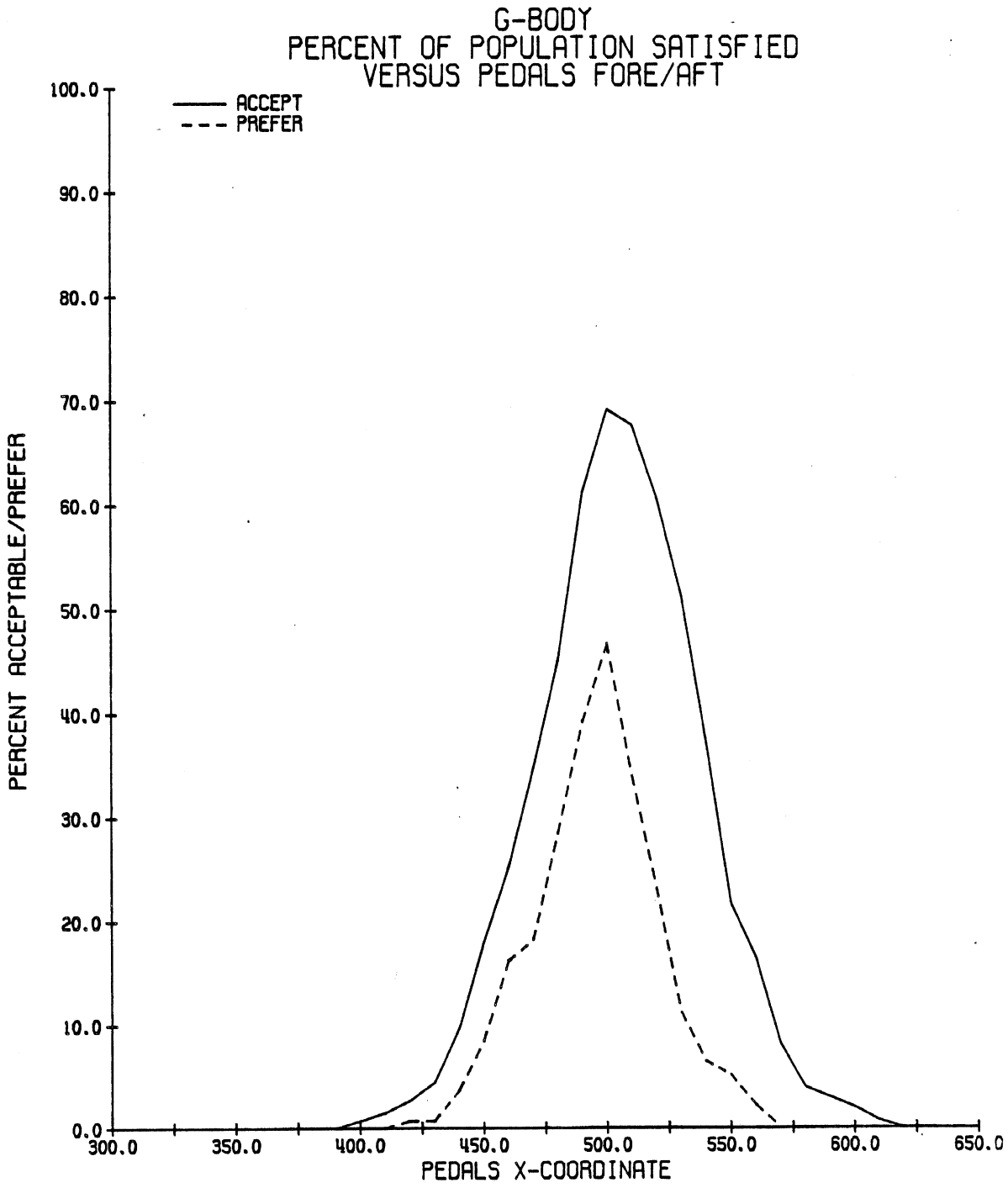

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 971
ACTUAL = 977
840.
880.
920.
960.
1000.
1040.
1080.
1120.
PREFERRED STEERING WHEEL POSITION (mm)
(mean (*) +/- 1 s.d.)

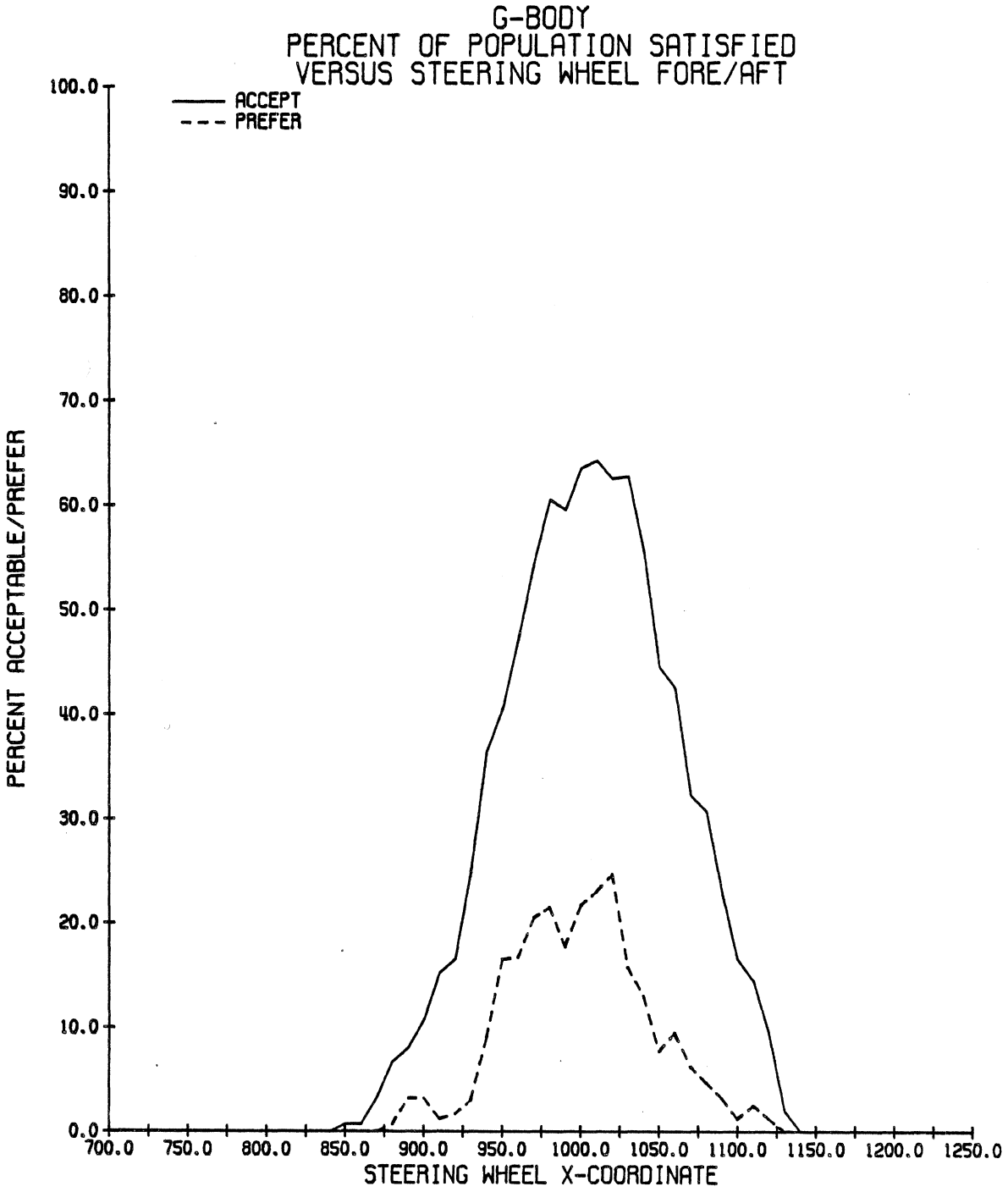

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 1019
ACTUAL =1067
900.
940.
980.
1020.
1060.
1100.
1140.
1180.
PREFERRED SHIFT KNOB X-POSITION (mm)
(mean (*) +/- 1 s.d.)

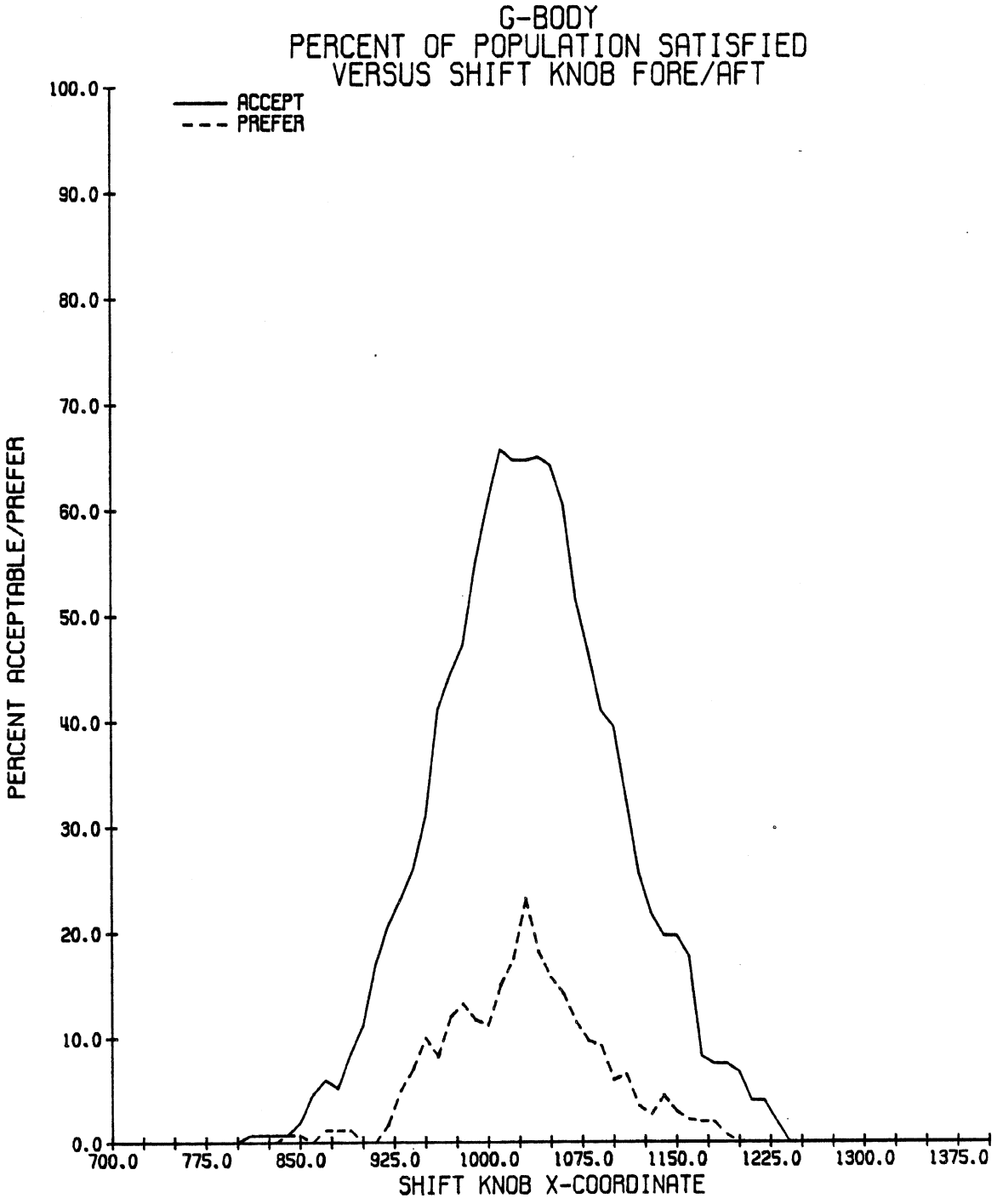

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
MEAN PREFERRED = 362
ACTUAL = 390
300.
325.
350.
375.
400.
425.
450.
475.
PREFERRED SHIFT KNOB Y-POSITION (mm)
(mean (*) +/- 1 s.d.)

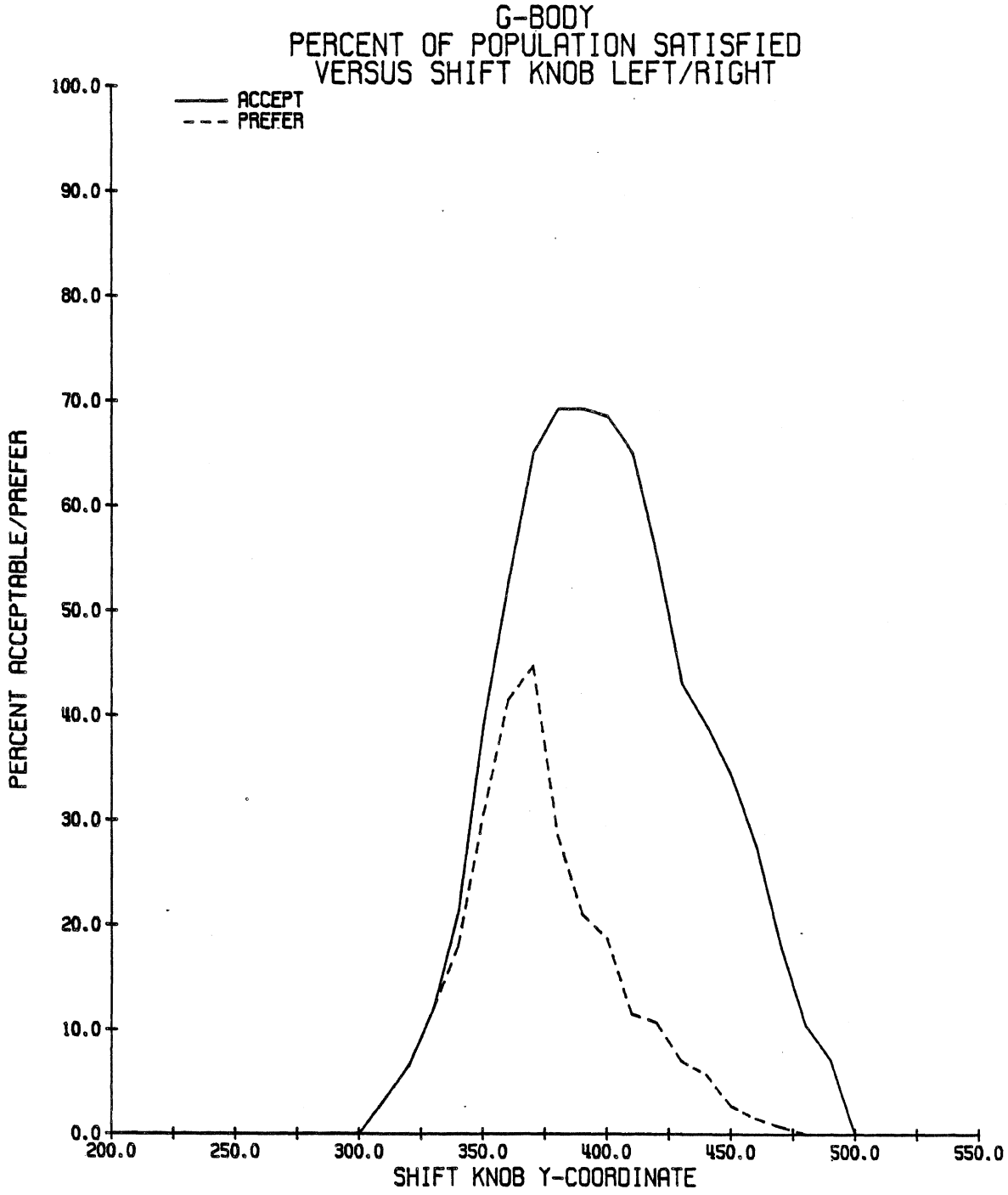

S-BODY
GROUP MEAN STATURE (cm)
190.
185.
180.
175.
170.
165.
160.
155.
150.
145.
Grp10
Grp9
Grp8
Grp5
Grp7
Grp4
Grp6
Grp3
Grp2
Grp1
ACTUAL
= 560
MEAN
PREFERRED
= 714
525.
575.
625.
675.
725.
775.
825.
875.
PREFERRED SHIFT KNOB Z-POSITION (mm)
(mean (*) +/- 1 s.d.)

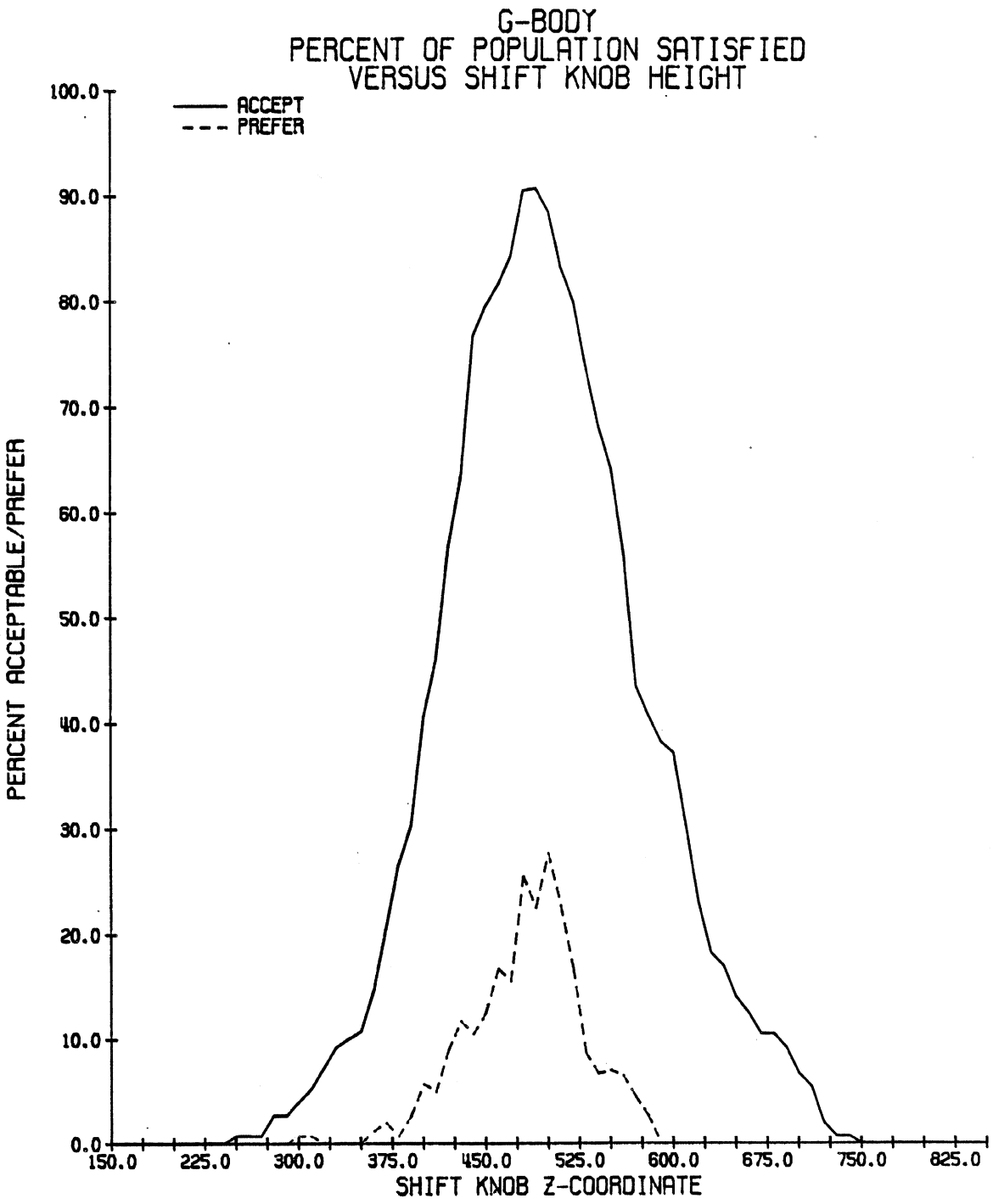
APPENDIX G
PLOTS OF ACCEPTANCE AND PREFERRED POSITION FUNCTIONS

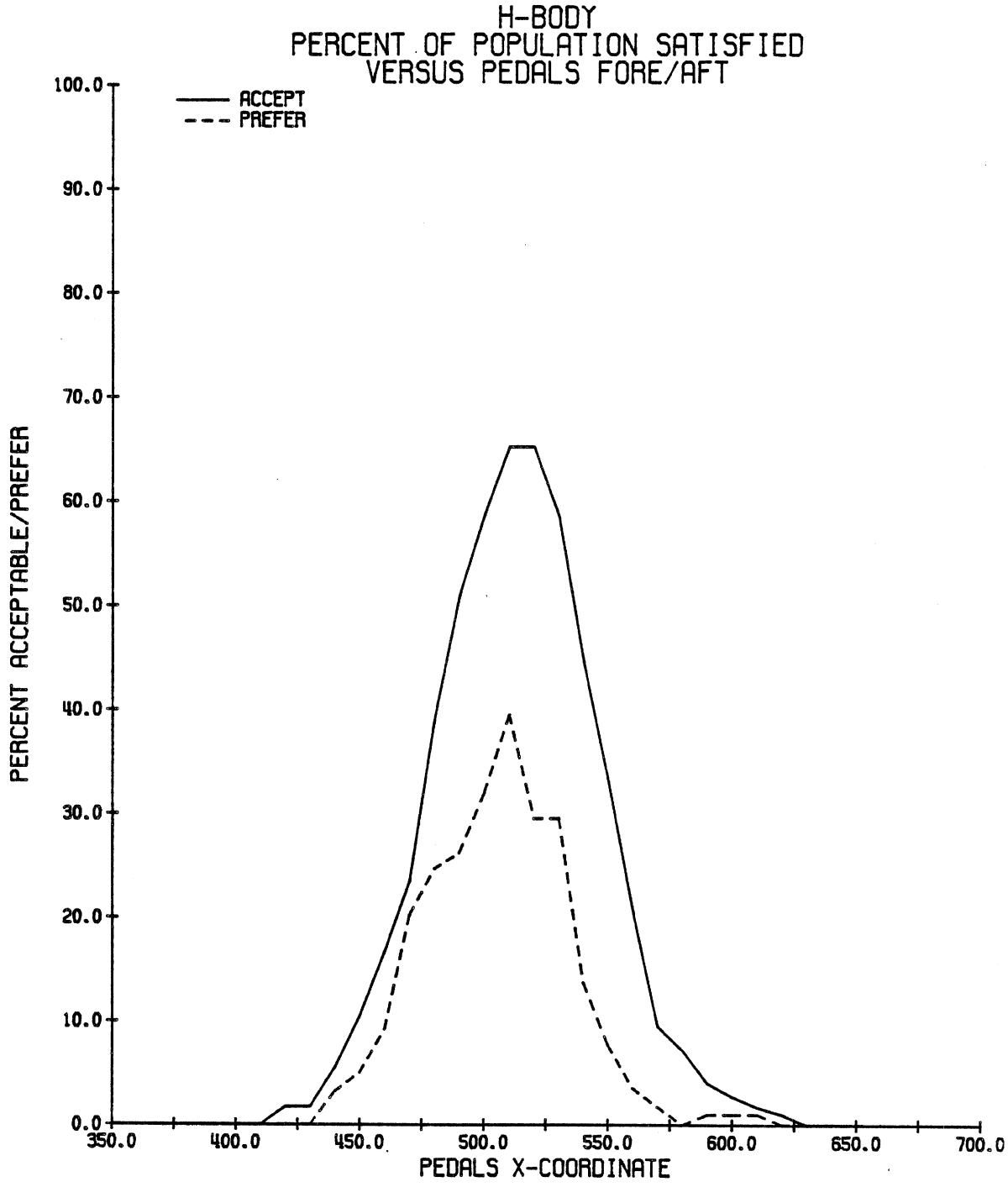

G-BODY
PERCENT OF POPULATION SATISFIED
VERSUS PEDALS FORE/AFT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
PEDALS X-COORDINATE

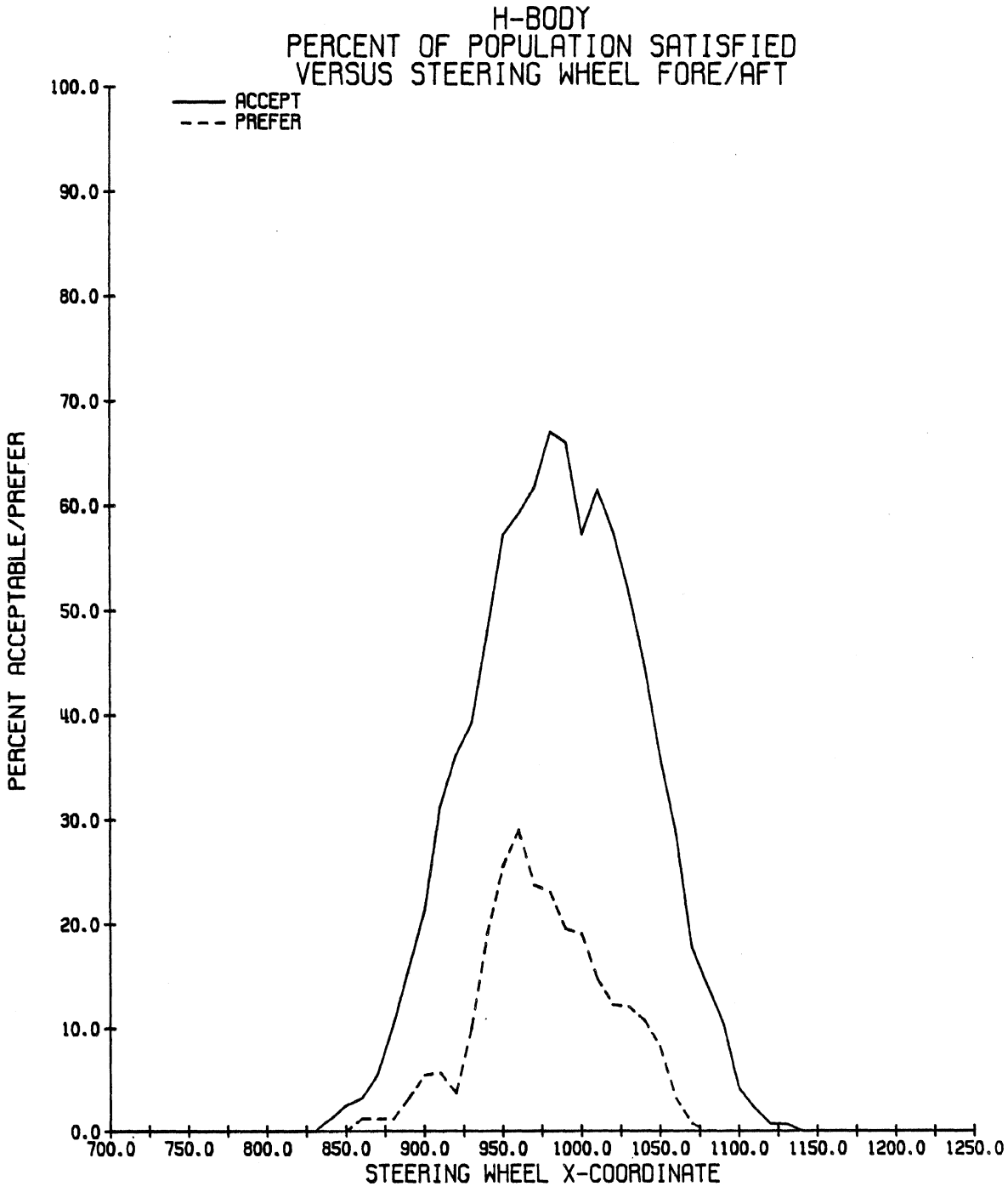

G-BODY
PERCENT OF POPULATION SATISFIED
VERSUS STEERING WHEEL FORE/AFT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
750.0
800.0
850.0
900.0
950.0
1000.0
1050.0
1100.0
1150.0
1200.0
1250.0
STEERING WHEEL X-COORDINATE

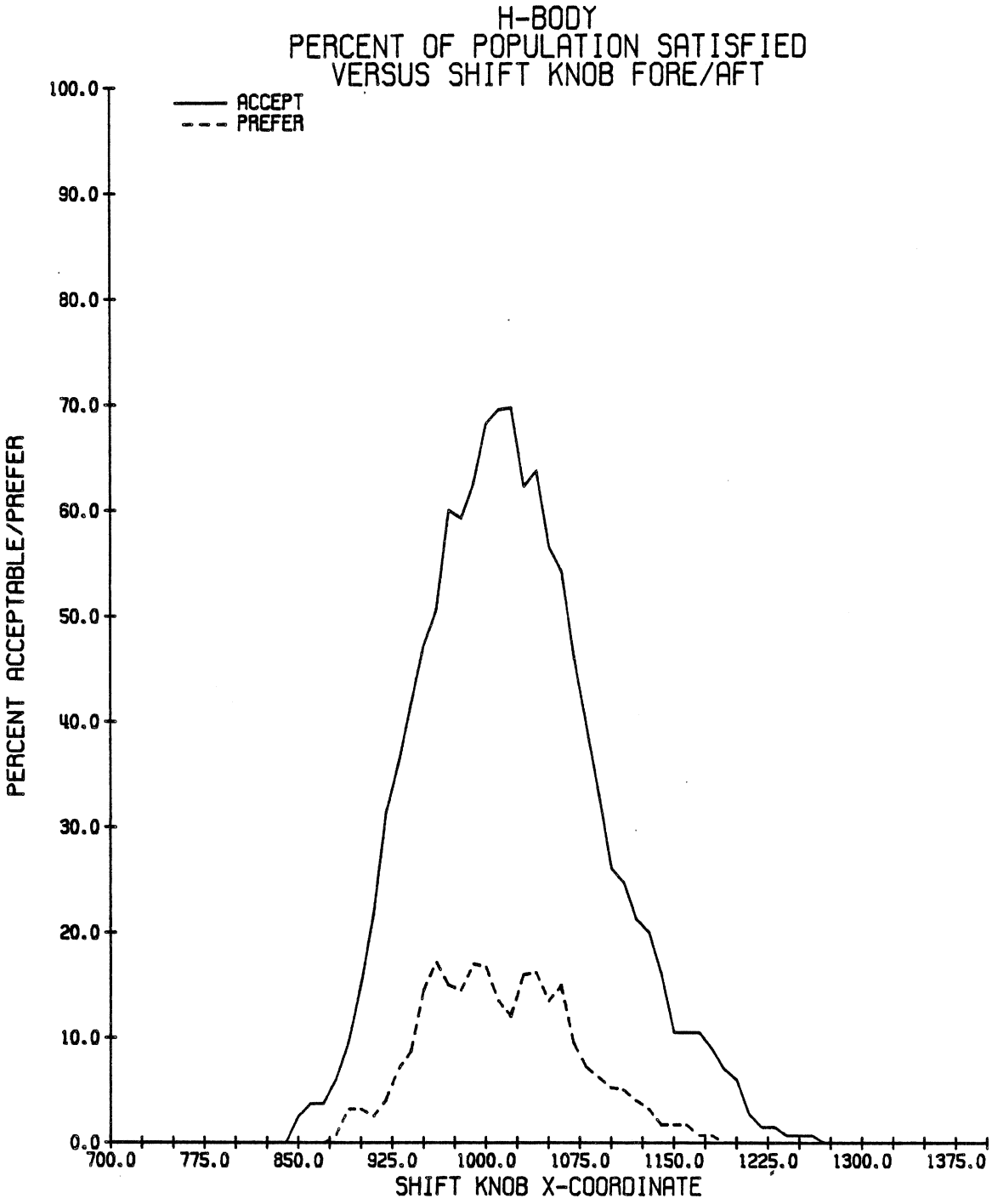

G-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB FORE/AFT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
775.0
850.0
925.0
1000.0
1075.0
1150.0
1225.0
1300.0
1375.0
SHIFT KNOB X-COORDINATE

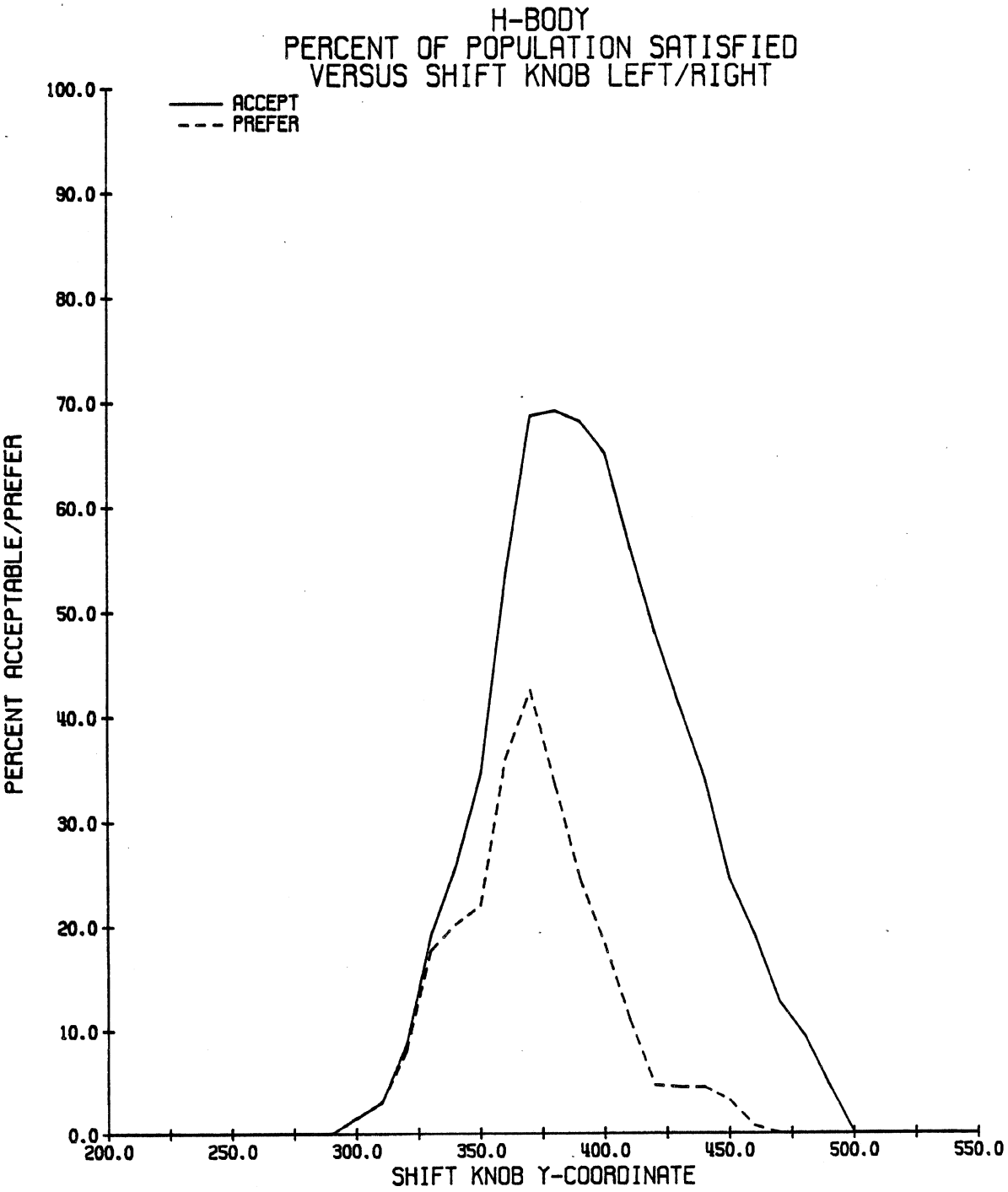

G-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB LEFT/RIGHT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
SHIFT KNOB Y-COORDINATE

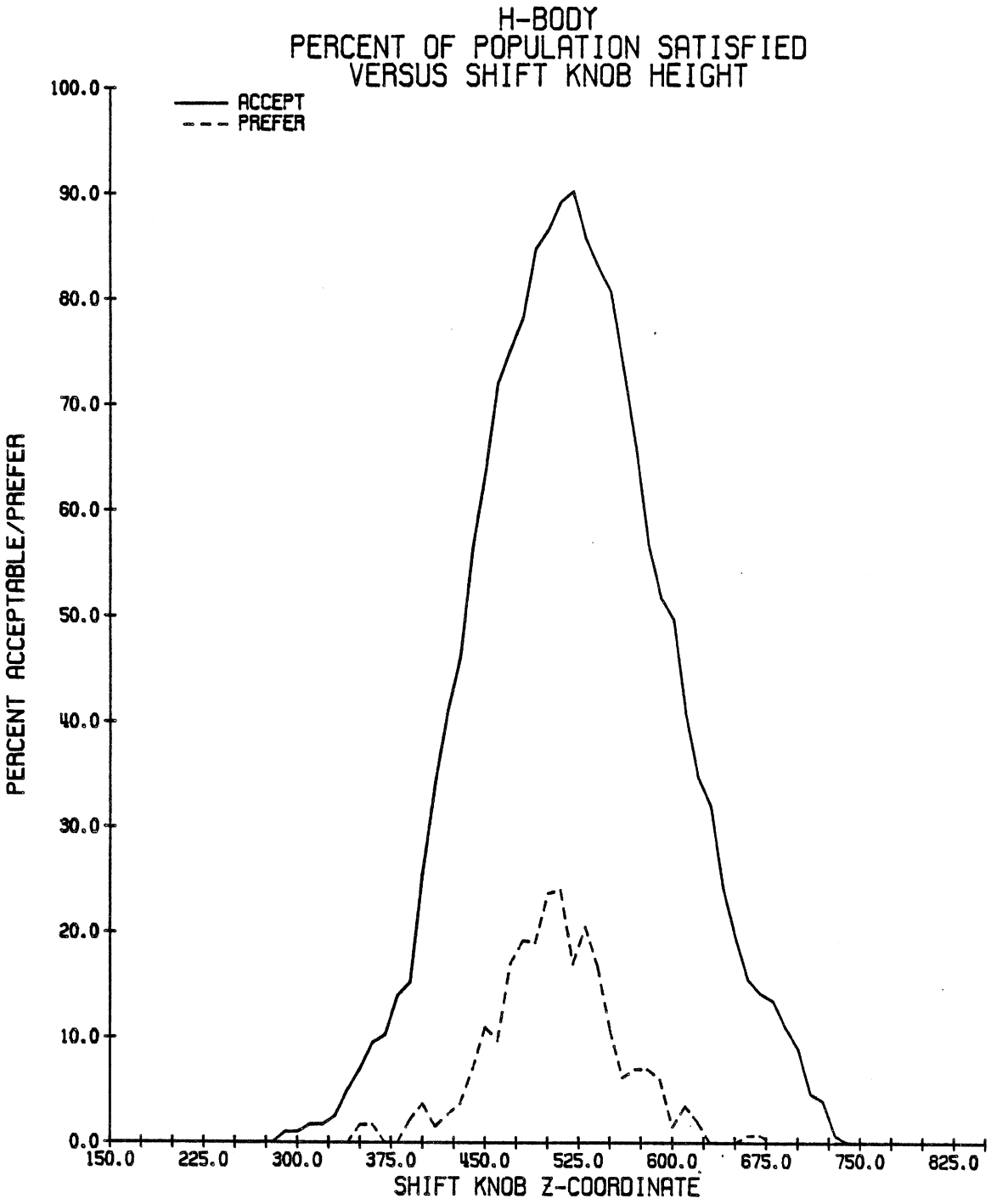

G-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB HEIGHT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
150.0
225.0
300.0
375.0
450.0
525.0
600.0
675.0
750.0
825.0
SHIFT KNOB Z-COORDINATE

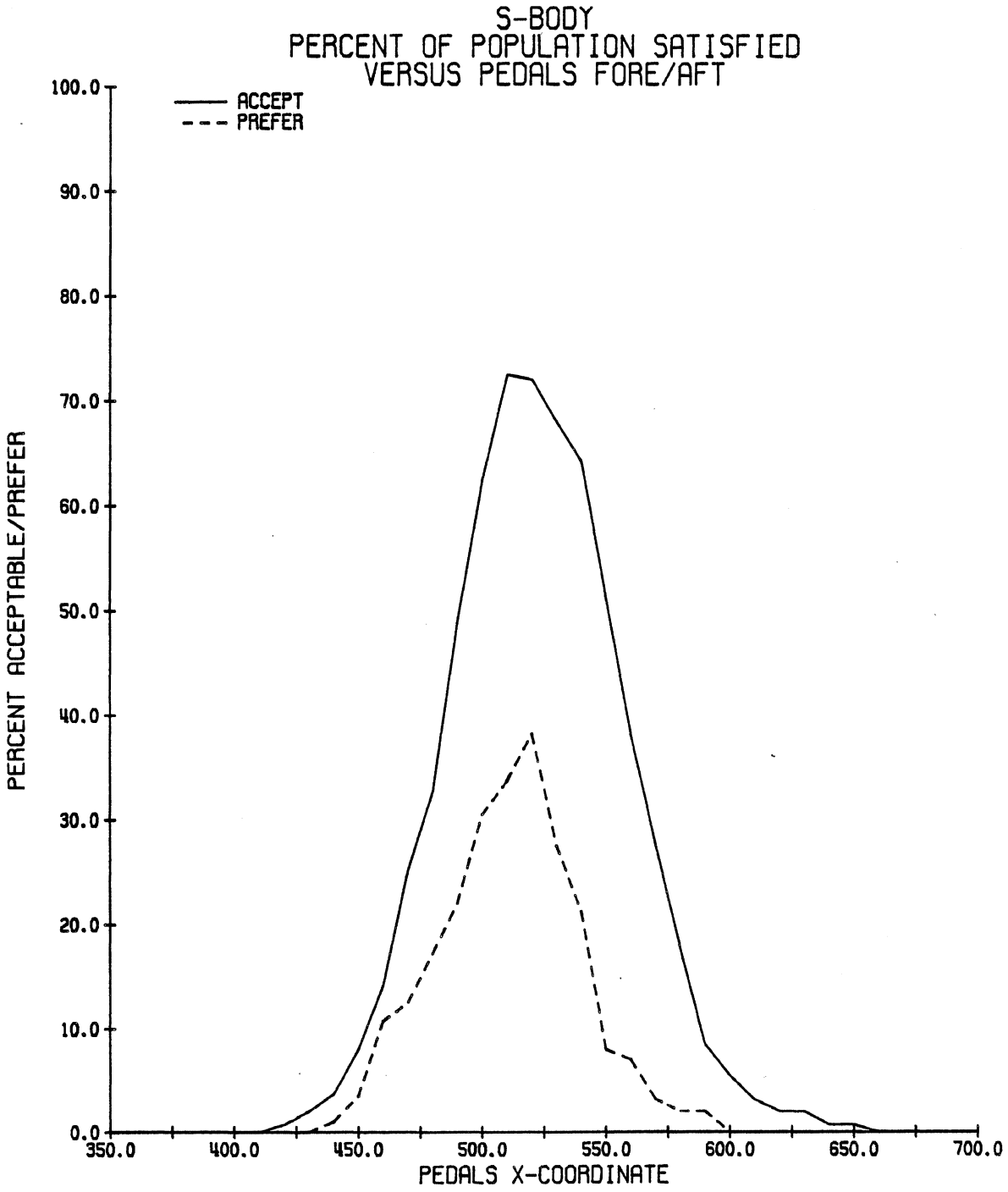

H-BODY
PERCENT OF POPULATION SATISFIED
VERSUS PEDALS FORE/AFT
ACCEPT
PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
PERCENT ACCEPTABLE/PREFER
350.0
400.0
450.0
500.0
550.0
600.0
650.0
700.0
PEDALS X-COORDINATE

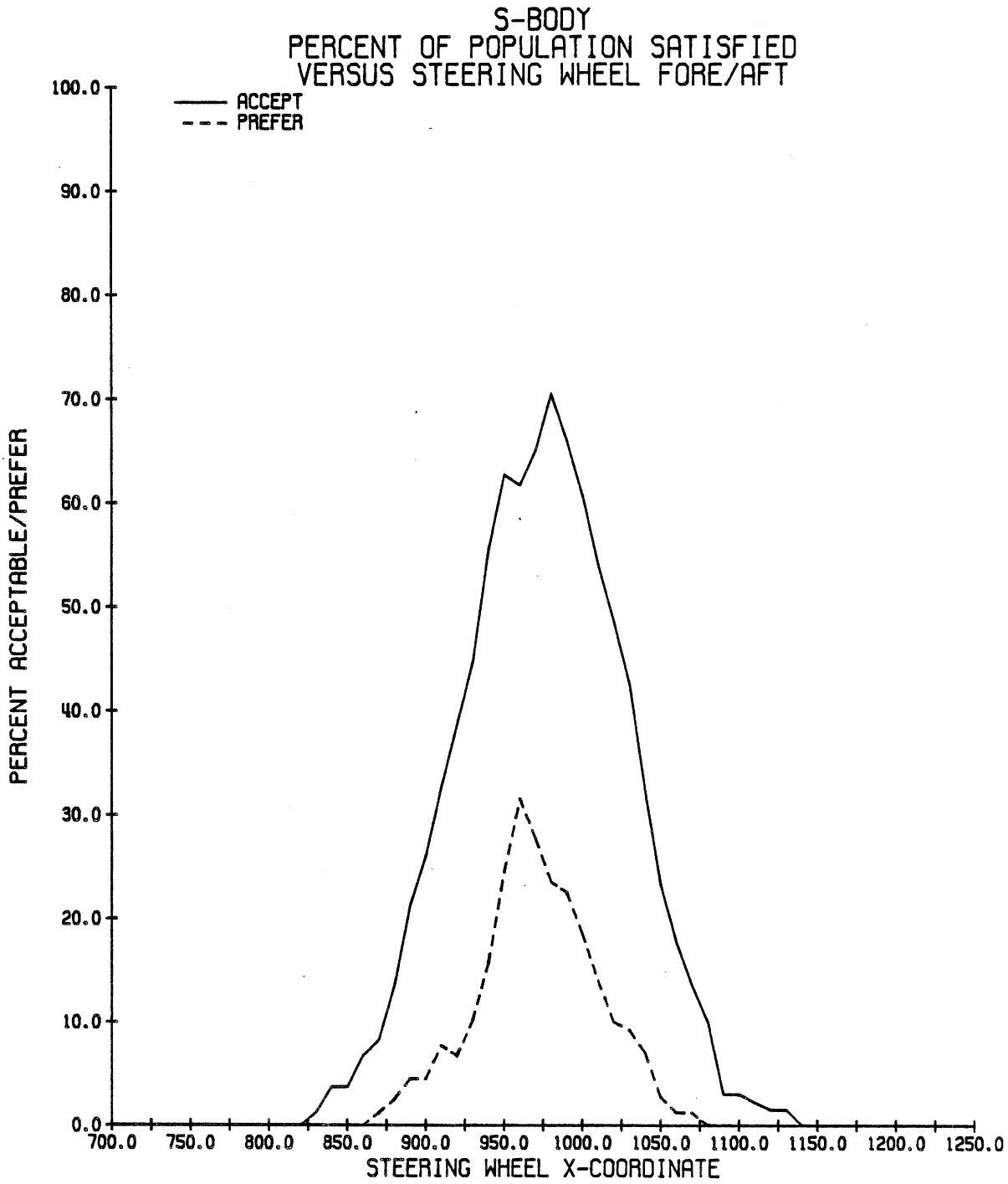

H-BODY
PERCENT OF POPULATION SATISFIED
VERSUS STEERING WHEEL FORE/AFT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
750.0
800.0
850.0
900.0
950.0
1000.0
1050.0
1100.0
1150.0
1200.0
1250.0
STEERING WHEEL X-COORDINATE

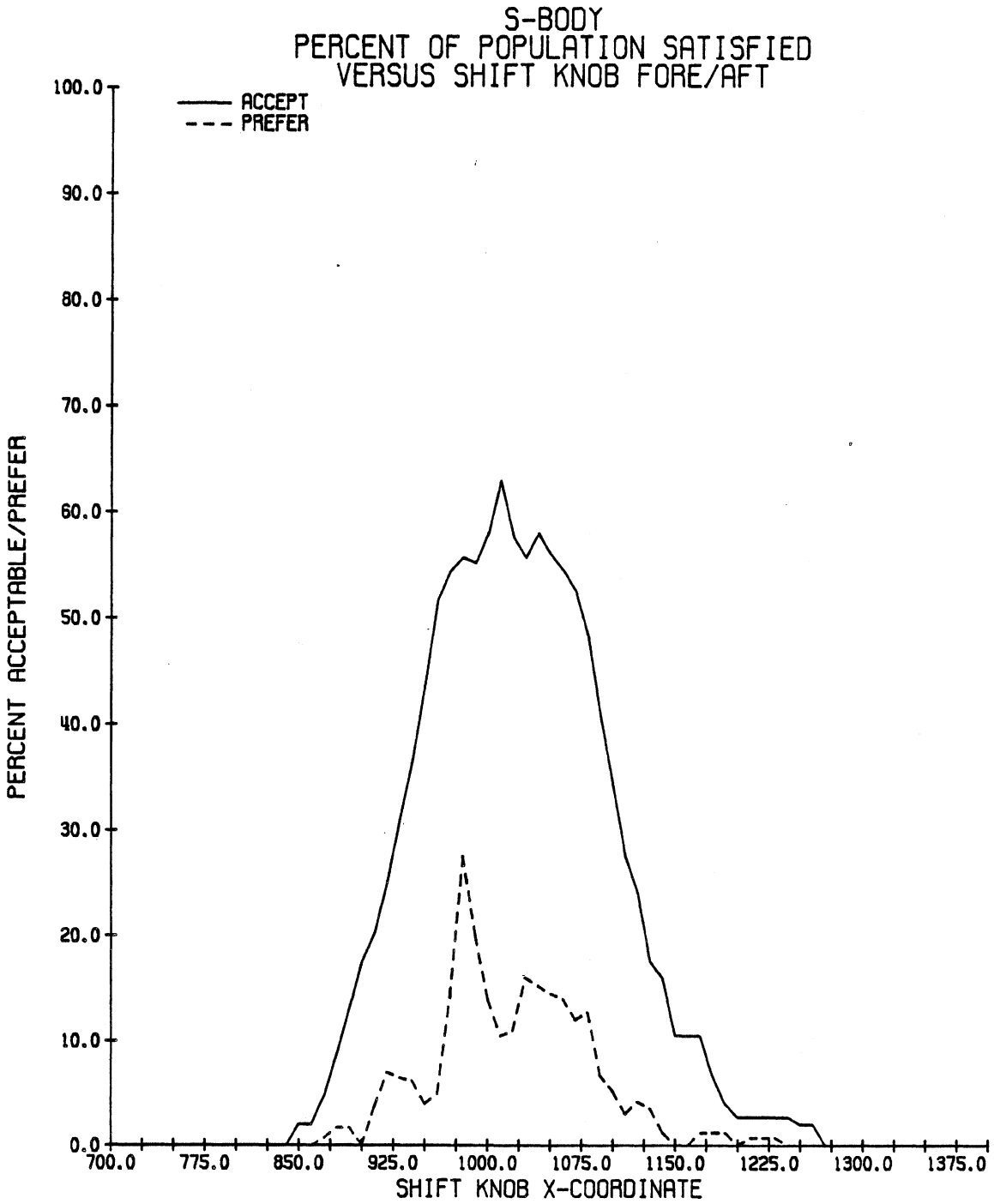

H-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB FORE/AFT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
700.0
775.0
850.0
925.0
1000.0
1075.0
1150.0
1225.0
1300.0
1375.0
SHIFT KNOB X-COORDINATE

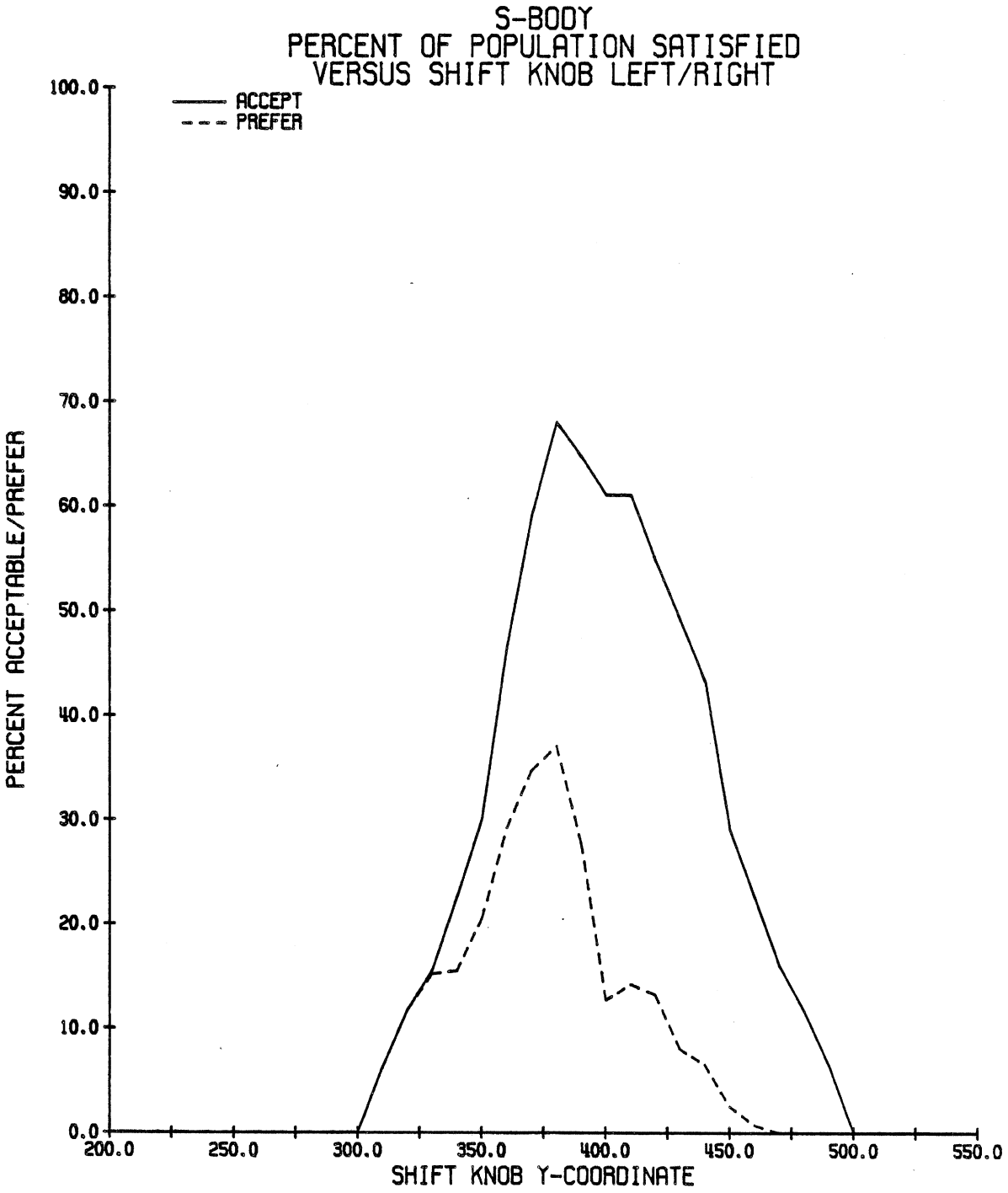

H-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB LEFT/RIGHT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
SHIFT KNOB Y-COORDINATE

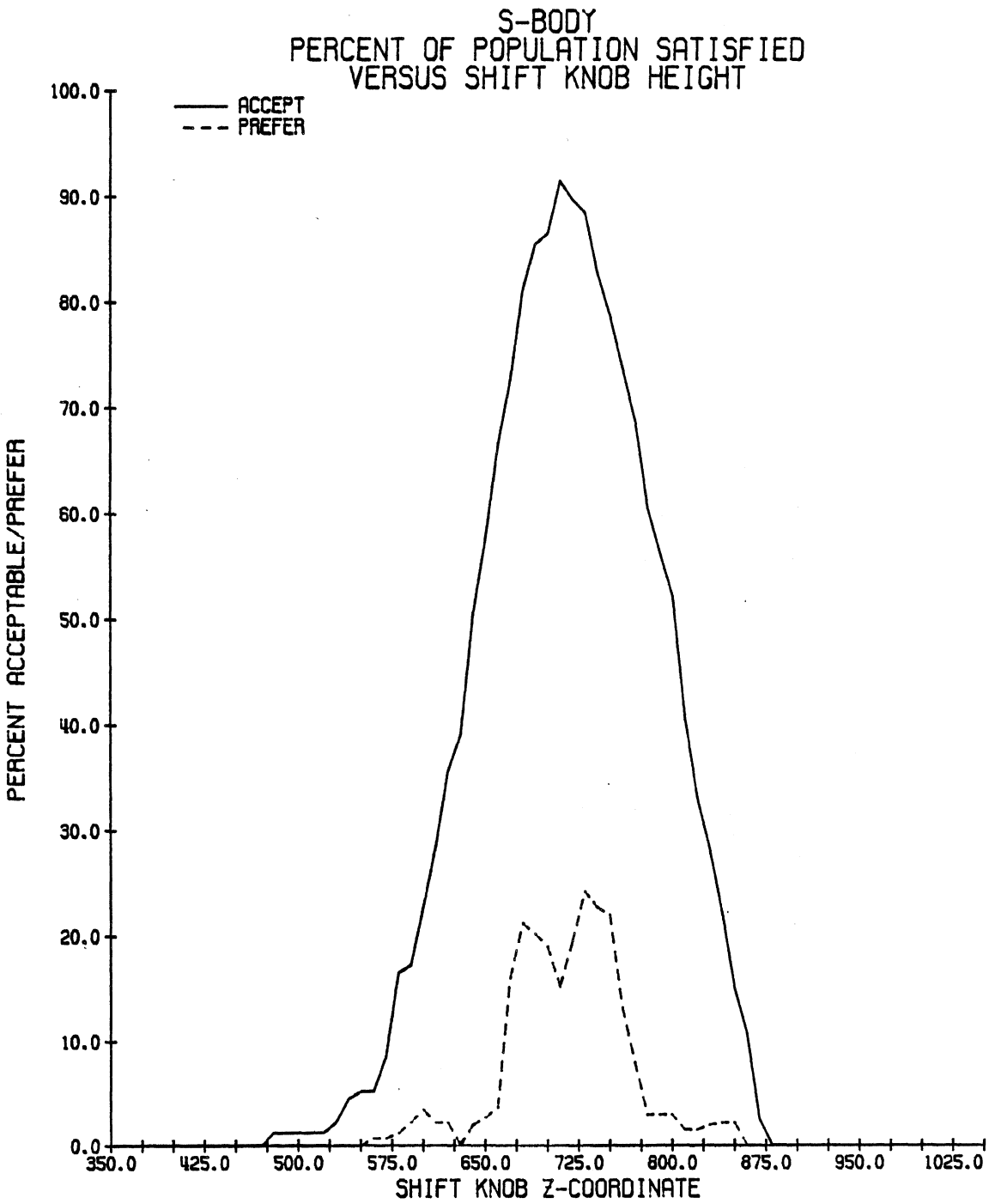

H-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB HEIGHT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
150.0
225.0
300.0
375.0
450.0
525.0
600.0
675.0
750.0
825.0
SHIFT KNOB Z-COORDINATE


S-BODY
PERCENT OF POPULATION SATISFIED
VERSUS PEDALS FORE/AFT
ACCEPT
PREFER
PERCENT 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
PEDALS X-COORDINATE


S-BODY
PERCENT OF POPULATION SATISFIED
VERSUS STEERING WHEEL FORE/AFT
ACCEPT
PREFER
PERCENT 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
STEERING WHEEL X-COORDINATE


S-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB FORE/AFT
ACCEPT
PREFER
PERCENT 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
775.0
850.0
925.0
1000.0
1075.0
1150.0
1225.0
1300.0
1375.0
SHIFT KNOB X-COORDINATE


S-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB LEFT/RIGHT
ACCEPT
PREFER
PERCENT ACCEPTABLE/PREFER
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
SHIFT KNOB Y-COORDINATE


S-BODY
PERCENT OF POPULATION SATISFIED
VERSUS SHIFT KNOB HEIGHT
ACCEPT
PREFER
PERCENT 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
425.0
500.0
575.0
650.0
725.0
800.0
875.0
950.0
1025.0
SHIFT KNOB Z-COORDINATE

APPENDIX H
GROUP MEAN DIFFERENCES IN CONDITIONAL CONTROL LOCATIONS

Table H-1
Mean Differences of Preferred Brake and Clutch Positions vs. Preferred Brake Positions (mm)*

GROUP	G	H	S
1	5	10	1
2	5	7	7
3	4	7	-1
4	8	11	6
5	3	12	-2
6	3	9	6
7	5	12	2
8	4	7	-3
9	9	5	0
10	4	3	3
ALL	5	8	2

* + values indicate that the pedals were moved closer to the driver, i.e. positive x-direction, when considering the clutch and brake together.

Table H-2
Mean Differences of Preferred Shift Knob X-Positions with Console/Armrest vs. Preferred Shift Knob X-Positions (mm)*

GROUP	G	H	S
1	5	10	1
2	-21	-8	-20
3	-1	-2	-10
4	-5	-34	-4
5	-8	-6	-4
6	-9	-5	4
7	-13	-25	-3
8	-6	-3	-2
9	1	-18	-11
10	-12	-1	-29
ALL	-9	-12	-9

* + values indicate that the shift knob was moved back toward the driver, i.e. positive x-direction, when considering the console/armrest.

Table H-3
Mean Differences of Preferred Shift Knob
Y-Positions with Console/Armrest
vs. Preferred Shift Knob Y-Positions (mm)*

GROUP	G	H	S
1	0	-9	0
2	-15	-4	-8
3	-5	-4	0
4	-2	-5	-3
5	-2	-3	-2
6	-4	-5	5
7	-1	-7	-2
8	0	-4	-8
9	-1	-5	0
10	0	4	-11
ALL	-3	-4	-3

* + values indicate that the shift knob was moved to the right of, or away from, the seat when considering the console/armrest.

Table H-4
Mean Differences Of Preferred Shift Knob
Z-Positions with Console/Armrest
vs. Preferred Shift Knob Z-Positions (mm)*

GROUP	G	H	S
1	8	22	8
2	28	44	20
3	14	8	38
4	20	9	40
5	26	24	7
6	22	15	22
7	30	35	43
8	11	20	18
9	12	12	17
10	9	14	19
ALL	18	20	23

* + values indicate that the shift knob was moved upward from its original position when considering the console/armrest.

Table H-5
Mean Differences of Preferred Console/Armrest
X-Positions with Shift vs. Preferred
Console/Armrest X-Positions (mm)*

GROUP	G	H	S
1	84	88	51
2	73	110	67
3	53	79	57
4	65	80	46
5	43	64	24
6	35	47	33
7	43	53	40
8	33	22	44
9	17	36	40
10	26	37	16
ALL	47	62	42

* + values indicate that the console/armrest was moved back (x-direction) when considering the console/armrest and shift together.

Table H-6
Mean Differences of Preferred Console/Armrest
Z-Positions with Shift vs. Preferred
Console/Armrest Z-Positions (mm)*

GROUP	G	H	S
1	3	-7	3
2	-5	1	-14
3	-5	-9	-6
4	-6	-5	-10
5	-8	-9	-7
6	-8	-8	-8
7	-4	-2	-4
8	-6	-3	-3
9	1	-10	0
10	-4	-5	-5
ALL	-4	-6	-5

* + values indicate that the console/armrest was moved upward when considering the console/armrest and shift together.

APPENDIX I
GROUP MEAN ARMREST AND ELBOW LOCATIONS

Table I-1
Comparisons of Mean Preferred Positions
of the Door Armrest Height
for Two Chrysler Studies
in Vehicle Coordinates (mm)

GROUP	Armrest Location Study mean (s.d.)	Control Position Study mean (s.d.)	Difference
G-BODY			
1	513 (47)	488 (25)	25
2	525 (46)	481 (18)	44
3	528 (36)	473 (36)	55
4	518 (38)	487 (48)	31
5	513 (30)	447 (26)	66
6	507 (47)	476 (48)	31
7	530 (46)	476 (34)	54
8	525 (42)	460 (25)	65
9	542 (59)	478 (31)	64
10	511 (36)	458 (19)	53
ALL	521 (42)	472 (33)	49
H-BODY			
1	547 (40)	530 (34)	17
2	542 (41)	506 (8)	36
3	545 (26)	492 (48)	53
4	537 (37)	518 (50)	19
5	529 (25)	474 (19)	55
6	531 (40)	500 (51)	31
7	571 (42)	520 (48)	51
8	535 (49)	488 (19)	47
9	555 (60)	497 (35)	58
10	530 (26)	486 (24)	44
ALL	542 (40)	501 (39)	41
S-BODY			
1	747 (32)	726 (28)	21
2	746 (19)	722 (18)	24
3	768 (27)	703 (36)	65
4	738 (31)	718 (48)	20
5	744 (29)	680 (21)	64
6	733 (32)	706 (49)	27
7	703 (35)	713 (38)	-10
8	739 (26)	690 (18)	49
9	750 (26)	699 (25)	51
10	737 (20)	697 (25)	40
ALL	746 (28)	705 (34)	41

Table I-2
Comparisons of Mean Preferred Positions
of the Console/Armrest Height
for Two Chrysler Studies
in Vehicle Coordinates (mm)

GROUP	Armrest Location Study mean (s.d.)	Control Position Study mean (s.d.)	Difference
G-BODY			
1	488 (28)	475 (31)	13
2	495 (25)	471 (33)	24
3	511 (22)	445 (36)	66
4	464 (33)	465 (32)	- 1
5	458 (23)	421 (34)	37
6	476 (43)	445 (52)	31
7	482 (42)	448 (24)	34
8	469 (26)	441 (25)	28
9	482 (50)	437 (44)	45
10	464 (42)	431 (32)	33
ALL	479 (36)	448 (37)	31
H-BODY			
1	507 (27)	505 (37)	2
2	522 (28)	501 (26)	21
3	515 (25)	463 (40)	52
4	499 (25)	486 (33)	13
5	477 (18)	457 (40)	20
6	485 (50)	466 (56)	19
7	505 (38)	475 (22)	30
8	494 (21)	473 (27)	21
9	504 (47)	470 (36)	34
10	478 (35)	456 (38)	22
ALL	498 (34)	475 (39)	23
S-BODY			
1	702 (17)	715 (21)	- 13
2	717 (27)	697 (27)	20
3	712 (25)	685 (35)	27
4	679 (41)	692 (39)	- 13
5	675 (26)	665 (30)	10
6	704 (49)	691 (48)	13
7	703 (35)	695 (20)	8
8	708 (31)	686 (24)	22
9	705 (29)	698 (24)	7
10	678 (28)	672 (32)	6
ALL	698 (34)	690 (32)	8

Table I-3
Comparisons of Mean Differences
Between the Console and Door Armrest
Heights for Two Chrysler Studies
in Vehicle Coordinates (mm)

GROUP	Armrest Location Study mean (s.d.)	Control Position Study mean (s.d.)	Difference
G-BODY			
1	25 (41)	13 (22)	12
2	30 (43)	10 (26)	20
3	17 (30)	28 (31)	-11
4	54 (41)	22 (49)	33
5	55 (40)	26 (41)	29
6	31 (23)	32 (34)	- 1
7	48 (54)	28 (33)	20
8	57 (48)	19 (15)	38
9	59 (48)	40 (33)	19
10	47 (34)	28 (28)	19
ALL	42 (41)	25 (32)	17
H-BODY			
1	41 (37)	25 (32)	16
2	20 (38)	5 (25)	15
3	31 (22)	28 (38)	3
4	38 (30)	32 (35)	6
5	52 (28)	17 (44)	35
6	45 (30)	34 (38)	11
7	66 (47)	45 (49)	21
8	42 (47)	15 (19)	27
9	52 (44)	26 (28)	26
10	52 (41)	30 (25)	22
ALL	44 (38)	26 (35)	18
S-BODY			
1	45 (30)	11 (19)	34
2	29 (19)	25 (22)	4
3	56 (34)	18 (23)	38
4	59 (39)	26 (29)	33
5	70 (39)	15 (27)	55
6	28 (37)	15 (33)	13
7	51 (27)	18 (26)	33
8	31 (28)	4 (15)	27
9	45 (36)	1 (17)	44
10	59 (40)	25 (23)	34
ALL	47 (35)	16 (24)	31

Table I-4
Comparisons of Mean Preferred Positions
of the Console/Armrest in the X-Direction
for Two Chrysler Studies
in Vehicle Coordinates (mm)

GROUP	Armrest Location Study mean (s.d.)	Control Position Study mean (s.d.)	Difference
G-BODY			
1	1164 (36)	1105 (86)	59
2	1141 (34)	1081 (76)	60
3	1184 (55)	1124 (41)	60
4	1193 (71)	1136 (85)	57
5	1178 (55)	1130 (73)	48
6	1174 (42)	1119 (47)	55
7	1166 (56)	1134 (44)	32
8	1205 (59)	1141 (44)	64
9	1177 (26)	1204 (70)	-27
10	1215 (41)	1201 (47)	14
ALL	1180 (51)	1138 (71)	42
H-BODY			
1	1182 (43)	1098 (65)	84
2	1146 (46)	1092 (68)	54
3	1186 (46)	1150 (72)	36
4	1187 (58)	1133 (77)	54
5	1192 (37)	1143 (66)	49
6	1170 (44)	1121 (41)	49
7	1154 (41)	1116 (53)	38
8	1206 (44)	1134 (65)	72
9	1165 (40)	1180 (41)	-15
10	1217 (36)	1192 (63)	25
ALL	1180 (47)	1136 (67)	44
S-BODY			
1	1153 (51)	1110 (77)	43
2	1153 (59)	1099 (86)	54
3	1188 (72)	1153 (68)	35
4	1182 (68)	1127 (77)	55
5	1193 (50)	1154 (54)	39
6	1186 (51)	1136 (42)	50
7	1159 (53)	1127 (87)	32
8	1178 (52)	1166 (54)	12
9	1163 (40)	1199 (51)	-36
10	1214 (61)	1214 (48)	0
ALL	1177 (57)	1148 (72)	29

Table I-5
Preferred Position Results for
ELBOW LOCATIONS ON DOOR ARMREST
in Vehicle Coordinates (mm)

Group	N	Mean Preferred Position (s.d.) G	H	S
1	10	1231 (55)	1220 (36)	1231 (59)
2	10	1261 (54)	1247 (51)	1260 (58)
3	10	1291 (49)	1290 (57)	1284 (42)
4	10	1276 (56)	1272 (63)	1273 (38)
5	10	1355 (42)	1339 (38)	1352 (50)
6	10	1304 (24)	1290 (44)	1284 (43)
7	10	1305 (45)	1295 (36)	1291 (45)
8	10	1327 (41)	1301 (40)	1324 (39)
9	10	1365 (32)	1344 (27)	1361 (40)
10	10	1378 (43)	1375 (61)	1368 (42)
ALL	100	1308 (62)	1297 (63)	1303 (62)

Table I-6
Preferred Position Results for
ELBOW LOCATIONS ON CENTER ARMREST
in Vehicle Coordinates (mm)

Group	N	Mean Preferred Position (s.d.) G	H	S
1	10	1286 (62)	1269 (46)	1261 (59)
2	10	1314 (57)	1312 (41)	1305 (69)
3	10	1342 (57)	1344 (48)	1314 (54)
4	10	1363 (59)	1347 (72)	1326 (44)
5	10	1395 (74)	1402 (69)	1382 (54)
6	10	1370 (33)	1356 (47)	1328 (30)
7	10	1398 (30)	1366 (34)	1360 (50)
8	10	1389 (28)	1380 (40)	1365 (39)
9	10	1449 (44)	1407 (48)	1397 (43)
10	10	1455 (49)	1445 (67)	1431 (40)
ALL	100	1376 (71)	1363 (70)	1347 (67)

APPENDIX J
SUBJECT COMMENTS DURING TESTING

SUMMARY OF SUBJECT COMMENTS DURING TESTING BY BODY STYLE

PREFERRED LOCATIONS:

SEAT

•Subject feels that the seat cushion is too long or the angle of the front edge is too high such that it is uncomfortable behind their knee when operating the pedals.
G-body: 1
H-body: 1
S-body: 7

•Subject would like to have a seat back angle that is more upright than is currently available.
G-body: 8
H-body: 6
S-body: 19

•The seat should be higher.
G-body: 1
H-body: 2
S-body: 1

•The seat is comfortable.
G-body: 1
S-body: 2

•The seat is too high.
S-body: 4

•The head rest is uncomfortable; too high and bulky.
G-body: 1

•Detent position depends on length of trip.
H-body: 2

•The side contouring of the seat interferes with elbows.
S-body: 1

•Shoulders feel too crammed against the back of the seat.
H-body: 1

PEDALS

•Subject feels that it is difficult to find a compromising position for the brake/clutch positions.
G-body: 2
H-body: 2
S-body: 1

•The clutch should be further rearward from the brake (i.e. toward the driver) than in the existing configuration.
H-body: 1

•The brake and clutch should be closer together, i.e. more level with each other in the x-direction.
G-body: 2
H-body: 2
S-body: 1

•The brake and clutch are too close together in the lateral or y-direction.
H-body: 1

•Clutch travel is too long.
G-body: 1
S-body: 1

•Brake travel is too long.
G-body: 2
H-body: 1

•The clutch pedal is too high off the floor.
G-body: 1

•The accelerator is too far to the right with respect to the seat centerline.
G-body: 1

•The accelerator pedal should be angle more toward the driver (i.e. it is too flat and causes discomfort to the ankle).
S-body: 4

•The brake and the accelerator are too far away in the lateral direction.
G-body: 2
S-body: 1

•It is difficult to compromise control positions such that the brake can comfortably be reached without the leg hitting the wheel.
G-body: 1

•The preferred position of the pedals depends on what shoes are being worn.
G-body: 1

•The pedal pads are too small.
H-body: 1

•The dead pedal (foot rest) should be closer to the driver.
H-body: 1

STEERING WHEEL

•The steering wheel is too low and touches the knees.
G-body: 3
H-body: 1

•The wheel is too high.
G-body: 1
S-body: 1

•The wheel is tilted too far away from the driver.
G-body: 2
H-body: 5
S-body: 3

•The wheel should be tilted further from the driver.
G-body: 4
S-body: 1

SHIFT KNOB

•The subject would prefer to have the shift lever on the steering column.
G-body: 1
S-body: 1

•The subject would like to select a new detent position now that the shift knob has been considered.
G-body: 1

•In reaching fifth gear, it is uncomfortable to have to roll the shoulder forward.
G-body: 1

•The shift knob is most comfortable when fifth gear is just in arms reach.
G-body: 1

•The subject does not want to lift the arm/hand in an upward direction when moving from the steering wheel to the shift knob.
G-body: 1

•A comfortable shift knob location is dependent on the steering wheel location.
G-body: 1

•Because of the shape of the shift knob, subject needs to grab it form the side rather than the top and therefore he needs to select a higher location.
H-body: 1

ARMRESTS

•The subject would like to have a center armrest in their own vehicle.
G-body: 1
S-body: 1

•The center armrest should be closer to the seat.
G-body: 13
H-body: 11
S-body: 3

•Subject does not use armrests/would not want them in own vehicle.
G-body: 4
H-body: 4
S-body: 1

•Both armrests should be closer to the seat.
G-body: 4
H-body: 3

•The door armrest should be closer to the seat.
G-body: 2
H-body: 4
S-body: 2

•The subject would prefer to not have any console armrest.
G-body: 2
H-body: 1
S-body: 3

•The subject would never use both armrests at the same time.
G-body: 2

•Subject mentioned that they always use a console armrest.
G-body: 1

•Subject felt that the console armrest should be further away from the seat.
G-body: 1
H-body: 1

•The door armrest should be further away from the seat.
H-body: 2

•The left elbow hits the door armrest when turning the wheel when armrest is in the preferred position.
G-body: 1

•Subject would rather use the sill than the door armrest.
H-body: 2
S-body: 2

•The console armrest is not long enough.
H-body: 3

•Would not want a console armrest in a manual transmission vehicle.
H-body: 1
S-body: 1

•Only uses an armrest when corresponding hand is not on the wheel.
H-body: 2

•The console armrest is not wide enough.
S-body: 6

•The preferred location is more dependent on the low clearance and arm motion than on comfortability.
S-body: 1

ACCEPTABLE LIMITS

PEDALS

•Subject doesn't like to lift the right foot to go from the accelerator to the brake when determining the maximum limit.
G-body: 2

•The maximum limit is reached when legs hit the steering wheel.
H-body: 1

•The maximum limit is when subject's shoe catches on brake.
H-body: 1

•The maximum limit is determined by the dead pedal•to•clutch distance in the x-direction.
H-body: 1

STEERING WHEEL

•The maximum limit is reached when legs hit the wheel.
G-body: 2

•If the wheel was tilted differently, acceptable limits would also be different.
S-body: 1

SHIFT KNOB

•Leverage is important in determining the maximum acceptable limit.
G-body: 1

•Subject mentioned that they now realize that their preferred shift knob position should be higher.
G-body: 2

•If the armrests were still being considered, limits may be different.
H-body: 1

•Acceptable limits are inter•dependent (i.e. if shift knob were further back in the x-direction, subject would accept a higher shift knob location).
S-body: 2

•Maximum shift height is determined by the strain on the shoulder.
S-body: 1

•Minimum shift height is determined by the arm hitting the side of the seat.
S-body: 1

CANT ANGLE

•Acceptable cant angles are determined by interference with the armrests.
G-body: 3

•Lower armrests would enable a greater acceptable range for cant angles.
G-body: 1

•Subject would accept different cant angles depending on length of trip.
G-body: 1

•Some cant angles are more acceptable with one hand on the wheel rather than with both hands on the wheel.
S-body: 1

•Could accommodate to an off-center wheel by shifting in the seat.
H-body: 1

•Cant angles interfere with the legs.
H-body: 1

•The twist or rotation of the steering column is more unacceptable than the lateral off-center displacement.
G-body: 1
S-body: 1

•Subject's current vehicle has an off•centered steering wheel.
S-body: 1

APPENDIX K
QUESTIONNAIRE RESULTS

Table K-1
Subject Vehicles By Group

Vehicle Make and Model	GROUP # 1	2	3	4	5	6	7	8	9	10	All
AMC:											
Alliance	0	0	0	0	0	0	1	0	0	0	1
Hornet	0	1	0	0	0	0	0	0	0	0	1
Chevy-Pontiac-Olds-Buick:											
Camaro	0	0	0	0	0	0	0	0	1	0	1
Chevette	0	1	0	1	0	0	0	1	0	0	3
Citation	0	0	0	0	1	0	0	1	0	0	2
Corvette	0	0	0	0	0	0	0	0	0	1	1
Cutlass	0	0	0	0	0	0	0	0	0	1	1
Grand Am	0	0	0	1	0	0	0	1	0	0	2
J-2000	1	0	0	0	0	0	0	1	0	0	2
Sunbird	0	0	0	0	0	1	0	0	0	0	1
Chrysler-Plymouth-Dodge:											
Colt	0	0	0	0	0	0	0	1	0	0	1
Daytona	0	0	0	0	0	0	1	0	0	0	1
Horizon	0	0	0	1	0	0	0	0	0	0	1
Reliant	1	0	0	0	0	0	0	0	0	0	1
Vista Wagon	0	1	0	0	0	0	0	0	0	0	1
Voyager	0	0	0	0	0	0	1	0	0	0	1
Datsun-Nissan:											
Pick-up	0	0	0	0	0	0	0	1	0	0	1
Stanza	0	0	0	2	0	0	0	0	0	0	2
Ford-Mercury:											
Aerostar	0	0	0	0	0	0	0	0	1	0	1
Bobcat	0	0	0	0	0	1	0	0	0	1	2
Bronco	0	1	0	0	1	0	0	0	1	0	3
Escort	0	0	1	0	1	2	0	0	1	1	6
Fairmont	0	1	0	0	0	0	0	0	1	0	2
LTD	0	0	0	0	0	0	1	0	0	0	1
Mustang	0	0	0	0	0	0	0	0	1	0	1
Pinto	0	0	0	0	0	0	0	0	0	1	1
Ranger	1	0	0	0	0	0	0	0	0	0	1
Tempo	0	1	0	0	2	1	0	1	0	0	5
Topaz	0	1	1	0	0	0	1	0	0	0	3
Lynx	2	0	0	1	0	0	0	0	0	0	3
LN7	0	0	0	0	0	0	0	1	0	0	1

Vehicle Make and Model	Group #										
	1	2	3	4	5	6	7	8	9	10	All
Honda:											
Accord	0	1	2	1	1	0	0	0	0	0	5
Civic	0	0	1	0	1	1	0	1	0	0	4
CRX	0	0	0	0	0	0	0	1	0	0	1
Mazda:											
321	0	0	0	0	0	0	0	1	0	0	1
Renault:											
LeCar	0	0	0	1	0	0	0	0	0	0	1
SAAB:											
900 Turbo	0	0	1	0	0	0	0	0	0	0	1
Subaru:											
GL Wagon	0	0	0	1	0	0	0	1	0	1	3
Suzuki:											
Samuri	0	0	1	0	0	0	0	0	0	0	1
Toyota:											
Celica	1	0	0	0	0	0	0	0	0	1	2
Corolla	1	1	1	0	0	1	0	0	0	1	5
Corona	0	1	0	0	1	0	0	0	0	0	2
Land-Cruiser	0	0	0	0	0	0	1	0	0	0	1
Pick-up	0	0	0	0	0	0	0	0	0	1	1
SR5 Wagon	0	0	0	0	0	0	1	0	0	0	1
Tercel	1	0	1	0	1	1	0	0	0	0	4
Volkswagon:											
Beetle	1	0	0	0	0	0	1	0	0	0	2
Rabbitt	1	0	0	1	0	0	0	0	2	0	4
Volvo:											
DL	0	0	1	0	0	0	0	0	0	0	1
GL	0	0	0	0	0	0	0	0	0	1	1

Table K-2
Questionnaire Results

1.) Front to Back Seat Adjustment:

Response	Group 1	2	3	4	5	6	7	8	9	10	All
It is adequate	10	7	9	9	7	8	6	10	9	6	81
Not enough forward adj.	0	2	1	1	0	0	0	0	0	0	4
Not enough rearward adj.	0	1	0	0	2	0	2	0	2	4	11

2.) Seat Height

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Fine	4	5	7	8	8	6	7	8	8	7	68
Too low	4	3	2	2	1	2	1	1	0	1	17
Too high	1	2	0	0	0	0	0	1	0	1	5
Adjustable	0	0	3	0	0	0	2	0	1	1	7

3.) Seat Back Angle Adjustment

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Doesn't Adjust	0	1	3	2	4	1	2	1	4	4	19
Adequate Adjustment	6	7	8	7	5	7	4	8	5	6	63
Would like more upright	4	2	2	2	0	0	0	1	1	1	13
Would like further back	0	1	0	0	0	0	1	0	1	1	4

4.) Height of Brake Pedal from the Floor

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Too high	0	1	0	2	0	0	0	0	1	1	5
Too low	2	0	0	1	0	0	0	0	0	1	4
Fine	8	9	10	7	9	8	8	10	9	7	85

5.) Distance of the Brake Pedal from the Accelerator Pedal Sideways

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Too close	0	0	1	0	0	0	0	2	1	1	5
Too far	0	1	0	0	0	0	0	0	0	0	1
Fine	10	9	9	10	9	8	8	8	9	9	89

6.) Distance of the Brake Pedal from the Accelerator Pedal Toward the Driver

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Fine	10	6	9	10	9	8	7	9	9	7	84
Too close	0	1	0	0	0	0	0	1	0	3	5
Too far	0	1	1	0	0	0	1	0	1	0	4

7.) In Operating the Brake and Accelerator Pedal

Response	Group 1	2	3	4	5	6	7	8	9	10	All
No problems	8	7	9	10	7	7	6	8	7	7	76
Shoe sometimes catches on brake	2	3	1	1	1	1	2	1	1	3	16

8.) In Operating the Clutch Pedal

Response	Group 1	2	3	4	5	6	7	8	9	10	All
No problems	5	4	7	6	6	6	5	9	6	6	60
Need to sit closer to steering wheel than would like to operate clutch pedal	4	5	1	3	2	1	1	0	2	0	19
Left foot sometimes catches on clutch pedal	0	1	1	0	0	0	1	0	0	2	5

9.) Steering Wheel Location

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Too high	1	1	1	1	0	1	1	0	2	1	9
Too low	0	0	1	0	1	0	1	0	0	3	6
Column interferes w/knees	0	1	0	0	2	0	0	1	0	0	4
Wheel rim interferes w/knees	0	0	0	1	0	0	0	0	1	3	5

9.) Steering Wheel Location (continued)

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Wheel is too close when I sit so I can operate pedals	2	4	1	0	1	0	0	0	0	0	8
Wheel is too far away when I sit so I can operate pedals	0	1	0	0	0	0	0	1	0	0	2
Interferes w/view of instrument panel	0	3	2	2	0	1	2	2	3	3	18
Too far off center from the seat	0	0	0	0	1	0	0	0	1	1	3
Interferes w/view out front window	0	1	1	0	0	0	0	0	0	0	2
Fine	7	4	4	6	5	6	4	5	4	2	47

10.) Shift Knob Location

Response	Group 1	2	3	4	5	6	7	8	9	10	All
Too far forward	2	4	2	2	3	3	0	0	2	2	20
Too far back	0	0	0	0	0	0	0	0	0	0	0
Too high	0	0	0	0	0	0	0	0	0	1	1
Too low	0	0	0	2	0	0	0	0	0	1	3
Too hard to operate	1	3	1	3	0	1	1	0	1	0	11
Too close to seat	0	0	0	0	0	0	0	0	0	0	0
Too far to right	1	1	3	1	2	1	0	1	1	0	11
Fine	6	4	4	3	5	5	5	4	6	5	47

Table K-3
List of Subject Comments
From Questionnaire

Group #	Comment
1	"Seat back is too low."
2	"Seat cushion is too long and is uncomfortable behind the knees. It makes it difficult to work the pedals."
2	"The accelerator is too close to the floor with respect to the brake. It's too far away."
2	"The clutch pedal is too close to the brake."
3	"Shoulder belt is uncomfortable when seat is far enough forward to operate the pedals."
3	"The steering wheel is too large."
4	Two subjects commented that: "It is difficult to operate the shift when going into 'reverse' or '5th' gear."
5	"The accelerator pedal is too small."
6	"I would like to be able to adjust the seat height."
6	"My left foot sometimes catches on the brake pedal."
7	"I would not buy a car without an adjustable seat back angle."
7	"The brake pedal is higher than the accelerator."
8	Two subjects commented that: "The shift knob interferes with the passenger's left leg."
9	"The seat height should be adjustable."
9	"The accelerator pedal is too close to the side of firewall."
10	"The stroke length of the clutch pedal is too long."