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LOCATIONS OF DRIVER KNEES RELATIVE TO KNEE BOLSTER DESIGN

FINAL REPORT

September 30, 1988

Submitted to:

Motor Vehicle Manufacturers Association
320 New Center Building
Detroit, Michigan 48202

UMTRI The University of Michigan Transportation Research Institute

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MVMA Project No. 6132

Final Report

Submitted to:

The Motor Vehicle Manufacturers Association
320 New Center Building
Detroit, Michigan 48202
September 30, 1988

by:

The University of Michigan
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Ann Arbor, Michigan 48109

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16. Abstract

Three-dimensional locations of driver knees were determined for fifty subjects ranging in stature from 5th percentile female to 95th percentile male. The data were collected in a laboratory seating buck that was adjusted to simulate sport car, sedan, and minivan seating packages for each subject. Stereophotogrammetric measurement techniques were used to determine the three-dimensional locations of seven targets on both knees for different conditions of the feet and seat. Results are reported in graphical and tabular form with the primary emphasis on the locations of the lower patella target which defines a critical impact point for knee bolster design. A complete set of target position data are available on 9-track magnetic tape or 5-1/4" floppy diskettes.

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SUMMARY

An adjustable laboratory seating buck was designed and developed for the purpose of collecting information on the three-dimensional locations of driver knees in seating packages spanning the range of passenger car seat heights. The base of the seating buck platform was bolted to the laboratory floor and provided for quick interchange of seats, pedals, steering wheel and floor/toepan modules so that subjects could be tested in three seating packages representing a GM Camaro, a Ford Escort, and a Chrysler Minivan during a single test session.

Three-dimensional locations of seven contrast targets placed on both knees of fifty subjects ranging in stature from 5th percentile female to 95th percentile male were determined using a four-camera stereophotogrammetry system and Direct Linear Transformation (DLT) calibration techniques. Knee positions were determined with the feet in different positions including the right foot on the accelerator pedal and brake and the left foot on the floor and toeboard. In addition to collecting data for the seat in the driver's preferred position, knee position data were also collected for the seat translated forward six inches in order to represent the knee positions after the onset of a frontal impact. Several measurements were also taken of each subject seated in each vehicle package including upper and lower leg angles, right heel position, and seated height.

Knee position results are presented and compared for the different test conditions in both graphical and tabular form. The distributions of driver seat position data are compared with predictions of SAE J1516 and J1517, The Seating Accommodation Model. Tangency cut-off ellipses are used to describe the distributions of the lower patella targets in top-view, side-view, and front-view planes.

I. INTRODUCTION AND OBJECTIVES

The decision by the National Highway Traffic Administration (NHTSA) to require passive restraints in the front seats of all passenger cars manufactured after September 1, 1989 will greatly increase the use of knee bolster/shoulder belt systems as a means of providing whole-body occupant restraint during frontal impacts. In order for such systems to be effective, however, the design and placement of the knee bolster relative to the driver's knees in the pre-impact or normal driving situation are critical, especially if trauma to the lower extremities is to be minimized. For example, it has been demonstrated (Culver and Viano, 1980; Viano and Culver, 1979) that if the knee bolster is too low, damage to the anterior cruciate ligament and/or fracture of the tibia are likely. To minimize impact forces, it is also important to minimize the distance from the knees to the bolster prior to the onset of impact.

Currently, positioning of knee bolsters is based on limited information of driver knee positions, derived primarily from two-dimensional kinematic models of the seated occupant using anthropometric and anatomical dimensions from the 5th percentile female, 50th percentile male, and 95th percentile male (Culver and Viano, 1979). In order to know how to design a knee bolster system that will have optimal effectiveness for the population of vehicle occupants, more complete and quantitative information describing the three-dimensional locations and range of locations for occupant knees is needed. This study was undertaken to help fill this need by quantifying the positions of driver knees in three different seating package configurations for a sample of adult subjects spanning U.S. adult population statures from 5th percentile females to 95th percentile males.

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. PROCEDURES

A. General Approach and Selection of Vehicle Packages

Due to the difficulty of efficiently and accurately collecting three-dimensional knee position data in actual vehicles, a laboratory seating buck was developed and utilized to simulate the desired seating packages. Based on previous studies of driver seat position, seat height was considered the most important package dimension influencing knee position and it was therefore desired to collect data for a set of seating packages spanning the range of seat heights for typical passenger vehicles. Initially, consideration was given to using generic seating packages for sport, mid-sized, and van-type vehicles by averaging package dimensions of representative vehicles from General Motors, Ford, and Chrysler vehicles. This approach was subsequently abandoned, however, in favor of using three specific vehicle package configurations covering the range of passenger car seat heights, with one vehicle selected from GM, Ford, and Chrysler, respectively. After examining the seat height dimensions (defined as the vertical distance from AHP to SgRP or H30) from popular vehicle models, the three vehicles shown in Table 1 were selected for the study.

TABLE 1

VEHICLES AND SEAT HEIGHTS REPRESENTED IN SEATING BUCK

Vehicle	Vehicle type	Seat Height (mm)
GM Camaro	Sport car	186
Ford Escort	Mid-sized sedan	260
Chrysler	Minivan	351

B. Seating Buck

As described below, the technique of stereophotogrammetry was selected as the best procedure available for collecting the three-dimensional knee position information. Because of the time, cost, and equipment involved in setting up and calibrating this data acquisition system and the need to test each subject in the three seating configurations during a single measurement session, it was required that all vehicle seating packages be represented in the same laboratory seating buck. Figure 1 illustrates the universal or interchangeable buck platform that was developed for this study to allow easy and quick changing between the Camaro, Escort, and Minivan seat/control packages by interchanging seat, steering wheel, brake pedal, accelerator pedal, and floor board modules. As illustrated, the ability to translate the seat and subject forward to obtain estimates of knee position subsequent to the onset of frontal impact was also designed into the buck.

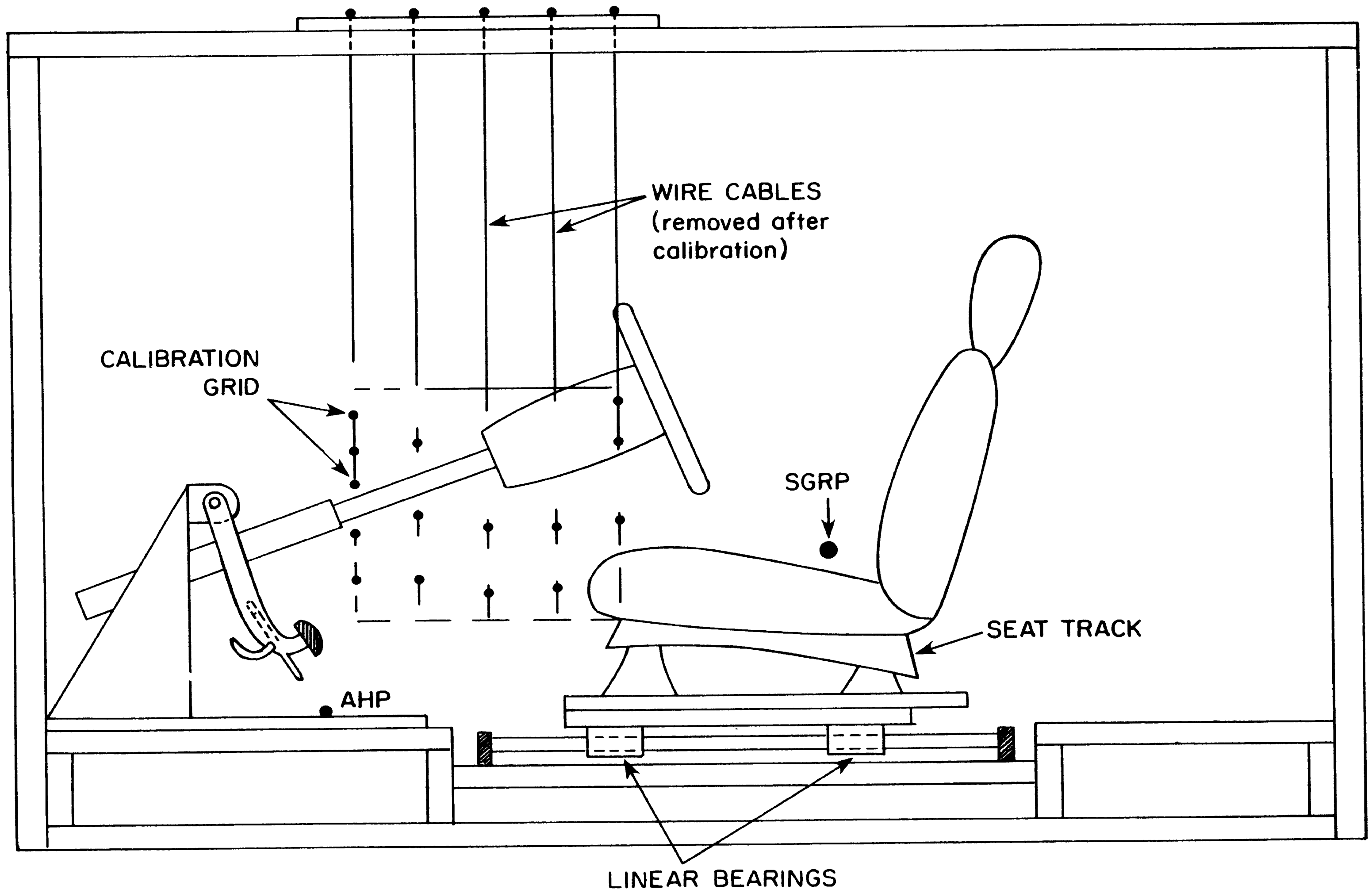


Figure 1. Sketch of test facility. Calibration grid is removed after fixed cameras (not shown) have photographed the array of targets.

Package drawings, dimensions, and vehicle components such as steering wheel/column assemblies, brake pedal and linkage assemblies, and seats were obtained from each of the companies and modified for use in the seating buck. Appendix A provides the package dimension information obtained and utilized in designing the buck and buck components. These dimensions, which include the locations of the seat track mounting bolts relative to the AHP, were used to construct an overlay drawing of the three vehicle seating packages. In addition, a half-scale model of the seating buck was fabricated as an aid to the design process.

Figures 2a through 2c show Camaro, Escort, and Chrysler Minivan seating buck configurations, respectively, while Tables A-2, A-4, and A-6 of Appendix A show the desired versus actual dimensions for the three packages. A platform base bolted to the laboratory floor includes support structures for attaching the three different steering/brake pedal assemblies and the accelerator pedals. The different seat assemblies attach to an aluminum plate fastened by means of linear bearings to two one-inch diameter shafts and a screw-motor actuator permits investigator control of seat position in the front/back direction. The seats are easily removed and exchanged by means of a specially designed cart that grips the plywood board to which each seat is fastened. Detent markers on the side of each seat provide a manual readout of preferred seat location. A single Accelerator Heel Point (AHP) on the buck provided a common reference point for all three seating packages.

As indicated previously and illustrated in the figures, each seating package mockup includes a module for the floor/toepan surface surrounding the pedals which were considered important to the study since these surfaces can directly affect the positions of the feet which in turn will affect the positions of the knees. This is especially true for the left foot which is normally placed on the floor or on the inclined foot rest area provided in most vehicles. These modules were fabricated by making molds of the floor/toepan surfaces from actual vehicles using 3M Corporation's Scotchcast material. Hardened Scotchcast contours taken from the vehicles were mounted to plywood boards and strengthened with body putty. The plywood board forming the heel surface of the buck was cut out to allow these floor/toeboard units to be inserted in place so that the contours are correctly located with respect to the pedals.

A 12 volt D.C. power supply was used to power a screw-motor actuator that translates the seat base along the X-axis, thereby simulating body translation during frontal impact. A pointer was attached at the appropriate position on each seat mounting board, so that it aligns with a mark on the seat buck structure when the seat is in the design position. A measuring scale allows the investigator to translate the seat forward or backward desired distances from this point. During subject testing, six inches of forward translation was used to approximate travel of the body during impact.

C. Stereophotogrammetric Measurement Technique

A stereophotogrammetry technique known as direct linear transformation, or DLT, was used to collect and determine three-dimensional coordinates of knee targets relative to

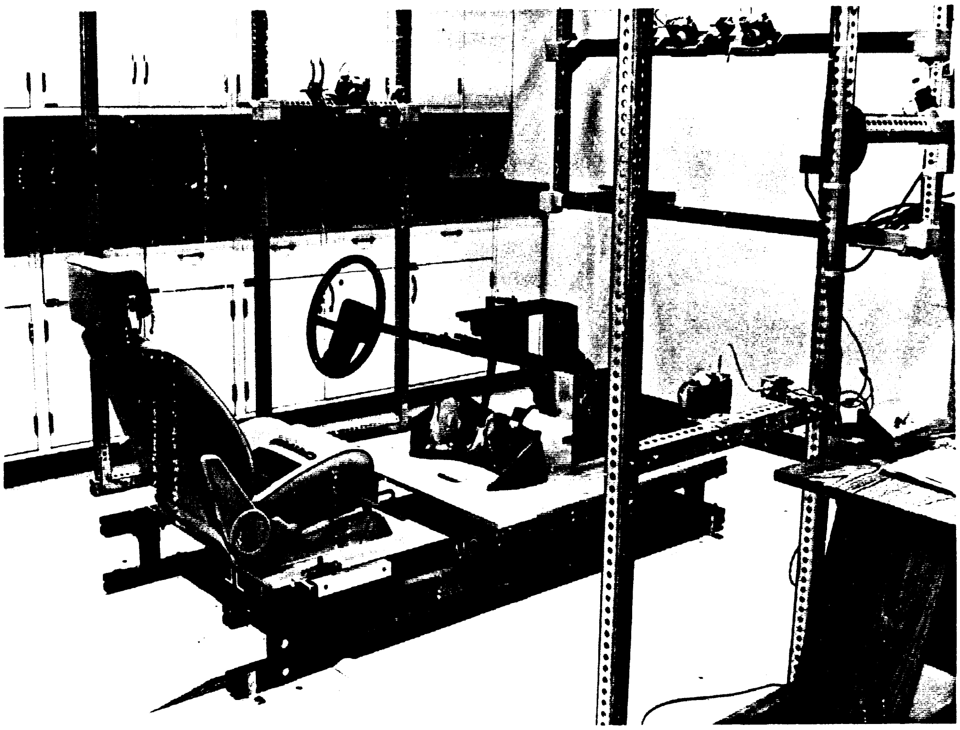


Figure 2a. Seating buck configured for GM Camaro.

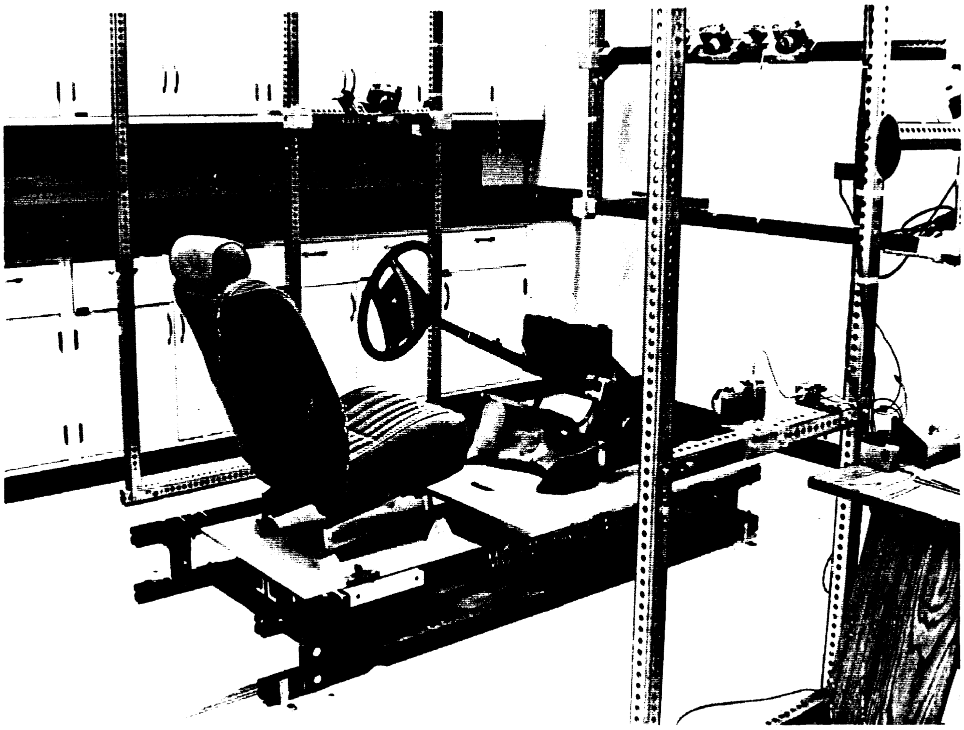


Figure 2b. Seating buck configured for Ford Escort.

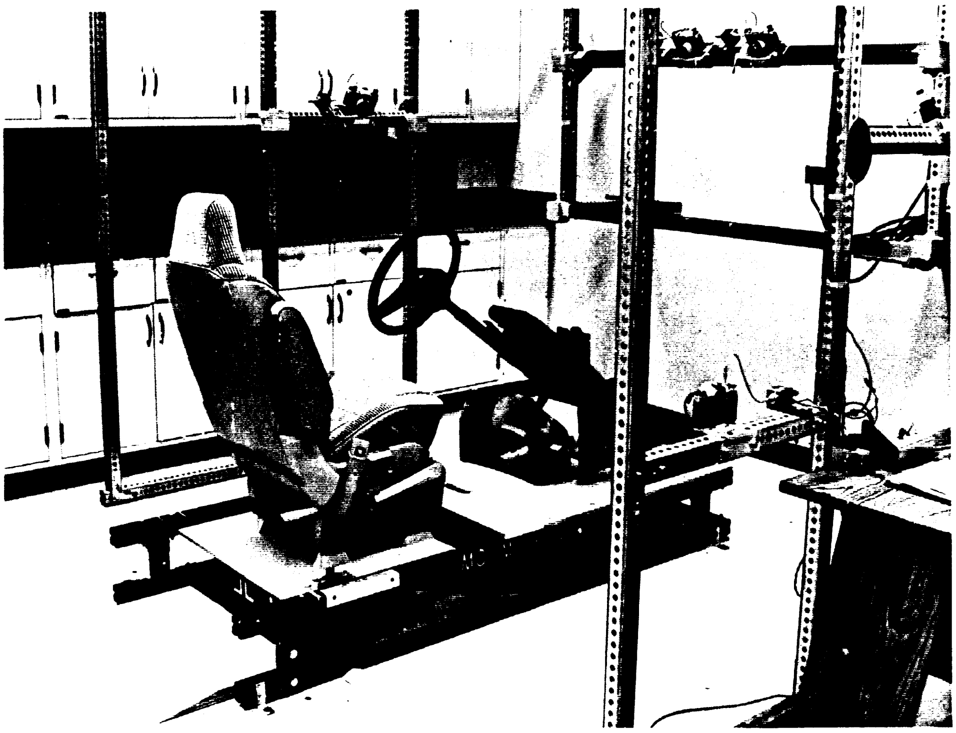


Figure 2c. Seating buck configured for Chrysler Minivan.

the common accelerator heel point. Figure 3 illustrates the physical setup and calibration grid which used four 35 mm cameras rigidly fixed in the laboratory and positioned so that at least two cameras could "see" each contrast target attached to subject knees and legs. A fifth camera was been positioned to provide a lateral-view photograph of each subject in their preferred seated position and posture, and was used to determine knee trajectories during seat translation for a subset of the subjects.

The "knee space" area of the buck was calibrated by photographing the three-dimensional grid of targets illustrated in Figure 3. Thirteen aircraft cables were suspended from precisely positioned holes in an aluminum plate. Five spherical nylon beads, dyed with different contrast colors, were strung on each wire at 100 mm intervals using a calibrated rod to provide 65 precisely positioned targets in the laboratory space where the knees were expected to be. A plumb weight at the end of each wire was suspended in a container of motor oil to reduce vibration and movement while the grid was being photographed.

Color slides of the calibration grid taken by each camera were digitized on an X-Y digitizer and these known-target data were used in the Direct Linear Differential (DLT) equations to determine the calibration coefficients of the DLT equations for the set of cameras and camera positions used. During this calibration process, the laboratory origin for the Cartesian coordinate system was selected to be a known number of millimeters below, in front of, and to the right of the most right, front, and lower bead in the grid. The X-axis was defined as positive rearward, the Y-axis as positive to the left, and the Z-axis as positive up, so that all coordinate values for knee targets would have positive values, thereby facilitating the analysis process. By measuring this most right, front, and lower bead from a known point on the seating buck, the three-space coordinates obtained from this calibration system can be expressed in terms of distances from AHP, or in terms of vehicle coordinates for each of the seating packages.

D. H-point Calibrations

An SAE J826 H-point machine was borrowed from Ford Motor Company and used to adjust and validate the seat locations and orientations on the buck. Since the AHP is a fixed point on the buck platform which is common for all three vehicles, the heel of the H-point machine was blocked at this X-coordinate on the heel surface during the calibrations. After an initial round of H-point "drops" on the three seats, modifications were made to the seat track supports to improve the calibration values.

Several trials of the H-point machine were made to obtain values within tolerance of design values. Since the seat base platforms attach to a translating platform on the buck, it was possible to correct for errors in H-point-to-AHP horizontal distances while keeping the seat track in the design detent position. Several trials in seat back angle were also required to obtain design specifications. Tables A-7 through A-9 show the final H-point calibration values obtained for each vehicle package.

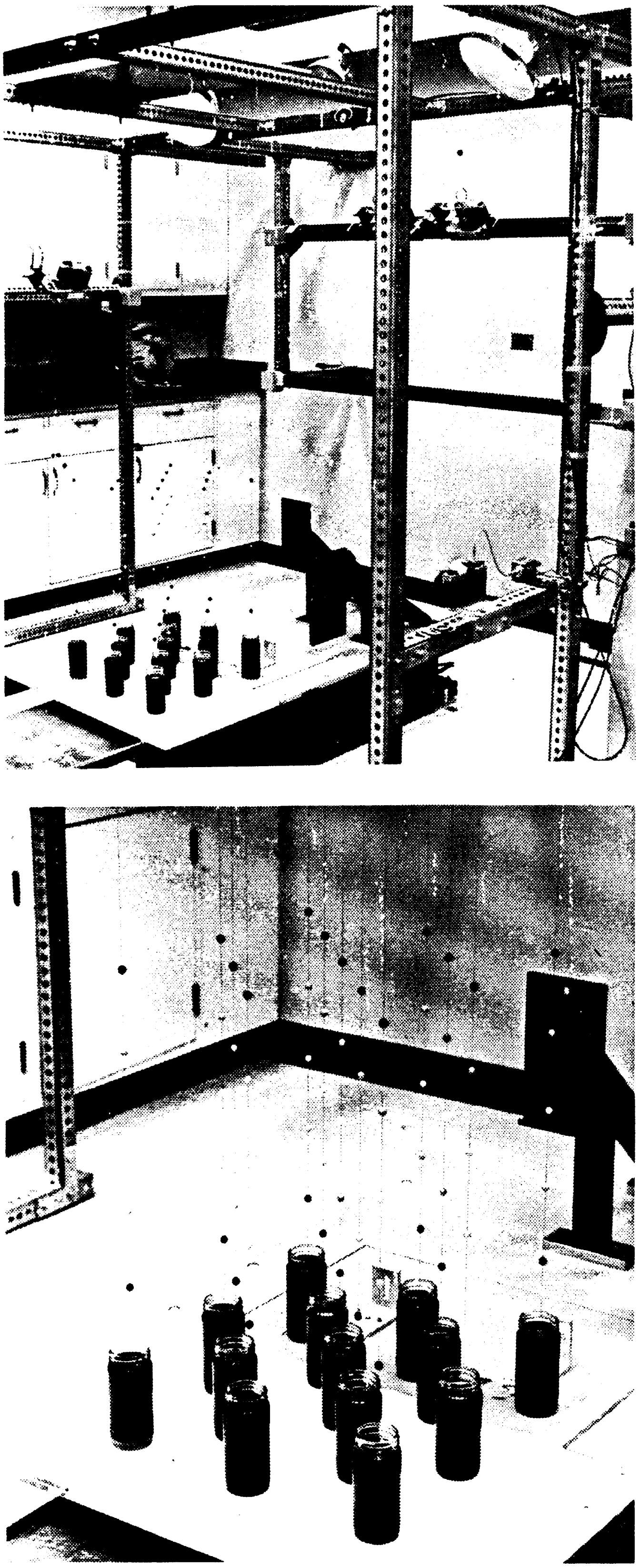


Figure 3. Four-camera stereophotogrammetry system and calibration grid for data collection.

E. Subject Population

The primary subject population used in this study consisted of fifty volunteer drivers ranging in stature from 5th percentile female to 95th percentile male. As shown in Table 2, the subjects were equally distributed in ten stature groups representing different proportions of the total population. Thus, the sample of fifty subjects is not matched to the distribution of stature in the U.S. adult population, but the results can be converted to a matched sample by application of appropriate weighting factors. By selecting five subjects in each stature group, it is felt that the effects of body proportion variability within a given stature range are better represented. In addition to the fifty subjects, two male 6′4″ drivers representing the 99th percentile occupant were tested.

TABLE 2

SUBJECT GROUP DEFINITIONS BY STATURE

Group #	Name	Mean percentile	percentile 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

Subjects determined to be qualified for the study by stature and screening of a health questionnaire were measured for the following standard anthropometric measurements to provide further definition and description of body size:

- Stature with shoes
- Stature without shoes

- Weight without shoes
- Erect sitting height
- Buttock-knee length
- Eye height (sitting)
- Shoulder height (sitting)
- Top of knee height (sitting)
- Hip breadth
- Shoulder breadth
- Shoulder-elbow length
- Forearm-hand length
- Heel-to-toe length with shoes
- Heel-to-BOF length with shoes

F. Measurement of Knee Locations

It was desired to collect three-dimensional knee position data for the seat translated forward (simulating occupant forward translation during impact) as well as for the seat in the driver's preferred position. In addition, since location of the knees is dependent not only on the geometry of the seating package and seat height which influence the drivers seat position and posture, but also on the position of the feet, it was desired to collect knee position data for likely scenarios of feet positions. As a result of these considerations, a set of four different seat/foot conditions were determined for data collection as follows:

1. Right foot on undepressed accelerator pedal
   Left foot on toeboard/rest area
   Seat in preferred location

2. Right foot on depressed accelerator pedal
   Left foot on toeboard/rest area
   Seat in translated forward position

3. Right foot on undepressed brake pedal
   Left foot anywhere (not measured)
   Seat in preferred location

4. Right foot on depressed brake pedal
   Left foot anywhere (not measured)
   Seat in translated forward position

While the most important knee point with regard to knee bolster positioning was considered to be the lower (i.e., anterior, inferior) margin of the patella since this defines the critical location with regard to the anterior cruciate ligament joining the femur and tibia, a number of additional targets were placed on and around both knees of the subjects to further define the knee position and for future analysis and applications. Thus, a total of seven contrast targets for photogrammetric digitization were placed at the following locations on each knee:

1. The top surface of the upper leg about 4 inches from the knee.
2. The upper margin of the patella.
3. The geometric center of the patella.
4. The lower margin of the patella just above the tibia.
5. Along the line of the tibia about 4 inches below the lower margin of the patella.
6. The palpated lateral femoral condyle.
7. The palpated medial femoral condyle.

Figure 4 illustrates these targets attached to a subject seated in the test buck. Targets at specific locations were color coded to facilitate identification during film digitization. In addition, certain targets, such as the lateral femoral condyles and upper leg targets, were made from 1/4-inch dowel rod so that they could be more easily identified by cameras viewing the skin surface at a low angle.

G. Other Seated Measurements

In addition to the collection of knee position data, a number of other measurements were collected with the subjects in their preferred seat position for each vehicle package.

- preferred seat detent
- relaxed sitting height
- approximate upper leg angle (X-Z plane)
- approximate lower leg angle (X-Z plane)
- approximate foot pitch angle (X-Z plane)
- approximate foot rotation angle
- location of right shoe heel/floor contact point with foot on accelerator pedal

Seat detent was measured by reading the position of the pointer attached to each seat. While seat front/back travel range was limited to that provided by the production seat tracks used in the study, subjects who desired to position the seat beyond the travel limits were accommodated by the seat translation capability of the seat buck platform. In these instances, the investigator moved the seat in detent increments and added or subtracted the number of additional detent spaces to the value read on the pointer. With the subject seated in a relaxed posture in his/her preferred seat location, the sitting height was measured with a standard anthropometer.

Leg angles were measured by means of an inclinometer attached to a flat aluminum bar that was placed along the surface of the upper or lower leg. Foot angles were measured by means of the two-degree-of-freedom device shown in Figure 5. With the subject in a comfortable driving position and the right foot on the undepressed accelerator pedal, the base of the device was positioned on the heel surface with the long axis in the X direction. The angle of the pivoting bar was adjusted and locked into position to approximate the orientation of the inner edge and bottom of the subject's foot inside his/her shoe. The two

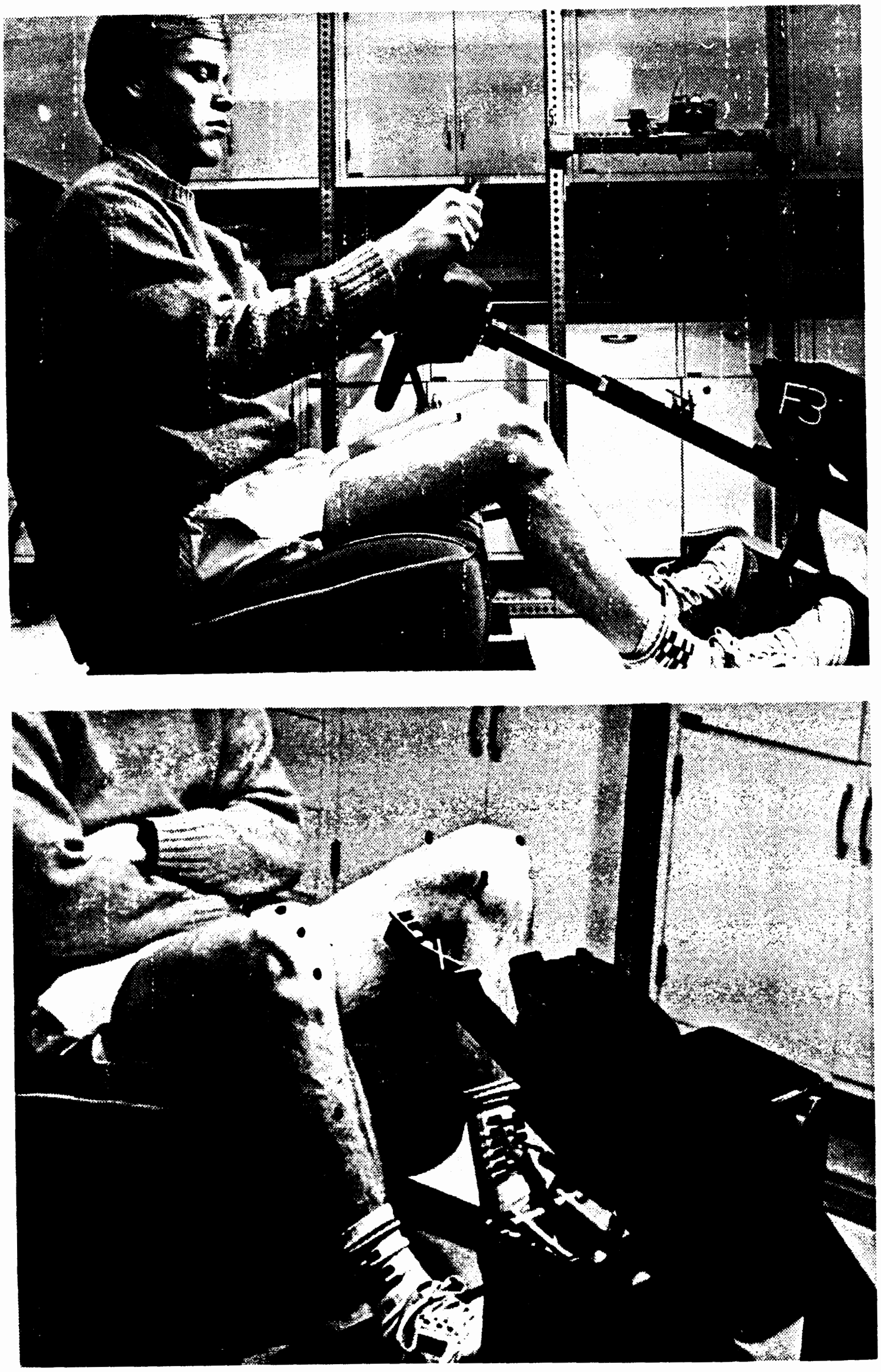


Figure 4. Subject seated in test buck showing location of knee and leg targets.

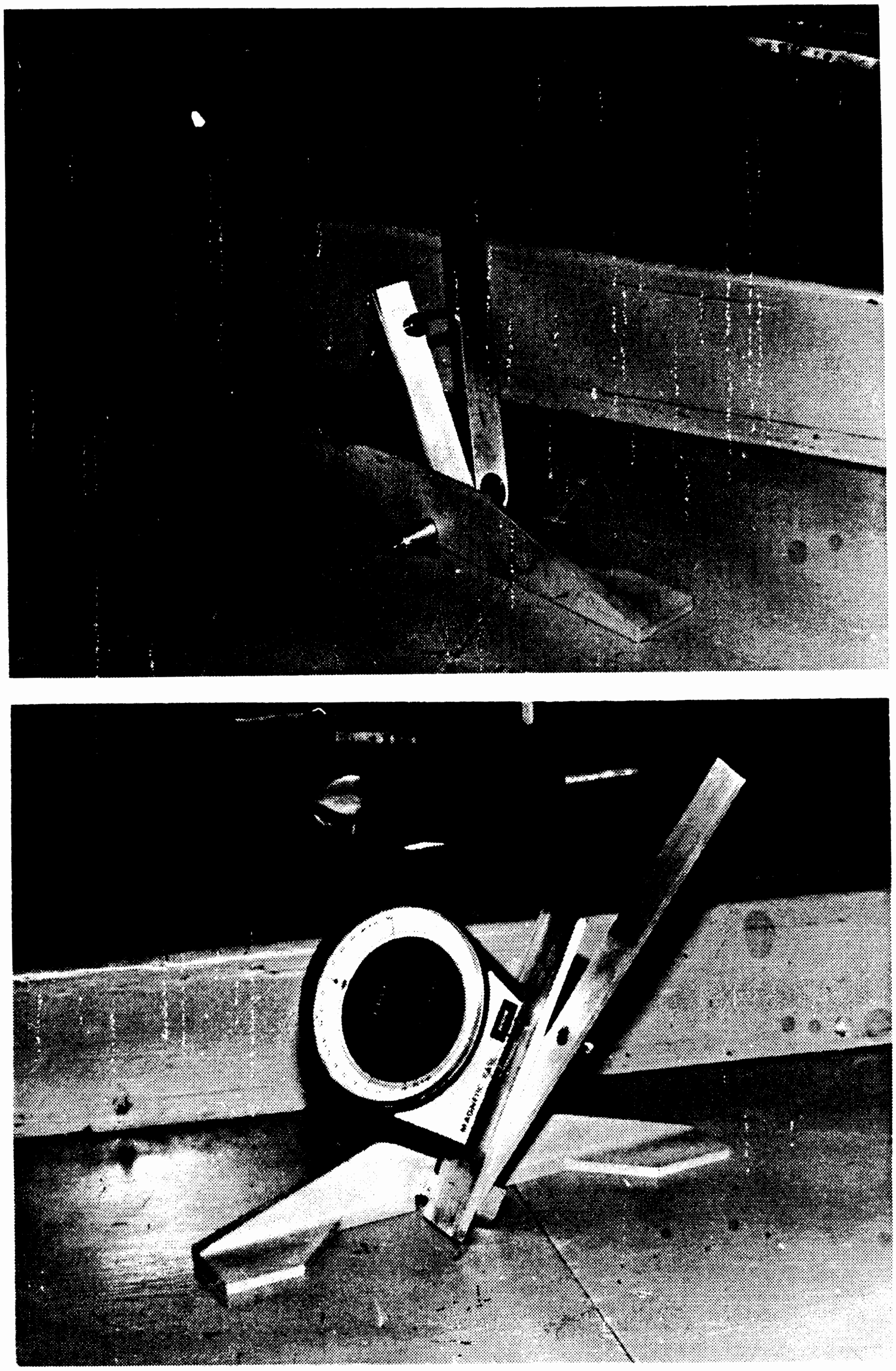


Figure 5. Apparatus for measuring foot pitch and foot rotation angles.

angles, foot pitch and rotation, were then determined in sequence using an inclinometer.

The contact point of each subject's right shoe heel with the heel surface was measured by placing a piece of paper on the heel surface and marking the subject's right heel with blue chalk. Reference marks on the paper at buck screw head locations allowed calculation of the chalk mark relative to AHP and other vehicle coordinates.

In addition to these measurements of the subject, shoe measurements were made for potential application to the seating accommodation model. These measurements included the length of each subject's shoe and the distance from the heel to the ball of the shoe sole.

H. Test Protocol

In order to facilitate the test procedures and data recording, the test protocol and data collection form illustrated in Figure 6 was developed. At the time of scheduling for their session, each subject was instructed to wear comfortable driving shoes and to bring shorts that they could change into so that their knees and legs could be targeted and photographed. In addition, they were instructed to take note of their feet positions and leg orientations (especially leg splay) as they drove their vehicle during the days between scheduling and testing. While a driver probably goes through a variety of leg orientations in the course of driving, it was felt that this awareness might help subjects achieve more typical or "normal" leg positions than might otherwise be obtained in a laboratory setting.

Upon arriving for their session, subjects were briefed on the purpose and procedures of the study and were requested to read and sign a consent form before changing into their shorts. Anthropometric measurements were taken, if they had not been collected in a previous visit, and the subject was instructed to sit down while the contrast targets were positioned on the knees. At this time, the shoe measurements were also taken.

With targets in place, the subject was instructed to step onto the buck which had been previously configured to one of the three vehicle packages with the seat in the full rearward detent. The subject was instructed to search for his/her preferred seat position while operating the steering wheel, brake pedal, and accelerator pedals in typical driving fashion. When satisfied with the seat location, the detent (including possible travel beyond the track limits) was noted and recorded on the data sheet. The subject was then instructed to assume a normal, relaxed posture looking straight ahead with legs in a "normal" orientation, the right foot on the undepressed accelerator pedal, and the left foot on the inclined floor pan. At this time, sitting height, foot and leg angles, and heel location were measured as previously noted and a right-side black and white photograph was taken. The steering wheel was then removed from the tubular column in order to have a clear view of the knees from the front cameras, and the four fixed cameras were fired simultaneously by means of a single switch connecting four solenoid actuators connected to the camera shutter buttons.

With the subject keeping his/her feet in the same positions, the investigator translated the seat forward six inches using the power adjuster, and a second set of

MVMA KNEE POSITION STUDY
DATA COLLECTION FORM

Date 4-8-87 Photo No. 46

Shoe Length from heel to toe 29.7 Time 4:00 Subject No. 10805

Shoe length from heel to ball 20.8

	CHRYSLER	CAMARO	FORD

******** TAKE SIDE PHOTOGRAPH ********
RELAXED NORMAL DRIVING POSTURE

	CHRYSLER	CAMARO	FORD
Detent	08	09	09
Sitting Height	119.6	099.8	111.8
Heel X	083	085	097
Heel Y	-16	-18	-04
Upper leg angle	07	12	12
Lower leg angle	61	31	44
Foot pitch angle	35	48	50
Foot rot. angle	90	90	79

******** REMOVE STEERING WHEEL - REPLACE WITH TARGETED EXTENSION ********

Photo 1: Rt. foot = ACCEL - UNDEP, Left foot = FOOT REST, SEAT NORMAL

46M1	46C1	46F1

******** Lights, Fire Cameras, Test Number Sequence ********

Photo 2: Rt. foot = ACCEL - DEP., Left foot = FOOT REST, SEAT FORWARD 6"

46M2	46C2	46F2

******** Lights, Fire Cameras, Wind Cameras, Test Number Sequence **********

Photo 3: Rt. foot = BRAKE - UNDEP, Left foot = FLOOR, SEAT NORMAL

46M3	46C3	46F3

******** Lights, Fire Cameras, Wind Cameras, Test Number Sequence ********

Photo 4: Rft. foot = BRAKE - DEP, Left foot = FLOOR, SEAT FORWARD 6"

46M4	46C4	46F4

******** Lights, Fire Cameras, Wind Cameras, Test Number Sequence ********

Figure 6. Sample data collection form.

photographs was taken. The seat was then moved back to the design position, the cameras were wound, the subject was instructed to place the right foot on the undepressed brake pedal and the left foot on the floor (rather than the inclined surface), and the third set of photographs was taken. The seat was again translated forward six inches, and, with the subject now depressing the brake through its full travel, the fourth and final set of photographs was taken.

After winding the four cameras to check that all had fired, the subject was moved back to the design position and instructed to step out of the buck. The seat, steering wheel/brake pedal, accelerator pedal, and floor pan modules were then changed to the next seating package and the process was repeated until each subject had been tested in all three seating packages. The order of testing in the different vehicle seating packages was rotated between subjects.

In order to obtain some additional information on the knee trajectory during forward translation, additional side-view photographs were taken for one subject in each group for the conditions of the right foot on the accelerator pedal and the seat translated forward three and six inches. Thus, for one subject in each stature group, lateral view photographs were obtained for the seat in three positions for each vehicle package.

I. Data Processing and Analysis

Measurement values recorded on the data sheet were subsequently keypunched into a data file on MTS where the measurements were converted into vehicle coordinate values where appropriate. For example, the heel-X and heel-Y values recorded on the sheet were measured relative to a fixed point on the buck, whose coordinates in the different vehicle reference systems were known. Similarly, sitting height was measured from the plywood seat base surface and was subsequently converted to a vehicle Z-coordinate and selected seat detents were transformed to H-point locations in vehicle X-coordinates. A separate MTS file was created in which all anthropometric data were stored while all X, Y, and Z digitized target data points were in a third file. A statistical package (MIDAS) was used to compile all the data in a single file, edit the data, compute new variables, generate statistical summaries, and set up data for various plotting routines.

III. RESULTS

A. Subject Anthropometry and Seated Measurements

Table 3 gives the mean values of subject age and standard anthropometric measurements for each subject group, for all females, all males, and all subjects, excluding the two extreme males. Similarly, Tables 4 through 6 summarize the group mean values and overall mean values of the seated measurements taken in the Camaro, Escort, and Minivan respectively. Sitting height shows the expected increase with vehicle seat height. It will be noted, however, that while mean erect sitting height (not taken in vehicle) increases about 13 cm from group 1 to group 10, relaxed sitting height increases only about 7 to 9 centimeters for each of the three vehicle seats.

It will also be noted that the upper leg angle tends to be greater for lower seat heights, and the lower leg angle, as expected, tends to be greater for higher seat heights. Foot pitch angle shows no obvious relationship with subject size or with gender but decreases with seat height. Foot rotation angles tend to be larger for males but show little relationship to seat height. Driver heel position is generally rearward of the AHP by an amount that is inversely related to vehicle seat height. Heel lateral position from the seat centerline also increases with increasing seat height and tends to be somewhat further from the centerline for females than for males.

B. Seat Position and SAE Accommodation Model

Because the knee position data have been collected in a laboratory buck rather than an actual vehicle under real-world driving conditions, and because knee position is influenced strongly by seat position, it is useful and instructive to examine the distributions of seat positions for the subject population and to compare these with SAE Seating Accommodation Model predictions. In order to determine percentiles of seat positions for the general driving population from the subject sample, the seat position data were weighted according to the percent of the population that each subject represents. For example, since there are five subjects in group 1 and this group represents approximately fifteen percent of the female population (i.e., 0 to 15th percentile), or 7.5 percent of the driver population (assuming equal males and females), each subject in this group counts for 1.5 percentile of the population (i.e., 7.5/5 = 1.5). Similarly, each subject in group 2 counts for 2.5 percentile of the population.

Using this procedure on the seat position data collected for each vehicle, the 2.5 through 97.5 percentile seat positions in vehicle coordinates were calculated. Using the package drawings from each vehicle and the SAE procedures from J1516 and J1517 for calculating the percentile seating accommodation distances from Ball of Foot (BOF) point, the subject-generated distributions were compared with those predicted by the accommodation model. The results are shown in Tables 7 through 9 and Figures 7a through 7c.

TABLE 3

MEAN VALUES OF STANDARD ANTHROPOMETRIC MEASUREMENTS

Group	Mean %ile	N	Gender	Age (Yrs.)	Weight		Stature w/Shoes		Stature w/o Shoes		Sitting Height		Buttock–Knee Length	
					Lbs.	(kg)	In.	(cm)	In.	(cm)	In.	(cm)	In.	(cm)
1	10	5	F	47	139	(63.3)	62.0	(158)	60.6	(154)	33.1	(84)	21.3	(54)
2	25	5	F	36	139	(63.0)	63.5	(161)	62.0	(157)	33.8	(86)	21.5	(55)
3	50	5	F	46	144	(65.5)	64.3	(163)	63.4	(161)	33.9	(86)	22.1	(56)
4	75	5	F	42	138	(62.9)	65.7	(169)	65.4	(166)	33.8	(86)	23.3	(59)
5	90	5	F	31	136	(61.7)	67.8	(175)	67.1	(170)	35.4	(90)	23.0	(58)
All Females		25	F	40	139	(63.3)	64.7	(164)	63.7	(162)	34.0	(86)	22.2	(56)
6	10	5	M	44	159	(72.4)	66.0	(168)	65.1	(165)	34.9	(89)	22.0	(56)
7	25	5	M	42	169	(76.7)	67.8	(172)	66.9	(170)	34.3	(87)	23.4	(59)
8	50	5	M	52	168	(76.2)	69.5	(177)	68.8	(175)	35.7	(91)	23.8	(60)
9	75	5	M	48	184	(83.4)	71.0	(180)	70.4	(179)	36.6	(93)	24.0	(61)
10	90	5	M	38	186	(84.5)	73.9	(188)	73.3	(186)	38.3	(97)	24.9	(63)
All Males		25	M	45	173	(78.6)	69.6	(177)	68.9	(175)	36.0	(91)	23.6	(60)
ALL SUBJECTS		50		43	156	(70.9)	67.2	(171)	66.3	(168)	35.0	(89)	22.9	(58)

TABLE 3 (Continued)
Mean Values of Standard Anthropometric Measurements

Group	Mean %ile	N	Gender	Eye Height		Shoulder Height		Knee Height		Hip Breadth		Shoulder Breadth	
				In.	(cm)	In.	(cm)	In.	(cm)	In.	(cm)	In.	(cm)
1	10	5	F	28.9	(73)	22.1	(56)	19.2	(47)	14.9	(38)	15.8	(40)
2	25	5	F	30	(75)	22.9	(58)	19.0	(48)	14.8	(37)	16.1	(41)
3	50	5	F	30	(75)	22.6	(57)	20.0	(51)	15.2	(39)	16.3	(41)
4	75	5	F	29.3	(74)	23.2	(59)	20.3	(52)	14.6	(37)	16.4	(42)
5	90	5	F	30.8	(78)	23.7	(60)	20.7	(53)	15.0	(38)	16.0	(41)
All Females		25	F	29.6	(75)	22.9	(58)	19.7	(50)	14.9	(38)	16.1	(41)
6	10	5	M	29.8	(76)	23.7	(60)	20.1	(51)	14.4	(37)	17.4	(44)
7	25	5	M	30.4	(77)	23.4	(60)	20.7	(53)	14.1	(36)	18.3	(46)
8	50	5	M	30.8	(78)	24.3	(62)	21.5	(55)	14.5	(37)	17.9	(46)
9	75	5	M	32.4	(82)	25.5	(65)	22.0	(58)	15.7	(40)	19.0	(48)
10	90	5	M	33.6	(85)	26.1	(66)	22.3	(57)	14.9	(38)	17.9	(45)
All Males		25	M	31.4	(80)	24.6	(63)	21.3	(54)	14.7	(37)	18.1	(46)
ALL SUBJECTS		50		30.5	(78)	23.8	(60)	20.5	(52)	14.8	(38)	17.1	(43)

TABLE 3 (Continued)
Mean Values of Standard Anthropometric Measurements

Group	Mean %ile	N	Gender	Shoulder–Elbow Length		Forearm–Hand Length		Heel–to–Toe Length w/Shoes		Heel–to–BOF Length w/Shoes	
				In.	(cm)	In.	(cm)	In.	(cm)	In.	(cm)
1	10	5	F	12.6	(32)	16.2	(41)	9.8	(25)	6.0	(15)
2	25	5	F	13.2	(34)	16.0	(41)	9.4	(24)	5.9	(15)
3	50	5	F	13.1	(33)	16.6	(42)	10.3	(26)	6.5	(17)
4	75	5	F	14.2	(36)	17.5	(44)	10.2	(26)	6.6	(17)
5	90	5	F	14.2	(36)	17.6	(45)	9.9	(25)	6.3	(16)
All Females		25	F	13.4	(34)	16.8	(43)	9.9	(25)	6.3	(16)
6	10	5	M	14.1	(36)	17.7	(45)	10.9	(28)	7.0	(18)
7	25	5	M	14.8	(38)	18.3	(46)	11.3	(29)	6.8	(17)
8	50	5	M	14.9	(38)	18.5	(47)	11.2	(29)	7.4	(19)
9	75	5	M	15.3	(39)	19.1	(48)	11.6	(29)	7.2	(18)
10	90	5	M	15.1	(38)	19.5	(50)	12.0	(30)	7.7	(20)
All Males		25	M	14.8	(37)	18.6	(47)	11.4	(29)	7.2	(18)
ALL SUBJECTS		50		14.2	(36)	17.7	(45)	10.7	(27)	6.7	(17)

TABLE 4

MEAN VALUES OF SEATED MEASUREMENTS: **CAMARO**

Group	Mean %ile	N	Gender	Sitting Height re: AHP	Re: Horizontal Upper Leg Angle	Re: Horizontal Lower Leg Angle	Foot Pitch Angle	Foot Rotation Angle	Heel-X* re: AHP	Heel-Y re: Seat Centerline	Seat Detent	Seat H-Point Translated
1	10	5	F	50.6	11.8	40.6	55.0	4.2	30.6	–85.2	0.6	751.0
2	25	5	F	51.7	6.4	38.6	62.2	3.4	16.2	–84.8	2.4	785.3
3	50	5	F	53.1	13.6	39.6	55.0	6.0	45.5	–75.0	3.8	811.9
4	75	5	F	51.1	14.2	37.8	57.0	3.4	43.0	–80.0	5.6	846.2
5	90	5	F	52.7	17.0	40.8	56.8	7.8	40.0	–76.2	5.6	846.2
All Females		25	F	51.8	12.6	39.4	57.2	4.9	34.6	–80.2	3.6	808.1
6	10	5	M	54.8	13.2	38.0	58.2	16.2	32.4	–58.4	3.8	811.9
7	25	5	M	52.9	18.4	41.0	47.4	6.6	67.4	–81.8	5.8	850.0
8	50	5	M	53.9	16.0	36.8	55.0	8.6	55.6	–71.8	7.4	880.5
9	75	5	M	56.7	14.2	34.2	57.0	13.6	50.0	–61.2	8.6	903.4
10	90	5	M	57.5	23.6	41.6	49.0	6.4	81.2	–69.0	8.6	903.4
All Males		25	M	55.2	17.1	38.3	53.3	10.3	57.3	–68.4	6.8	869.9
ALL SUBJECTS		50		53.5	14.8	38.9	55.3	7.7	46.2	–74.3	5.2	839.0

*Positive value corresponds to rearward of AHP.

TABLE 5

MEAN VALUES OF SEATED MEASUREMENTS: **ESCORT**

Group	Mean %ile	N	Gender	Sitting Height re: AHP	Re: Horizontal Upper Leg Angle	Re: Horizontal Lower Leg Angle	Foot Pitch Angle	Foot Rotation Angle	Heel-X* re: AHP	Heel-Y re: Seat Centerline	Seat Detent	Seat H-Point Translated
1	10	5	F	60.0	3.8	51.0	53.0	8.8	14.4	–118.6	–0.2	701.8
2	25	5	F	61.3	3.4	51.2	52.8	7.0	10.2	–126.4	2.2	732.2
3	50	5	F	62.1	7.6	50.4	54.0	8.2	12.0	–108.0	3.8	725.6
4	75	5	F	61.1	8.2	48.8	52.8	8.6	23.8	–115.2	6.6	788.1
5	90	5	F	62.7	10.0	49.2	55.8	11.0	14.8	–107.0	7.4	798.3
All Females		25	F	61.4	6.6	50.1	53.7	8.7	15.0	–115.0	4.0	754.6
6	10	5	M	63.7	8.4	49.6	49.4	14.6	25.6	–99.2	4.2	757.6
7	25	5	M	62.8	11.2	47.8	46.8	12.4	55.2	–108.6	8.6	813.5
8	50	5	M	63.8	10.8	46.0	50.2	14.6	24.4	–101.2	10.2	833.8
9	75	5	M	66.6	9.8	43.6	53.6	12.4	34.4	–103.6	12.8	866.9
10	90	5	M	67.9	15.6	48.6	47.4	13.0	61.2	–107.2	13.2	871.9
All Males		25	M	65.0	11.2	47.1	49.5	13.4	40.2	–104.0	9.8	828.8
ALL SUBJECTS		50		63.2	8.9	48.6	51.6	11.1	27.6	–109.5	6.9	791.7

*Positive values corresponds to rearward of AHP.

TABLE 6

MEAN VALUES OF SEATED MEASUREMENTS: MINIVAN

Group	Mean %ile	N	Gender	Sitting Height re: AHP	Re: Horizontal		Foot Pitch Angle	Foot Rotation Angle	Heel-X* re: AHP	Heel-Y re: Seat Centerline	Seat Detent	Seat H-Point Translated
					Upper Leg Angle	Lower Leg Angle						
1	10	5	F	67.8	1.4	67.2	40.4	8.2	17.0	–154.2	2.6	576.1
2	25	5	F	69.3	–0.8	67.8	40.2	6.8	11.0	–165.0	4.0	602.8
3	50	5	F	69.9	5.2	61.2	39.2	8.0	–1.4	–158.8	5.8	637.0
4	75	5	F	68.7	3.4	58.0	44.0	5.6	35.2	–161.8	7.8	675.1
5	90	5	F	70.9	7.6	64.2	40.8	8.0	19.0	–161.6	7.4	667.5
All Females		25	F	69.3	3.4	63.7	40.9	7.3	16.2	–160.3	5.5	631.7
6	10	5	M	71.9	4.0	62.8	40.0	12.2	7.0	–140.6	5.8	637.0
7	25	5	M	70.6	9.0	61.8	37.8	8.8	21.2	–172.4	7.2	663.7
8	50	5	M	72.9	8.2	64.2	41.0	10.6	16.8	–150.6	7.4	667.5
9	75	5	M	69.2	8.0	56.2	44.6	14.4	19.0	–144.5	9.4	705.6
10	90	5	M	75.5	14.2	63.6	40.8	11.0	23.2	–158.0	9.2	701.8
All Males		25	M	72.0	8.7	61.7	40.8	11.4	17.4	–153.2	7.8	675.1
ALL SUBJECTS		50		70.7	6.0	62.7	40.9	9.4	16.8	–156.8	6.7	653.4

*Positive value corresponds to rearward of AHP.

TABLE 7

COMPARISON OF SEAT POSITION FROM SAE J1517 MODEL
WITH STUDY RESULTS FOR GM CAMARO

Z = 181 mm
Design Detent = 9
H-pt. Coordinate = 3050 mm
Detent Spacing = 19.05 mm

BOF Coordinate = 2074 mm
95%ile AHP = 2143 mm
Design AHP = 2139 mm

Percentile	Detent	Vehicle Coord. of H-pt. (mm)	BOF to H-pt. (mm) Experimental	Model*	Difference
2.5	-1.5	2850	776	780	+4
5	-0.25	2874	800	796	-4
10	1.32	2904	830	816	-14
50	5.03	2974	900	883	-17
90	8.59	3042	968	952	-16
95	8.93	3049	975	971	-4
97.5	9.60	3061	987	987	0

Vehicle Coord. of H-pt. = (detent - design detent) (detent spacing) + (H-pt. Coord.)

= (detent - 9) (19.05) + 3050

*Using equations for selected seat position curves

TABLE 8

COMPARISON OF SEAT POSITION FROM SAE J517 MODEL WITH STUDY RESULTS FOR FORD ESCORT

Z = 260 mm
Design Detent = 11
H-pt. Coordinate = 3104 mm
Detent Spacing = 12.7 mm

BOF Coordinate = 2162 mm
95%ile AHP = 2251 mm
Design AHP = 2260 mm

Percentile	Detent	Vehicle Coord. of H-pt. (mm)	BOF to H-pt. (mm) Experimental	Model*	Difference
2.5	-1.67	2943	781	778	-3
5	-0.5	2958	796	795	-1
10	0.3	2968	806	813	+7
50	7.14	3055	893	876	-17
90	13.13	3131	969	940	-29
95	14.38	3147	985	956	-29
97.5	16.0	3168	1006	970	-36

Vehicle Coord. of H-pt. = (detent - design detent) (detent spacing) + (H-pt. Coord.)

= (detent - 11) (12.7) + 3104

*Using equations for selected seat position curves.

TABLE 9

COMPARISON OF SEAT POSITION FROM SAE J1517 MODEL WITH STUDY RESULTS FOR CHRYSLER MINIVAN

Z = 351 mm
Design Detent = 9
H-pt. Coordinate = 1334 mm
Detent Spacing = 19.05 mm

BOF Coordinate = 479 mm
95%ile AHP = 604 mm
Design AHP = 636 mm

Percentile	Detent	Vehicle Coord. of H-pt. (mm)	BOF to H-pt. (mm) Experimental	Model*	Difference
2.5	0.5	1172	693	742	+49
5	1.75	1196	717	758	+41
10	2.69	1214	735	774	+39
50	5.92	1275	796	833	+37
90	9.85	1350	871	895	+24
95	10.44	1361	882	909	+27
97.5	10.75	1367	888	923	+35

Vehicle Coord. of H-pt. = (detent - design) detent (detent spacing) + (H-pt. Coord.)

= (detent - 9) (19.05) + 1334

*Using equations for selected seat position curves.

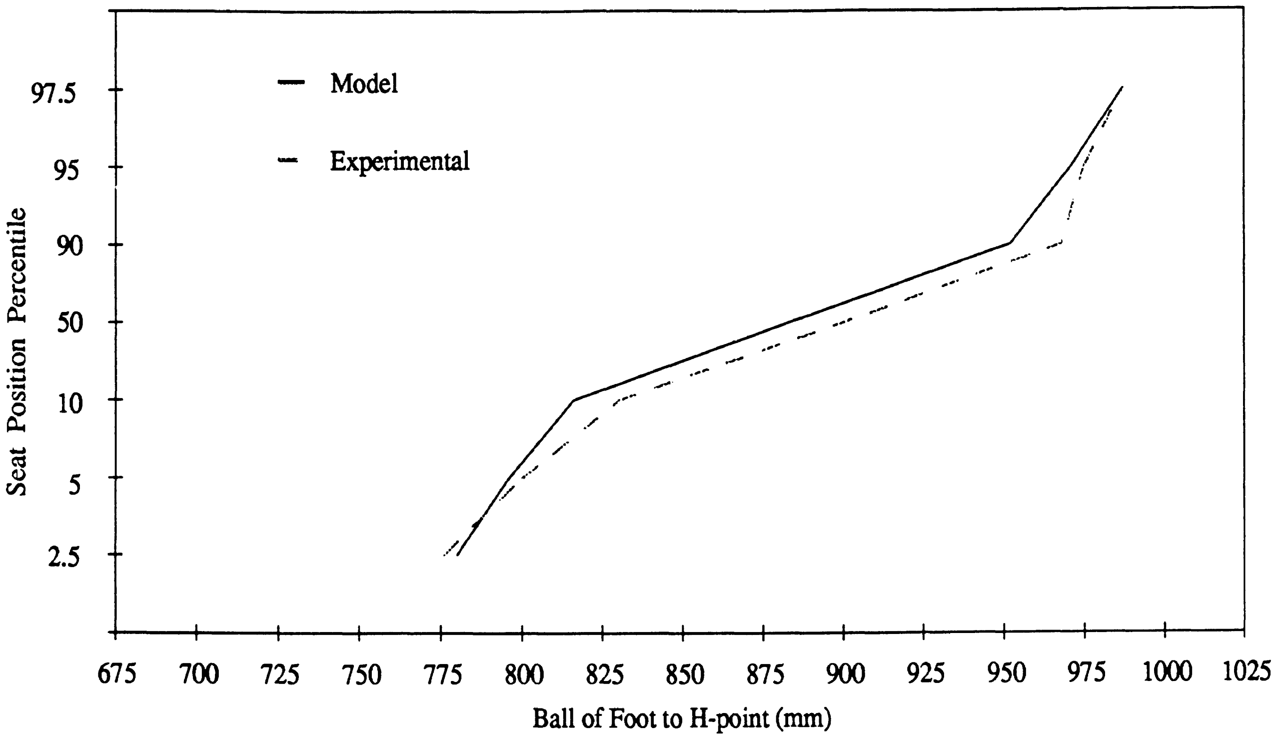


Figure 7a. Comparison of seat position percentiles from weighted subject data with predictions of SAE Accommodation Model for GM Camaro.

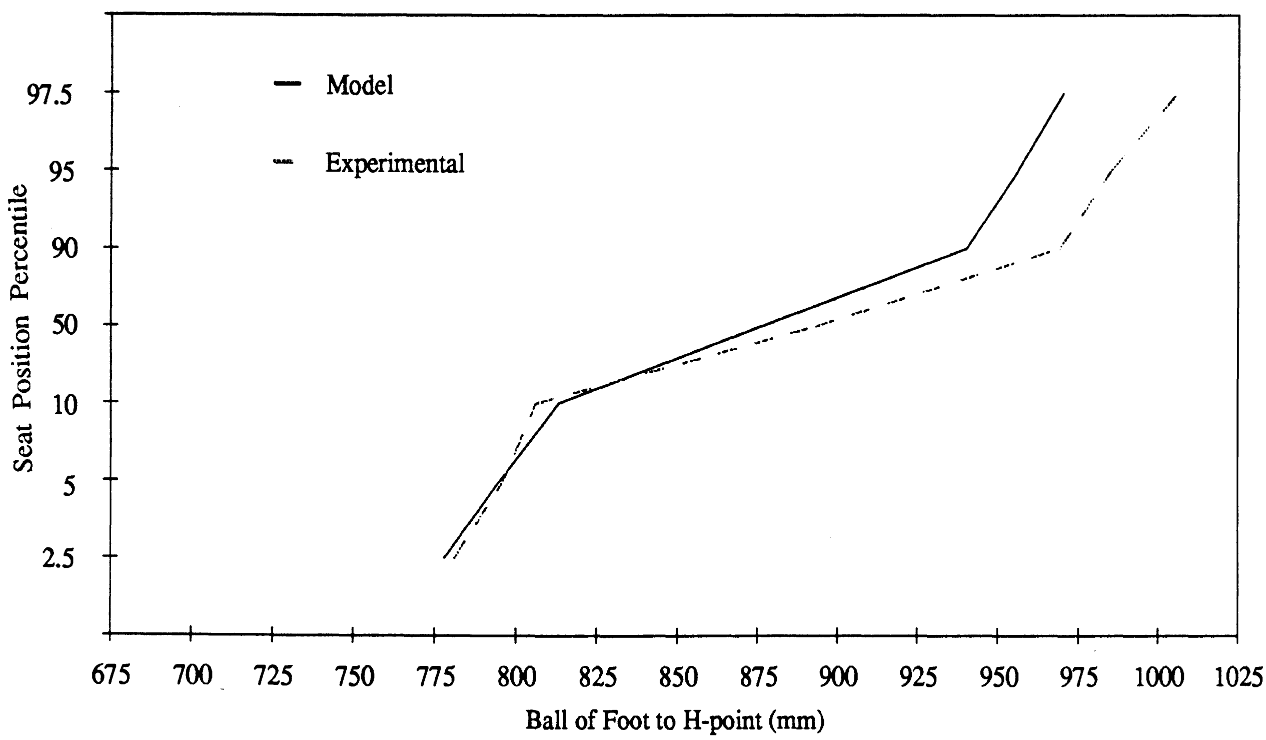


Figure 7b. Comparison of seat position percentiles from weighted subject data with predictions of SAE Accommodation Model for Ford Escort.

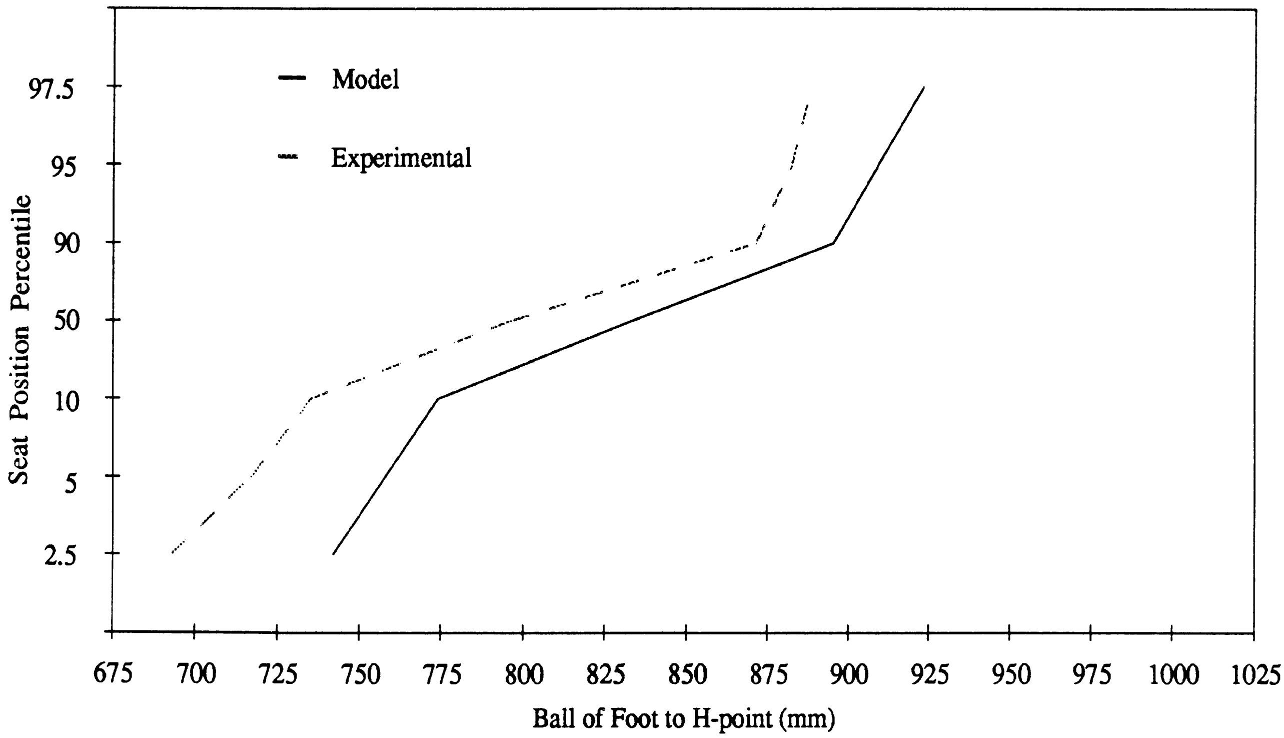


Figure 7c. Comparison of seat position percentiles from weighted subject data with predictions of SAE Accommodation Model for Chrysler Minivan.

For the Camaro, the model predictions and experimental data compare very favorably throughout the seating range. For the Escort, the model and data agree very well at the forward end of seat travel but diverge toward the rearward end with the data suggesting that drivers sit further rearward than the model predicts. For the Minivan, however, it is seen that the model and the study data do not agree very well throughout the seating range. The model predicts that drivers would sit more rearward than they did in the study. The reason for this consistent (i.e., across the whole range) difference between model and experiment in the Minivan is not readily apparent, but should be kept in mind when using the knee position data presented in subsequent sections. The fact that the model and experiment agreed well for the Camaro and much of the Escort seat travel range suggests that subjects were able to make reasonable estimates of seat position in the laboratory seating buck. It is possible that the seating accommodation model does not predict accurately for seat heights near the upper range of passenger vehicles.

C. Knee Position re AHP

It will be recalled that each knee was targeted with seven targets to fully define the knee locations. While three-dimensional coordinate data from all these targets are available on computer tape for future use and analysis by auto industry personnel, a subset of these targets and data will be presented here in order to simplify and summarize the results in a more concise but, hopefully, useful way.

Appendices B through D provide a pictorial overview of the knee position results relative to the AHP for all seat, vehicle, and foot conditions. In Appendix B, all five of the targets defining the midline of the leg across the knee (i.e., excluding lateral and medial epicondyle points) have been used to provide a "picture" of the knee contours for all fifty two subjects (i.e., includes two tall males). Appendix C presents the same plots except that only the three targets defining the upper margin, center, and lower margin of the patella have been plotted in order to better display the knee position. For purposes of defining "the" location of the knee, a single target is useful. As indicated previously, the lower margin of the patella is probably the most useful point in terms of knee bolster design since it represents the critical point below which a knee bolster impact will cause ligament and tibia damage, and where effectiveness of lower torso restraint will also be reduced. Appendix D repeats the same set of plots using only this lower patella target to define the location of each subject's knees.

Appendix E shows plots of the group mean five-point knee contours for the three vehicles for the normal untranslated seat position with right foot on the accelerator pedal and the left foot on the toepan or footrest area. The two tall subjects in group 11 are also included and are shown by the dashed line connected by the symbol "Z". As indicated and expected, the knees of these tall subjects are placed further from the seat centerline than other subjects and, in general, the shorter subjects and females tend to have their knees located closer to the centerline of the seat. Also shown in this appendix are three plots that show the group mean locations of the lateral and medial epicondyle points.

Using the lower margin of the patella target as a definition for driver knee position, Tables 10 through 12 summarize and compare the overall mean statistics for the X-, Y-, and Z-locations of driver knees for the 50 subjects in groups 1 through 10 for the different test and vehicle conditions. For comparison between vehicles, X- and Z-position results are given in distances from the AHP, and Y-position distances are given relative to the seat centerline. These data are compared graphically for the different foot, seat, and vehicle conditions in the simplified Box and Whisker plots of Figures 8a through 10b where the test condition number corresponds to the scenarios outlined in the Procedures section of this report (Measurement of Knee Locations). The bar plots in Appendix F illustrate the difference in knee positions in the X-, Y-, and Z-directions for the different subject groups (i.e. different stature) as well as the different vehicles.

D. Knee Position Data Described by Tangency Ellipses

It has become a common practice to attempt to describe the distribution of three-dimensional position data, where the distributions of data in any direction can be assumed to be Normal or Gaussian, by means of two-dimensional ellipses such as the eyellipses described in SAE J941 (Meldrum 1965, Roe 1975). Figure 11 (modified from Roe 1975) illustrates the method of computing the parameters for these two-dimensional ellipses which involve means, standard deviations, and linear regressions of the bivariate distributions of data points. As pointed out by Meldrum (1965), the ellipse so described can be considered to enclose a certain percentage of the data points (e.g., 95 percent for a 95th percentile ellipse) and to define the locus of straight line tangencies, any one of which cuts off a specified percentage of the points.

Figures 12 through 15 illustrate plots of 99th percentile and 95th percentile tangency ellipses in the X-Z and X-Y planes respectively, using the lower margin of the patella target in the initial untranslated seat position. Table 13 gives the parameter values for these knee ellipses and gives results for both the 99th and 95th percentile tangency ellipses for the three vehicles. The tables of Appendix G give the 95th and 99th percentile tangency knee ellipse results for all foot, seat, and vehicle conditions tested for, where again the data are presented relative to the AHP of each vehicle. Following the tables are plots of 95th percentile knee tangency ellipses for the three vehicles.

E. Trajectories of Driver Knees during Seat/Body Translation

The figures in Appendix H present lateral view contours for the right knee of ten drivers, one selected from each of the subject groups. In each case the foot is on the undepressed accelerator pedal and the seat is in the normal, translated-3"-forward, and translated-6"-forward positions, respectively. In these plots, the boxes with an "X" inside designate the lateral femoral condyle points and help visualize the knee trajectories. While, in several cases, there is a slight arc to the path of the condyles, the knee generally follows a fairly straight line under these static conditions of body translation. In every case the knee moves upward as the body translates forward, but the amount of upward movement is inversely related to the seat height, being the least for the Minivan and the greatest for the Camaro. Figure 16 compares the overall averages of knee trajectory angles (assuming a

TABLE 10

OVERALL SUBJECT X–COORDINATE STATISTICS RE: AHP
FOR LOWER MARGIN OF PATELLA (mm)

Leg/Foot/Seat Condition	N	Mean	Minimum	Maximum	Range cm	(in)
CAMARO						
RIGHT KNEE						
Accel/untranslated	50	392.1	292.7	472.7	18.0	(7.1)
Accel/translated 6"	50	291.5	186.6	387.4	20.1	(7.9)
Brake/untranslated	50	419.5	360.4	500.9	14.0	(5.5)
Brake/translated 6"	50	302.1	255.7	407.8	15.2	(6.0)
LEFT KNEE						
Toe Pan/untranslated	50	391.9	288.3	485.0	19.7	(7.7)
Toe Pan/translated 6"	50	295.5	188.0	396.9	20.9	(8.2)
Floor/untranslated	50	420.6	293.8	540.7	24.7	(9.7)
Floor/translated 6"	50	311.6	185.3	429.7	24.4	(9.6)
ESCORT						
RIGHT KNEE						
Accel/untranslated	50	329.7	236.1	430.8	19.5	(7.7)
Accel/translated 6"	50	209.2	102.3	314.9	21.3	(8.4)
Brake/untranslated	50	353.4	275.1	438.5	16.3	(6.4)
Brake/translated 6"	50	223.3	133.9	327.6	19.4	(7.6)
LEFT KNEE						
Toe Pan/untranslated	50	328.2	237.1	425.7	18.9	(7.4)
Toe Pan/translated 6"	50	210.1	103.8	319.0	21.5	(8.4)
Floor/untranslated	50	346.0	31.4	459.4	22.8	(9.0)
Floor/translated 6"	50	214.4	100.3	319.7	21.9	(8.6)
MINIVAN						
RIGHT KNEE						
Accel/untranslated	50	210.0	98.4	314.6	21.6	(8.5)
Accel/translated 6"	50	74.9	–33.0	188.5	22.2	(8.7)
Brake/untranslated	50	230.7	153.0	313.2	16.0	(6.3)
Brake/translated 6"	49	85.3	13.4	197.3	18.4	(7.2)
LEFT KNEE						
Toe Pan/untranslated	50	199.1	94.0	303.0	20.9	(8.2)
Toe Pan/translated 6"	50	68.5	–39.4	185.8	22.5	(8.9)
Floor/untranslated	50	210.4	90.4	338.8	24.8	(9.8)
Floor/translated 6"	50	68.7	–15.2	195.0	21.0	(8.3)

TABLE 11

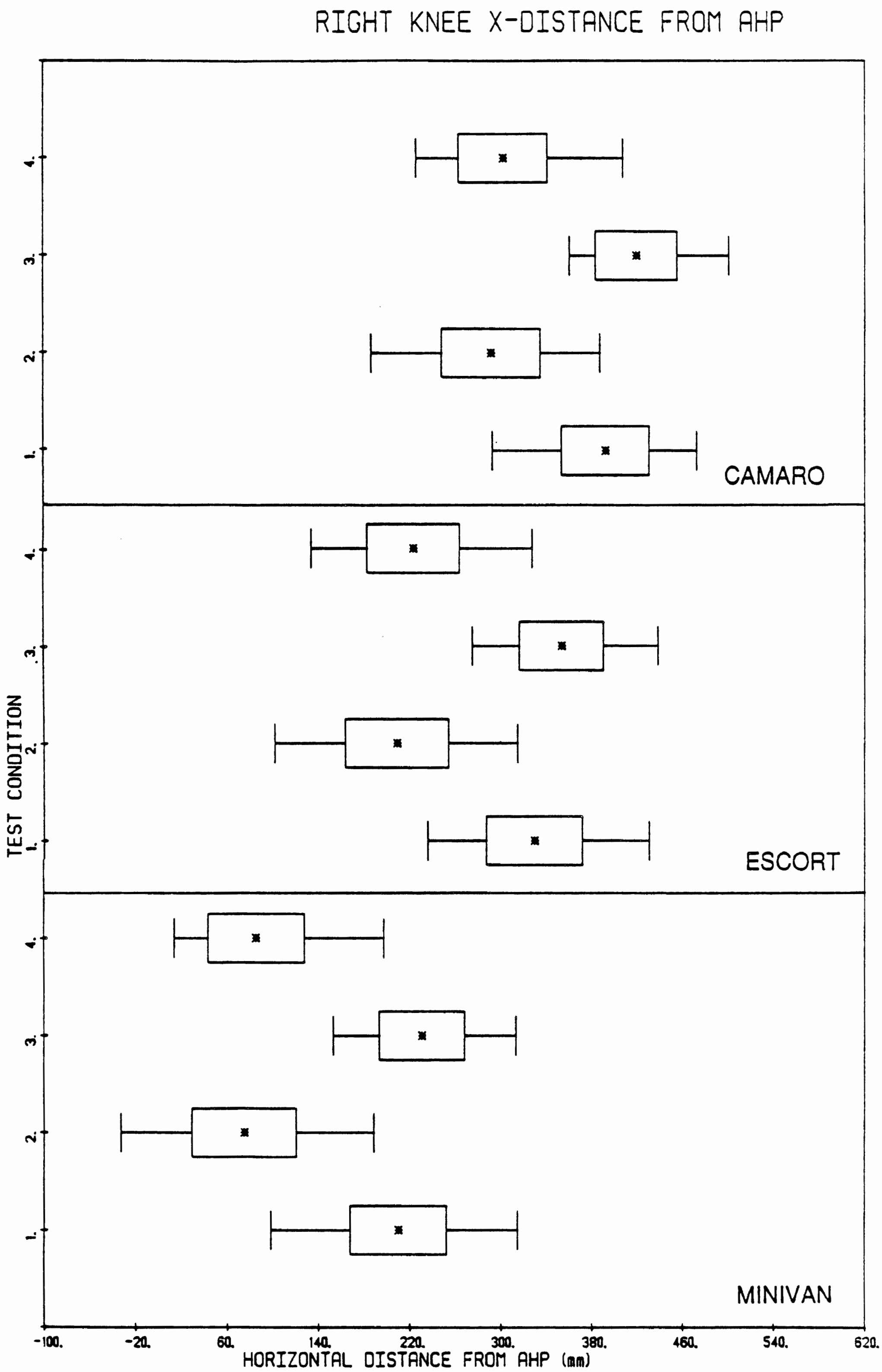
OVERALL SUBJECT Y-COORDINATE STATISTICS RE: SEAT CENTERLINE FOR LOWER MARGIN OF PATELLA (mm)

Leg/Foot/Seat Condition	N	Mean	Minimum	Maximum	Range	
					cm	(in)
CAMARO						
RIGHT KNEE						
Accel/untranslated	50	−114.3	−224.7	−36.0	18.9	(7.4)
Accel/translated 6"	50	−112.5	−212.8	−49.6	16.3	(6.4)
Brake/untranslated	50	−68.1	−176.8	23.8	20.1	(7.9)
Brake/translated 6"	50	−73.8	−185.6	16.7	20.2	(8.0)
LEFT KNEE						
Toe Pan/untranslated	50	172.0	81.2	288.9	20.8	(8.2)
Toe Pan/translated 6"	50	179.6	87.5	289.2	20.2	(7.9)
Floor/untranslated	50	182.1	89.3	283.5	19.4	(7.7)
Floor/translated 6"	50	183.8	87.4	308.1	22.1	(8.7)
ESCORT						
RIGHT KNEE						
Accel/untranslated	50	−131.4	−224.2	−40.2	18.4	(7.2)
Accel/translated 6"	50	−136.6	−225.0	−61.8	16.3	(6.4)
Brake/untranslated	50	−89.7	−193.6	−6.1	18.8	(7.4)
Brake/translated 6"	50	−98.0	−189.4	−18.5	17.1	(6.7)
LEFT KNEE						
Toe Pan/untranslated	50	159.3	95.1	279.7	18.5	(7.3)
Toe Pan/translated 6 "	50	161.9	77.1	282.1	20.5	(8.1)
Floor/untranslated	50	173.7	57.0	316.1	25.9	(10.2)
Floor/translated 6"	50	171.3	57.0	282.8	22.6	(8.9)
MINIVAN						
RIGHT KNEE						
Accel/untranslated	50	−163.1	−258.7	−84.7	17.4	(6.9)
Accel/translated 6"	50	−161.7	−259.2	−76.7	18.3	(7.2)
Brake/untranslated	50	−120.1	−232.4	−22.0	21.0	(8.3)
Brake/translated 6"	49	−122.4	−212.2	−52.4	16.0	(6.3)
LEFT KNEE						
Toe Pan/untranslated	50	155.2	68.7	272.8	20.4	(8.0)
Toe Pan/translated 6"	50	158.2	78.1	276.5	19.8	(7.8)
Floor/untranslated	50	156.8	69.2	265.9	19.7	(7.7)
Floor/translated 6"	50	161.3	66.4	269.2	20.3	(8.0)

TABLE 12

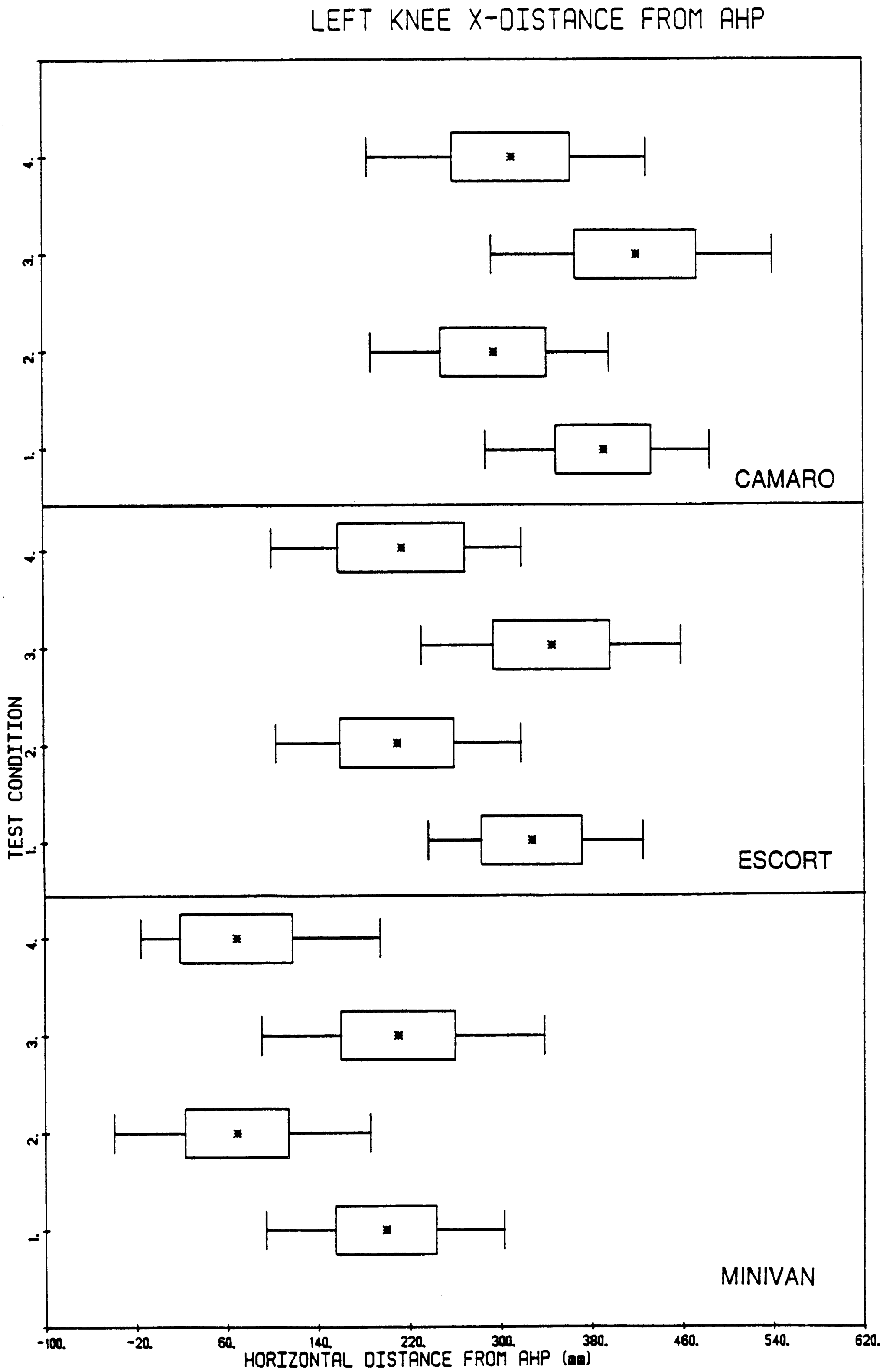
OVERALL SUBJECT Z–COORDINATE STATISTICS RE: AHP
FOR LOWER MARGIN OF PATELLA (mm)

Leg/Foot/Seat Condition	N	Mean	Minimum	Maximum	Range cm	Range (in)
CAMARO						
RIGHT KNEE						
Accel/untranslated	50	366.8	308.1	451.5	14.3	(5.7)
Accel/translated 6"	50	447.9	401.0	514.3	11.3	(4.5)
Brake/untranslated	50	408.2	350.7	477.7	12.7	(5.0)
Brake/translated 6"	50	451.1	375.7	507.6	13.2	(5.2)
LEFT KNEE						
Toe Pan/untranslated	50	362.1	301.3	454.0	15.3	(6.0)
Toe Pan/translated 6"	50	451.2	398.9	514.6	11.6	(4.6)
Floor/untranslated	50	406.8	297.4	512.7	21.5	(8.5)
Floor/translated 6"	50	461.5	403.4	533.0	13.0	(5.1)
ESCORT						
RIGHT KNEE						
Accel/untranslated	50	416.6	380.5	462.1	8.2	(3.2)
Accel/translated 6"	50	476.7	426.8	529.8	10.3	(4.1)
Brake/untranslated	50	464.5	401.8	517.2	11.5	(4.5)
Brake/translated 6"	50	499.1	447.5	561.2	11.4	(4.5)
LEFT KNEE						
Toe Pan/untranslated	50	427.3	385.3	507.4	12.2	(4.8)
Toe Pan/translated 6"	50	491.0	443.7	547.0	10.3	(4.1)
Floor/untranslated	50	458.7	396.2	504.9	10.9	(4.3)
Floor/translated 6"	50	492.6	436.7	560.8	12.4	(4.9)
MINIVAN						
RIGHT KNEE						
Accel/untranslated	50	471.1	426.7	529.7	10.3	(4.1)
Accel/translated 6"	50	509.7	457.4	572.4	11.5	(4.5)
Brake/untranslated	50	516.2	436.1	593.1	15.7	(6.2)
Brake/translated 6"	49	526.3	487.1	613.9	12.7	(5.0)
LEFT KNEE						
Toe Pan/untranslated	50	462.8	397.8	539.0	14.1	(5.6)
Toe Pan/translated 6"	50	506.8	444.3	584.2	14.0	(5.5)
Floor/untranslated	50	488.2	423.5	560.6	13.7	(5.4)
Floor/translated 6"	50	503.1	428.1	583.0	15.5	(6.1)



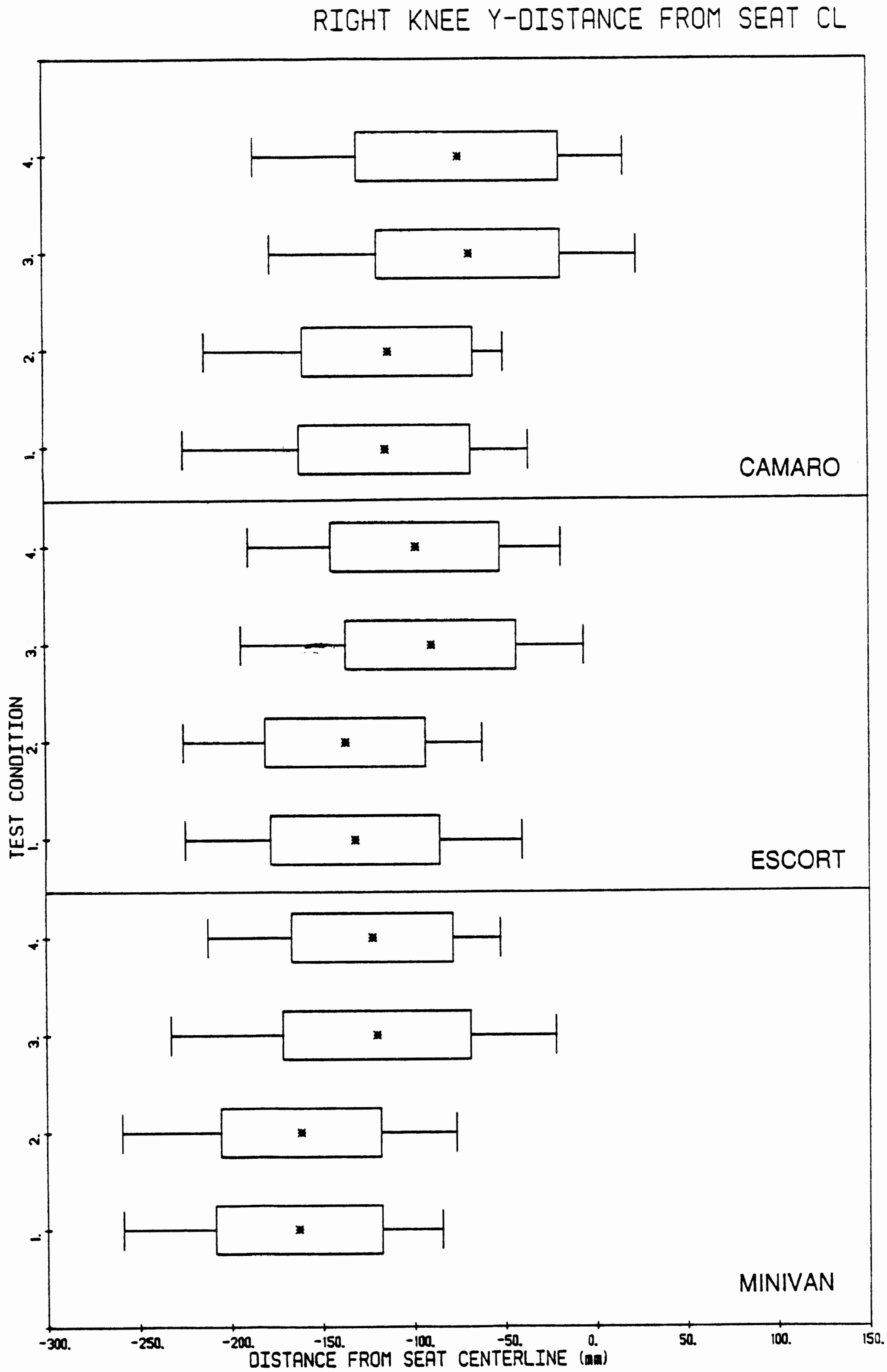
NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 8a. Simplified box and whisker plots for lower margin of right patella X-coordinate for different vehicle, foot, and seat conditions.



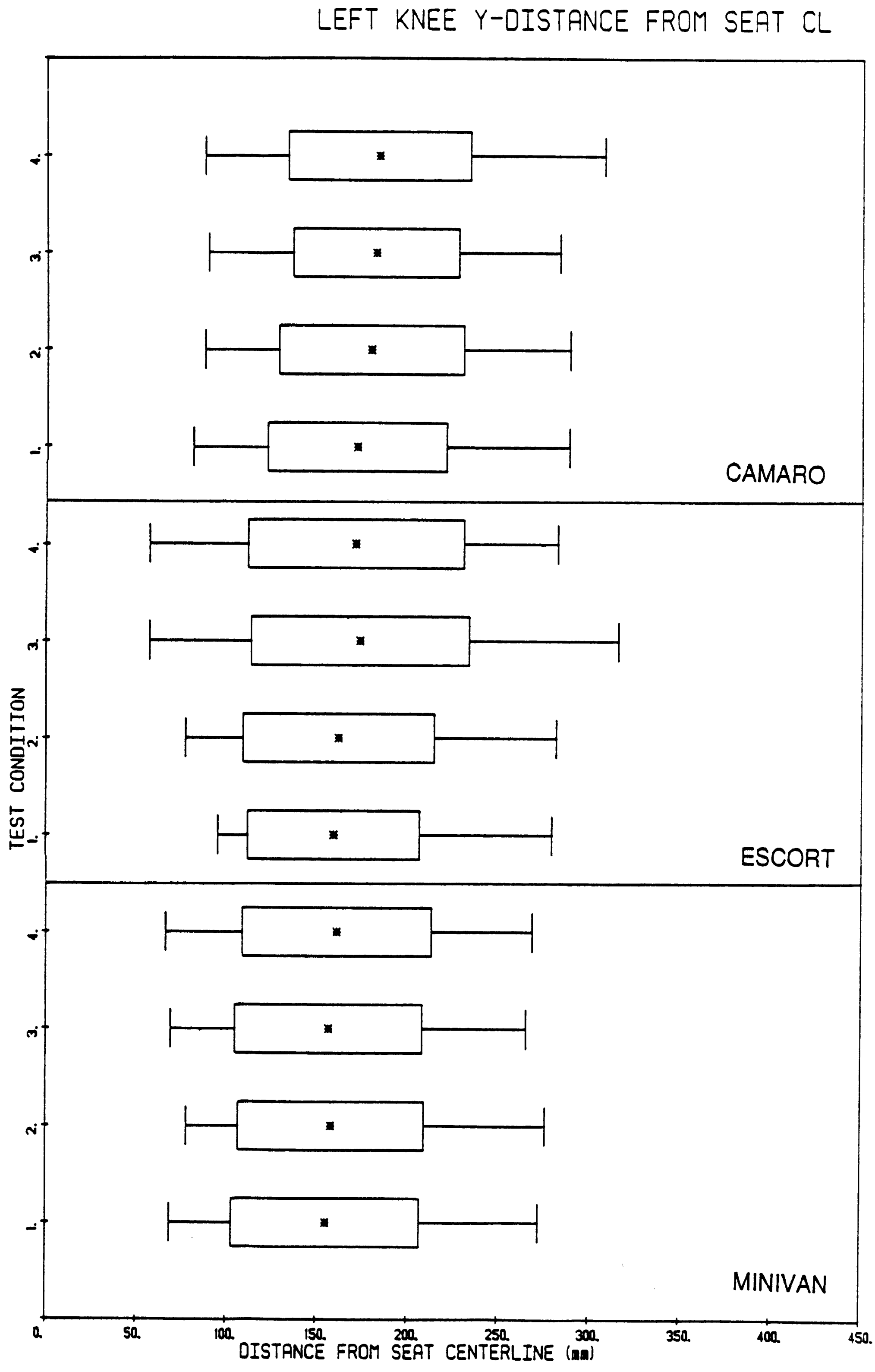
NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 8b. Simplified box and whisker plots for lower margin of left patella X-coordinate for different vehicle, foot, and seat conditions.



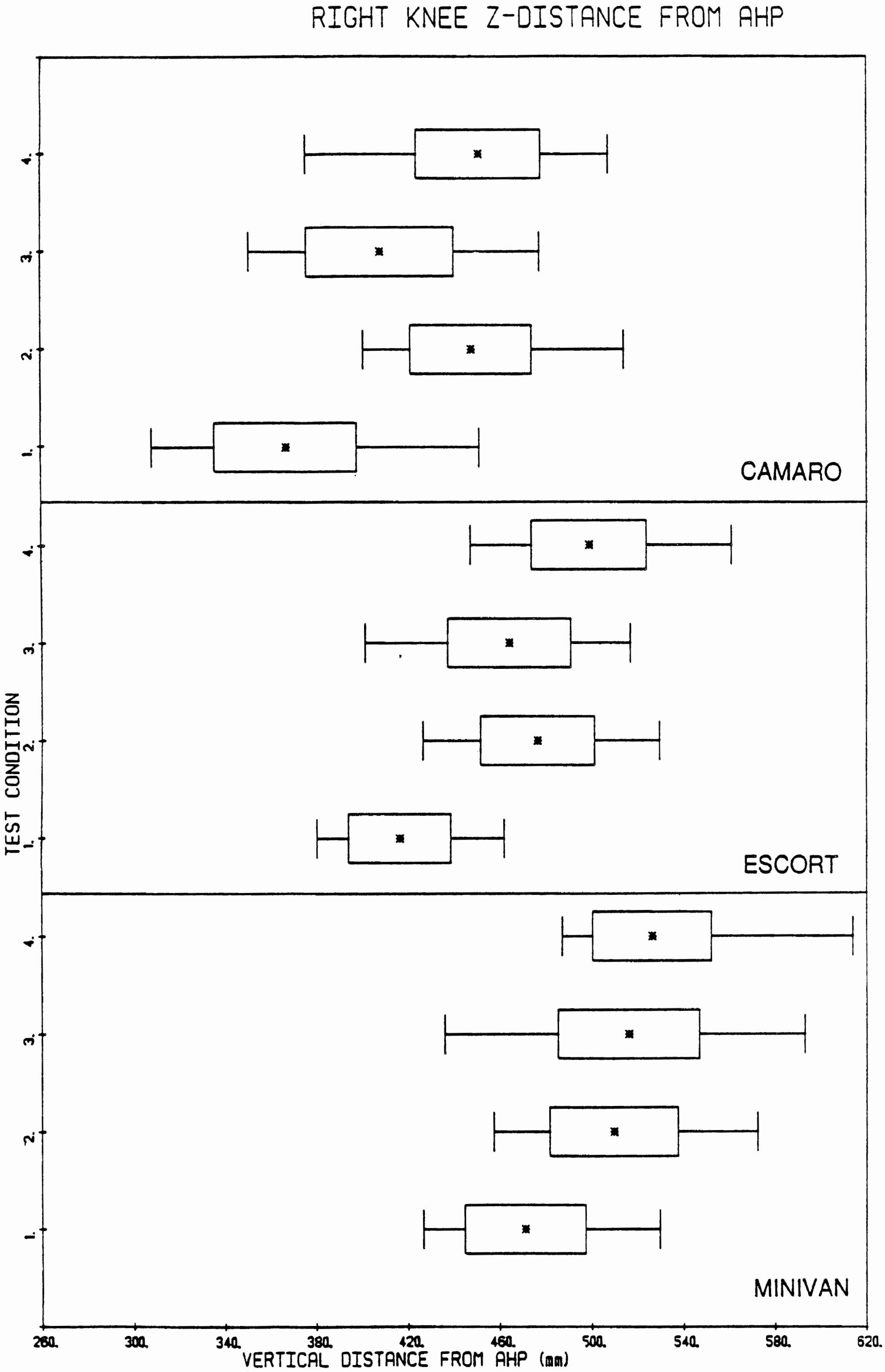
NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 9a. Simplified box and whisker plots for lower margin of right patella Y-coordinate for different vehicle, foot, and seat conditions.



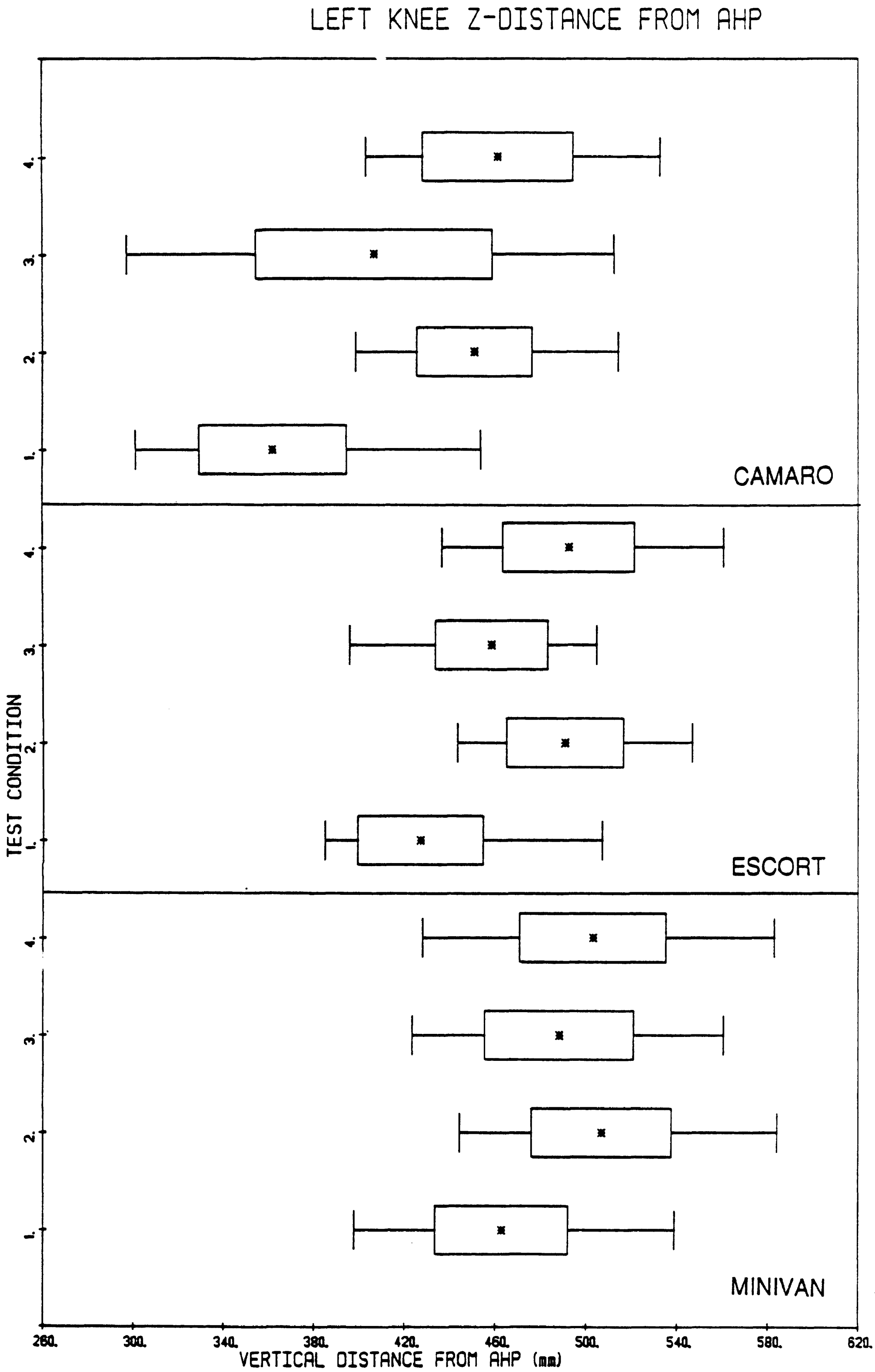
NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 9b. Simplified box and whisker plots for lower margin of left patella Y-coordinate for different vehicle, foot, and seat conditions.



NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 10a. Simplified box and whisker plots for lower margin of right patella Z-Coordinate for different vehicle, and seat conditions.



NOTE: For each condition, the asterisk indicates the overall mean value, the box indicates plus and minus one standard deviation, and the brackets indicate the maximum and minimum values. All distances are relative to AHP. See page 11 for description of test conditions 1 through 4.

Figure 10b. Simplified box and whisker plots for lower margin of left patella Z-Coordinate for different vehicle, and seat conditions.

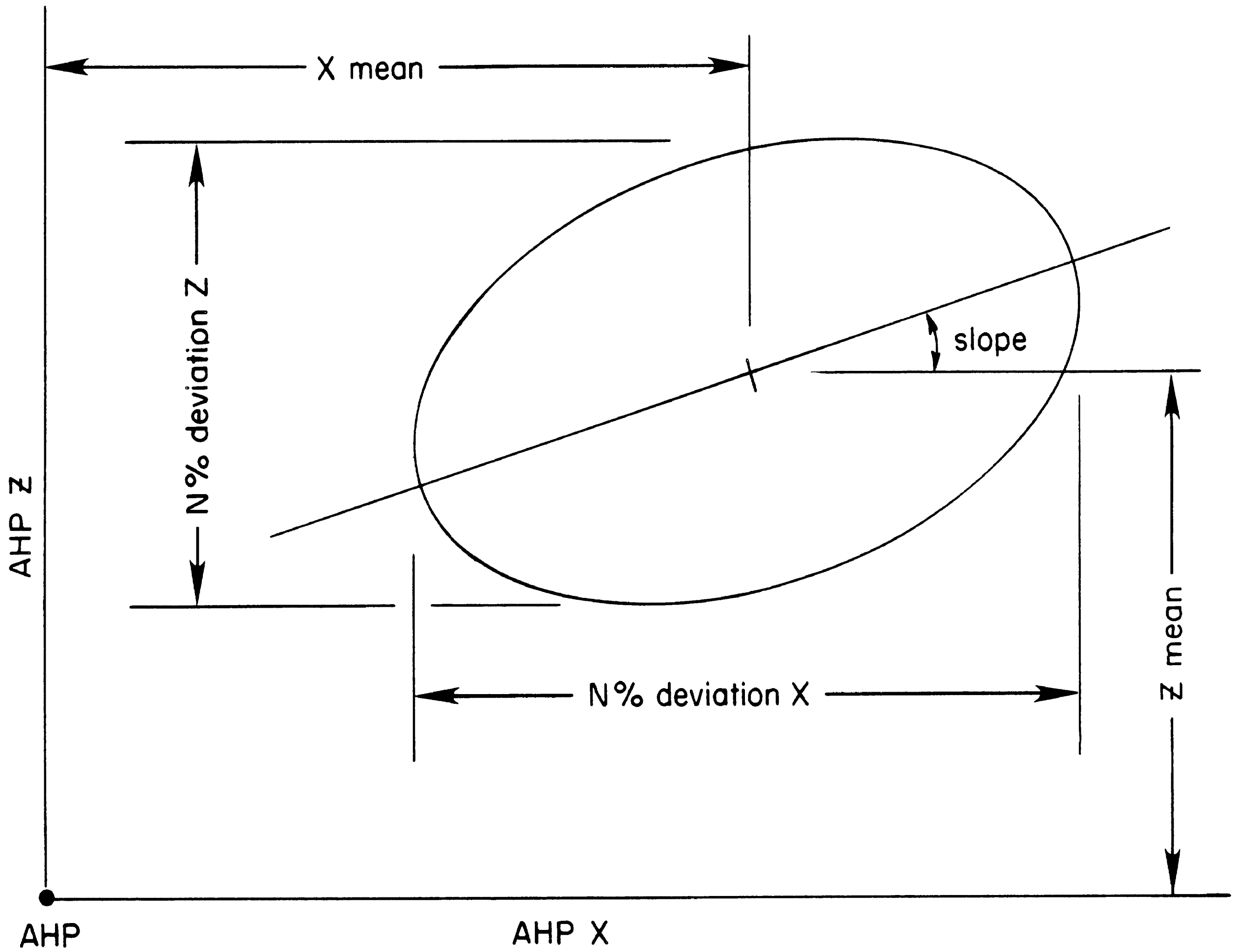


Figure 11. Illustration of two-dimensional tangency ellipse showing parameters computed from bivariate distribution of knee targets that describe N percentile knee ellipse in X-Z plane (from Hammond and Roe 1972).

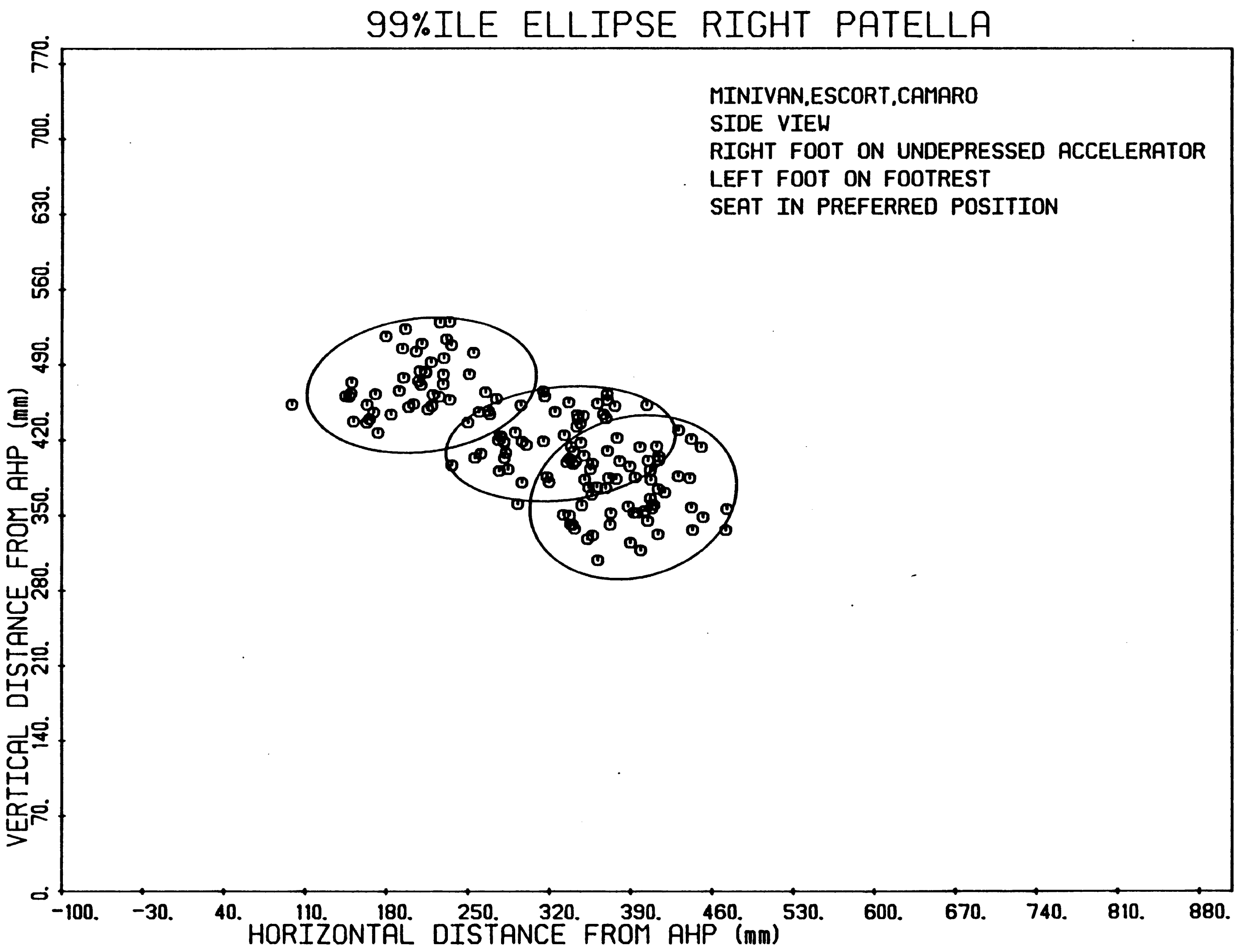


Figure 12. X-Z plane view of 99th percentile tangency ellipses for right knee with foot on undepressed accelerator pedal.

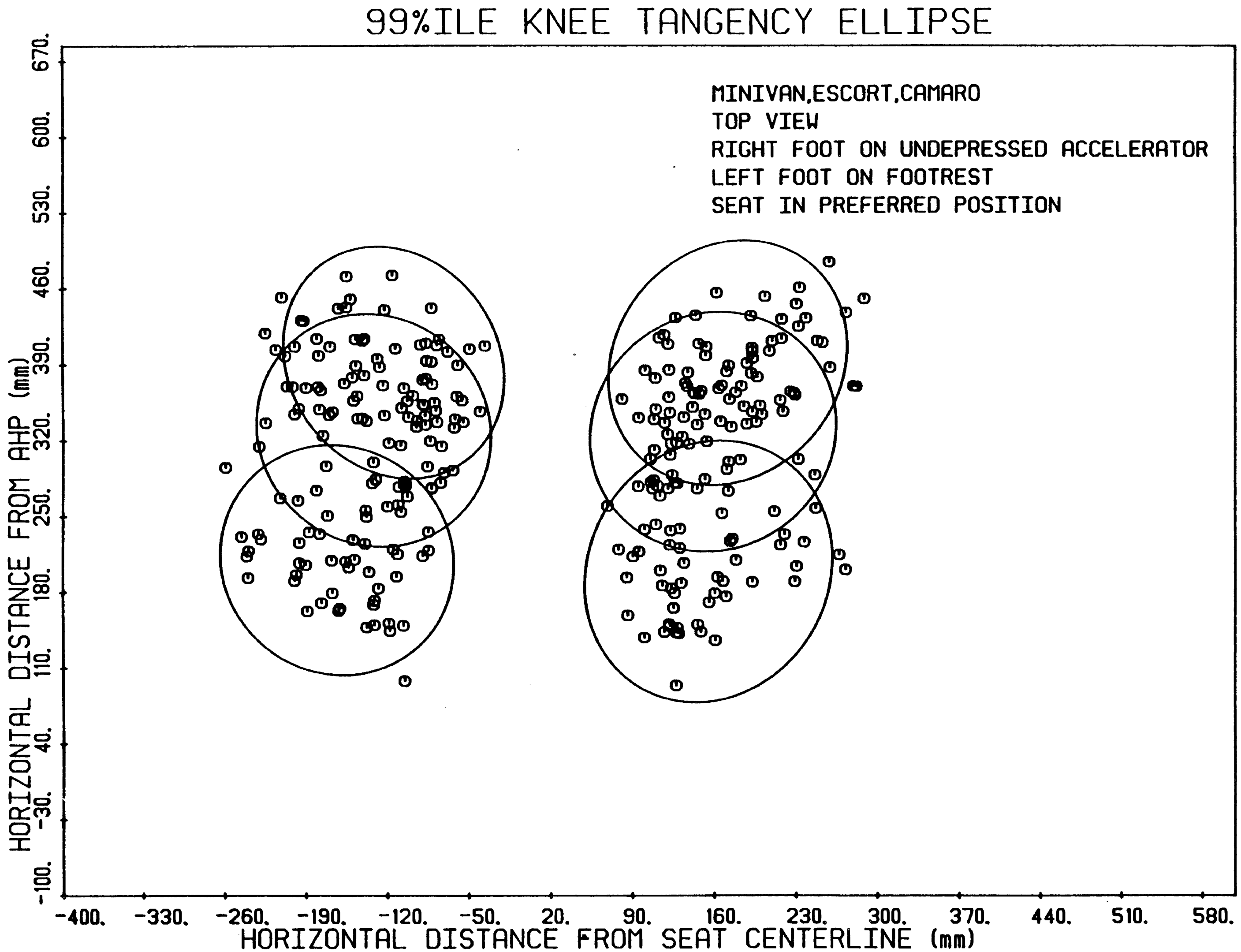


Figure 13. X-Y plane view of 99th percentile tangency ellipses for both knees with right foot on undepressed accelerator pedal and left foot on footrest.

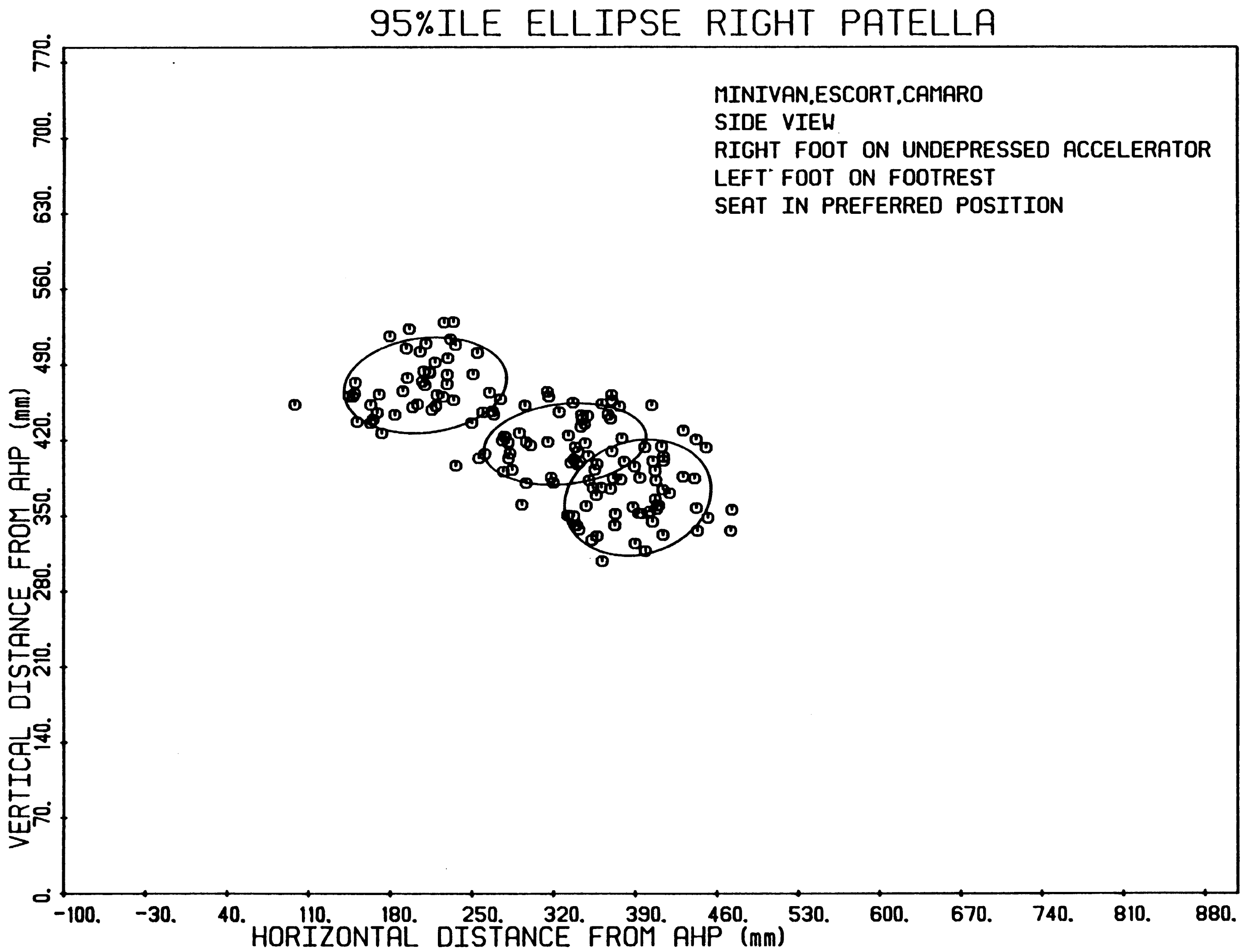


Figure 14. X-Z plane view of 95th percentile tangency ellipses for right knee with foot on undepressed accelerator pedal.

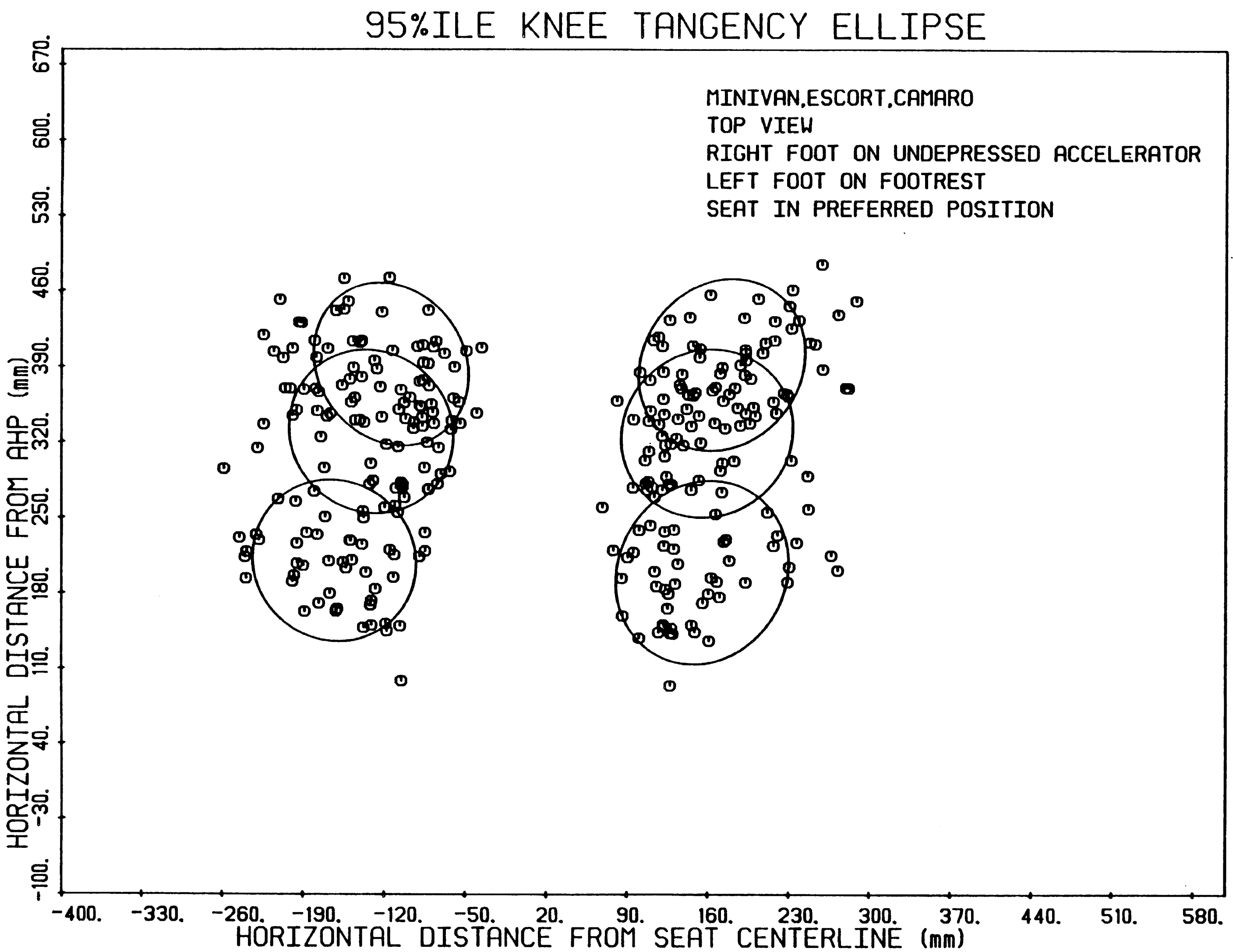


Figure 15. X-Y plane view of 95th percentile tangency ellipses for both knees with right foot on undepressed accelerator pedal and left foot on footrest.

TABLE 13

95%ILE AND 99%ILE DRIVER KNEE ELLIPSES
(RIGHT FOOT ON UNDEPRESSED ACCELERATOR/LEFT FOOT ON FOOTREST/SEAT NORMAL)

	Minivan		Escort		Camaro	
	Right Patella	Left Patella	Right Patella	Left Patella	Right Patella	Left Patella
Mean X	209.99	199.11	329.66	328.15	392.07	391.90
Mean Y	-163.12	155.21	-131.43	159.27	-114.27	171.97
Mean Z	471.05	462.82	416.60	427.33	366.83	362.05
X Std. Dev.	42.65	44.66	42.64	44.60	39.10	42.21
Y Std. Dev.	45.97	52.70	46.66	48.18	47.31	50.02
Z Std. Dev.	26.59	29.63	22.53	27.93	31.66	33.06
95% X*	140.75	147.38	140.71	147.18	129.03	139.29
95% Y	151.70	173.91	153.98	158.99	155.53	165.07
95% Z	87.75	97.78	74.35	92.17	104.48	109.10
99% X*	198.75	208.12	198.70	207.84	182.21	196.70
99% Y	214.22	245.58	217.44	224.52	220.46	233.09
99% Z	123.91	138.08	104.99	130.15	147.54	154.06
X/Z Slope	0.14	0.22	0.12	0.24	0.39	0.29
X/Y Slope	-2.75	2.86	-2.44	2.03	-2.11	1.95
Y/Z Slope	-0.33	0.39	-0.28	0.36	-0.35	0.32
X/Z Correlation	0.14	0.20	0.17	0.25	0.19	0.16
X/Y Correlation	-0.37	0.36	-0.52	0.63	-0.47	0.55
Y/Z Correlation	-0.43	0.56	-0.47	0.48	-0.33	0.30

Coordinate values are in mm.
* 95%ile and 99%ile accommodation centrally distributed about the mean.

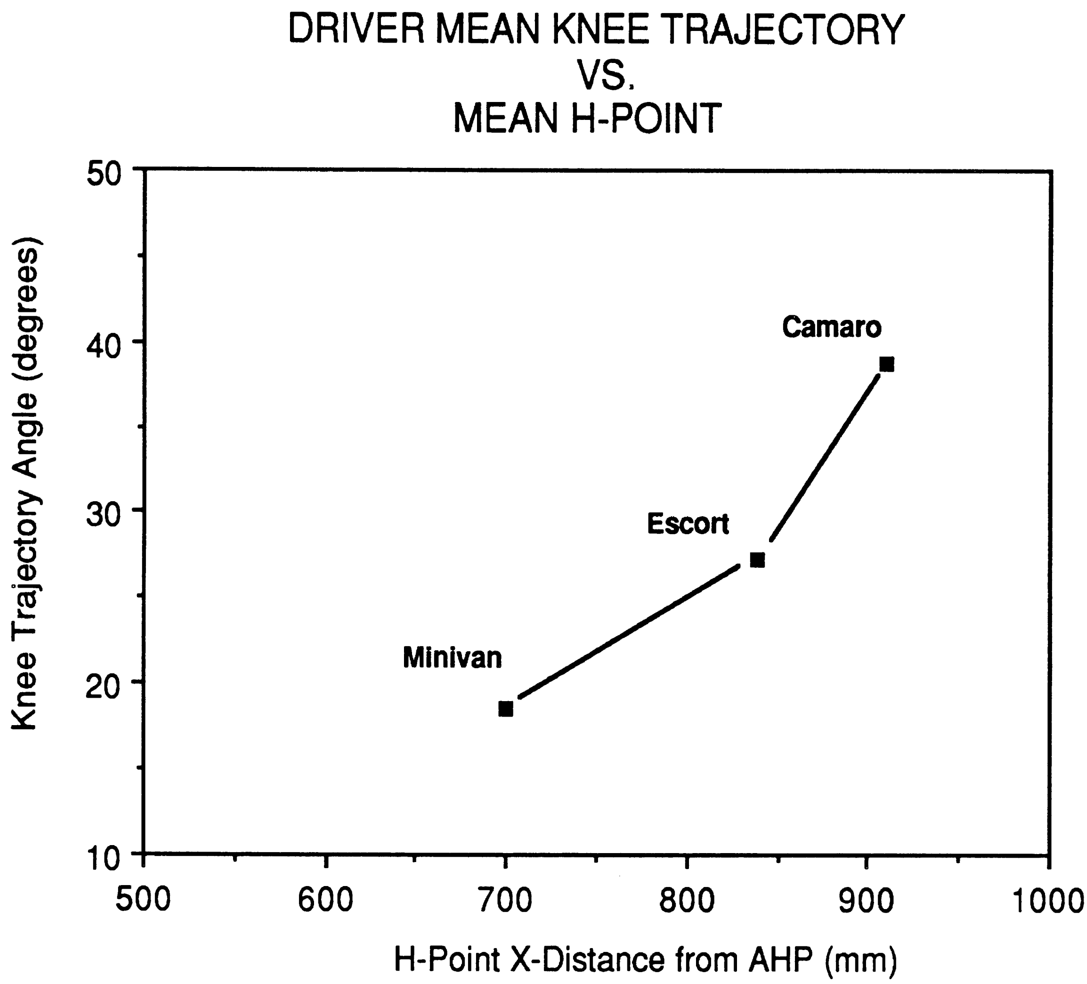


Figure 16. Comparison of knee trajectory angles for Camaro, Escort, and Minivan.

straight line trajectory) for the three vehicles. It is also interesting to note from the figures in Appendix H that, while there is some tendency for the knees of taller drivers to move up further for a given amount of seat translation, the intergroup differences are not as significant as one might expect from geometric analysis based on leg length.

F. Driver Heel Position

It will be recalled that the location of each subject's right heel position was recorded with the foot on the undepressed accelerator pedal and the seat in their preferred, untranslated position. Table 14 summarizes the heel location results relative to AHP and the seat centerline by subject group.

The X-coordinate of the right heel relative to AHP does not show a consistent relationship with driver size but does tend to be larger for males in the Escort and Camaro. In all but one case (group 3 for the Minivan), the mean value of the measured heel positions are rearward of the AHP. It is also seen that the overall difference between measured heel positions and AHP increases with decreasing vehicle seat height (i.e., largest for the Camaro and smallest for the Minivan). The lateral position of the heel relative to the seat centerline shows no relationship to driver size, but is clearly related to the vehicle seat height which, as indicated in Table 15, directly determines the lateral position of the accelerator pedal with respect to the centerline of the seat.

Figure 17 summarizes the overall heel position results for the three vehicles with respect to AHP and seat centerline. With regard to the rearward displacement of the heel relative to AHP, Table 16 compares the averages of measured foot pitch angles for all subjects with the J826 H-point specifications which determine accelerator pedal positioning relative to AHP. In all cases the measured foot angle is greater than the specified angle and the differences increase with decreasing seat height, thereby accounting for the relative differences in heel position observed.

As with knee position data, it is possible to describe the distribution of heel locations by tangency ellipses although, since the Z-coordinate for the heel is always the same for a given vehicle, the description is only in the X-Y plane. Figures 18 through 20 illustrate the 99th percentile heel tangency ellipses along with heel location data points for the three vehicles, while Table 17 presents the parameter values describing these ellipses.

G. Locations of Tibia Targets

The primary purpose of this study was to determine the locations of driver knees for designing and positioning knee bolsters in order to achieve optimal impact performance for the driving population during frontal crashes. In other words, the primary concern has been impact protection, and primary attention has therefore been given to the location of the lower margin of the patella in defining knee position. From a human factors point of view, however, it is equally important that the knee bolster not interfere with normal operation of the vehicle.

In particular, there is concern that positioning a knee bolster in the optimal location for driver restraint could present leg interference problems for some drivers as they move their right foot between the accelerator and brake pedals. While this study was not intended to address this problem, the location of the tibia target (approximately four inches below the lower margin of the patella target), particularly for the situation when the right foot is on the undepressed brake pedal, does provide some relevant information in this regard. Appendix I summarizes the information on tibia target positions for the right knee with the foot on the undepressed brake and accelerator pedals and the seat in the untranslated positions. Scatter plots, tibia ellipses, and their 95th and 99th percentile parameter values are presented.

TABLE 14

GROUP MEAN HEEL LOCATION RESULTS
(RIGHT FOOT ON UNDEPRESSED ACCELERATOR PEDAL)

Group No.	X-Coordinate re: AHP (mm)			Y-Coordinate re: Seat Centerline (mm)		
	Minivan	Escort	Camaro	Minivan	Escort	Camaro
1	17.0	14.4	30.6	–154.2	–118.6	–85.2
2	11.0	10.2	16.2	–165.0	–126.4	–84.8
3	–1.4	12.0	45.5	–158.8	–108.0	–75.0
4	35.2	23.8	43.0	–161.8	–115.2	–80.0
5	19.0	14.8	40.0	–161.6	–107.0	–76.2
6	7.0	25.6	32.4	–140.6	–99.2	–58.4
7	21.2	55.2	67.4	–172.4	–108.6	–81.8
8	16.8	24.4	55.6	–150.6	–101.2	–71.8
9	19.0	34.4	50.0	–144.6	–103.6	–61.2
10	23.2	61.2	81.2	–158.0	–107.2	–69.0
All	16.8	27.6	46.2	–156.8	–109.5	–74.35

TABLE 15

LATERAL POSITION OF THE ACCELERATOR PEDAL
RELATIVE TO SEAT CENTERLINE

Vehicle	Seat Height re: AHP	Seat Centerline Coordinate	Accel. Pedal Coordinate	Seat Centerline to Accel. Pedal
Camaro	186	370	255	115
Escort	260	330	165	165
Minivan	351	407	192	215

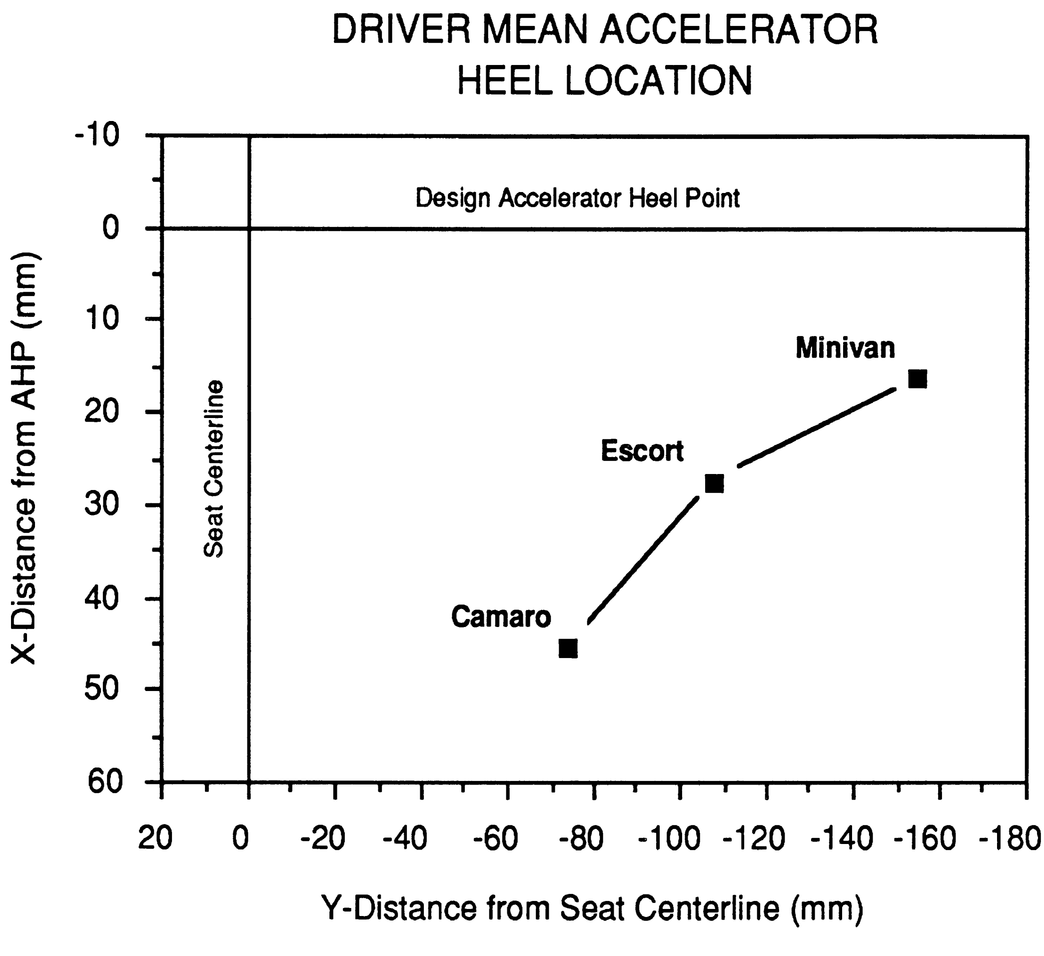


Figure 17. Comparison of overall mean heel positions relative to AHP and seat centerline.

TABLE 16

COMPARISON OF MEASURED MEAN FOOT ANGLES WITH J826 H-POINT FOOT ANGLE SPECIFICATIONS

Vehicle	Foot Angle Experimental	Foot Angle H-Point Machine
Minivan	41 degrees	44 degrees
Escort	51 degrees	60 degrees
Camaro	55 degrees	71 degrees

TABLE 17

95TH% AND 99TH% ACCELERATOR HEEL POINT ELLIPSES

Heel Point	Minivan (mm)	Escort (mm)	Camaro (mm)
Mean X	16.80	27.60	46.20
Mean Y	–156.76	–109.50	–74.34
X Std. Dev.	26.64	29.74	28.80
Y Std. Dev.	19.96	13.28	17.30
95% X*	88.71	99.03	95.90
95% Y	66.47	44.22	57.61
99% X*	124.12	138.59	134.21
99% Y	93.01	61.88	80.62
X/Y Slope	325.13	–438.71	364.00
X/Y Correlation	–0.13	0.13	–0.01

*95% and 99% accommodation centrally distributed about the mean.

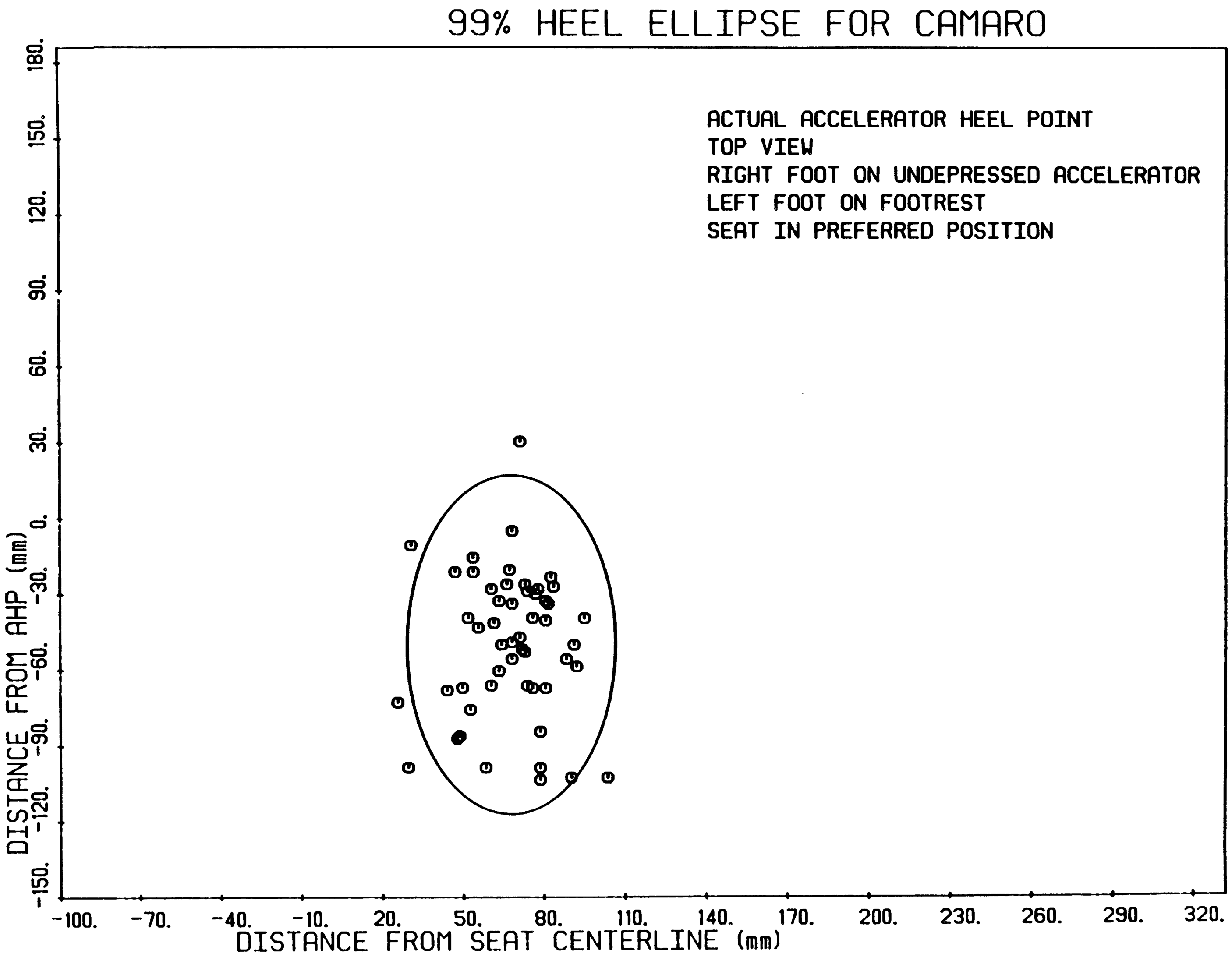


Figure 18. 99th percentile heel tangency ellipse for GM Camaro.

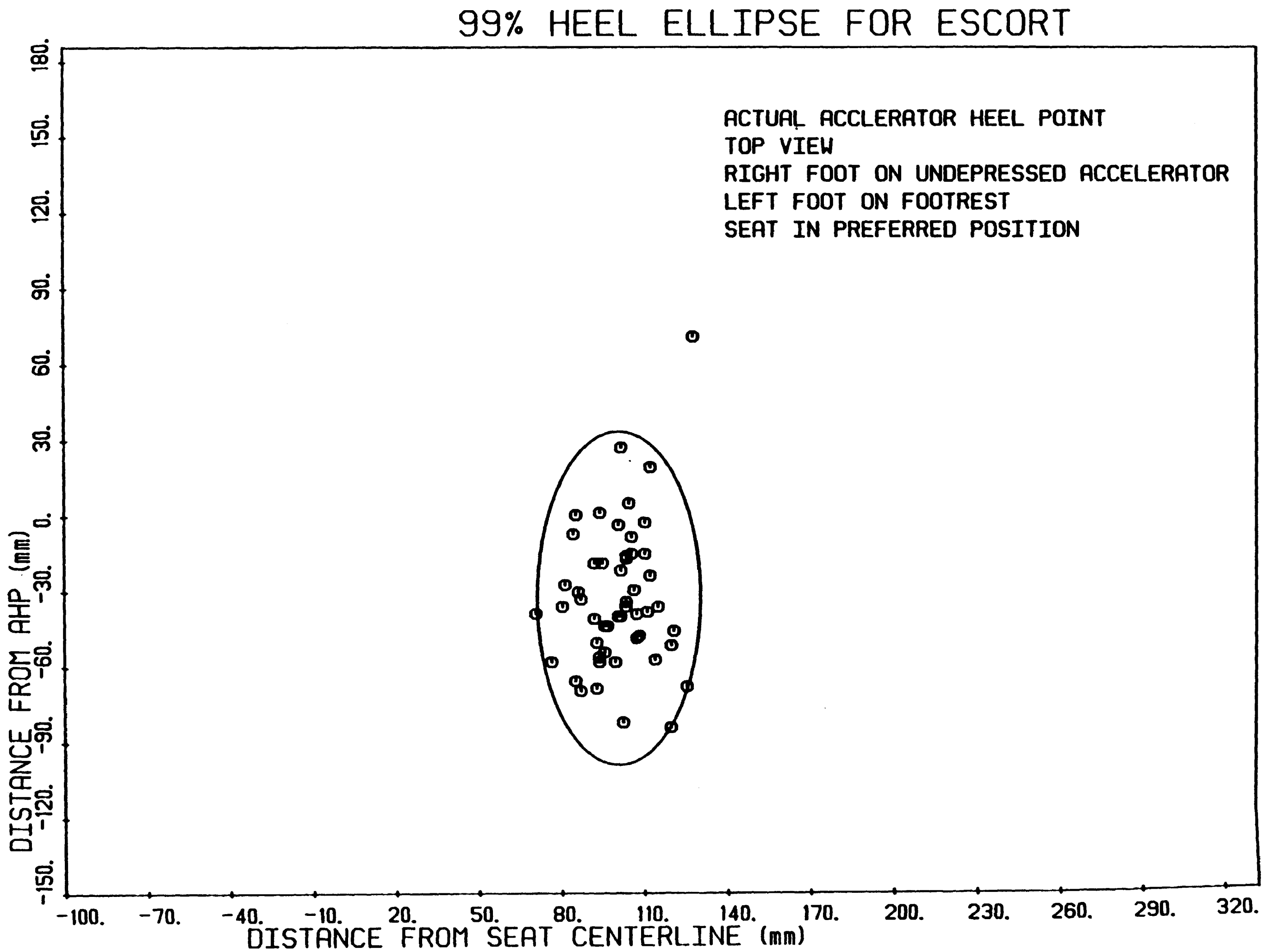


Figure 19. 99th percentile heel tangency ellipse for Ford Escort.

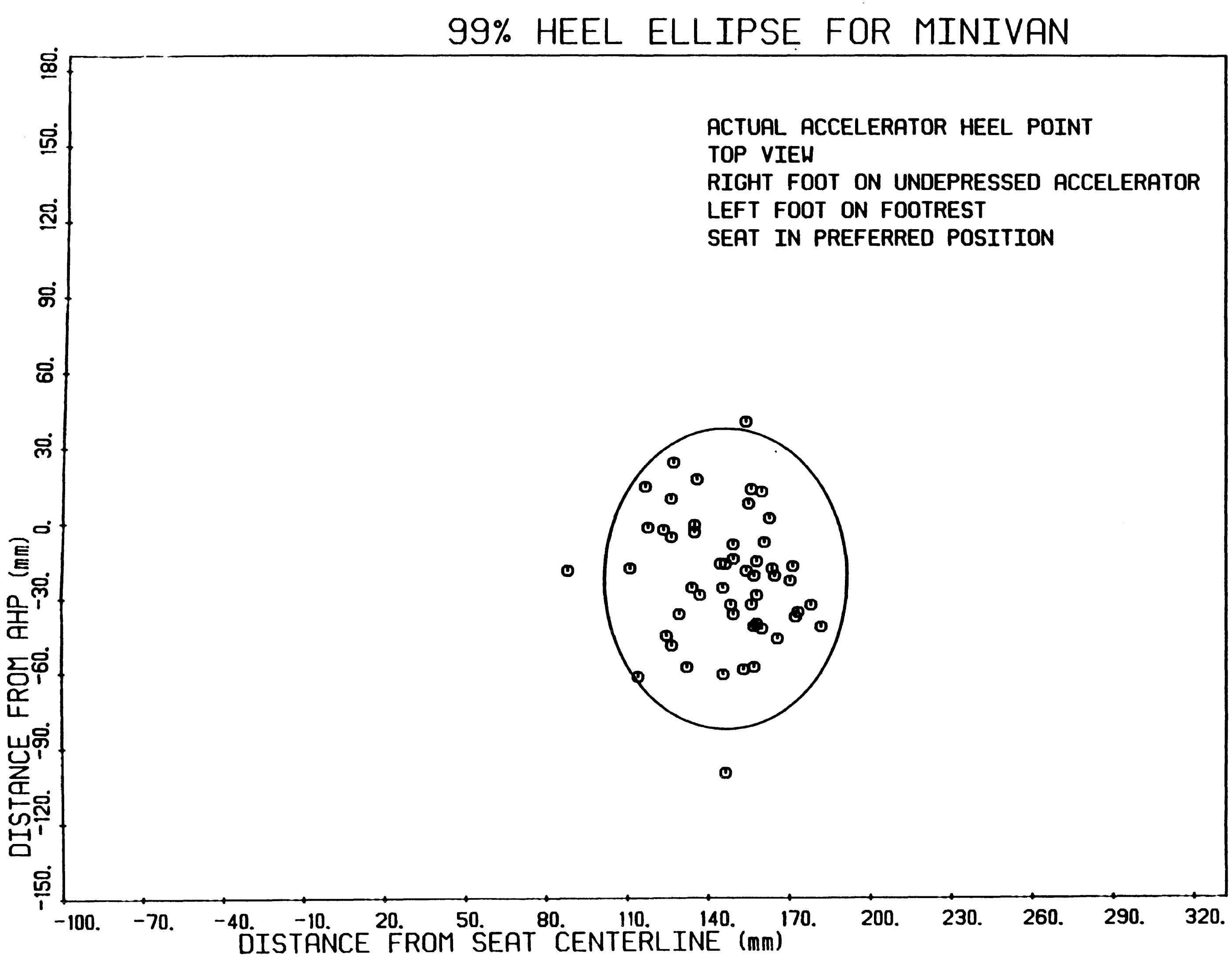


Figure 20. 99th percentile heel tangency ellipse for Chrysler Minivan.

IV. CONCLUSIONS AND RECOMMENDATIONS

This study provides new data describing the three-dimensional distributions of driver knees relative to the Accelerator Heel Point (AHP) and seat centerline for three vehicle packages spanning the range of passenger vehicle seat heights. While the data have been collected in a laboratory seating buck, comparison of the distributions of subject selected seat positions with those predicted by the SAE Seating Accommodation Model suggest that the results are a reasonable representation of real-world driver knee locations, especially with regard to the X- and Z-directions. While subjects were instructed to take note of their leg orientations while driving in the days preceding their test session in order to help them recreate typical leg splay conditions, it is possible that the amounts of leg splay demonstrated under test conditions are conservative representations of real-world conditions, especially for some of the female subjects.

Knee position data were also collected for the seat translated six inches forward of the subject's preferred position to estimate knee locations subsequent to the onset of vehicle impact. It is also recommended that the pre-impact knee position data be used in Crash Victim Simulation models to provide further insight into knee trajectories and post-impact knee positions resulting from torso and extremity kinematics during vehicle crashes. It is also suggested that the knee position data of this study be used to develop and validate an analytical model of driver knee position distributions that can serve as a design tool for knee bolster design and positioning in future vehicle package designs. In developing this model, consideration should be given to describing knee positions relative to the Ball-of-Foot (BOF) landmark which is becoming increasingly recognized as a more meaningful seating package reference point than AHP.

V. REFERENCES

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APPENDIX A

VEHICLE AND BUCK COORDINATES, DIMENSIONS, and H-point CALIBRATION VALUES

(1) positive X axis is toward rear

(2) positive Y axis is to left

(3) positive Z axis is up

For vehicle coordinates, Y origin is at center of vehicle and X and Z origins are forward of and below AHP's.

For buck coordinates, Y origin is at seat centerline and X and Z origins are at AHP.

Table A-1

GM CAMARO VEHICLE COORDINATES (mm)

	X	Y	Z
AHP	2139	--	423
SgRP (H-POINT)	3050	370	609
TOP CENTER STEERING WHEEL	2704	360	987
TOP CENTER BRAKE PAD	2140	381	604
BRAKE PIVOT POINT	2084	--	890
TOP CENTER ACCELERATOR PAD	2075	255	604
ACCELERATOR PIVOT POINT	1953	--	741
SEAT MOUNT (FRONT)	2688	--	445
SEAT MOUNT (REAR)	3020	--	400
BRAKE PAD ANGLE (w.r.t vert.)		22	
ACCELERATOR PAD ANGLE (w.r.t. vert.)		17	
STEERING WHEEL ANGLE (w.r.t. vert.)		18	
SEAT CENTER LINE		370	

Table A-2

GM CAMARO VEHICLE AND BUCK DIMENSIONS (mm)

	DESIGN	ACTUAL	ABS. DIFF.
STEERING WHEEL			
AHP TO CENTER (horiz.)	565	567	2
AHP TO CENTER (vert.)	564	564	0
STEERING WHEEL ANGLE (w.r.t. vert.)	18	21	3
SgRP (HIP POINT)			
AHP TO SgRP (horiz)	911	900	1
AHP TO SgRP (vert.)	179	177	2
ACCELERATOR PEDAL			
AHP TO TOP CENTER (horiz.)	-64	-66	2
AHP TO TOP CENTER (vert.)	176	175	1
SEAT C/L - CTR ACC. PAD	115	114	1
PAD ANGLE (w.r.t. vert.)	17	19	2
BRAKE PEDAL			
AHP TO TOP CENTER (horiz.)	1	-3	4
AHP TO TOP CENTER (vert.)	176	180	2
SEAT C/L - CTR BRAKE PAD	-52	-49	3
PAD ANGLE (w.r.t. vert.)	22	18	3
CTR BRAKE PAD - CTR ACC. PAD	165	161	4
SEAT MOUNTS			
AHP TO FRONT (horiz.)	549	556	7
AHP TO FRONT (vert.)	17	21	4
FRONT (w.r.t CENTERLINE)	172	172	0
AHP TO REAR (horiz.)	881	886	5
AHP TO REAR (vert.)	-28		

Table A-3

FORD ESCORT VEHICLE COORDINATES (mm)

	X	Y	Z
AHP	2260	--	418
SgRP (H-POINT)	3104	--	678
CENTER STEERING WHEEL	2734	329	1046
TOP CENTER BRAKE PAD	2223	299	607
BRAKE PIVOT POINT	2097	--	885
TOP CENTER ACCELERATOR PAD	2162	165	594
ACCELERATOR PIVOT POINT	2020	--	722
SEAT MOUNT (FRONT)	2685	--	441
SEAT MOUNT (REAR)	3105	--	410
BRAKE PAD ANGLE (w.r.t vert.)		35	
ACCELERATOR PAD ANGLE (w.r.t. vert.)		39	
STEERING WHEEL ANGLE (w.r.t. vert.)		26	
SEAT CENTER LINE		330	

Table A-4

FORD ESCORT PACKAGE AND BUCK DIMENSIONS (mm)

	DESIGN	ACTUAL	ABS. DIFF.
STEERING WHEEL			
AHP TO CENTER (horiz.)	474	471	3
AHP TO CENTER (vert.)	628	631	3
STEERING WHEEL ANGLE (w.r.t vert.)	26	27	1
SgRP (HIP POINT)			
AHP TO SgRP (horiz.)	844	--	--
AHP TO SgRP (vert.)	260	--	--
ACCELERATOR PEDAL			
AHP TO TOP CENTER (horiz.)	-98	-97	1
AHP TO TOP CENTER (vert.)	176	184	8
SEAT C/L - CTR ACC. PAD	165	163	2
PAD ANGLE (w.r.t. vert.)	39	41	2
BRAKE PEDAL			
AHP TO TOP CENTER (horiz.)	-37	-42	5
AHP TO TOP CENTER (vert.)	189	192	3
SEAT C/L - CTR BRAKE PAD	31	23	8
PAD ANGLE (w.r.t. vert.)	35	34	1
CTR BRAKE PAD - CTR ACC. PAD	134	132	2
SEAT MOUNTS			
AHP TO FRONT (horiz.)	425	456	31
AHP TO FRONT (vert.)	23	20	3
FRONT (w.r.t CENTER LINE)	--	--	--
AHP TO REAR (horiz.)	845	877	32
AHP TO REAR (vert.)	-8	-3	5

Table A-5

CHRYSLER MINIVAN PACKAGE COORDINATES (mm)

	X	Y	Z
AHP	636	--	199
SgRP (H-POINT)	1334	--	550
CENTER STEERING WHEEL	977	373	904
TOP CENTER BRAKE PAD	545	366	366
BRAKE PIVOT POINT	352	380	574
TOP CENTER ACCELERATOR PAD	495	192	334
ACCELERATOR PIVOT POINT	359	--	342
SEAT MOUNT (FRONT)	1081	--	189
SEAT MOUNT (REAR)	1413	--	198
BRAKE PAD ANGLE (w.r.t. vert.)		42	
ACCELERATOR PAD ANGLE (w.r.t. vert.)		47	
STEERING WHEEL ANGLE (w.r.t. vert.)		35	
SEAT CENTER LINE		407	

Table A-6

CHRYSLER MINIVAN VEHICLE AND BUCK DIMENSIONS (mm)

	DESIGN	ACTUAL	ABS. DIFF.
STEERING WHEEL			
AHP TO CENTER (horiz.)	341	339	2
AHP TO CENTER (vert.)	705	707	2
STEERING WHEEL ANGLE (w.r.t vert.)	35	35	0
SgRP (HIP POINT)			
AHP TO SgRP (horiz)	698	--	--
AHP TO SgRP (vert.)	351	--	--
ACCELERATOR PEDAL			
AHP TO TOP CENTER (horiz.)	-141	-143	2
AHP TO TOP CENTER (vert.)	135	141	6
SEAT C/L - CTR ACC. PAD	215	203	12
PAD ANGLE (w.r.t. vert.)	47	50	3
BRAKE PEDAL			
AHP TO TOP CENTER (horiz.)	-91	-88	3
AHP TO TOP CENTER (vert.)	167	162	5
SEAT C/L - CTR BRAKE PAD	41	39	2
PAD ANGLE (w.r.t. vert.)	42	40	2
CTR BRAKE PAD - CTR ACC. PAD	174	170	4
SEAT MOUNTS			
AHP TO FRONT (horiz.)	445	445	0
AHP TO FRONT (vert.)	-10	--	--
FRONT (w.r.t CENTER LINE)	--	--	--
AHP TO REAR (horiz.)	777	757	20
AHP TO REAR (vert.)	-1	--	--

Table A-7

SEATING BUCK H-POINT CALIBRATION VALUES
FOR GM CAMARO

	DESIGN	ACTUAL
AHP TO H-POINT (horiz.)	911	910
AHP TO H-POINT (vert.)	179	177
FOOT ANGLE	71	71
ANKLE ANGLE	87	87
HIP ANGLE	98	97
BACK ANGLE	26.5	26
KNEE ANGLE	133	134
SEAT DETENT		9

Table A-8

SEATING BUCK H-POINT CALIBRATION VALUES
FORD FORD ESCORT

	DESIGN	ACTUAL
AHP TO H-POINT (horiz.)	844	839
AHP TO H-POINT (vert.)	260	268
FOOT ANGLE	60	59.5
ANKLE ANGLE	87	87
HIP ANGLE	94.8	94.9
BACK ANGLE	24	24
KNEE ANGLE	122	1235
SEAT DETENT		11

Table A-9

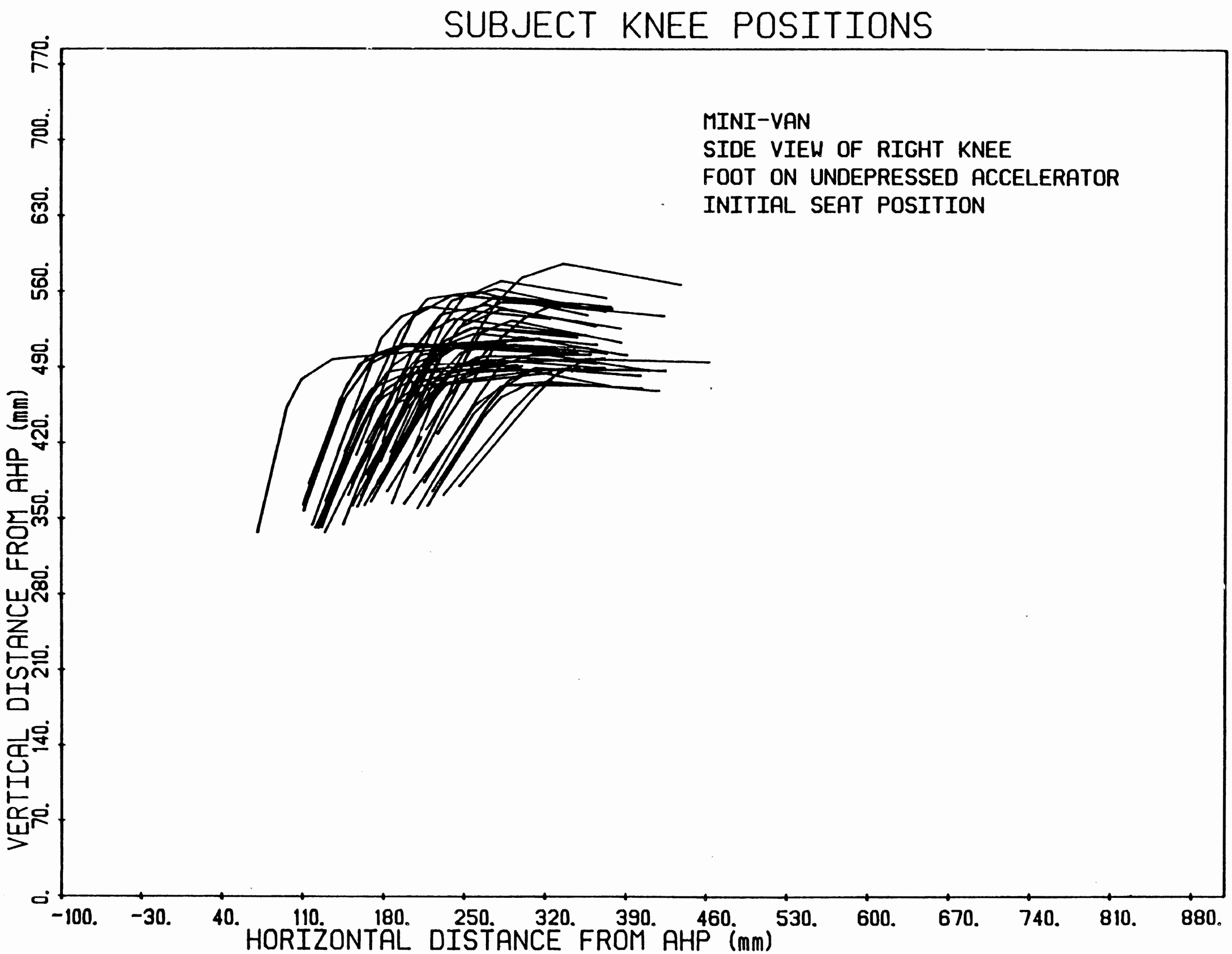
SEATING BUCK H-POINT CALIBRATION VALUES
FOR CHRYSLER MINIVAN

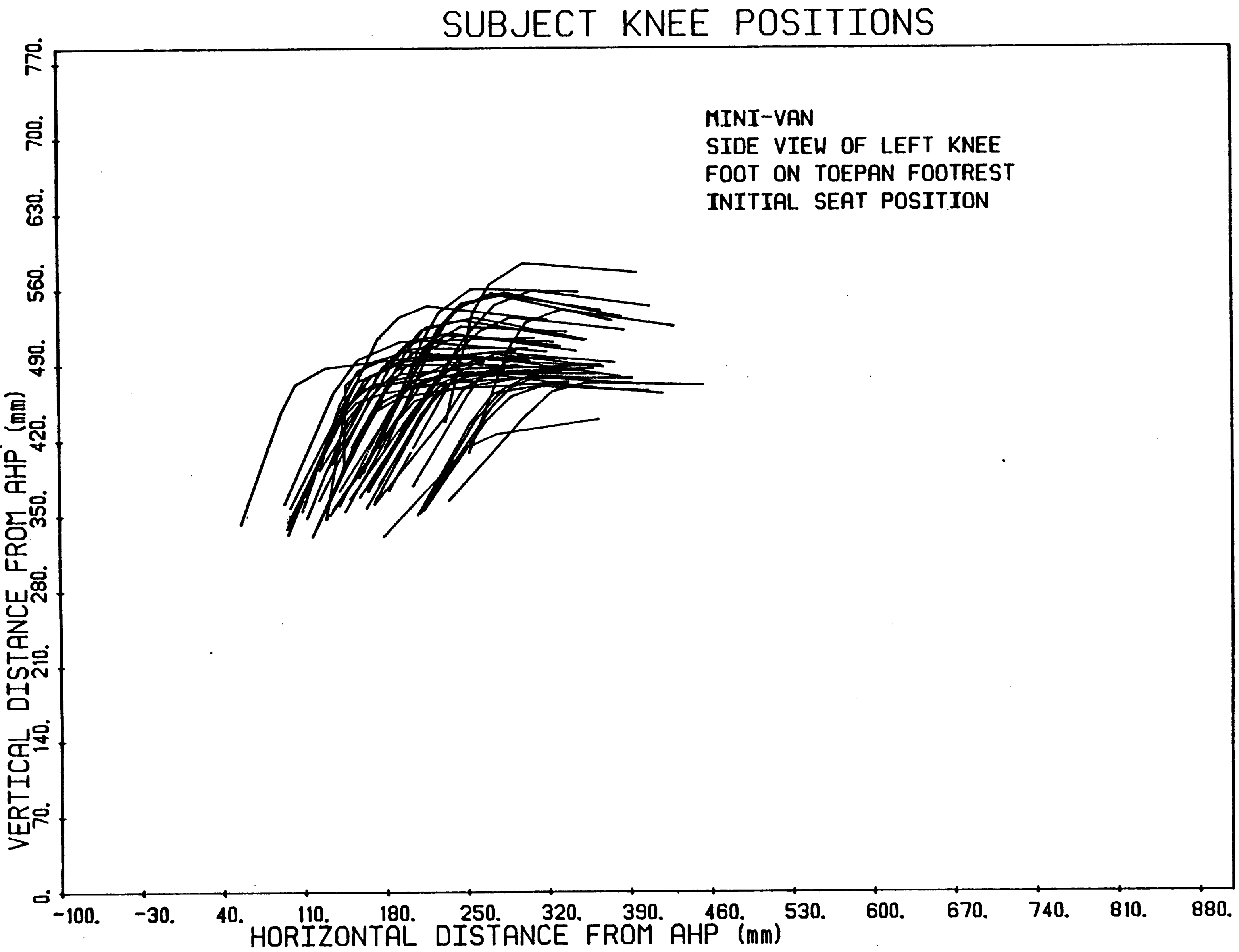
	DESIGN	ACTUAL
AHP TO H-POINT (horiz.)	698	700
AHP TO H-POINT (vert.)	351	343
FOOT ANGLE	44	44
ANKLE ANGLE	87	87
HIP ANGLE	91	90
BACK ANGLE	22	23
KNEE ANGLE	103	104

APPENDIX B

PLOTS OF KNEE CONTOURS BY SUBJECT USING FIVE MIDLINE TARGETS ON EACH LEG

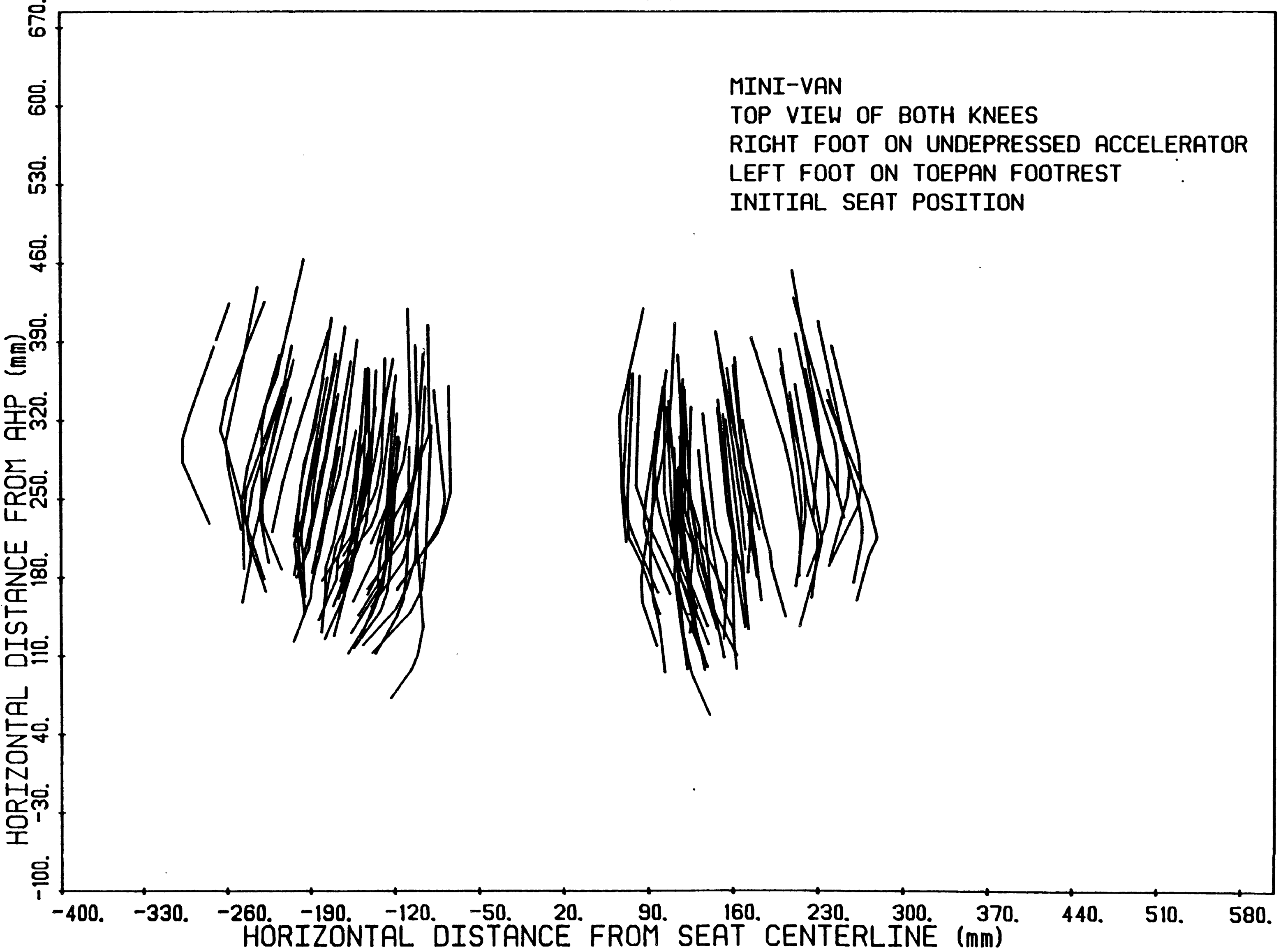
UNTRANSLATED SEAT CONDITIONS

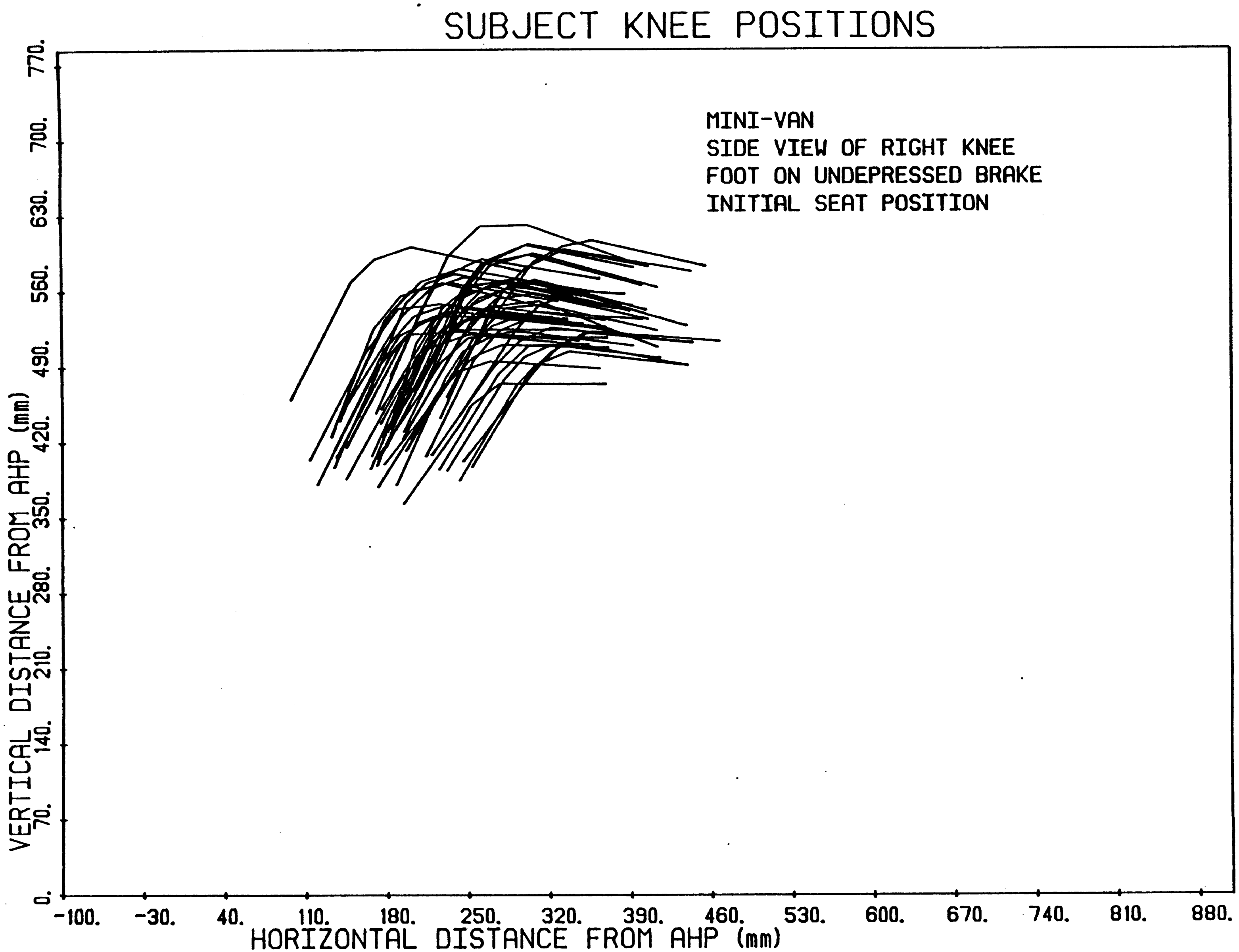

SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)



SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

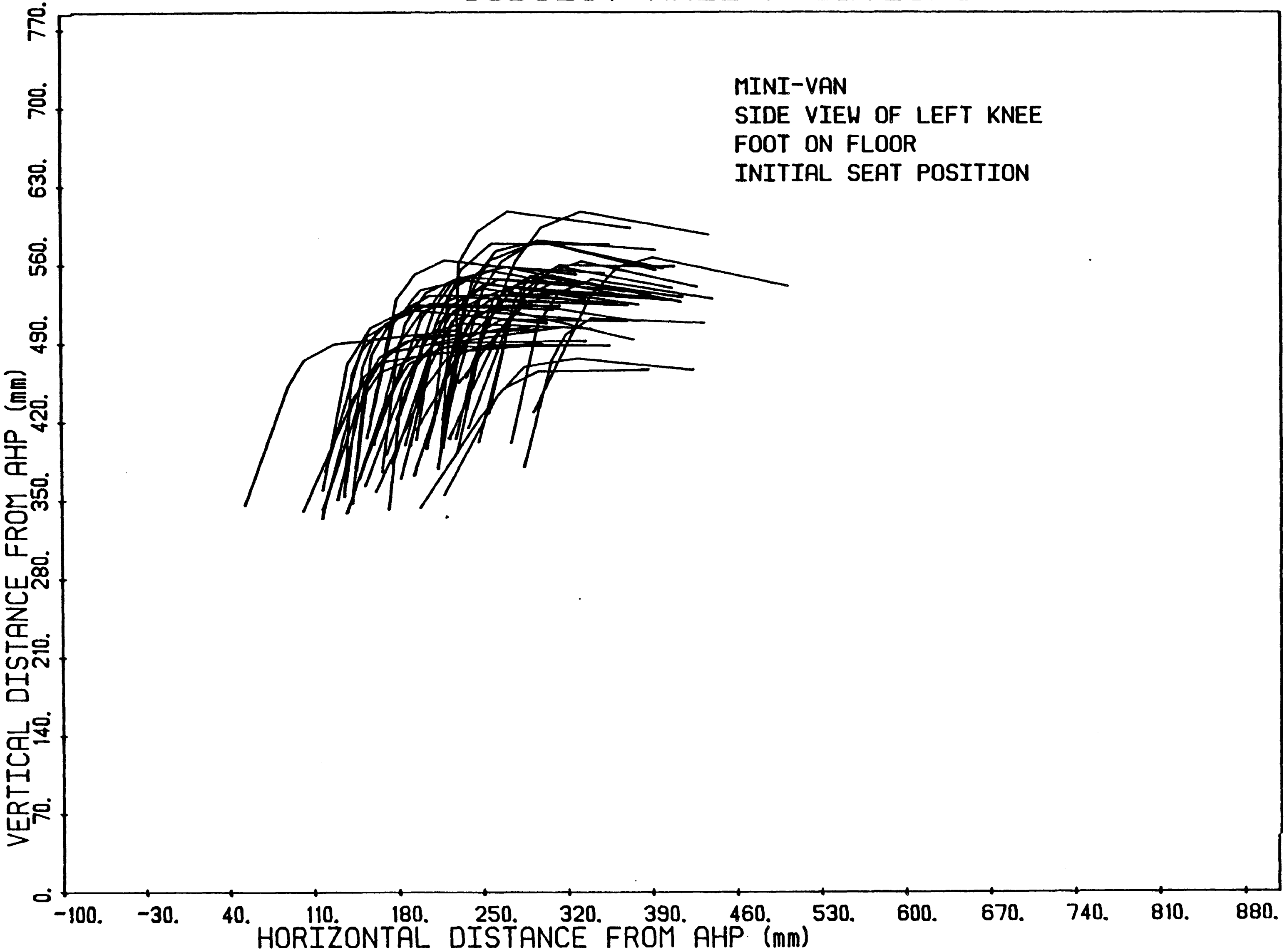
SUBJECT KNEE POSITIONS



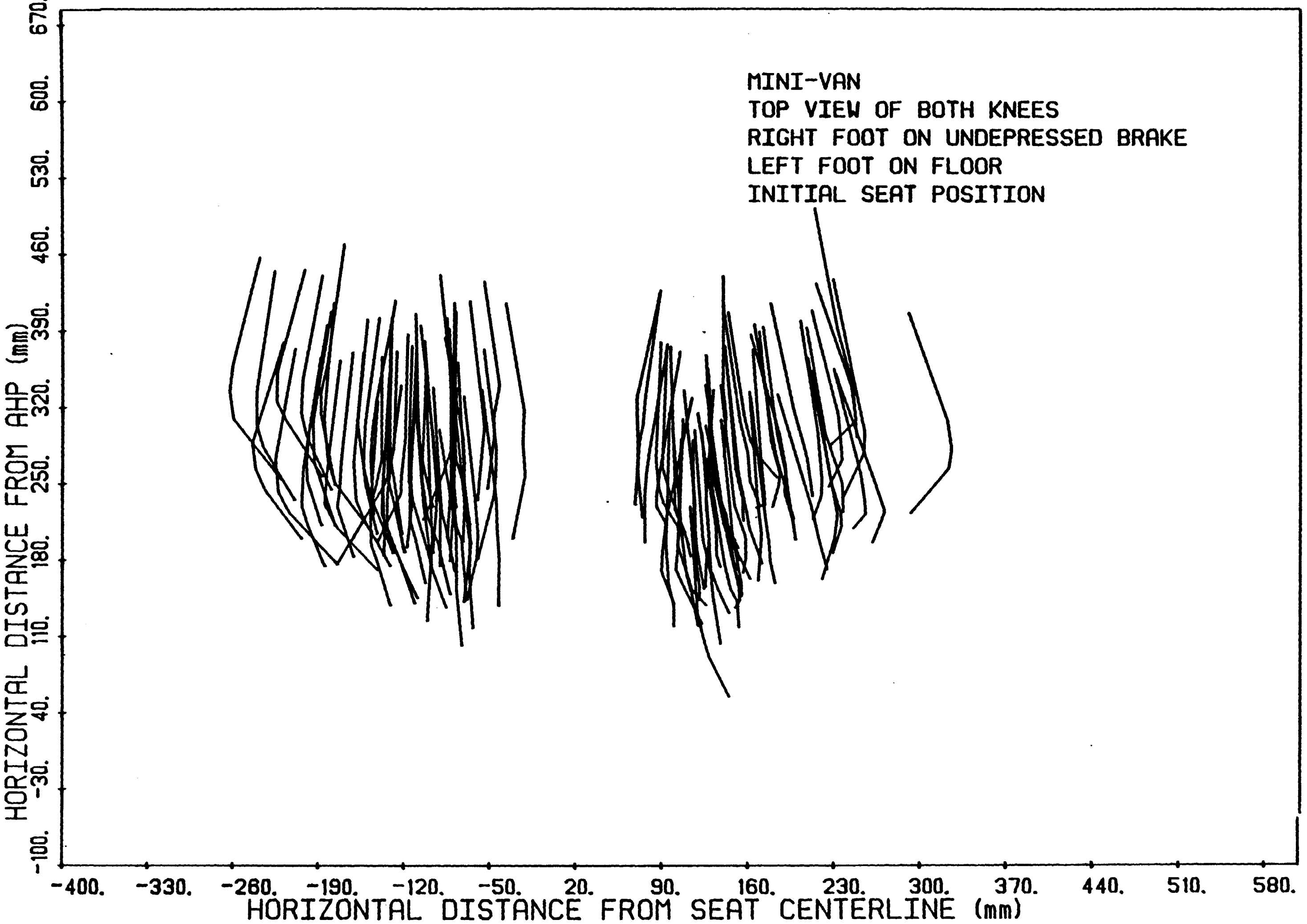


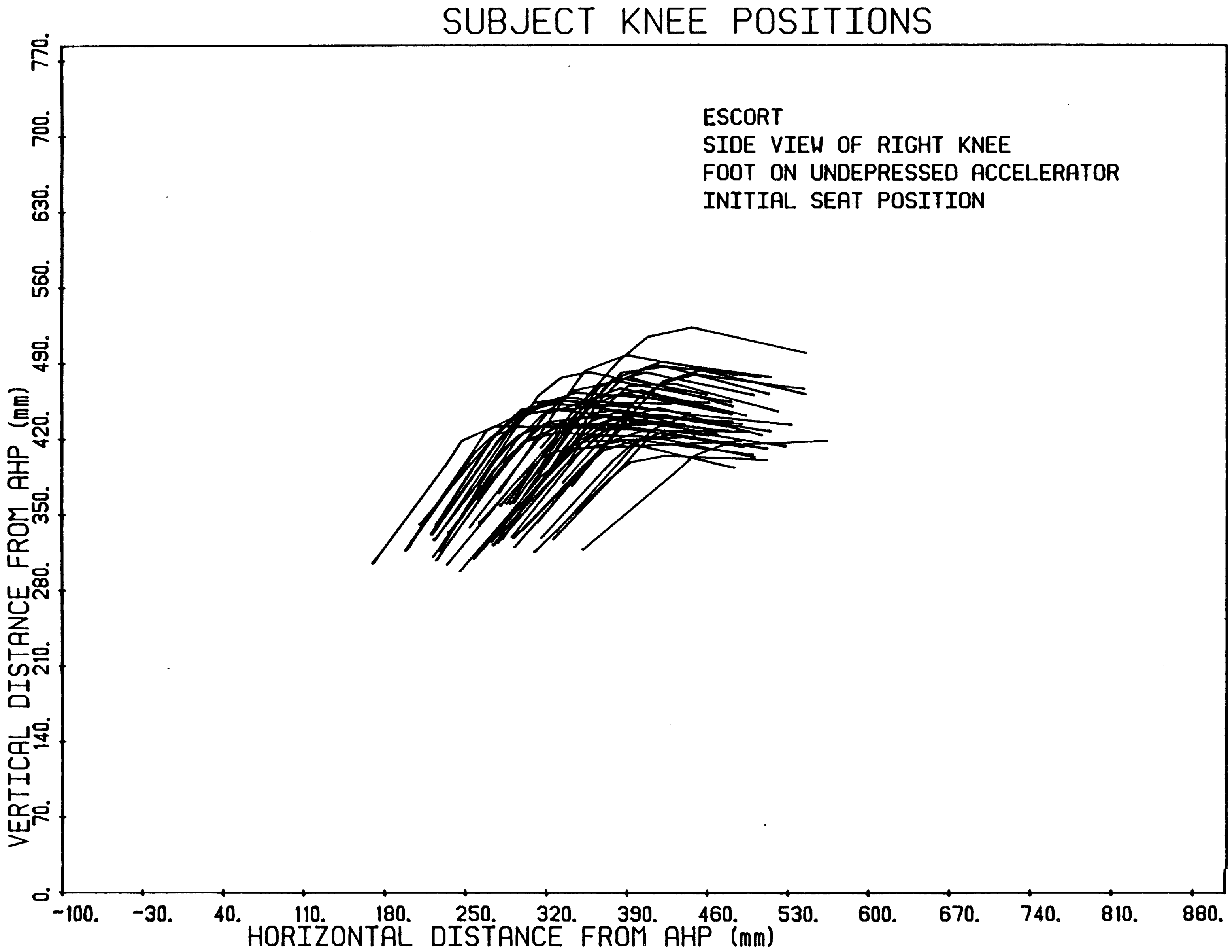
SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED BRAKE
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

SUBJECT KNEE POSITIONS

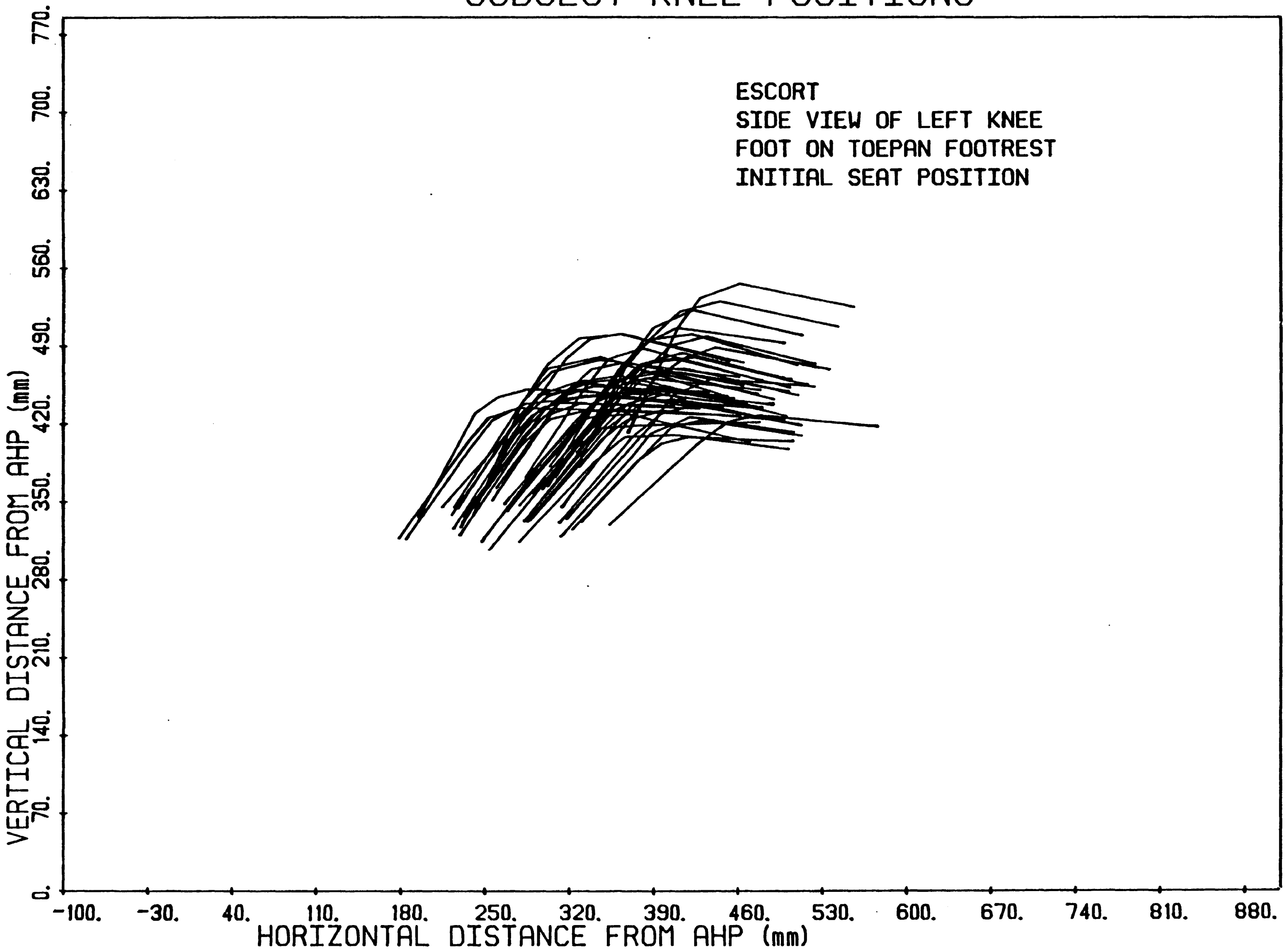


SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

SUBJECT KNEE POSITIONS



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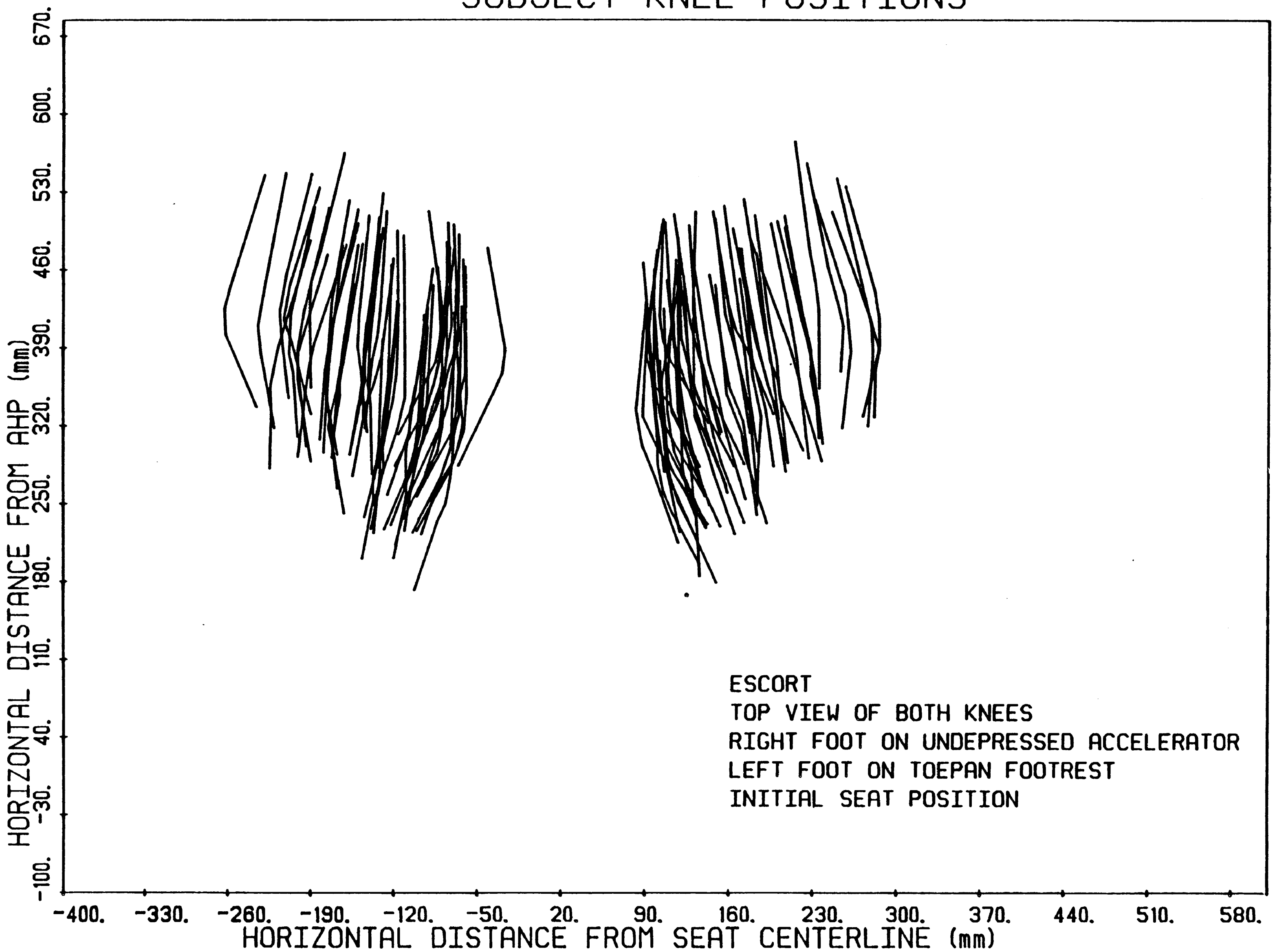
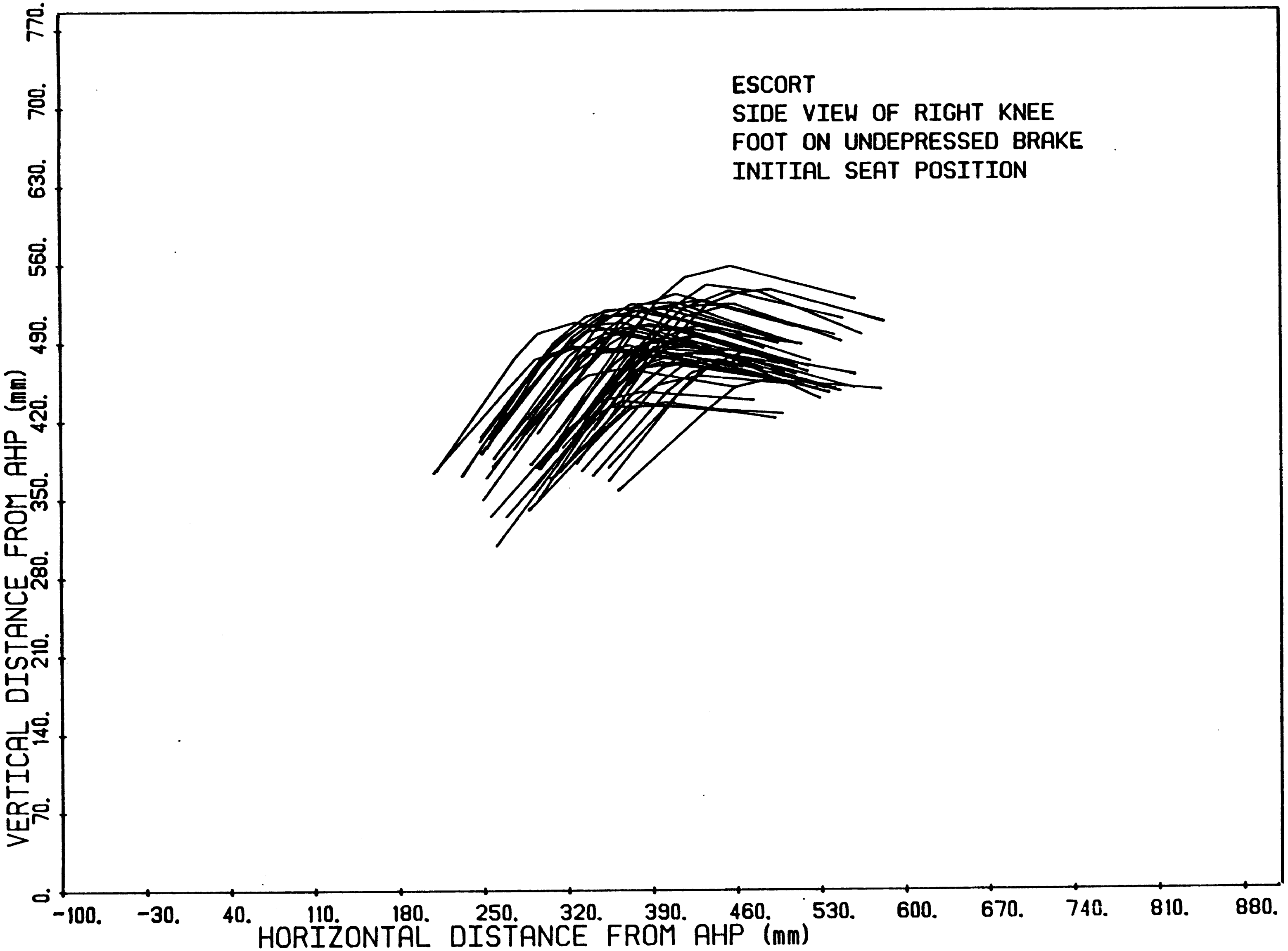
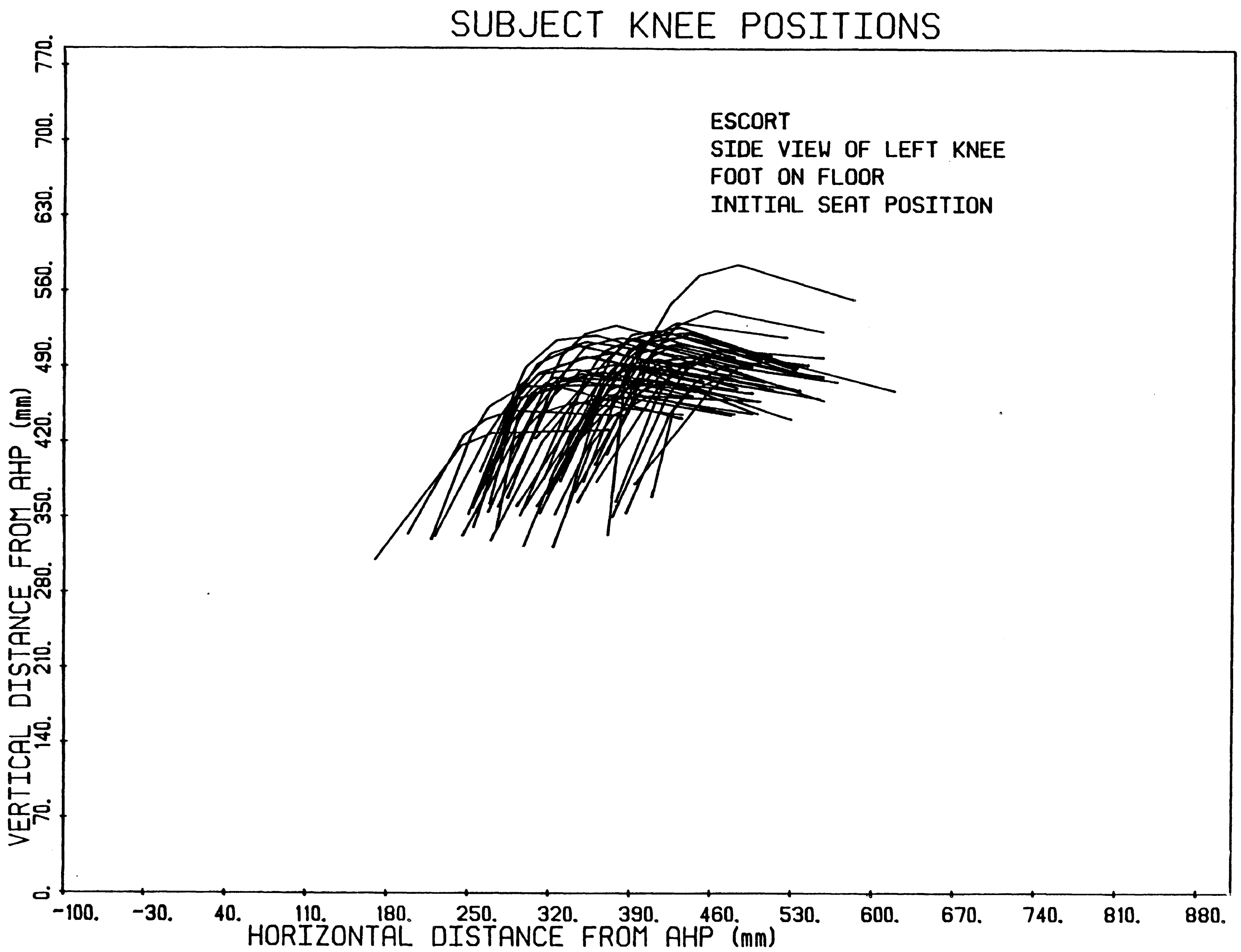
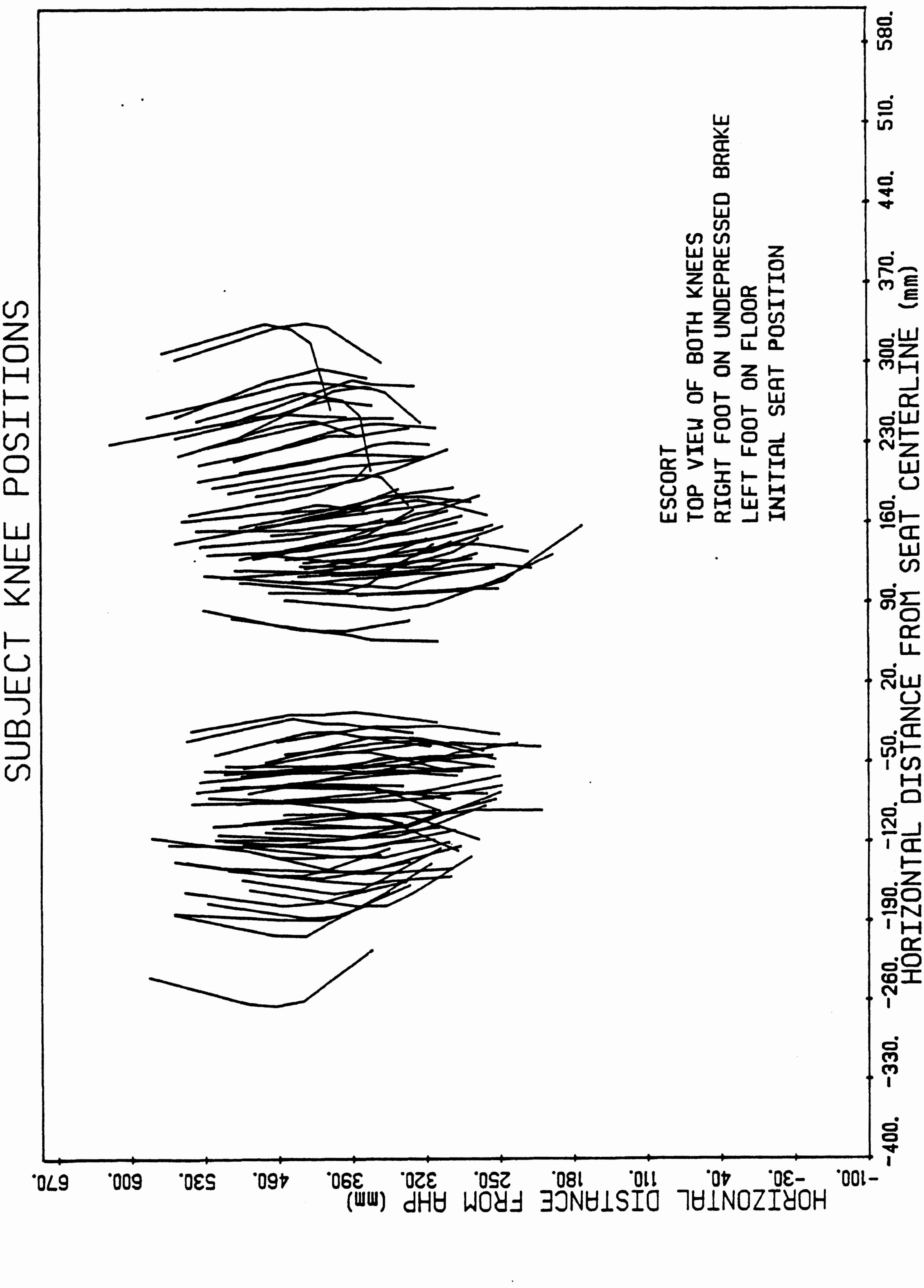
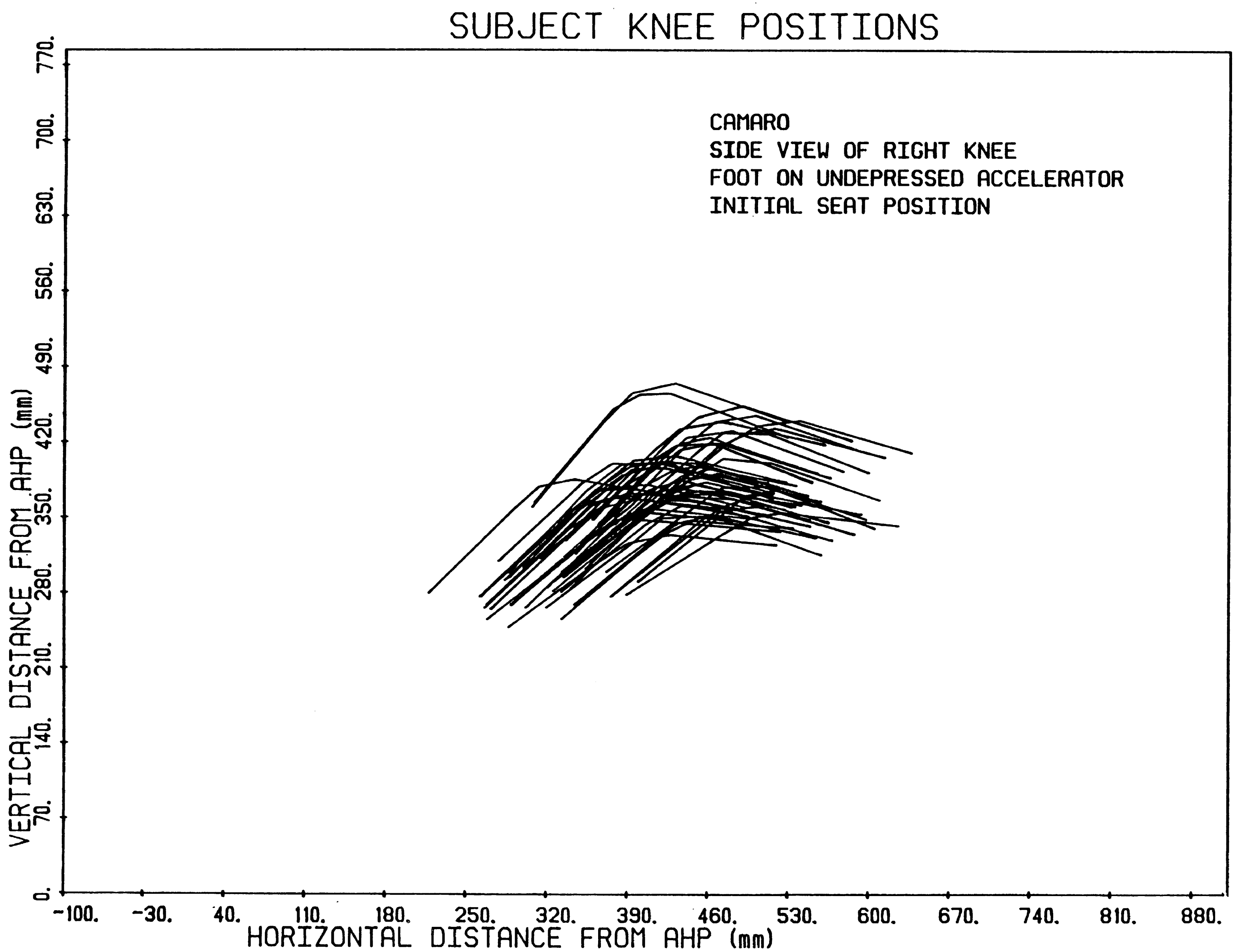


SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
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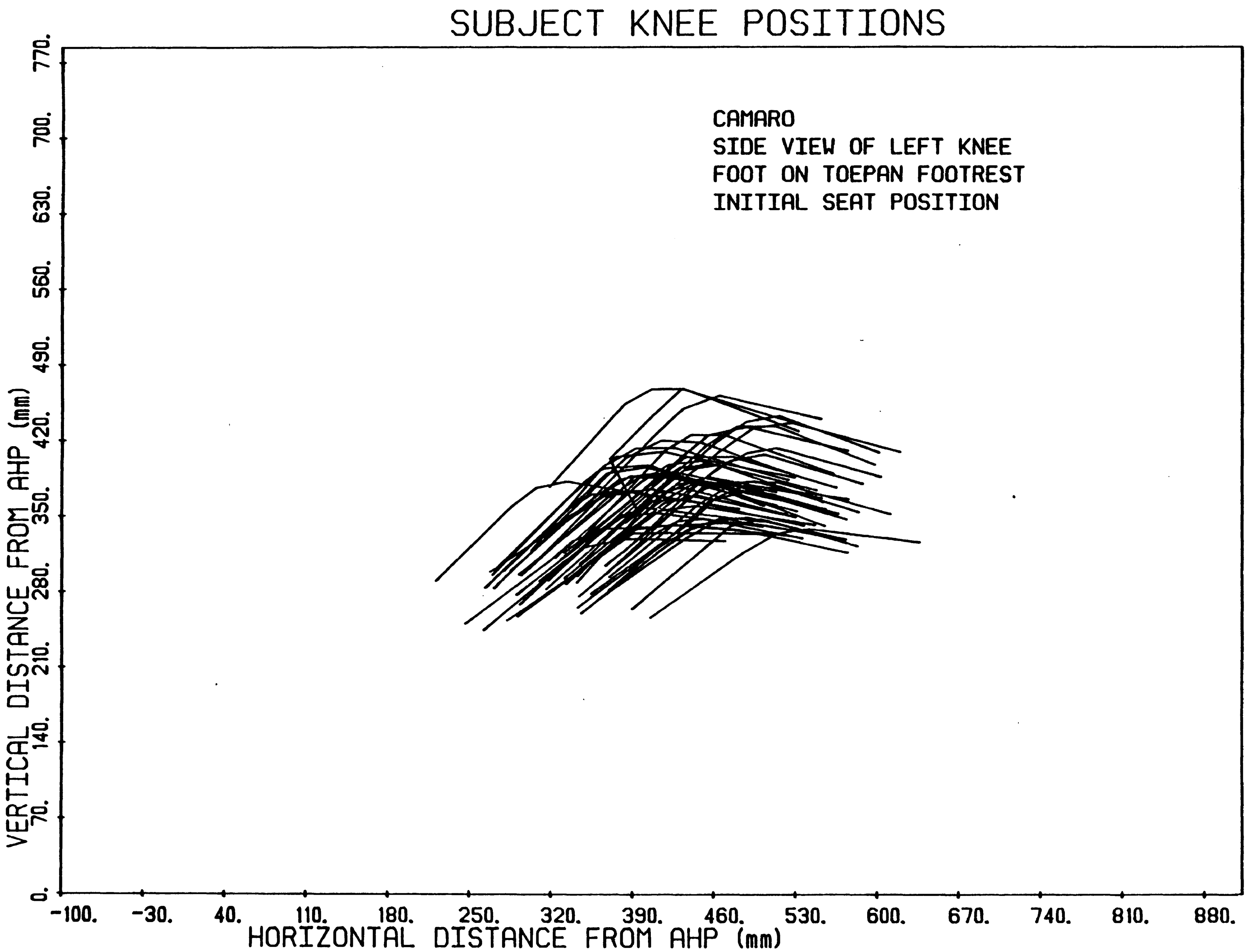
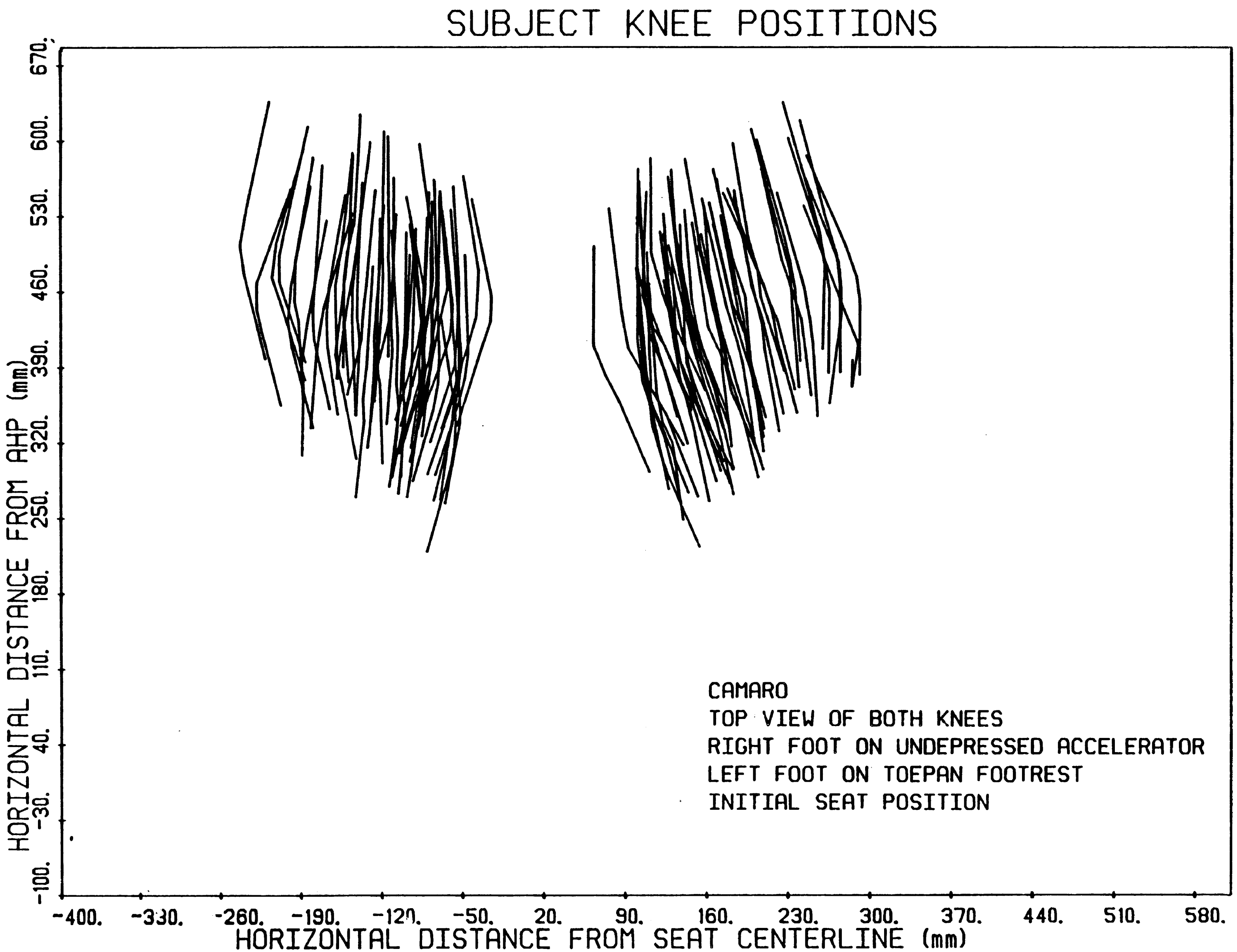
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

98


SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
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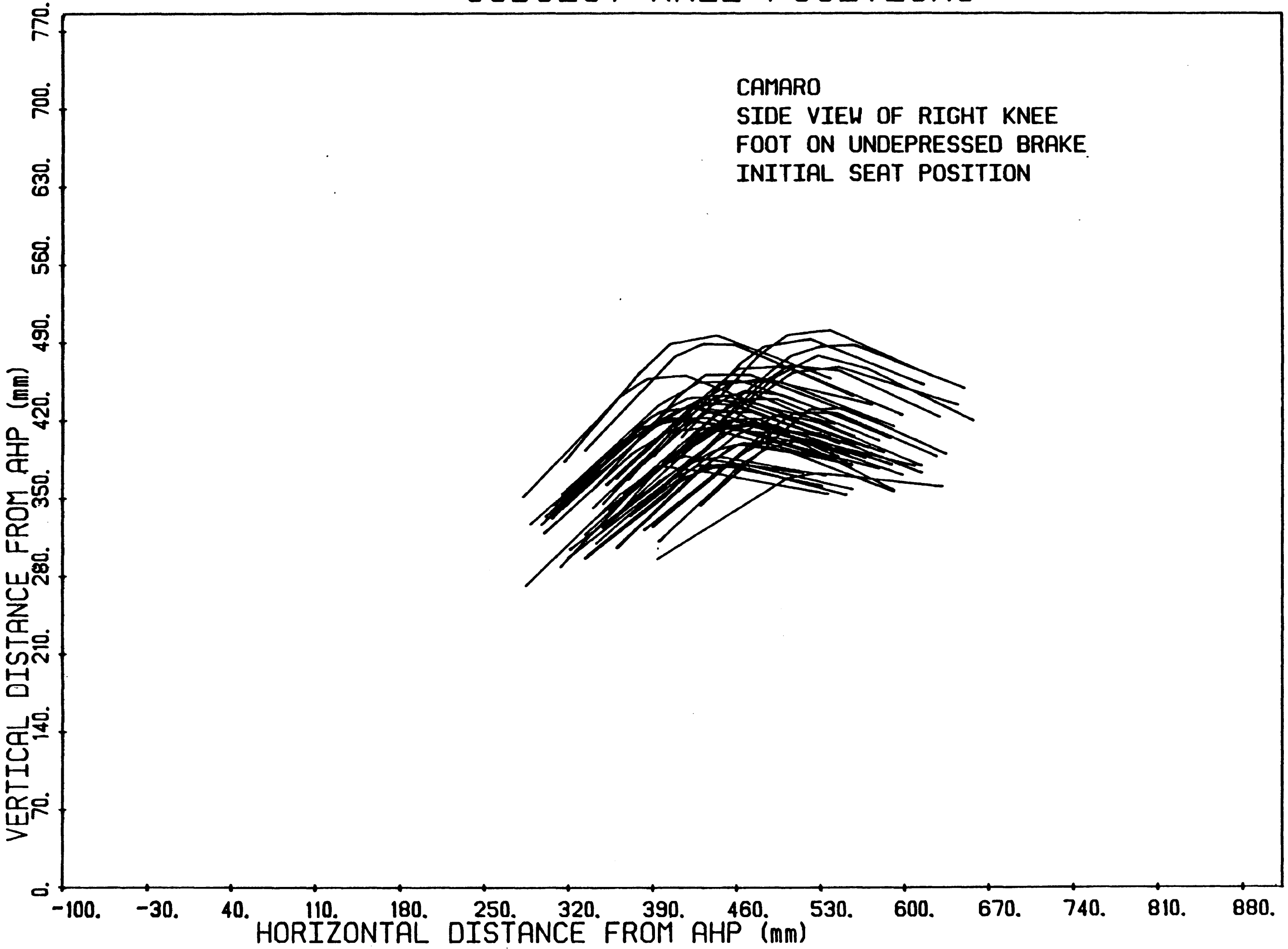
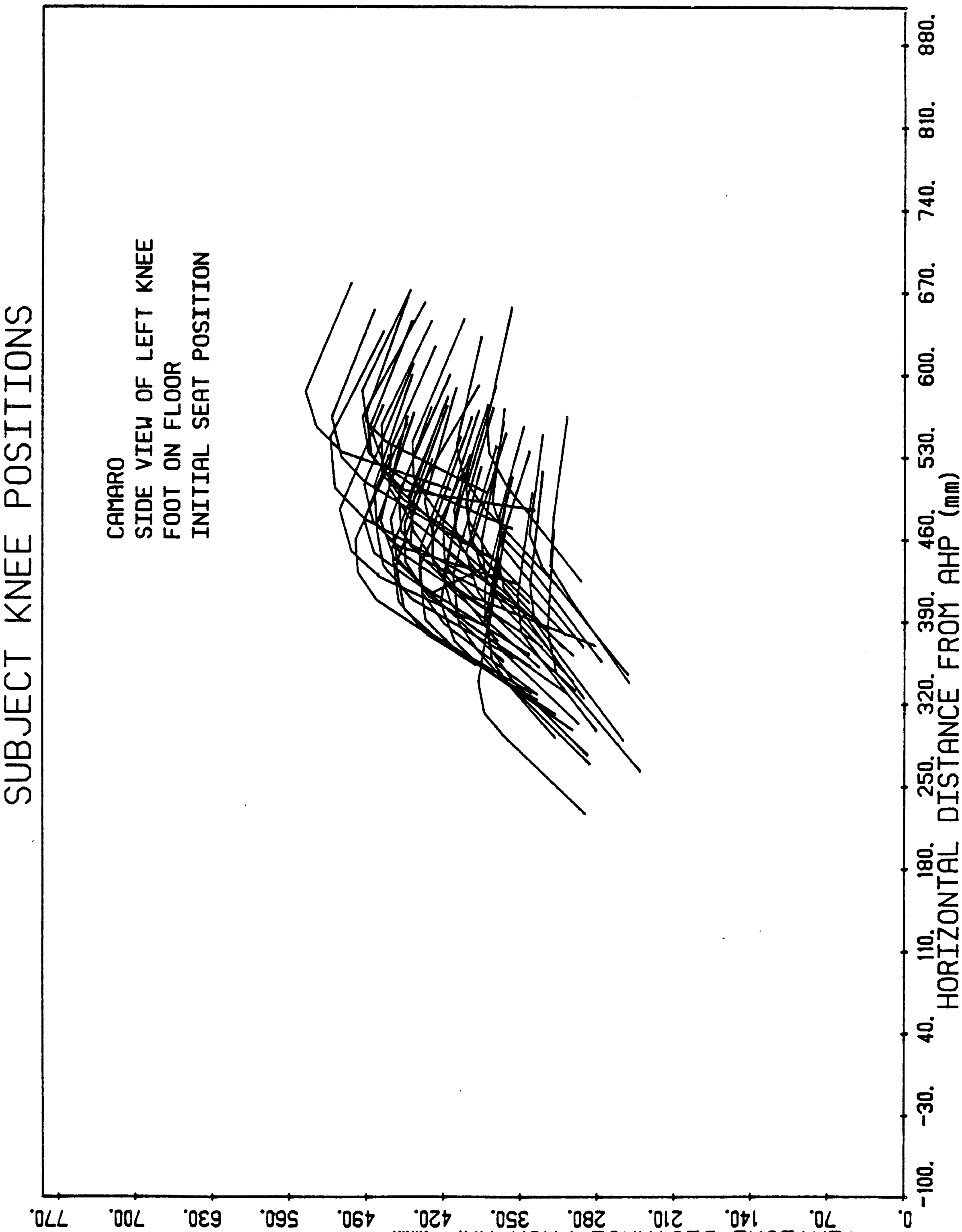
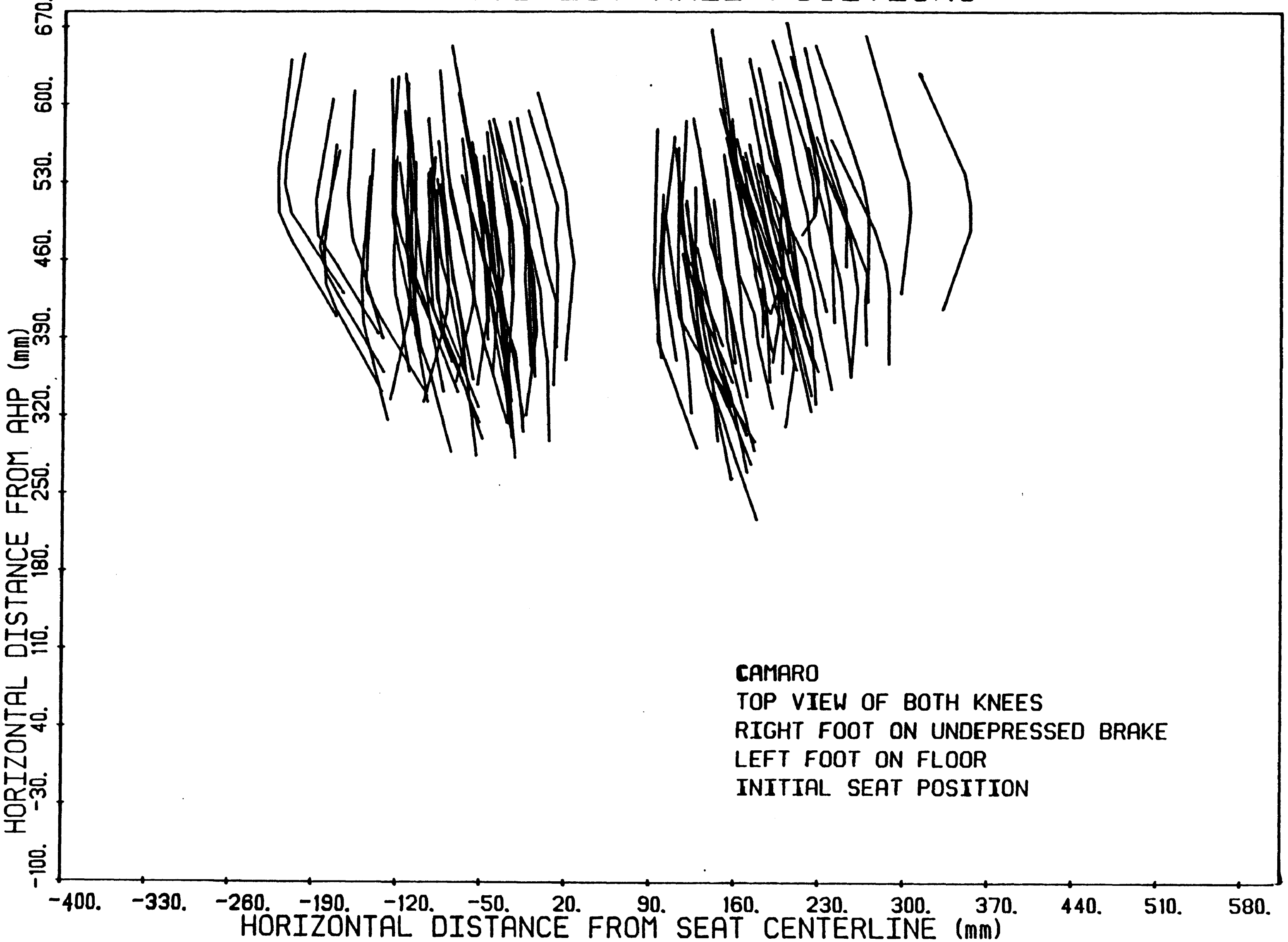
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION

SUBJECT KNEE POSITIONS



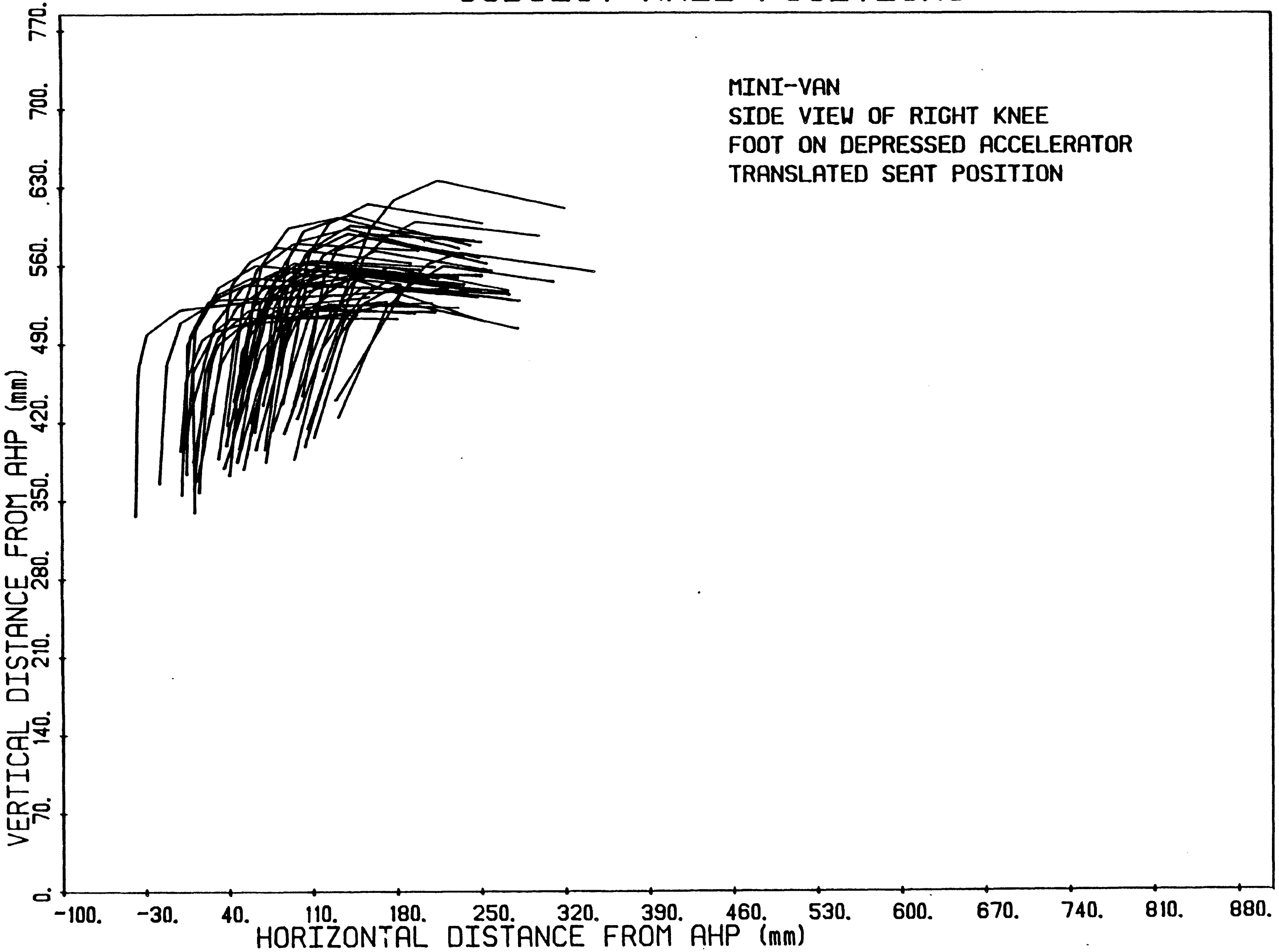

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.

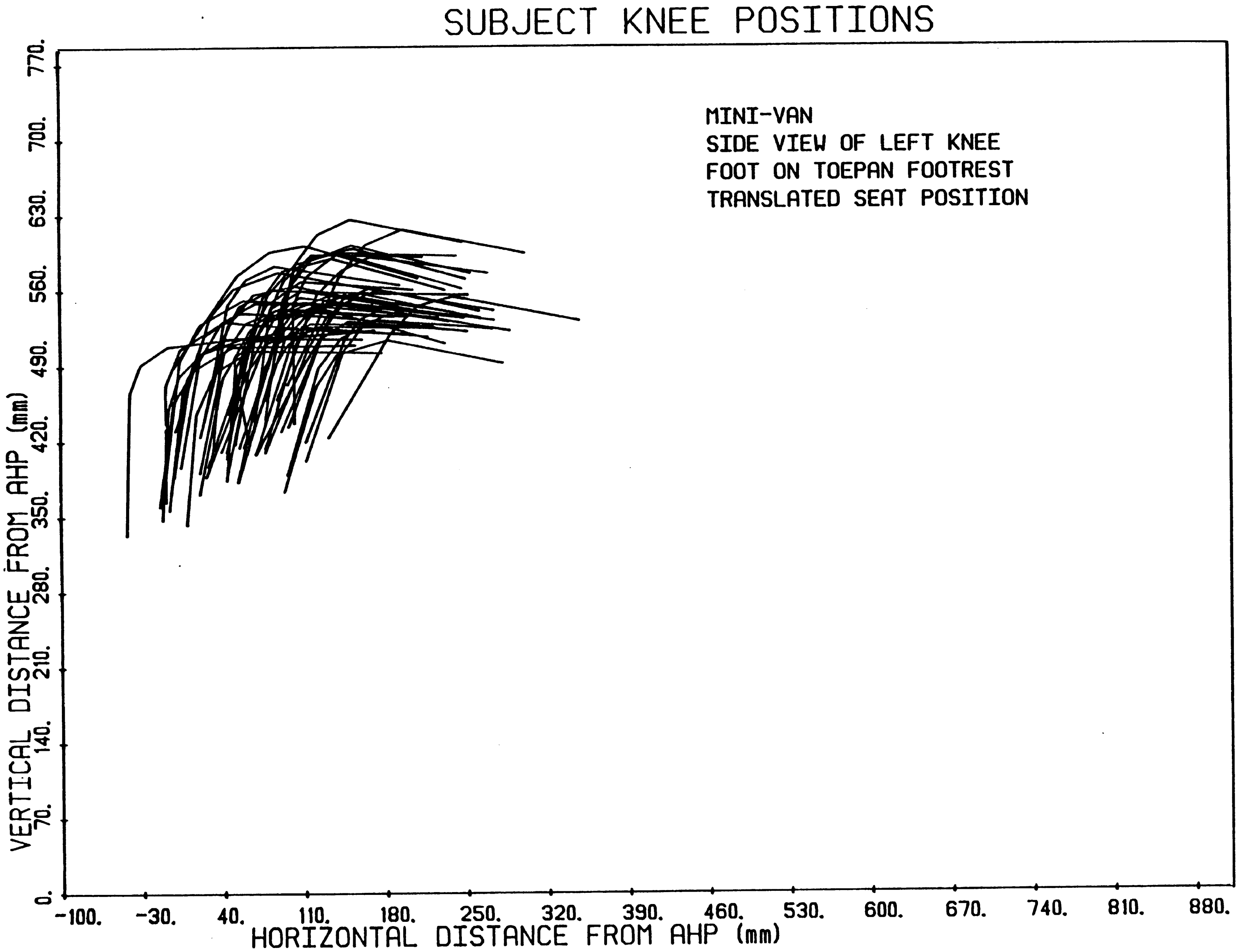
SUBJECT KNEE POSITIONS

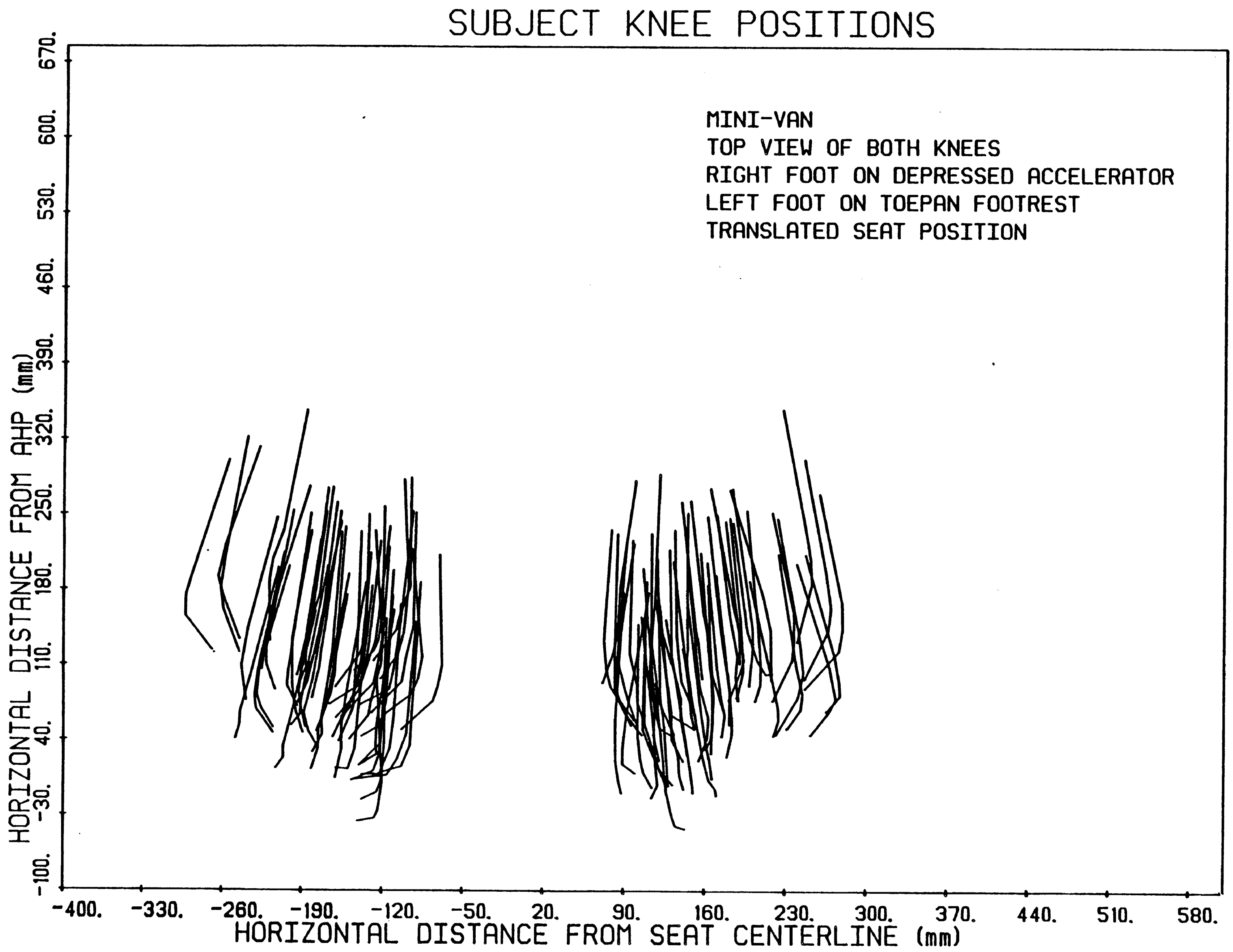


TRANSLATED SEAT CONDITIONS

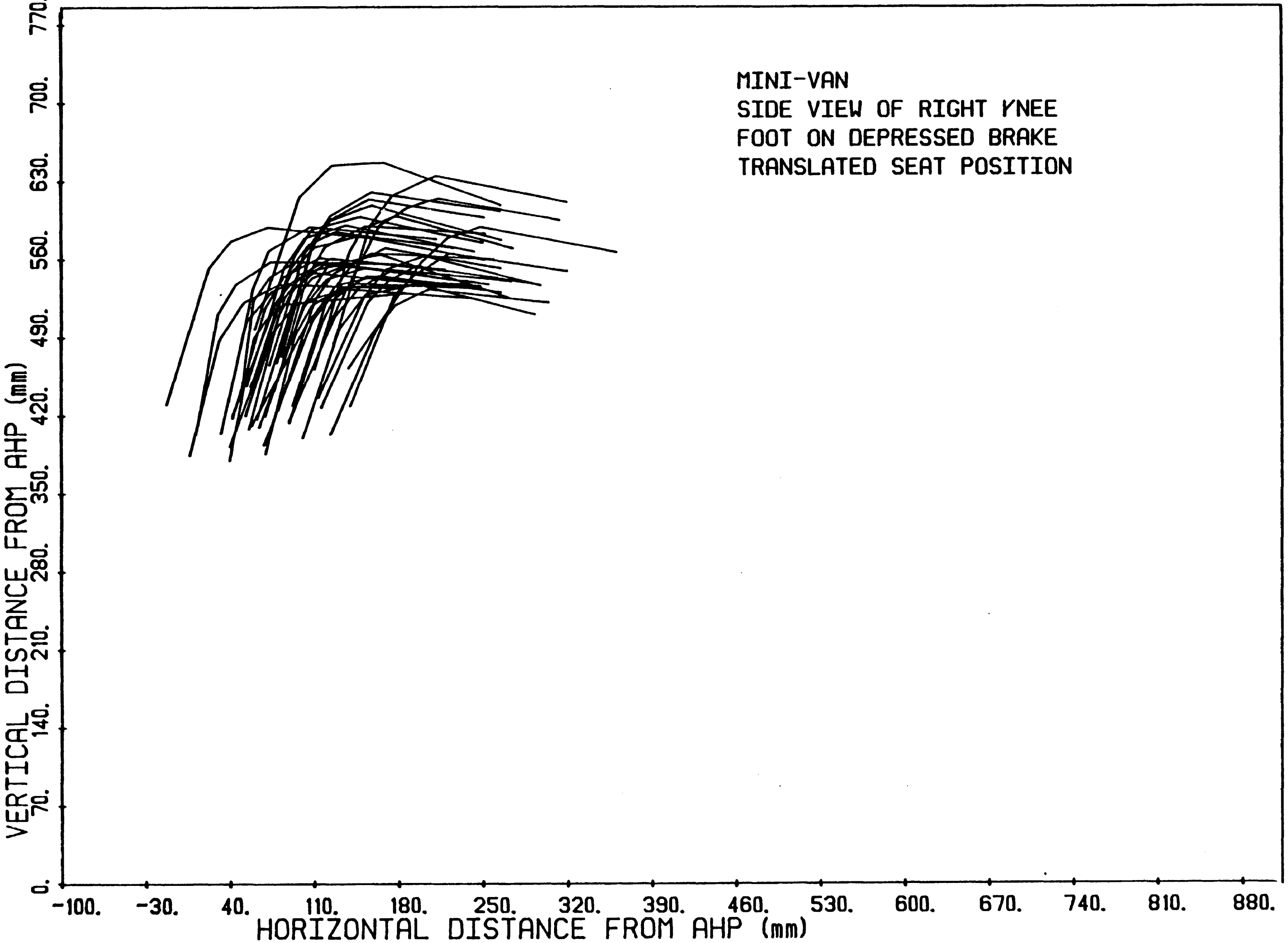
SUBJECT KNEE POSITIONS



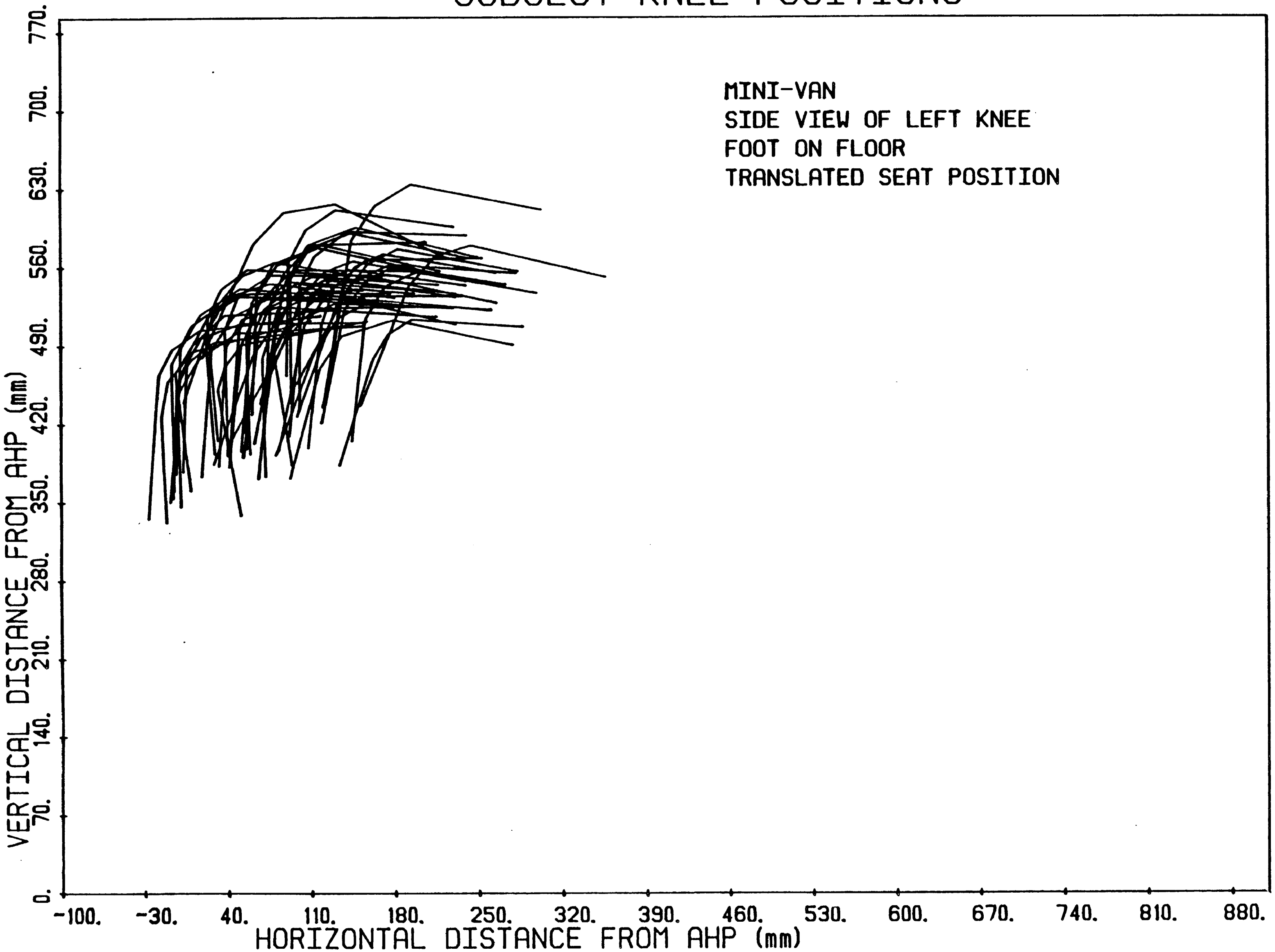

SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

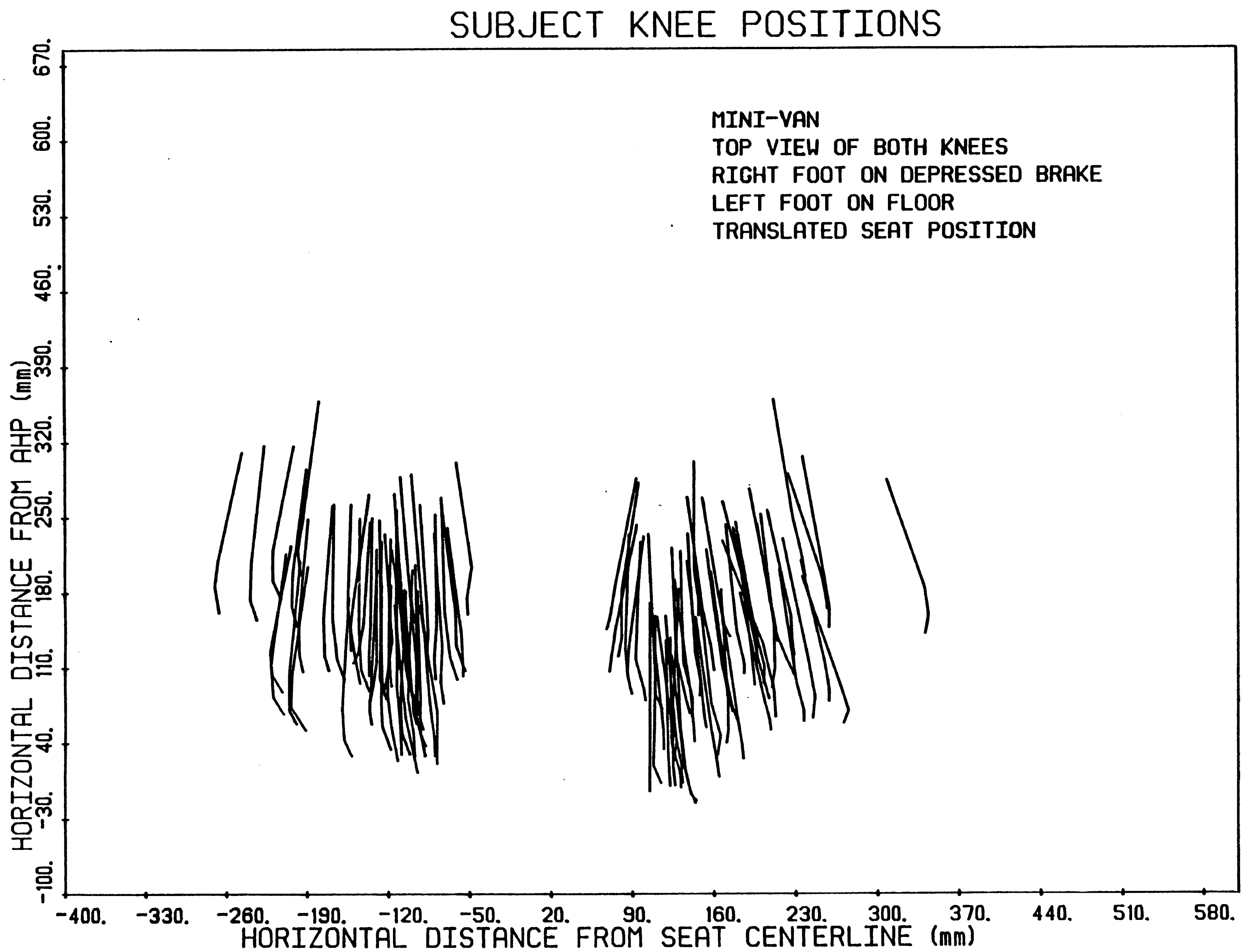

SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

SUBJECT KNEE POSITIONS



SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
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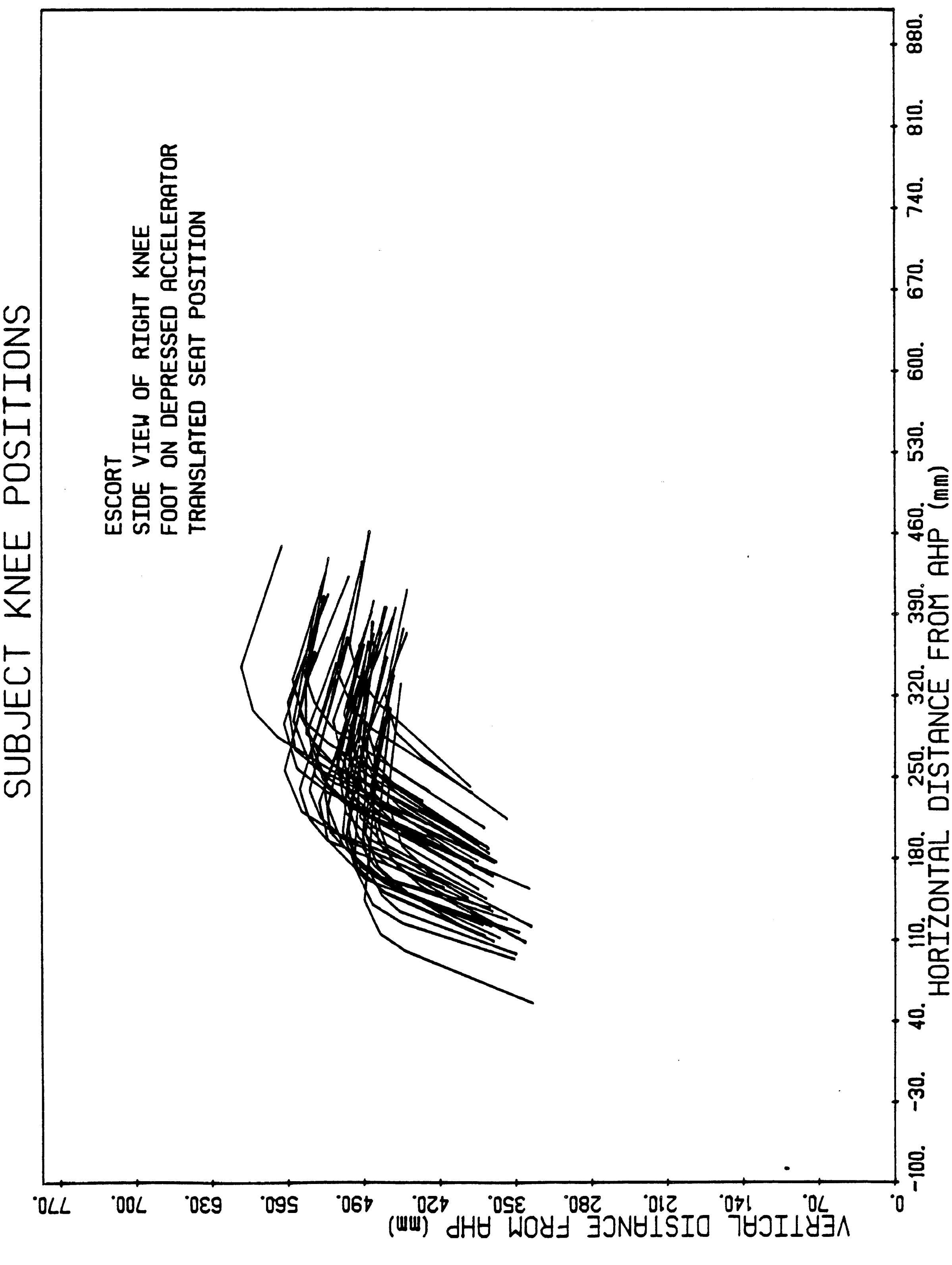
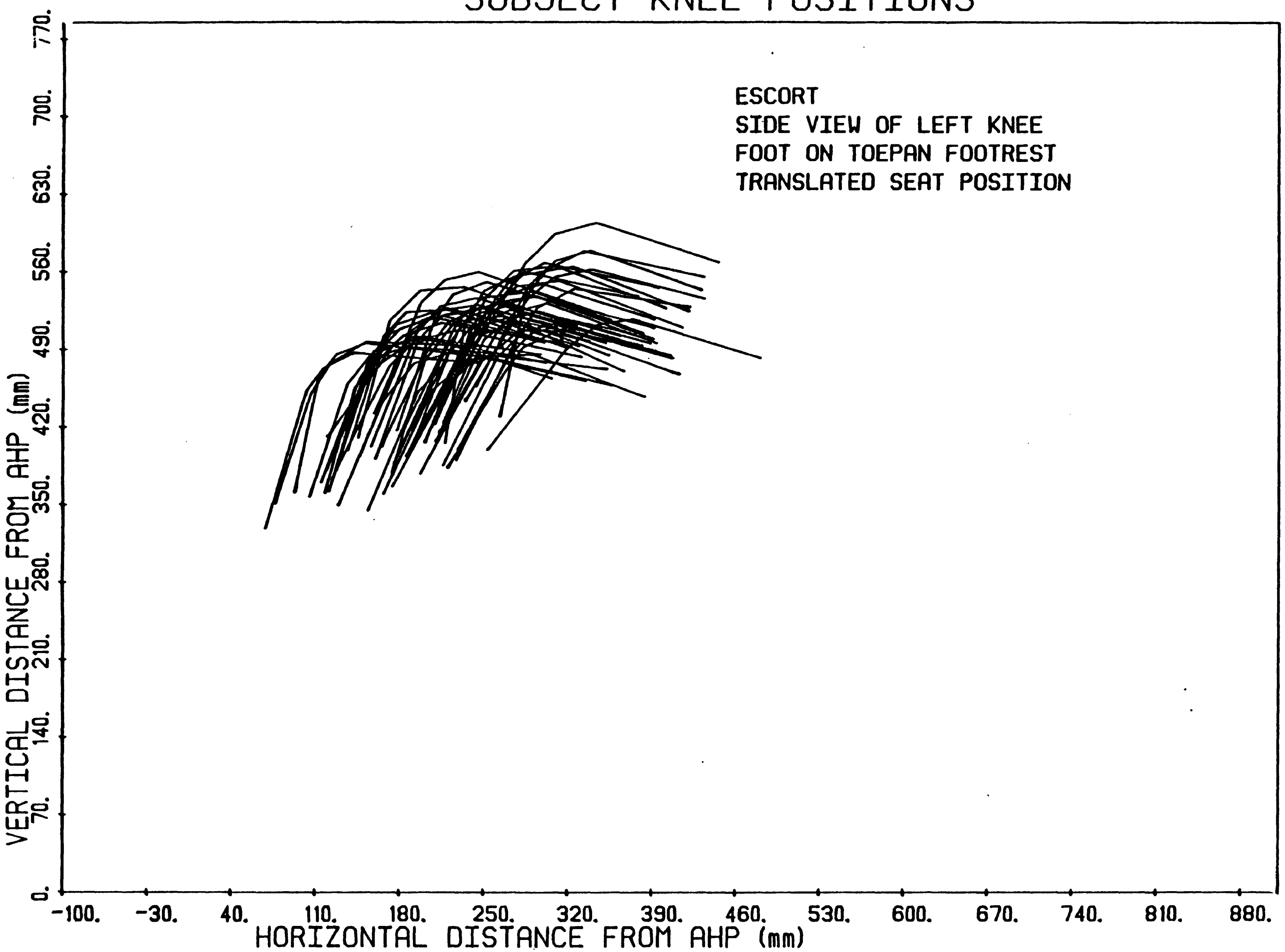
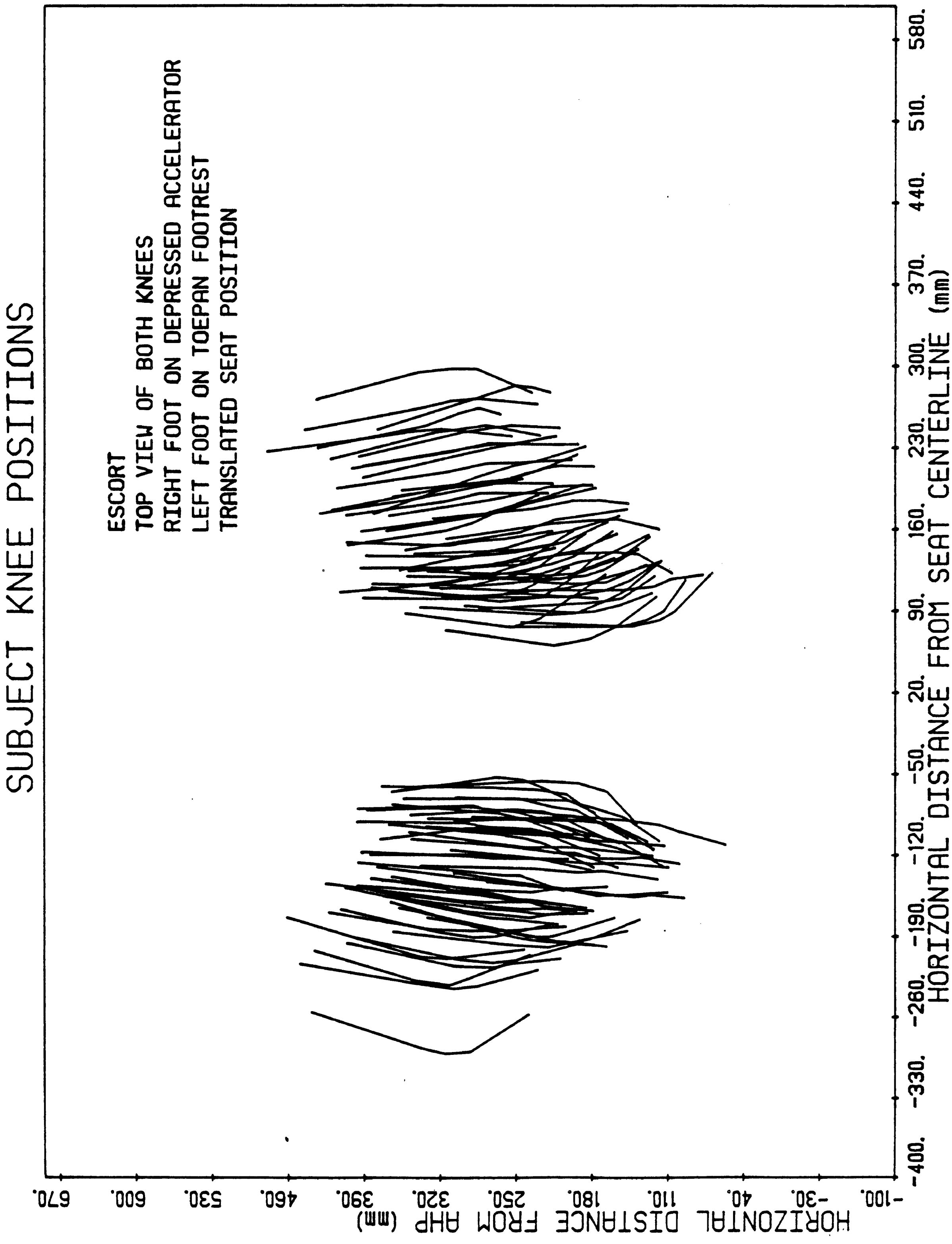
370.
440.
510.
580.


SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.

SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM AHP (mm)
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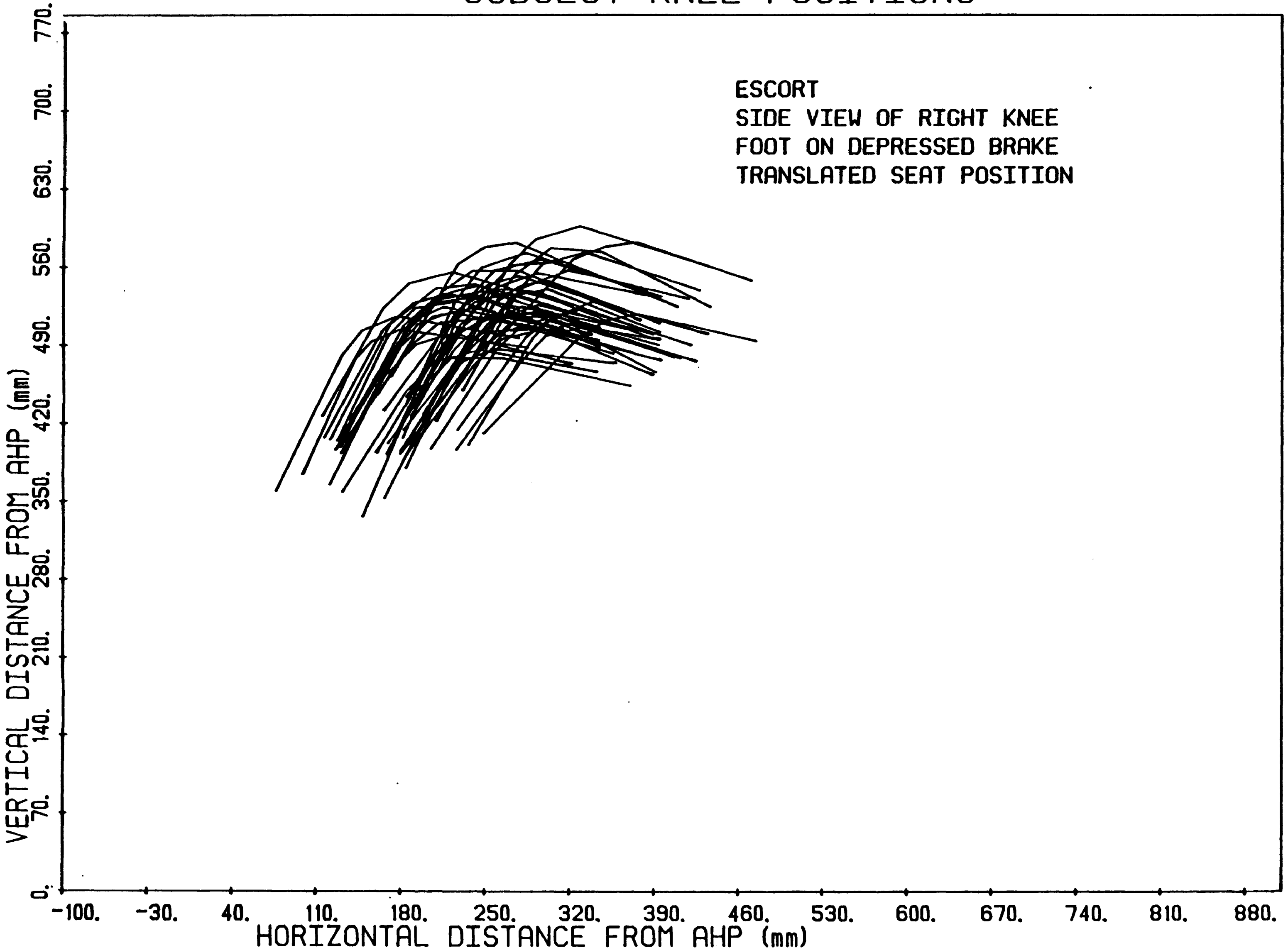
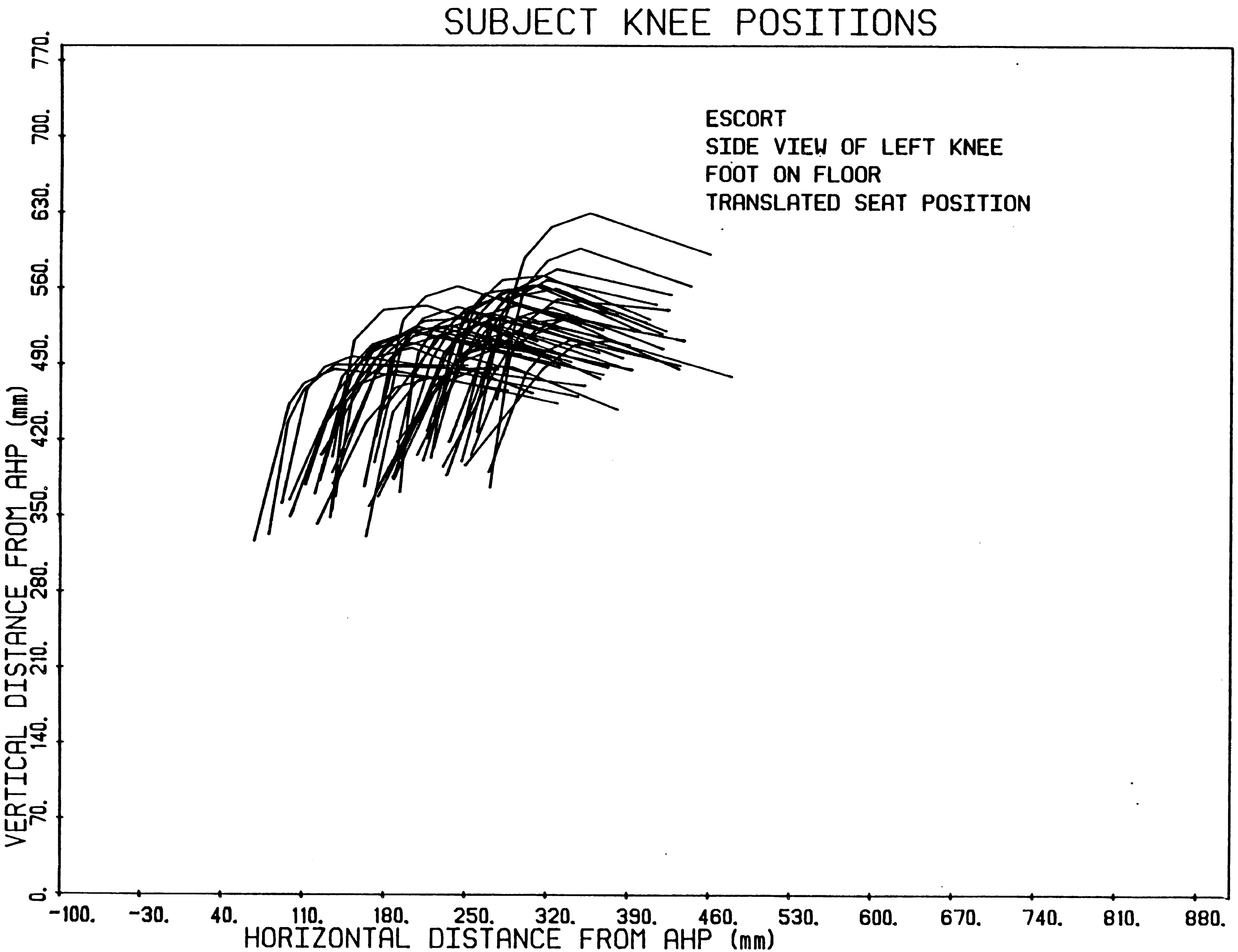
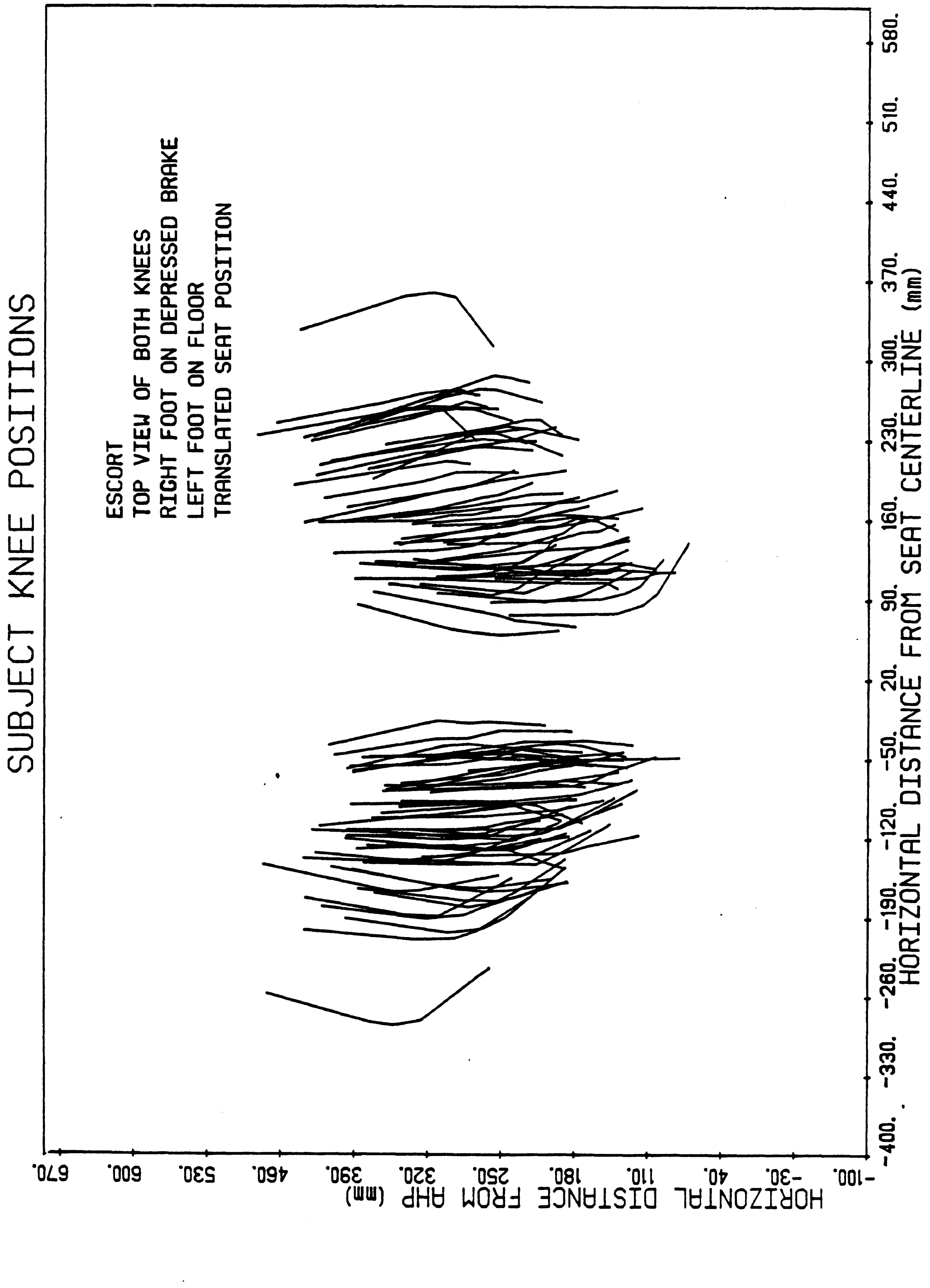
SUBJECT KNEE POSITIONS





SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.



SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM AHP (mm)
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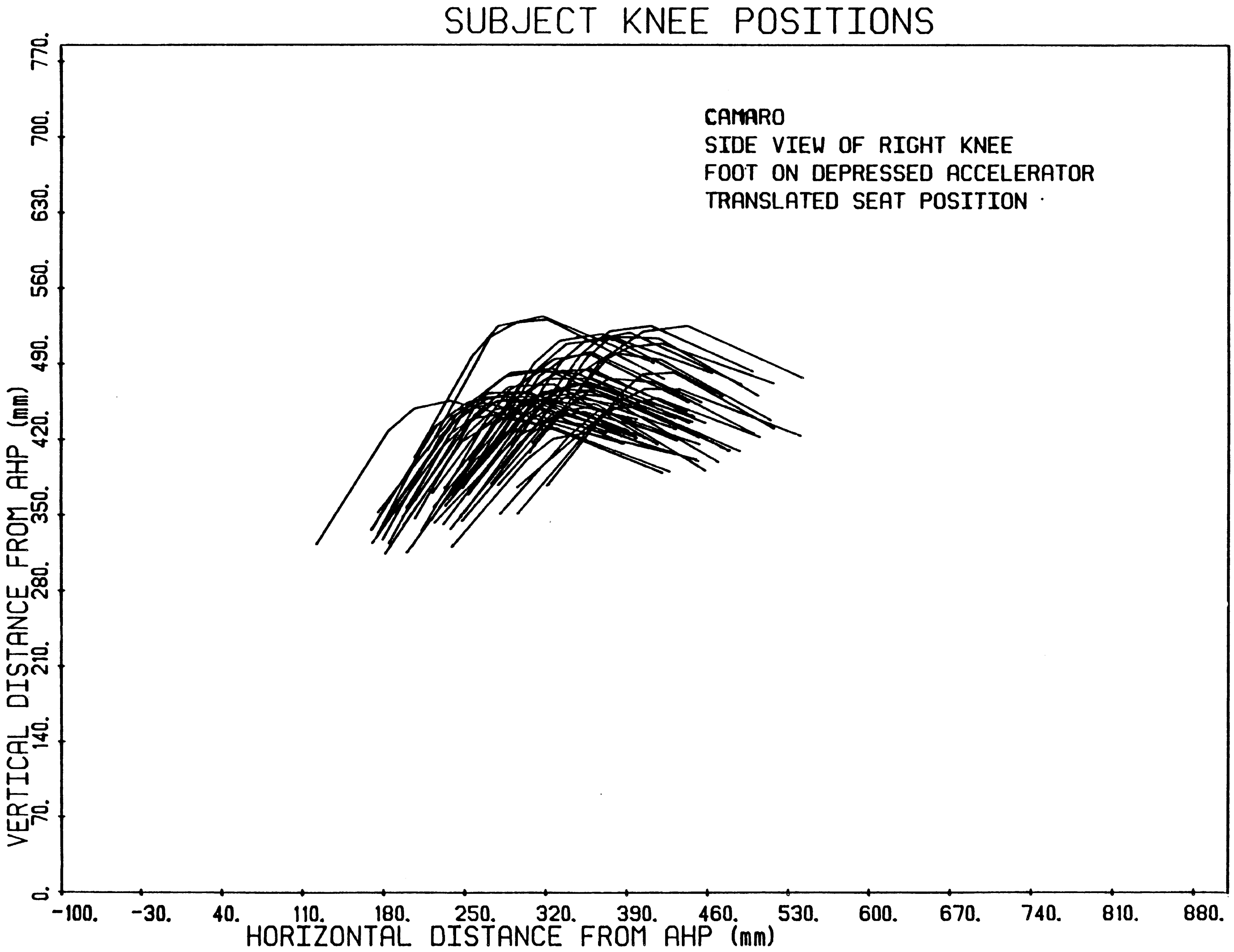

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
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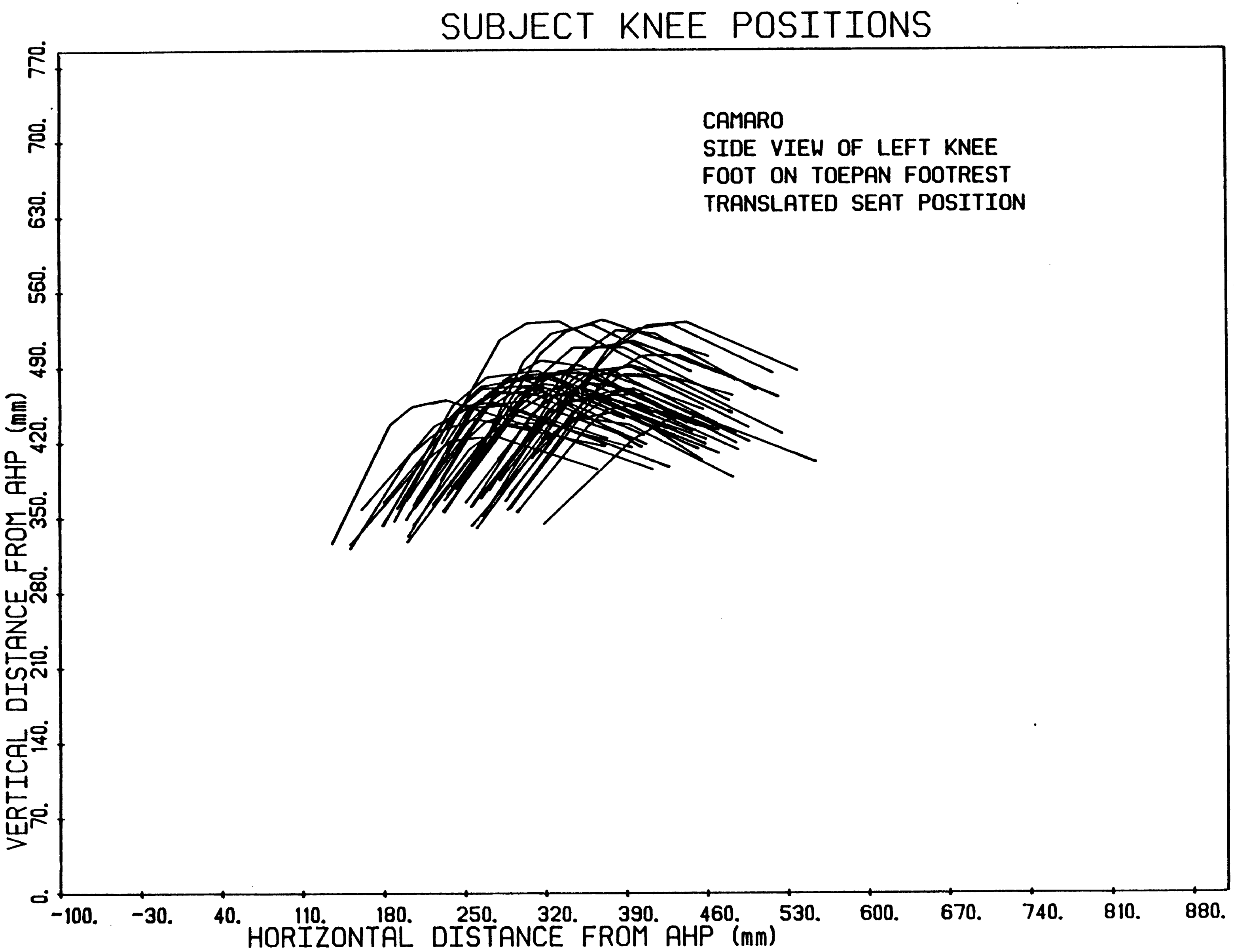
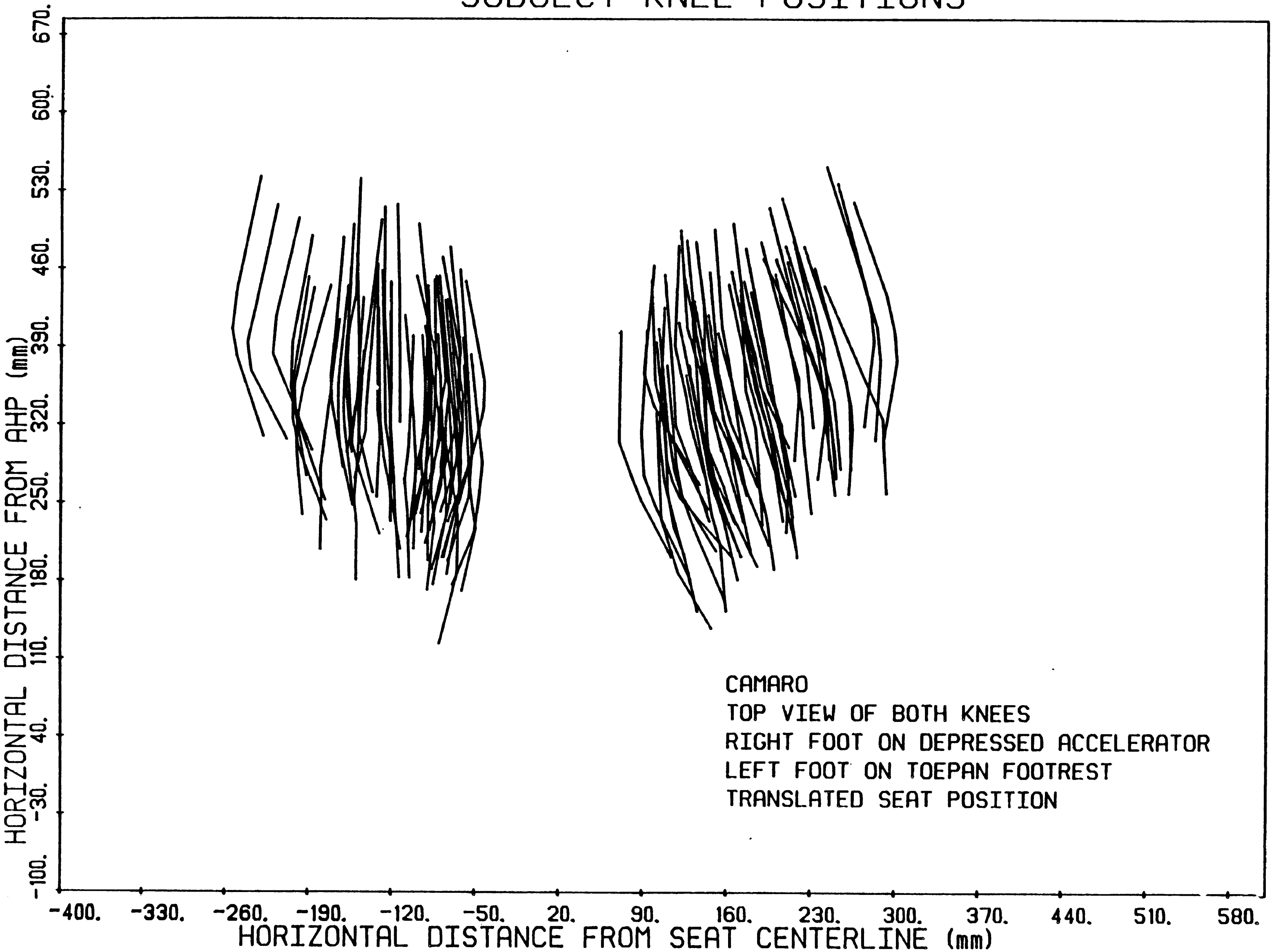
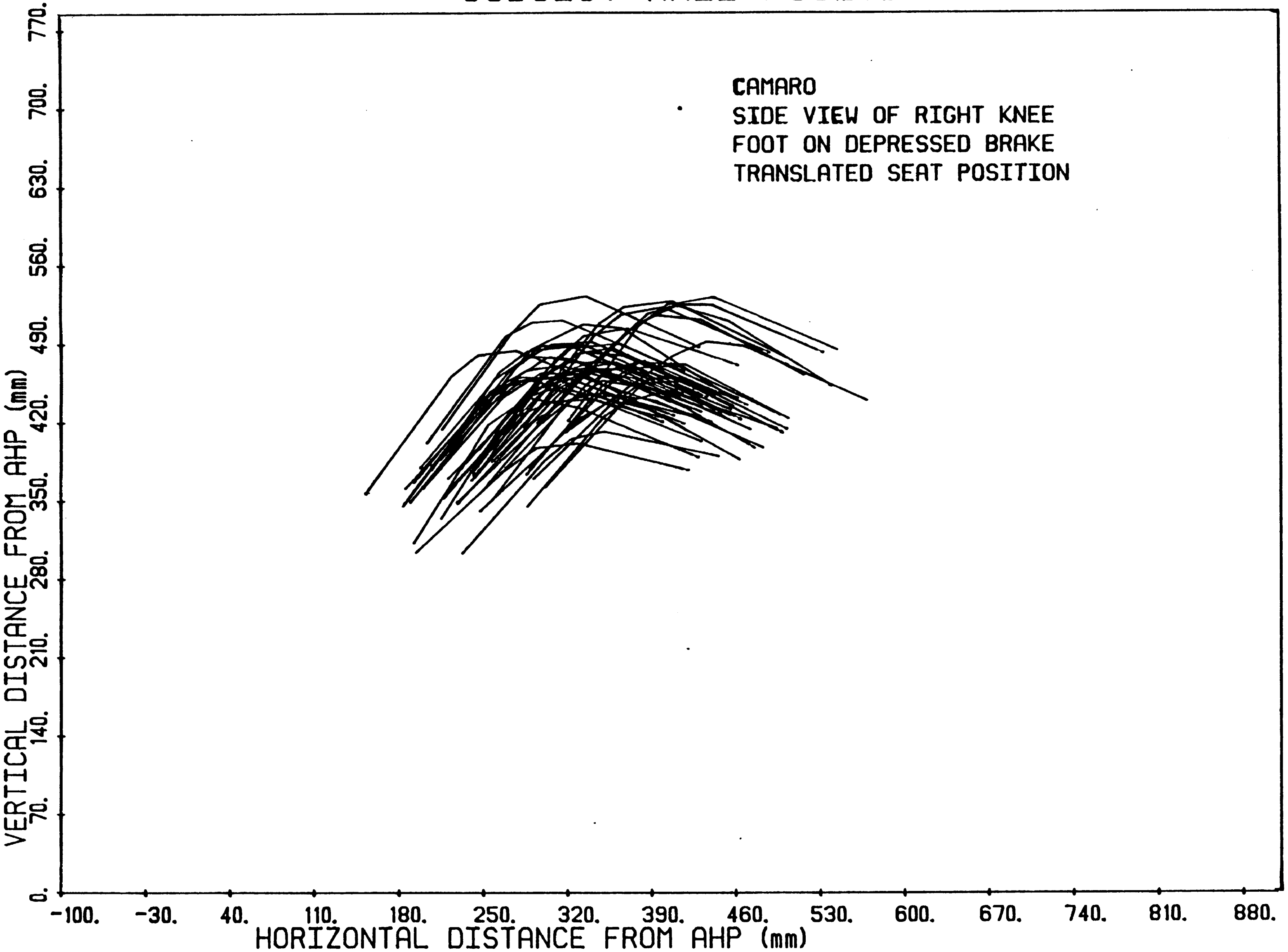
740.
810.
880.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

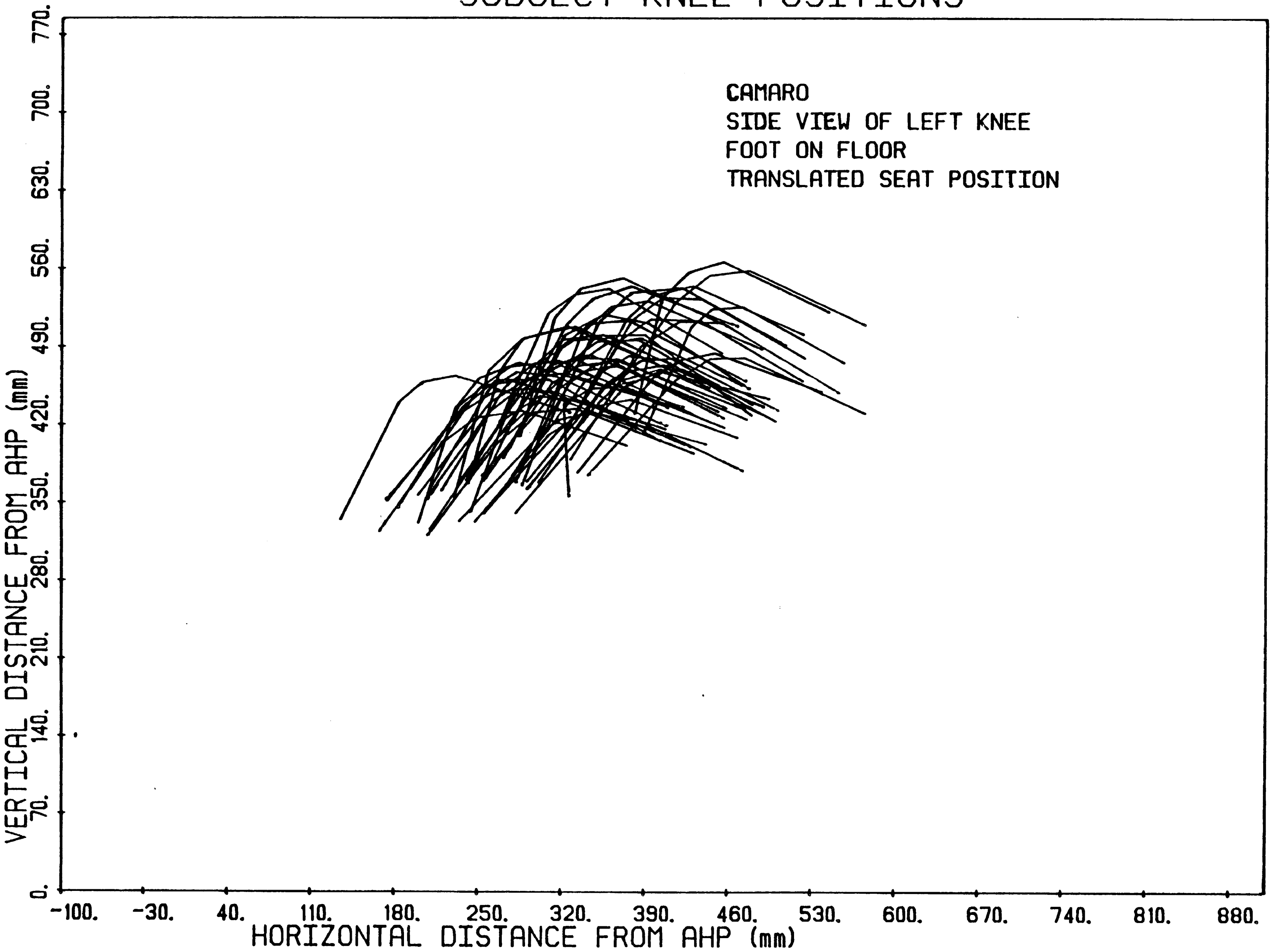
SUBJECT KNEE POSITIONS

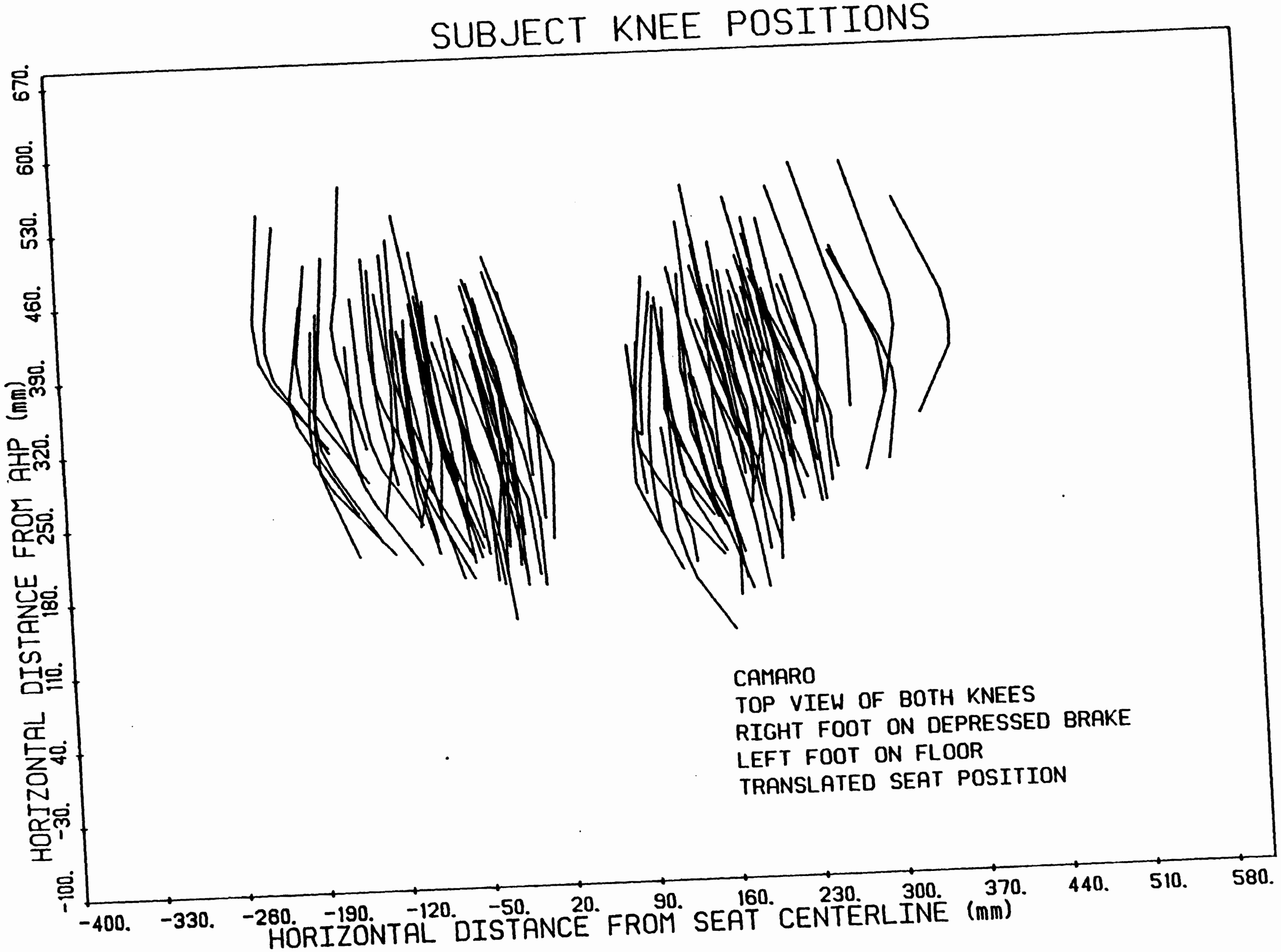


SUBJECT KNEE POSITIONS



SUBJECT KNEE POSITIONS



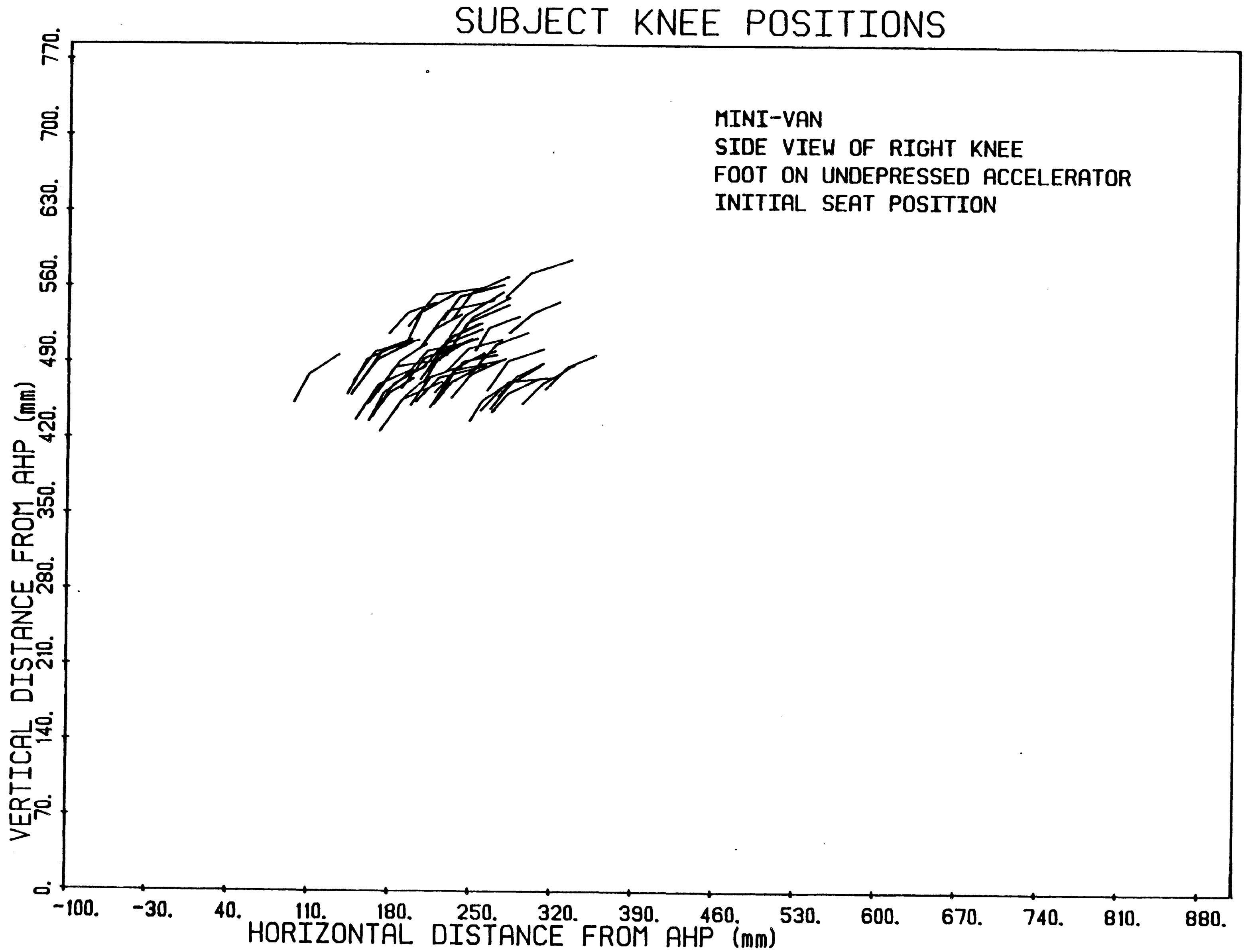


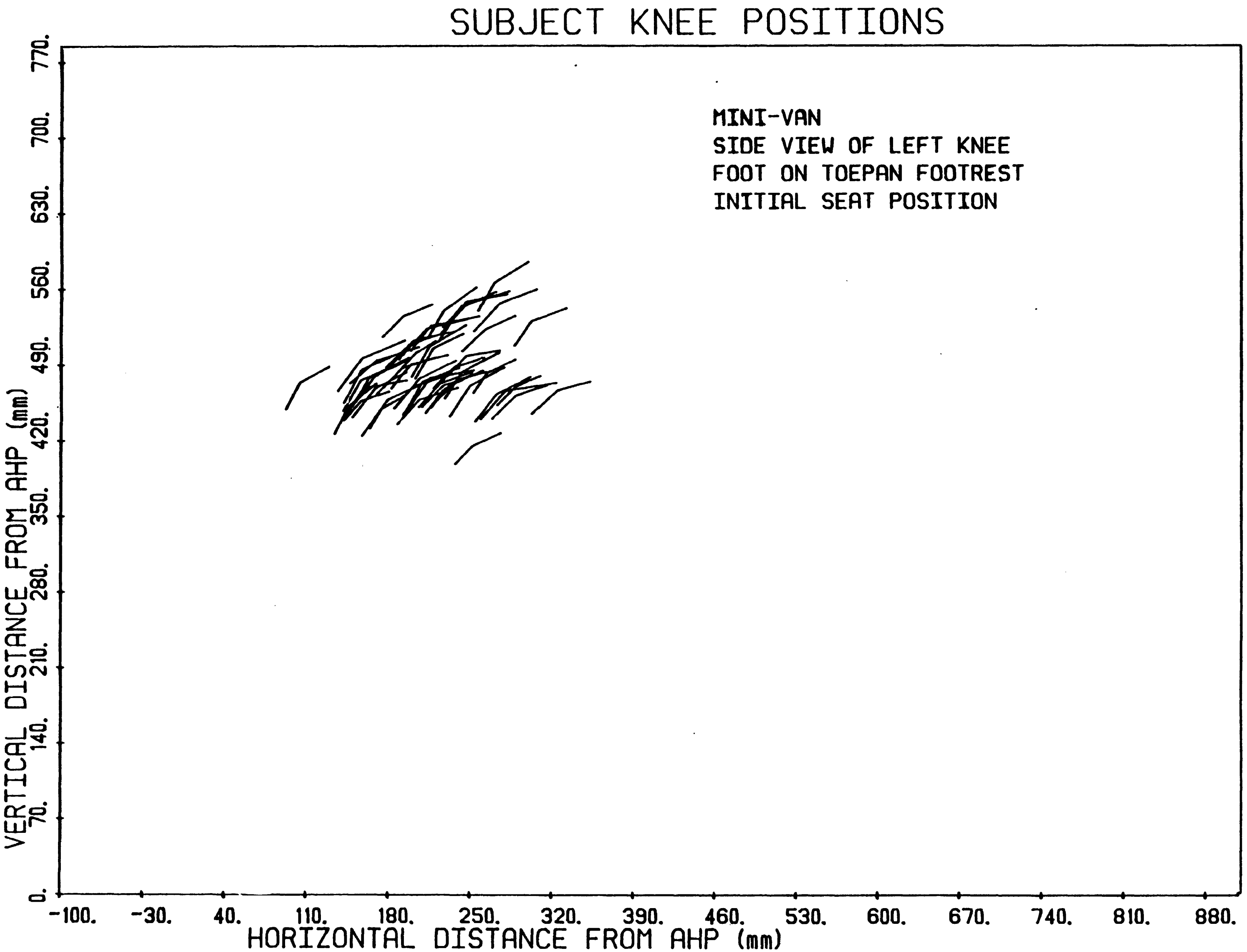
SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION

APPENDIX C

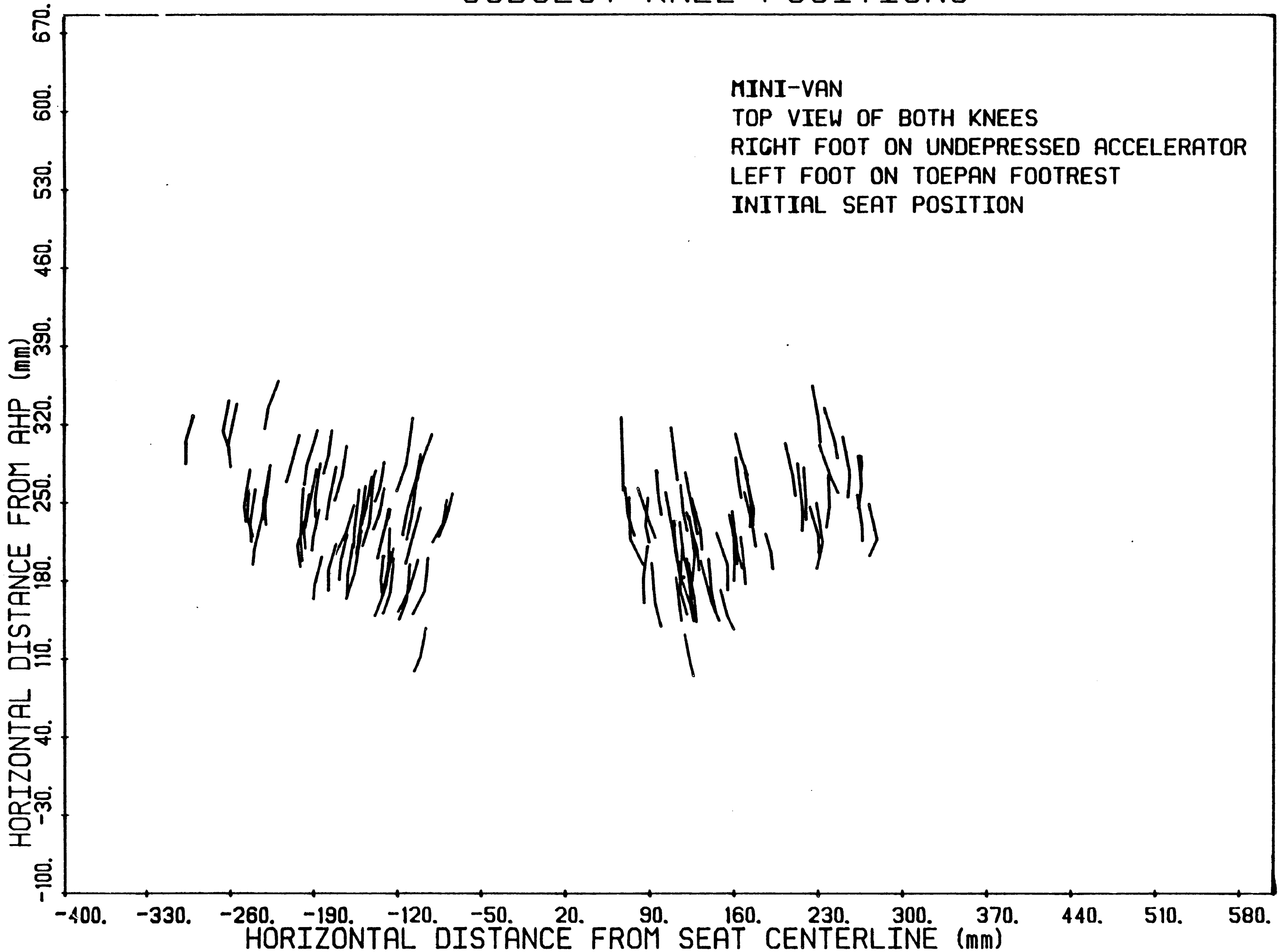
PLOTS OF KNEE LOCATIONS BY SUBJECT USING THREE MIDLINE TARGETS ON EACH PATELLA

UNTRANSLATED SEAT CONDITIONS

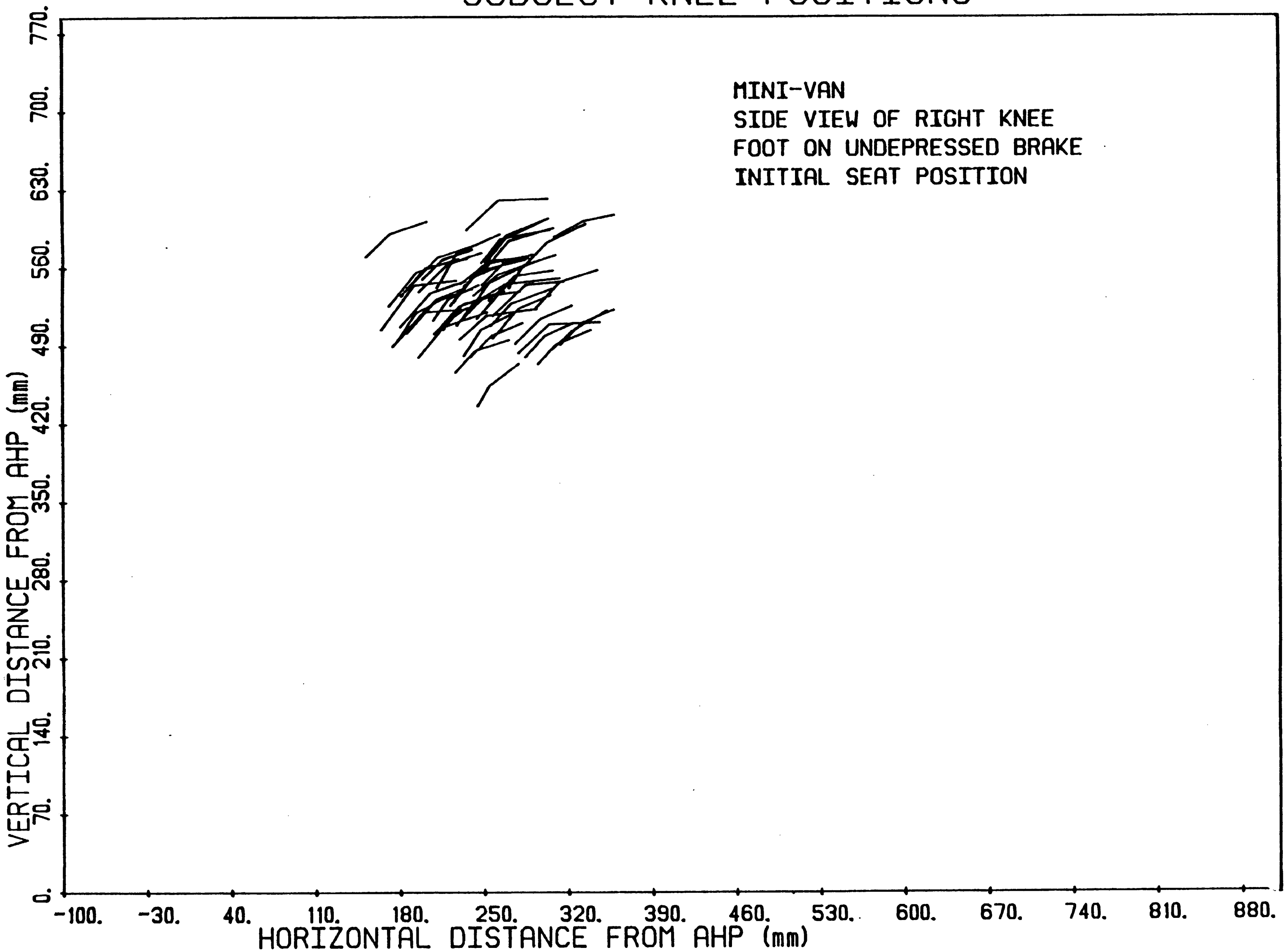

SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

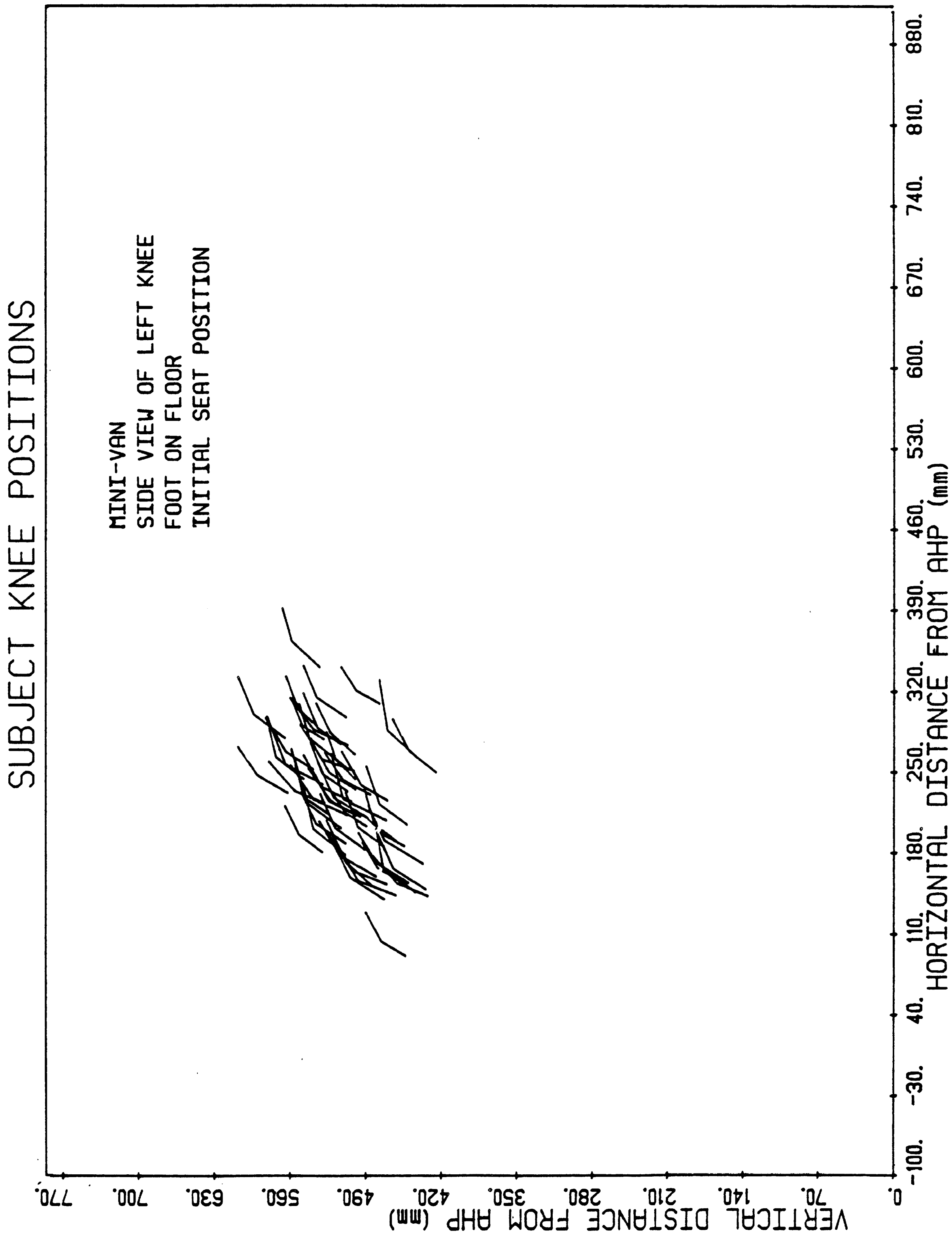

SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

SUBJECT KNEE POSITIONS



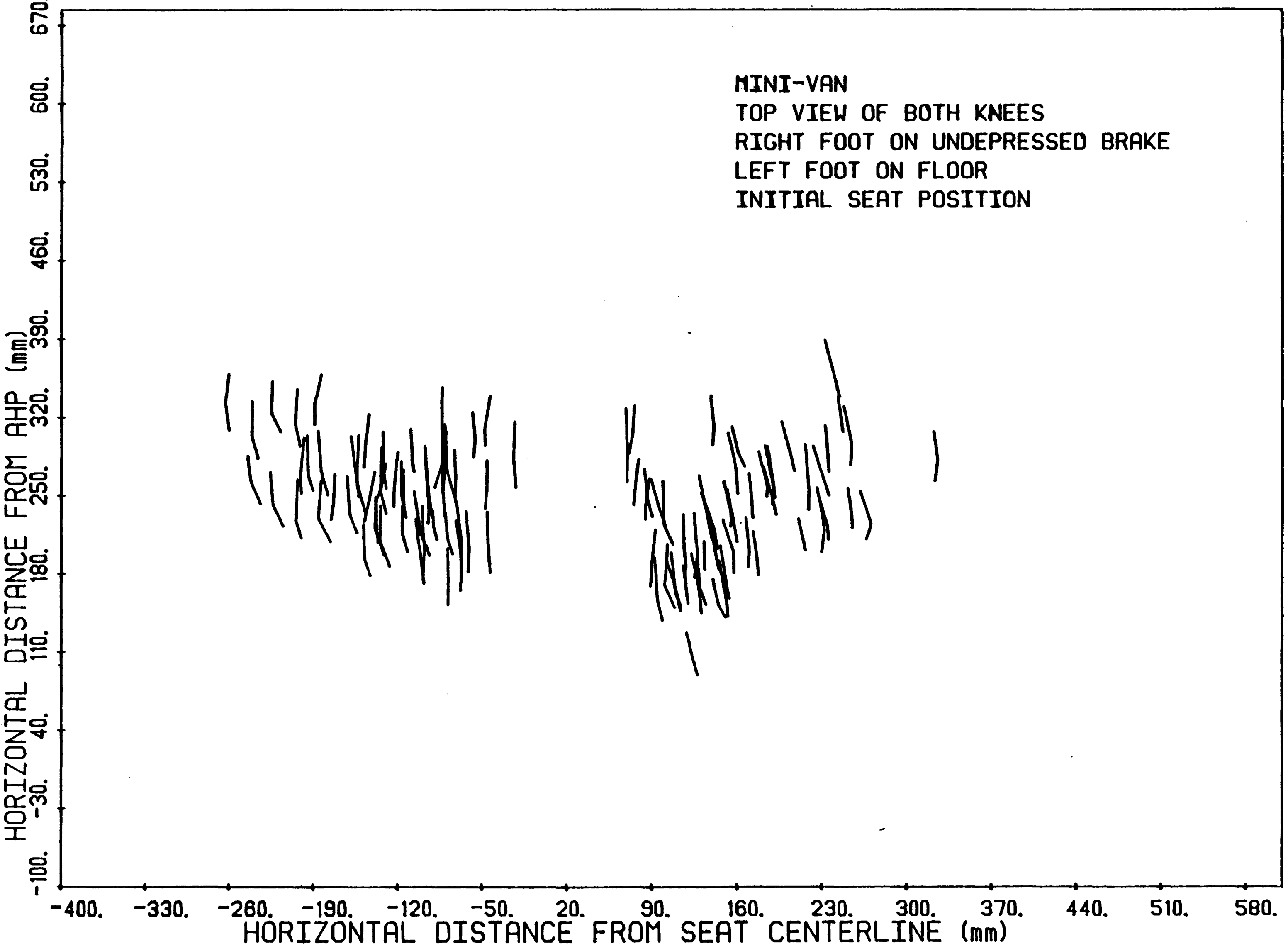
SUBJECT KNEE POSITIONS



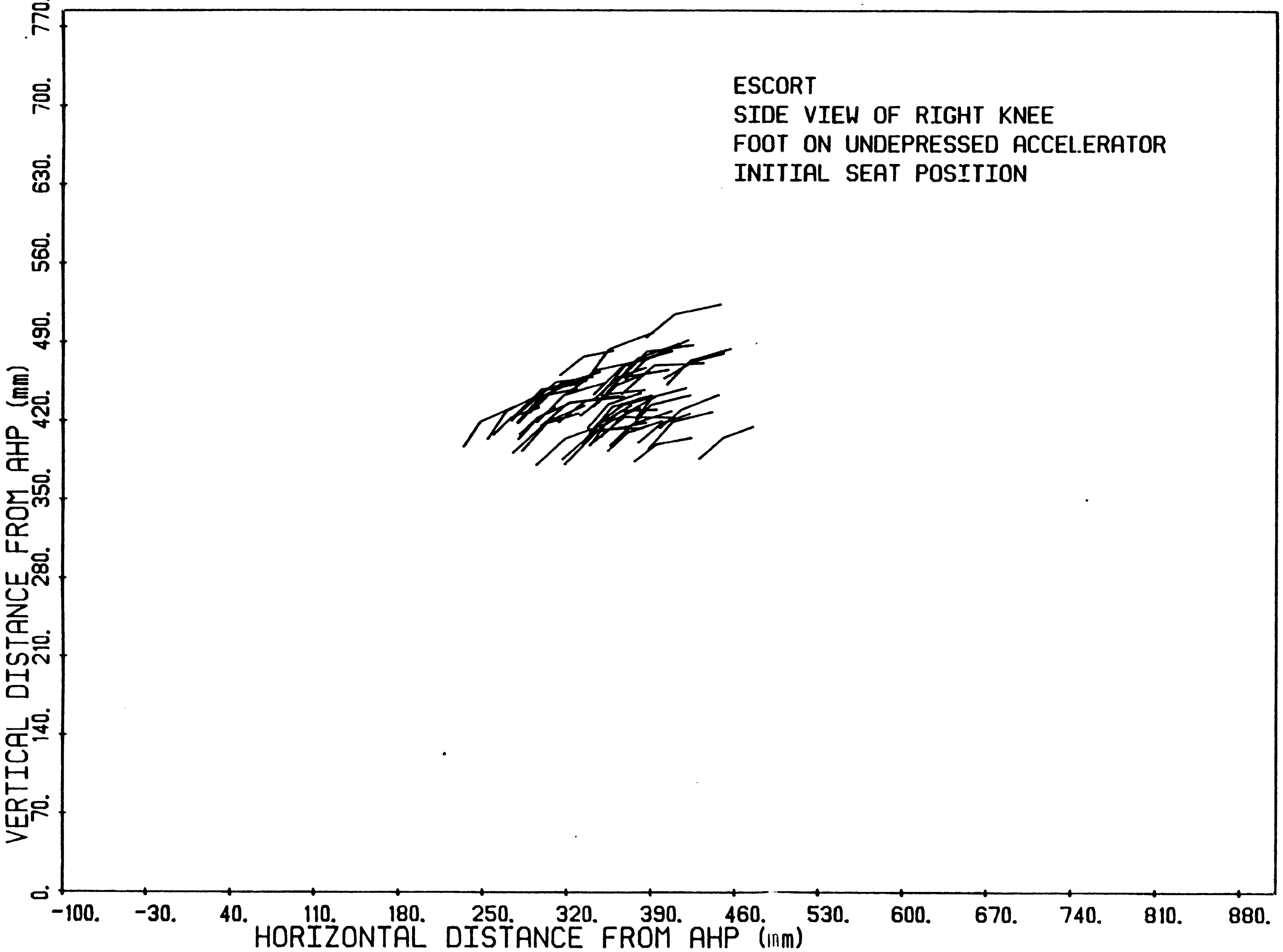


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
HORIZONTAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
VERTICAL DISTANCE FROM AHP (mm)

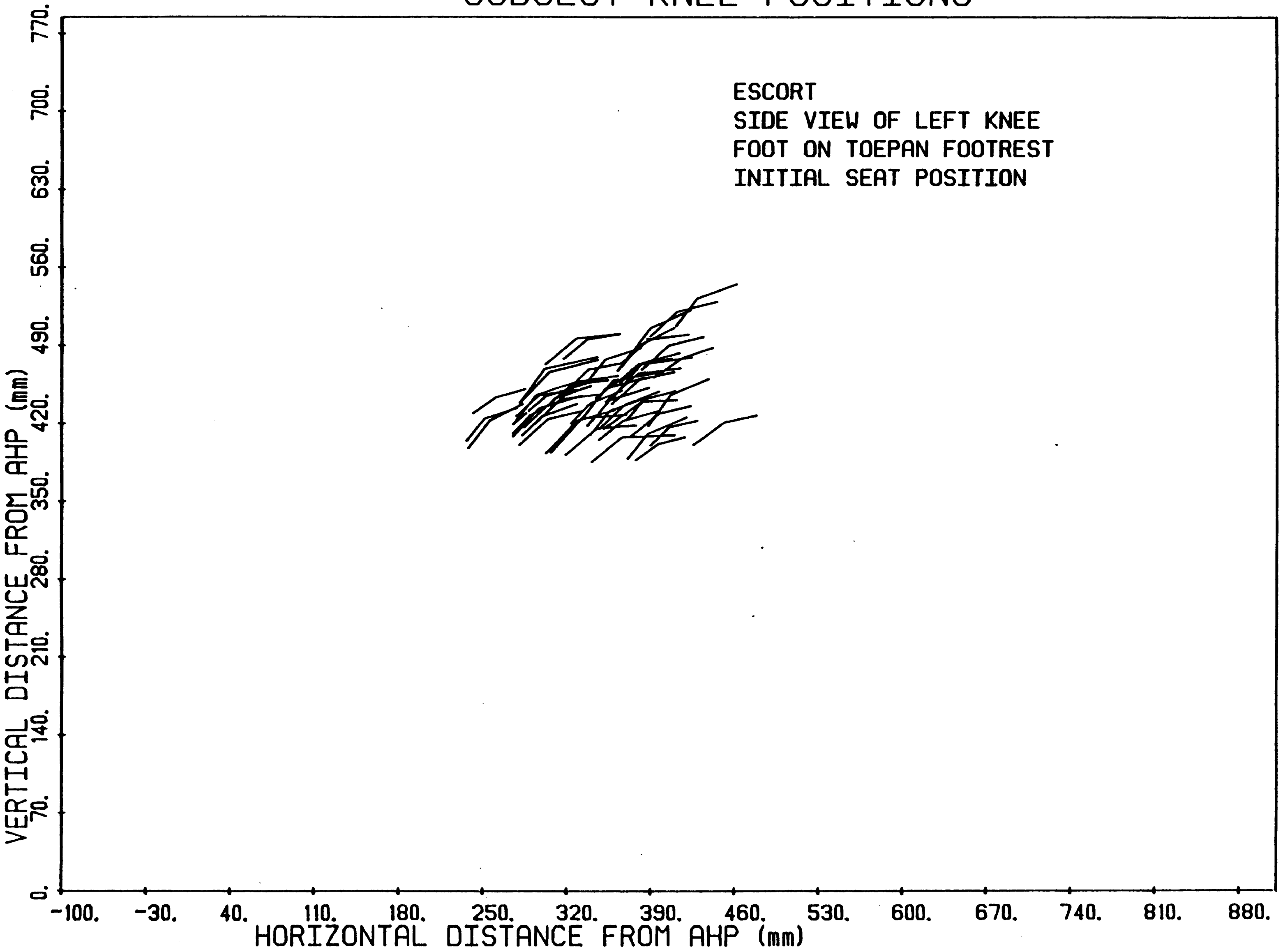
SUBJECT KNEE POSITIONS

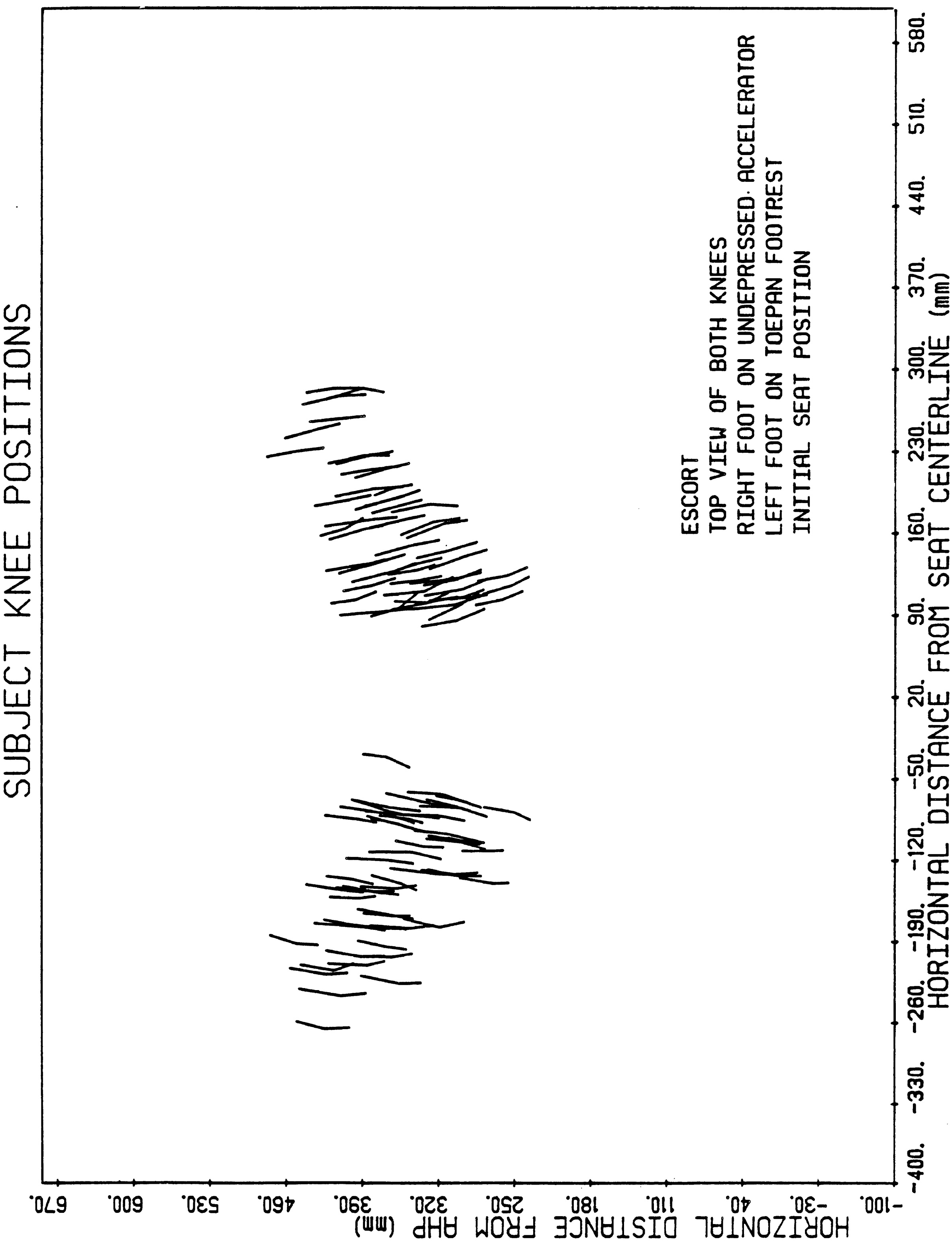


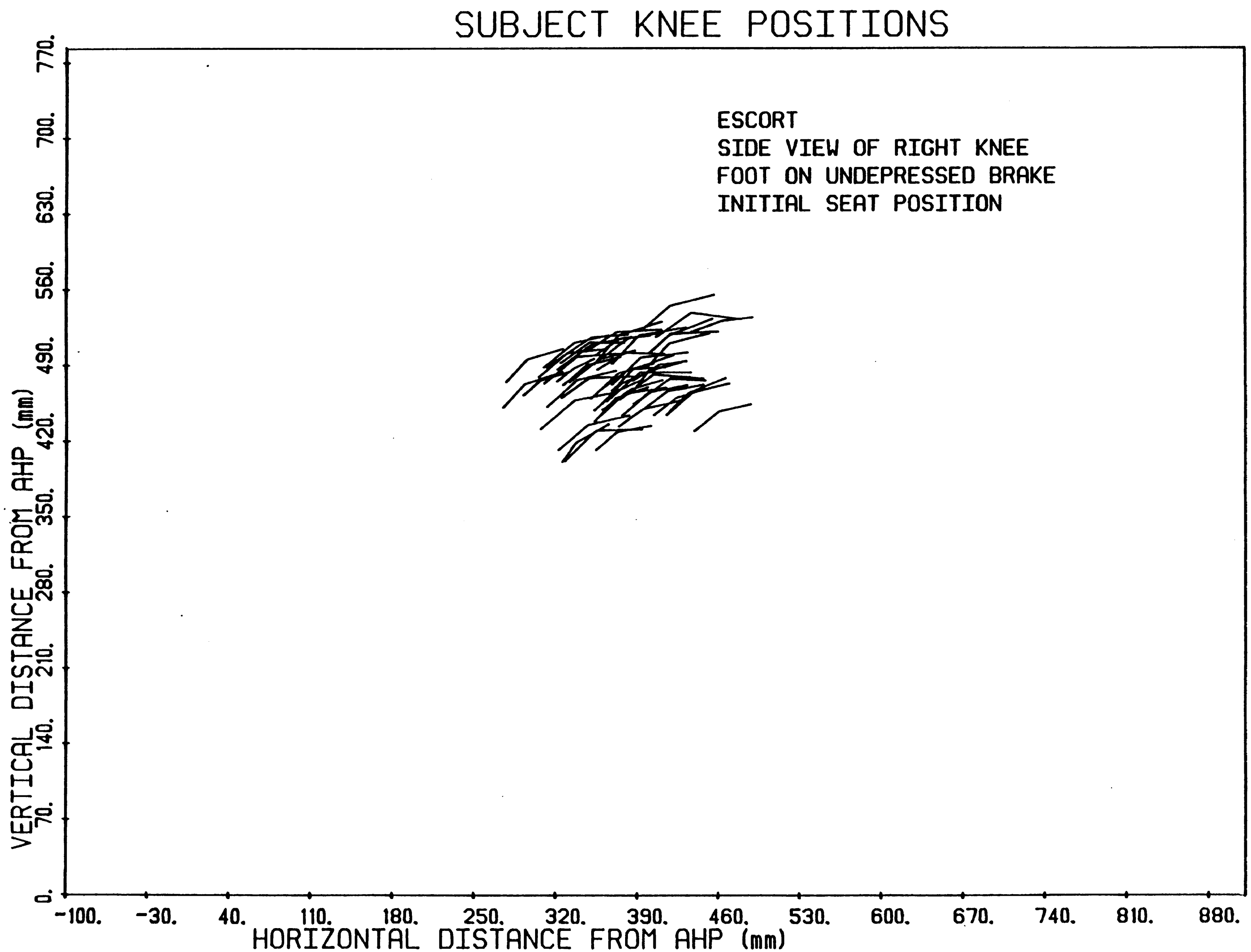
SUBJECT KNEE POSITIONS

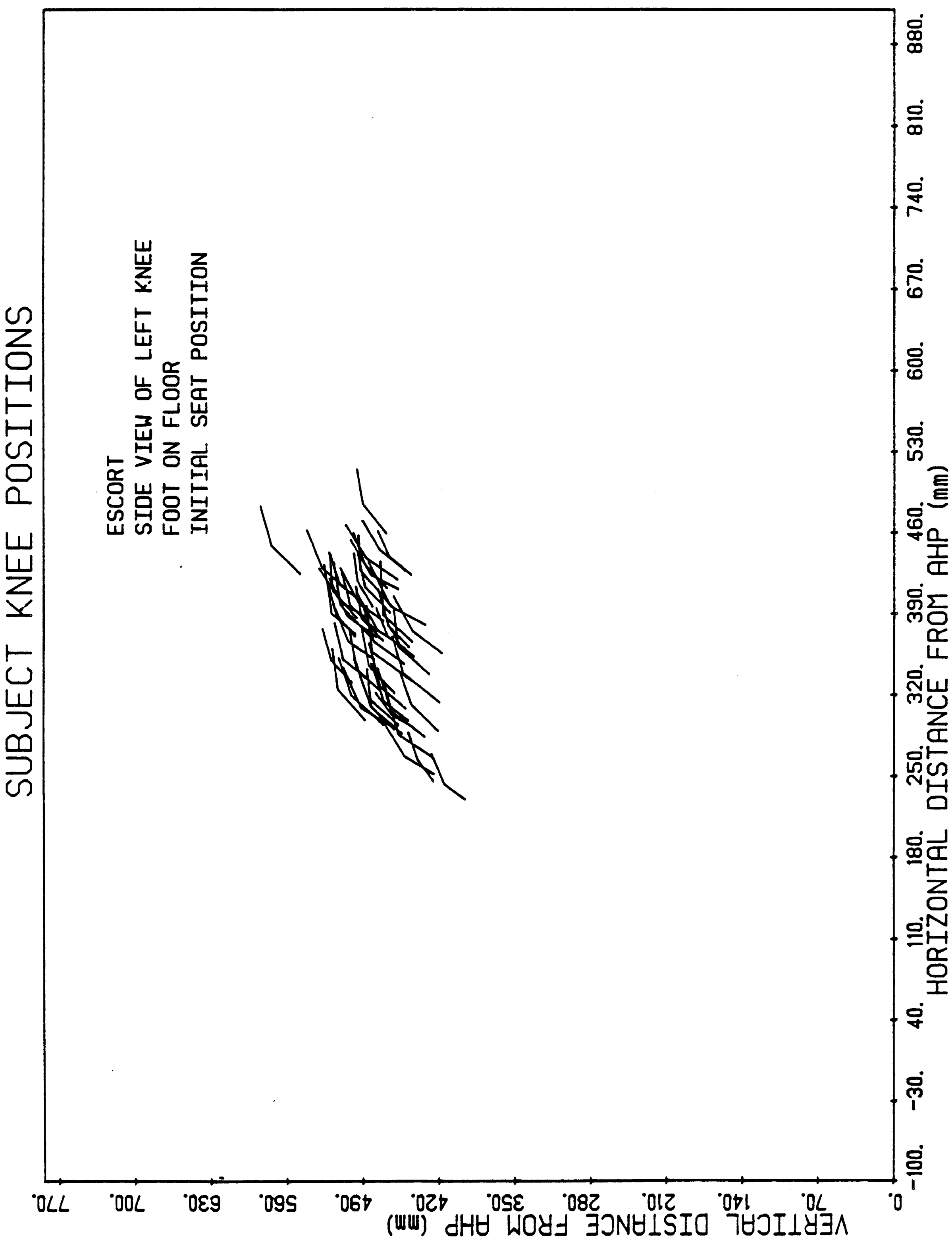


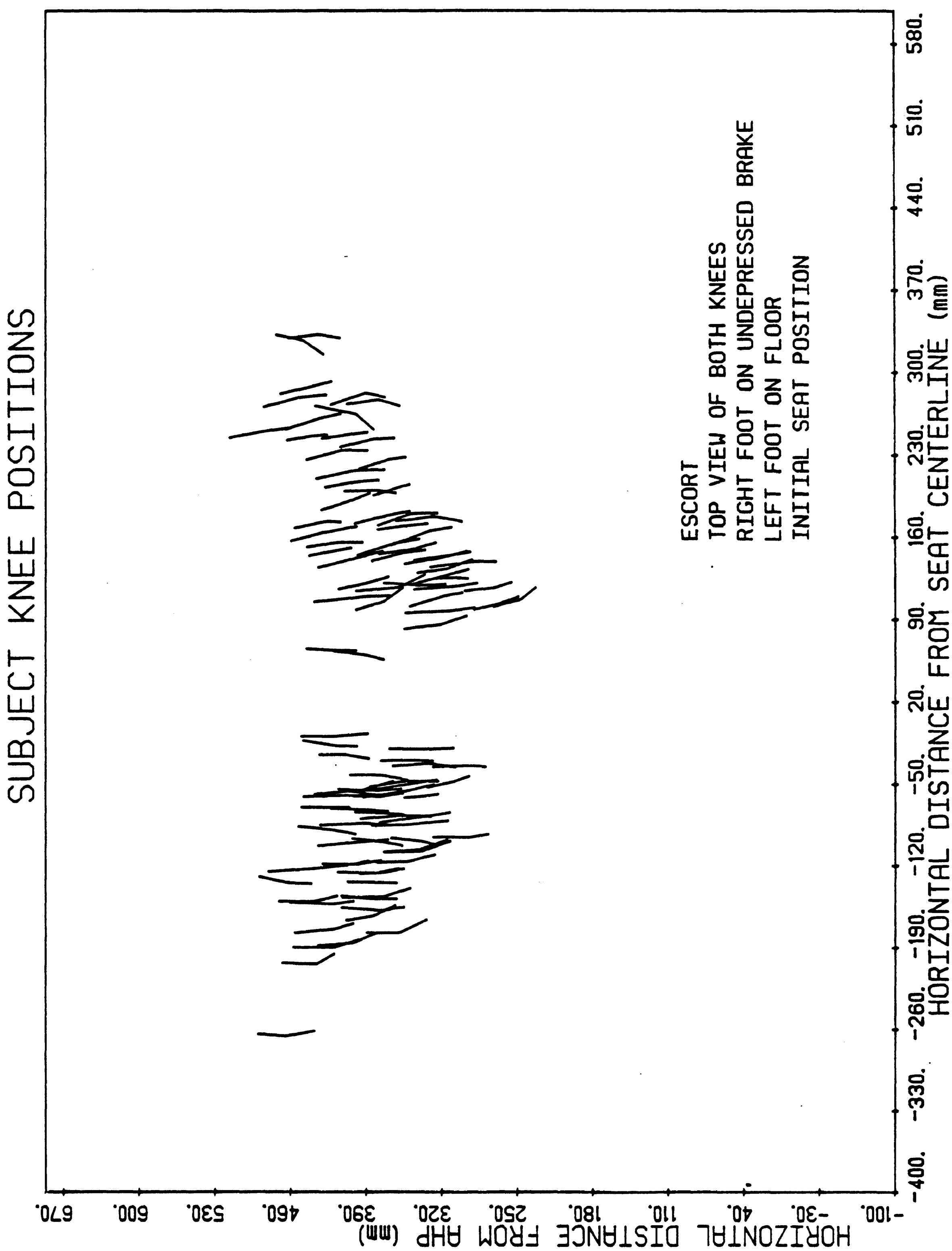
SUBJECT KNEE POSITIONS

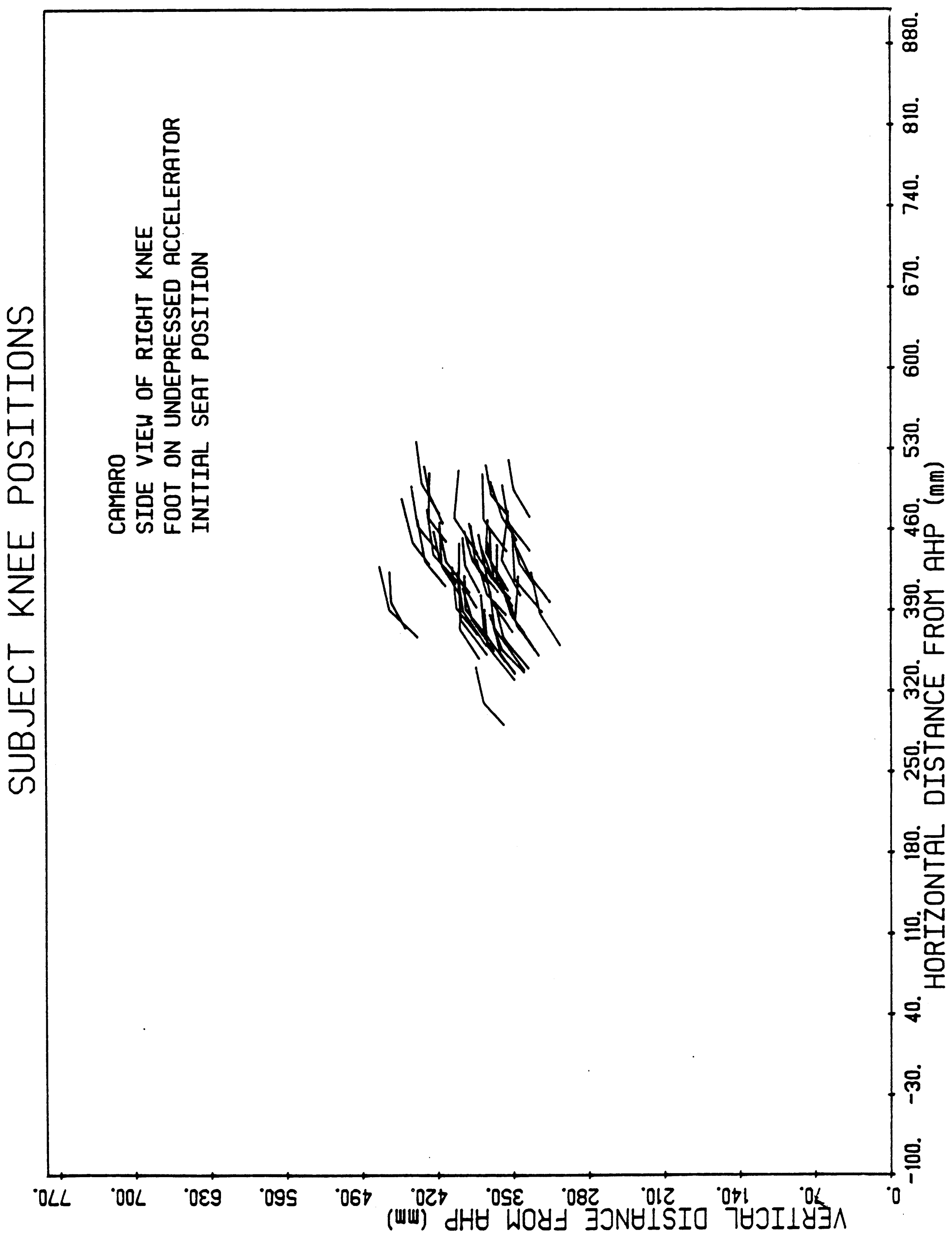



SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM AHP (mm)

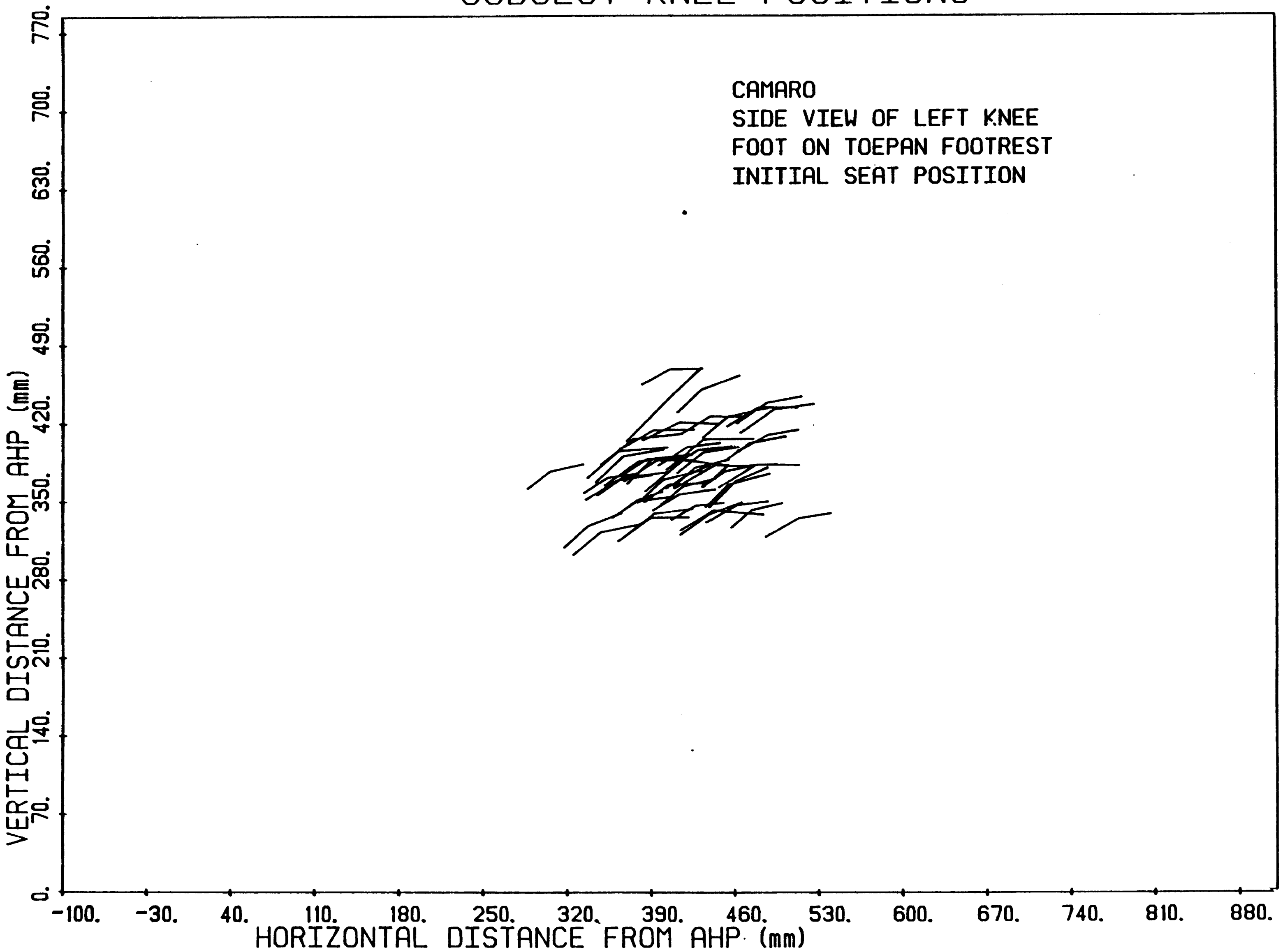

SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED BRAKE
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

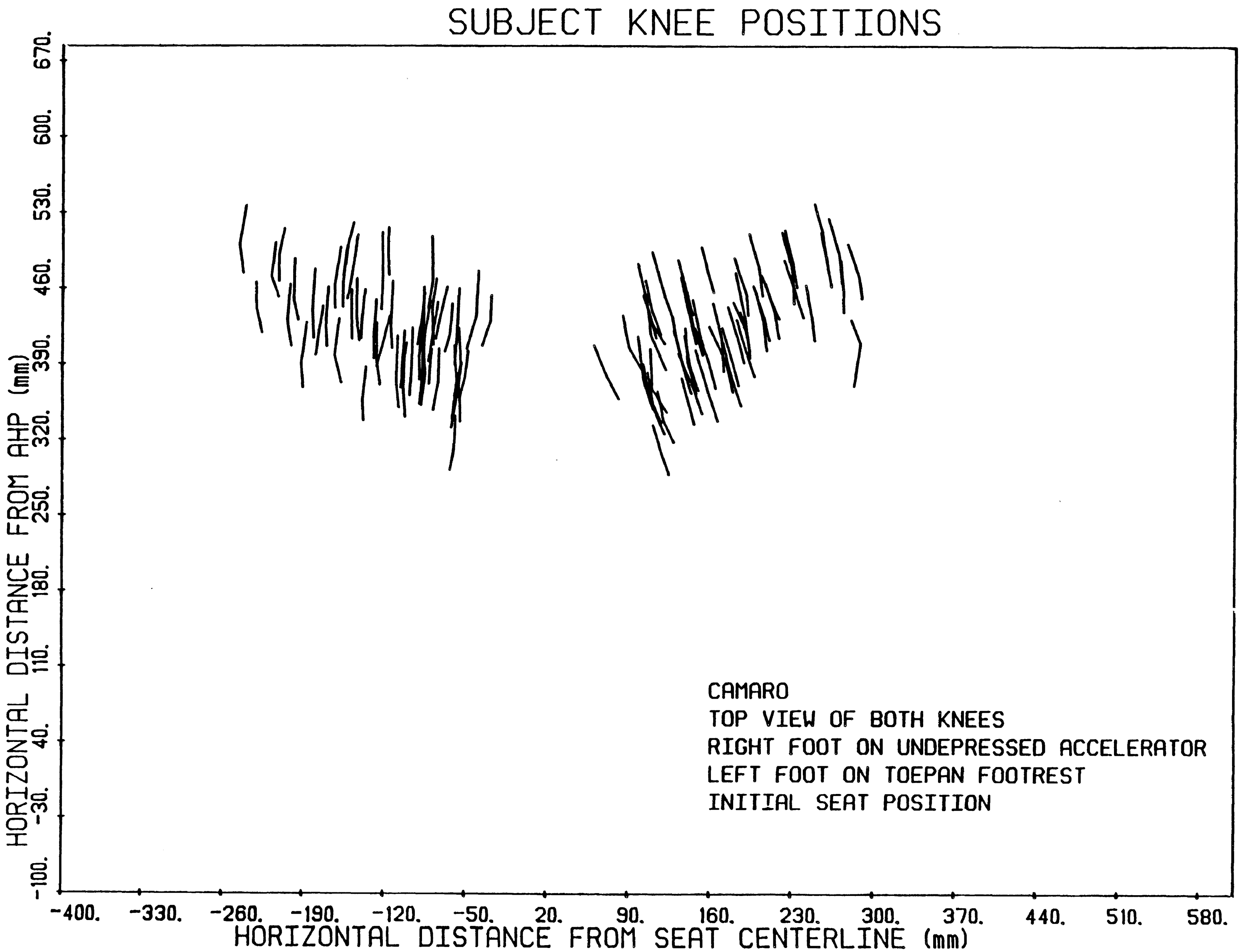

SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
VERTICAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.


SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
HORIZONTAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
VERTICAL DISTANCE FROM AHP (mm)

SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
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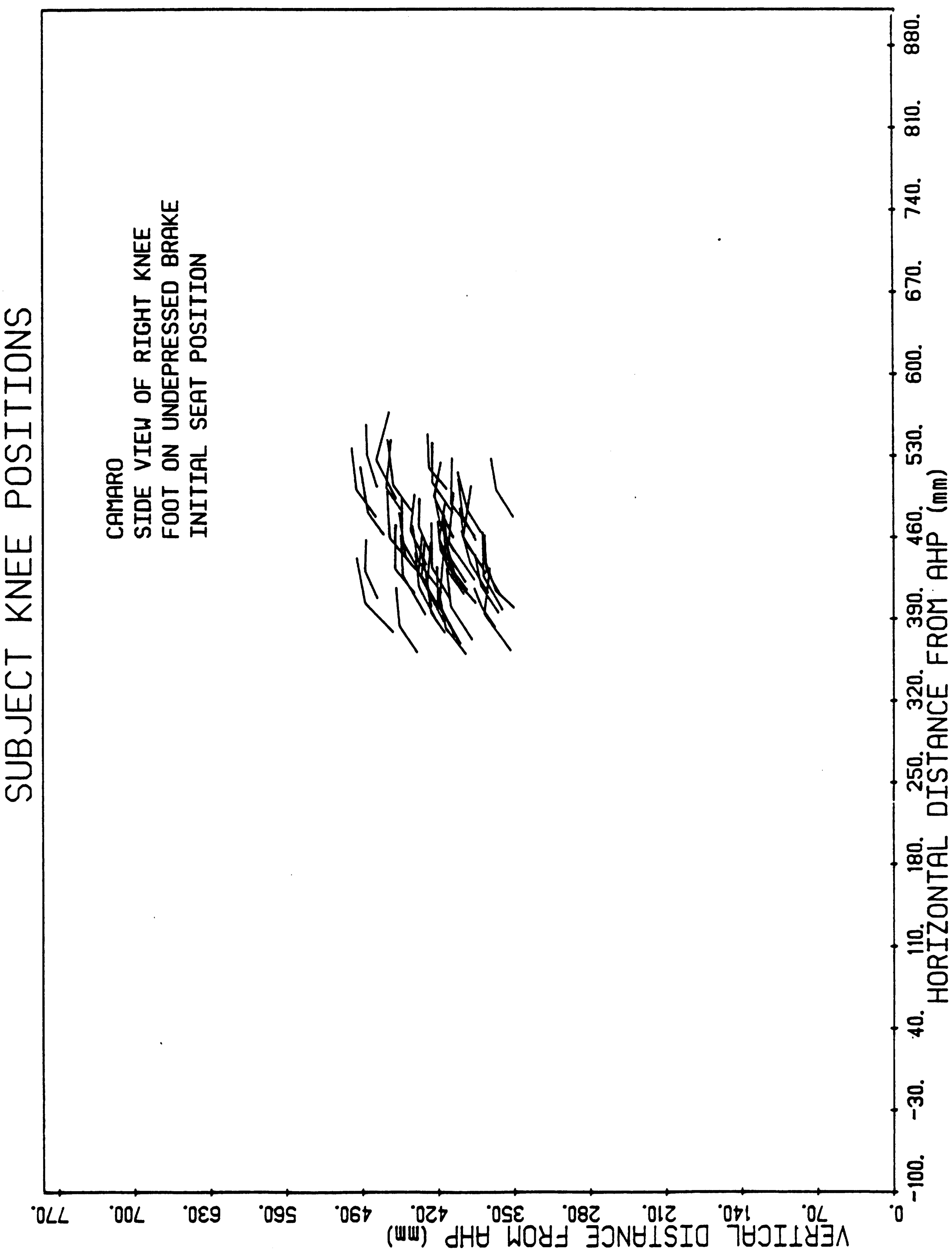
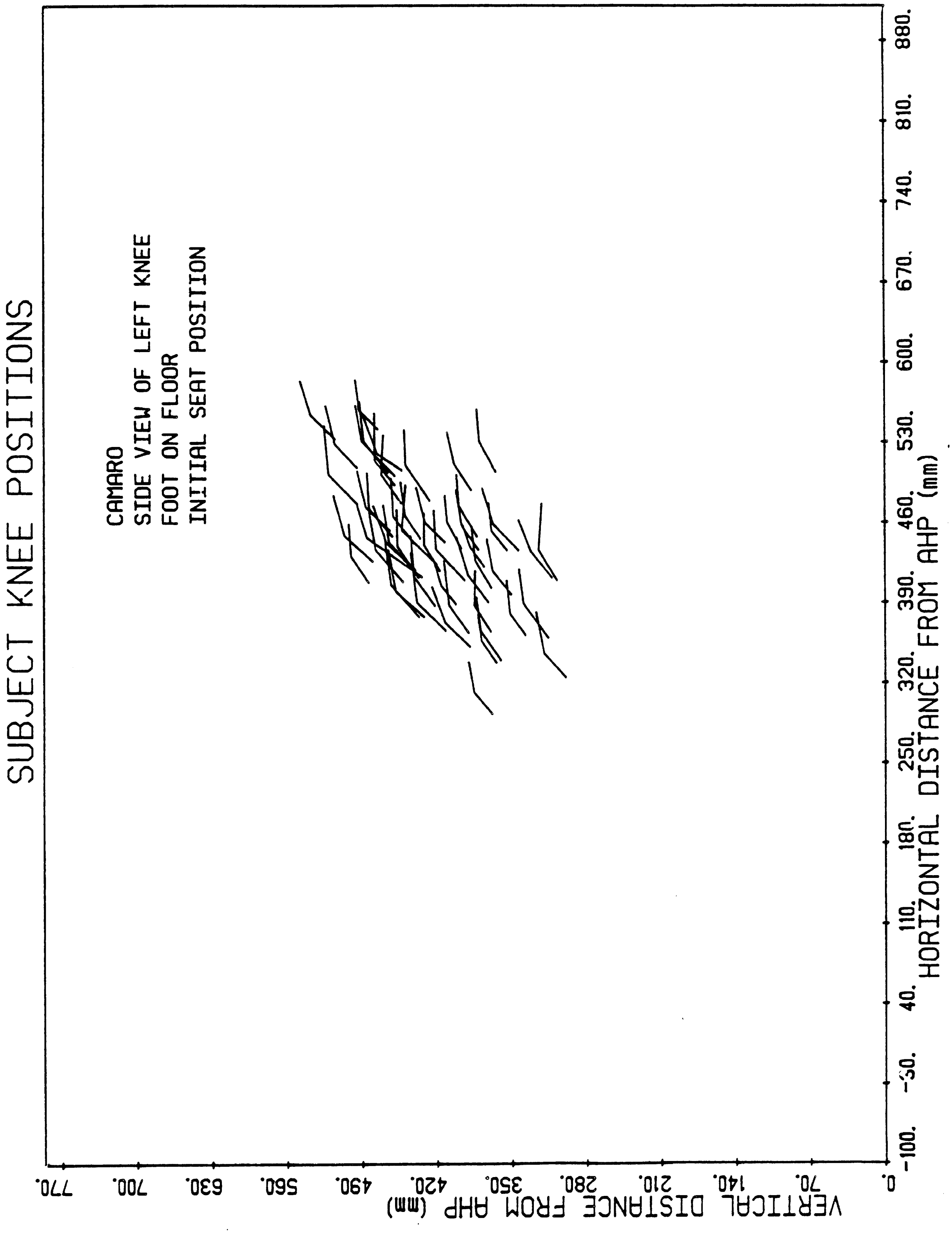
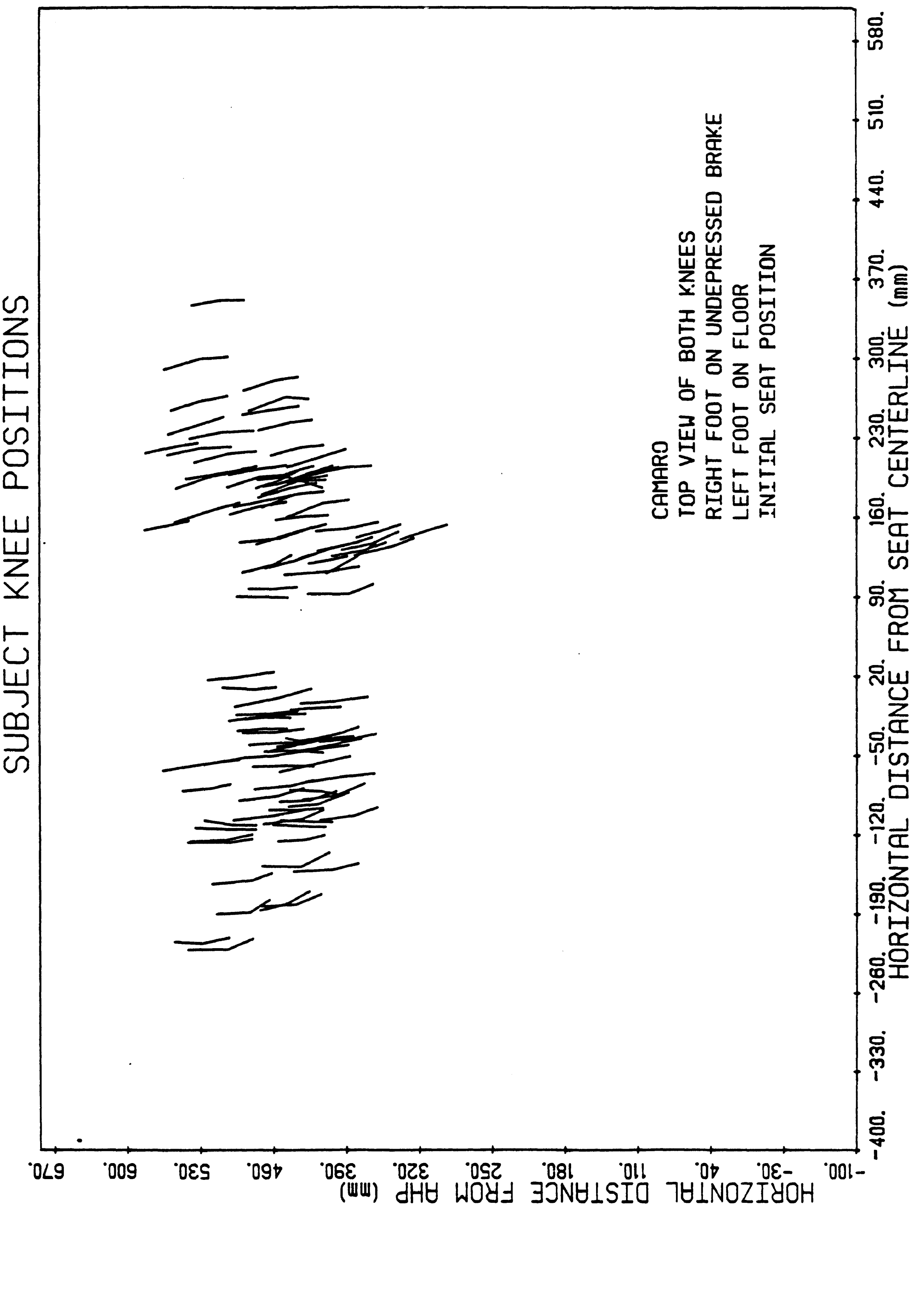
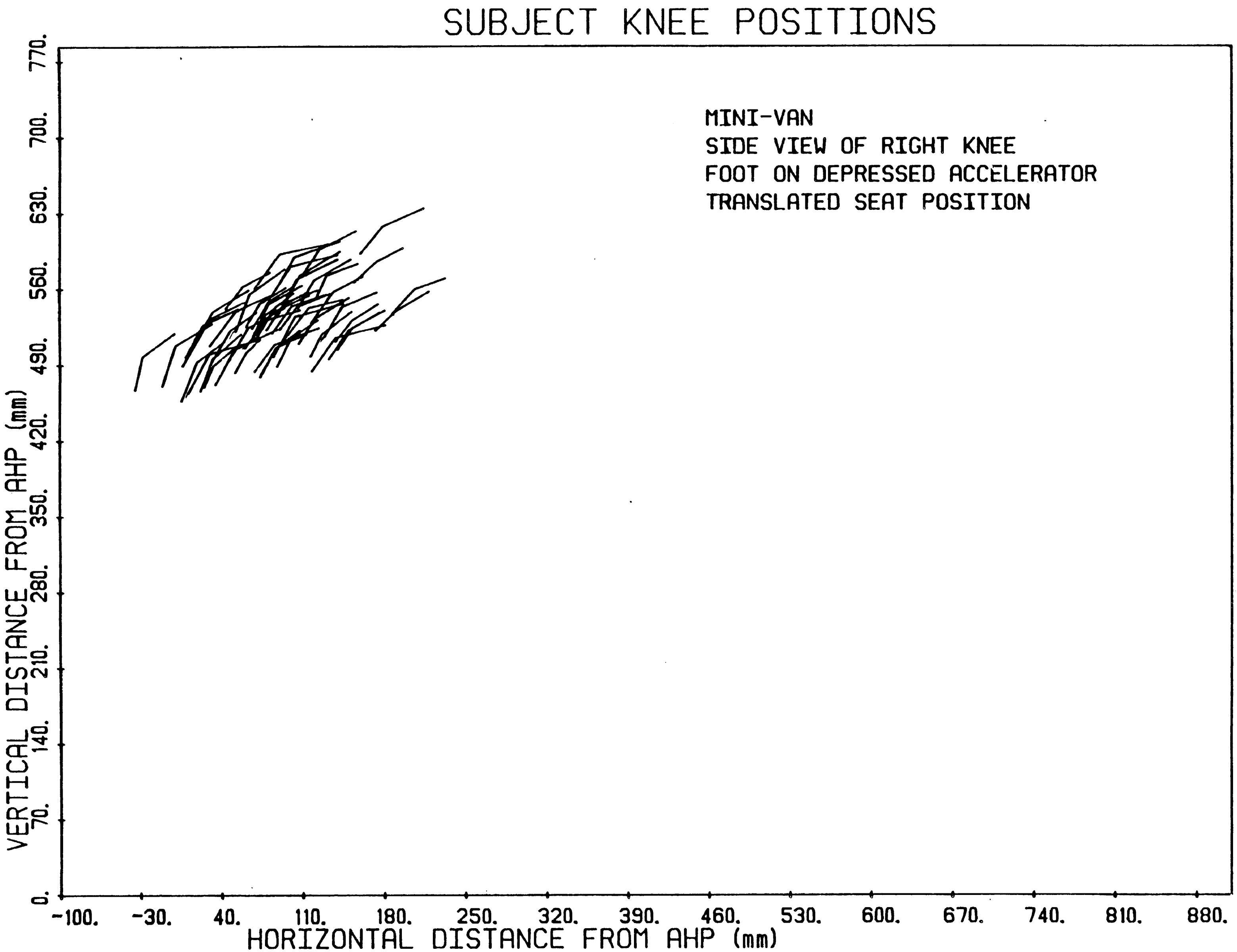
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION

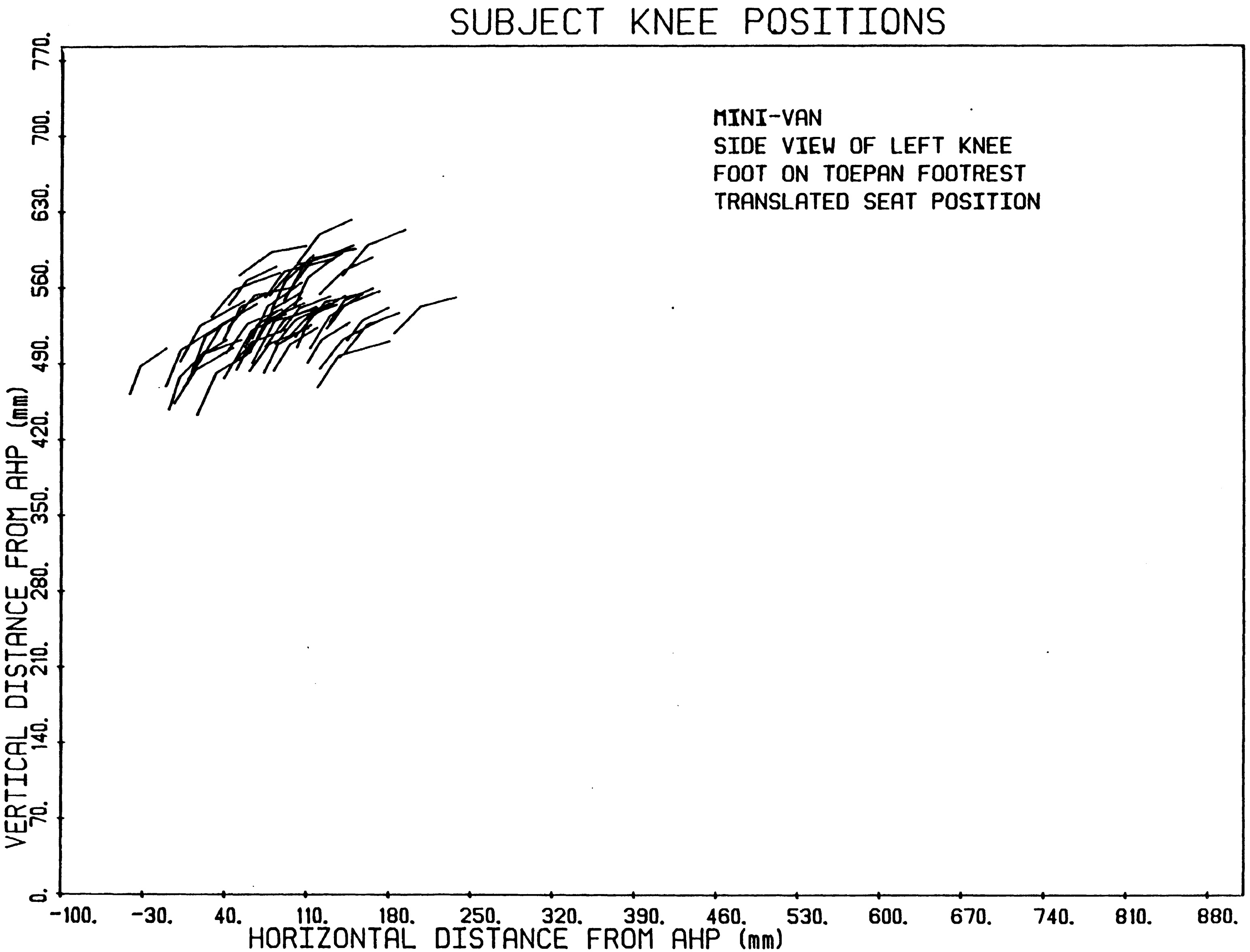

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED BRAKE
INITIAL SEAT POSITION
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
VERTICAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
VERTICAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.


SUBJECT KNEE POSITIONS
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
INITIAL SEAT POSITION
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM AHP (mm)

TRANSLATED SEAT CONDITIONS


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
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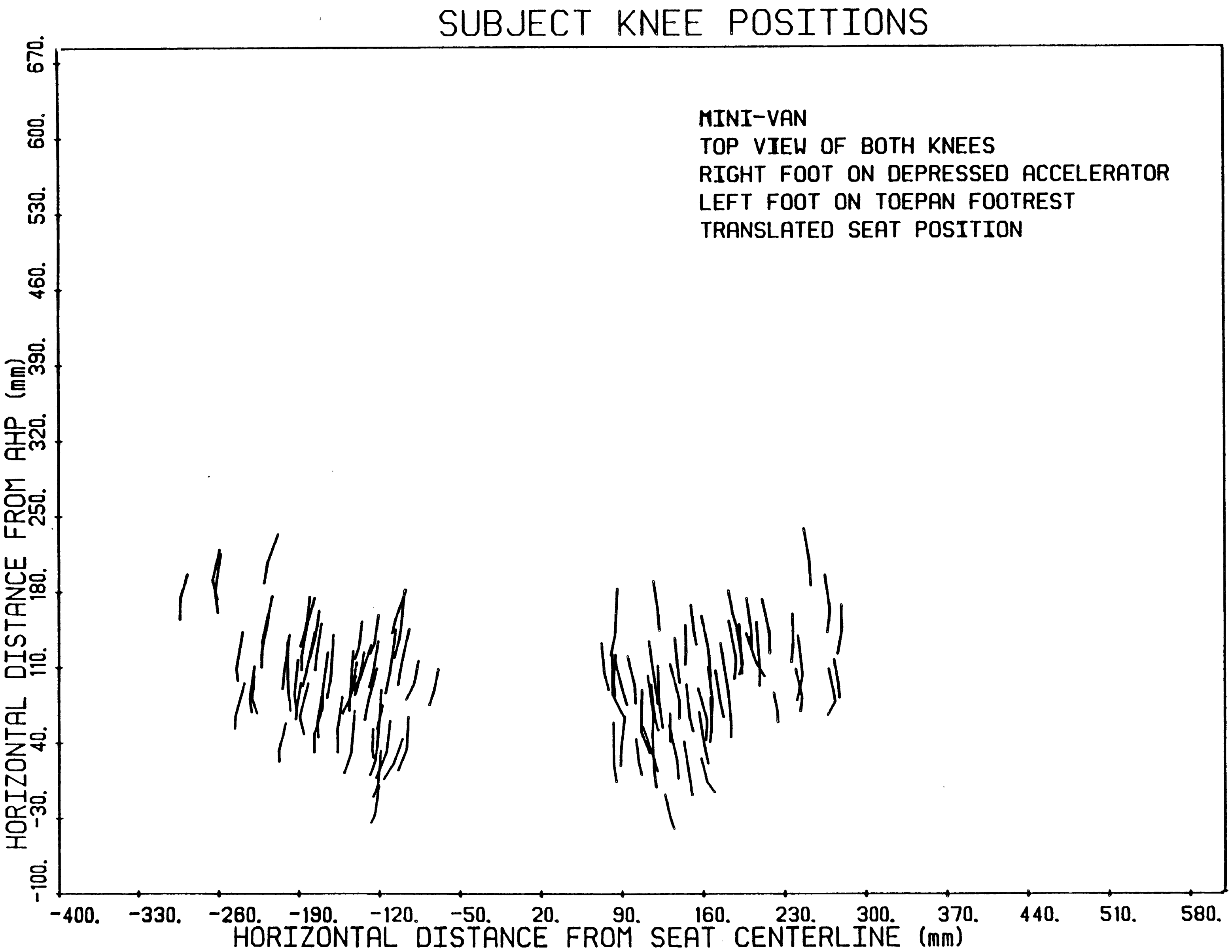
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
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320.
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460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
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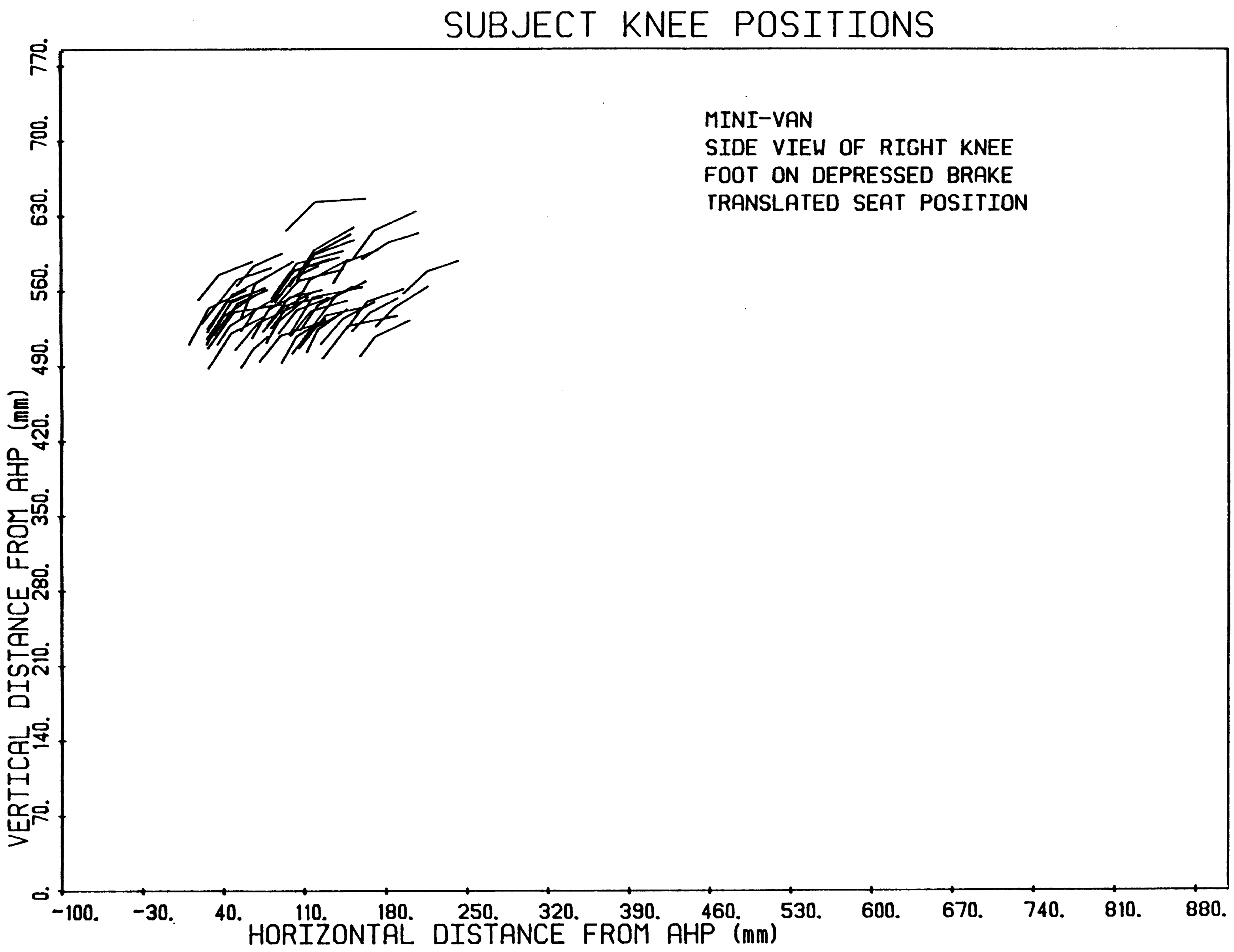
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED BRAKE
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
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390.
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530.
600.
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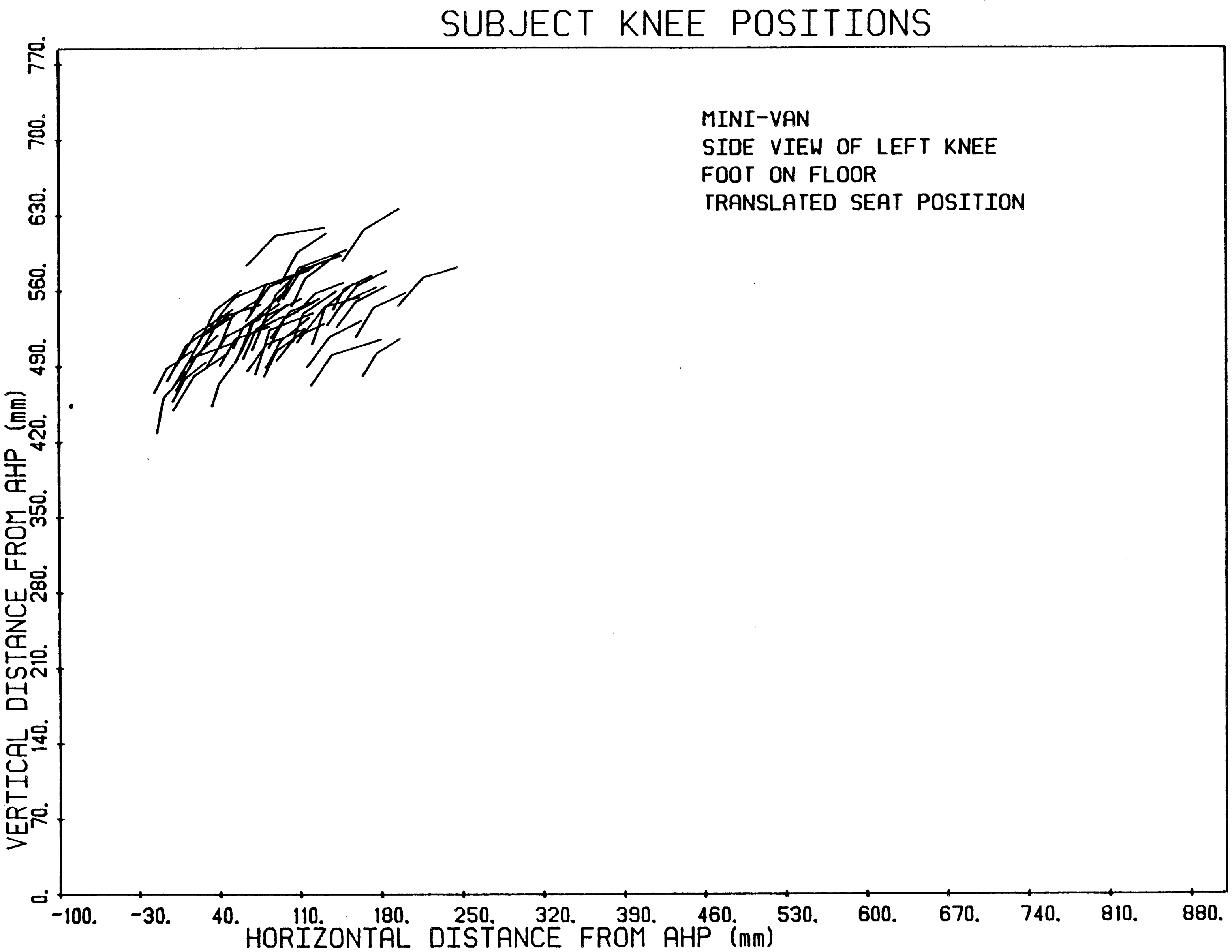
740.
810.
880.


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
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600.
670.
740.
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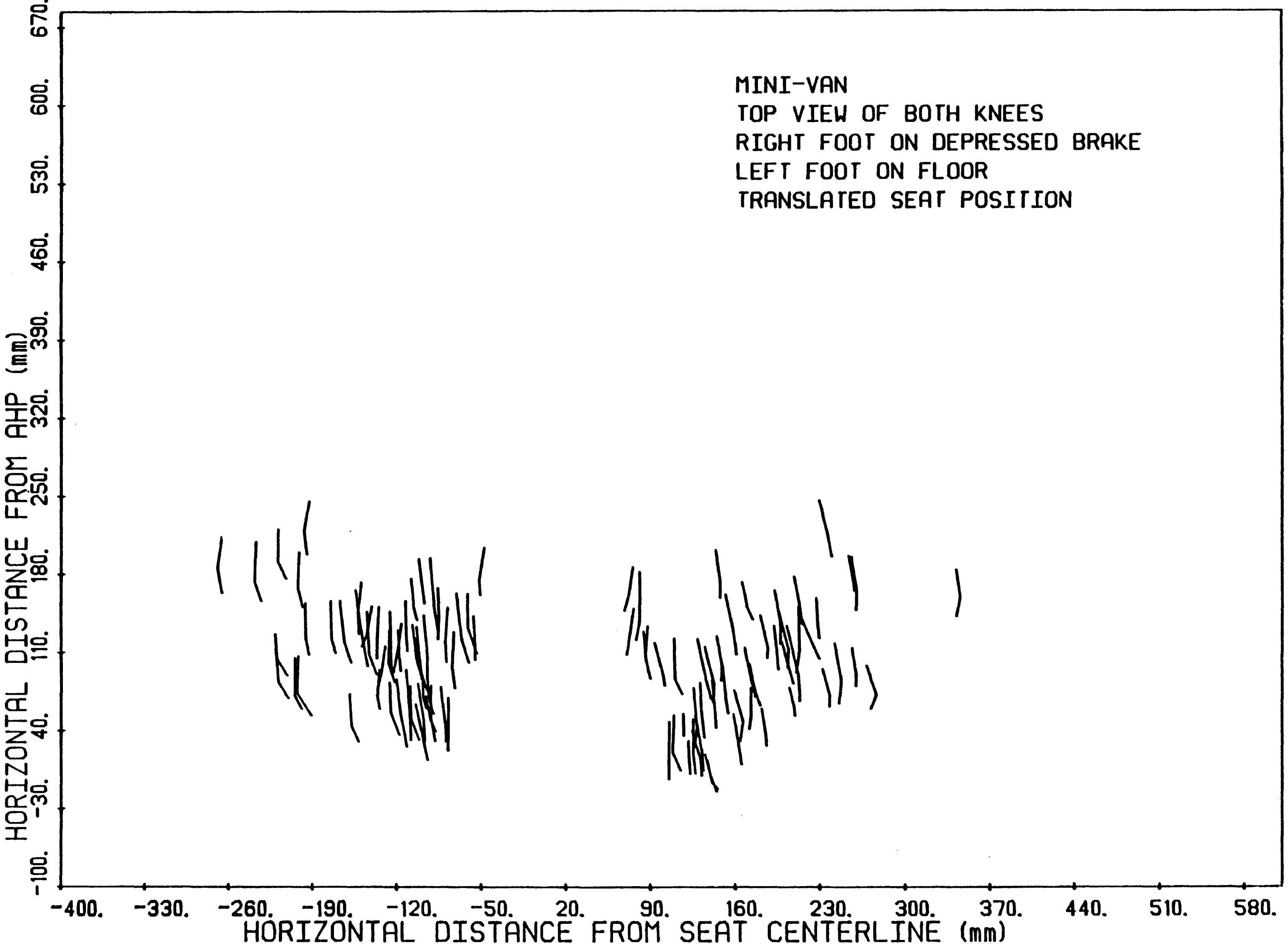
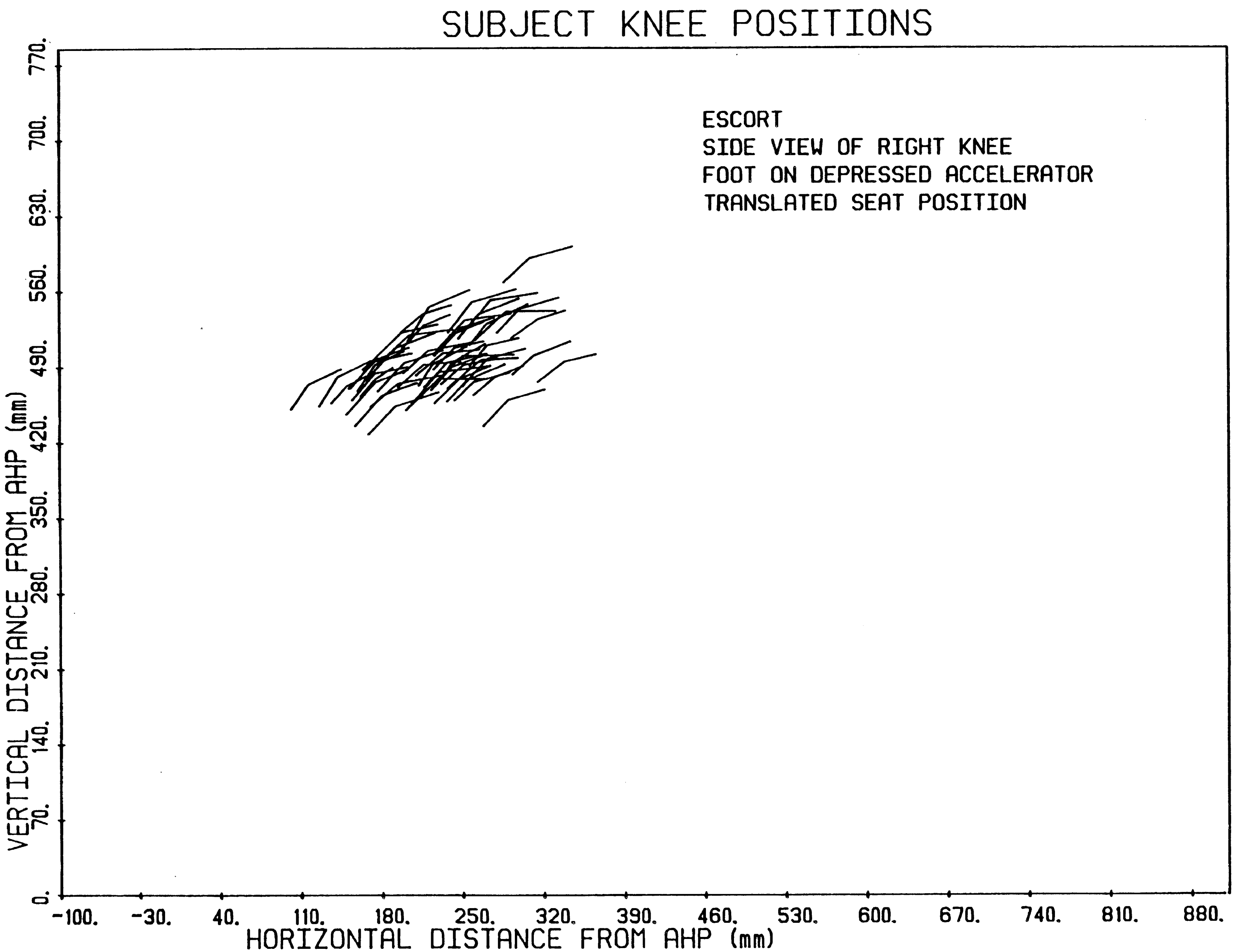
880.

SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
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770.
-100.
-30.
40.
110.
180.
250.
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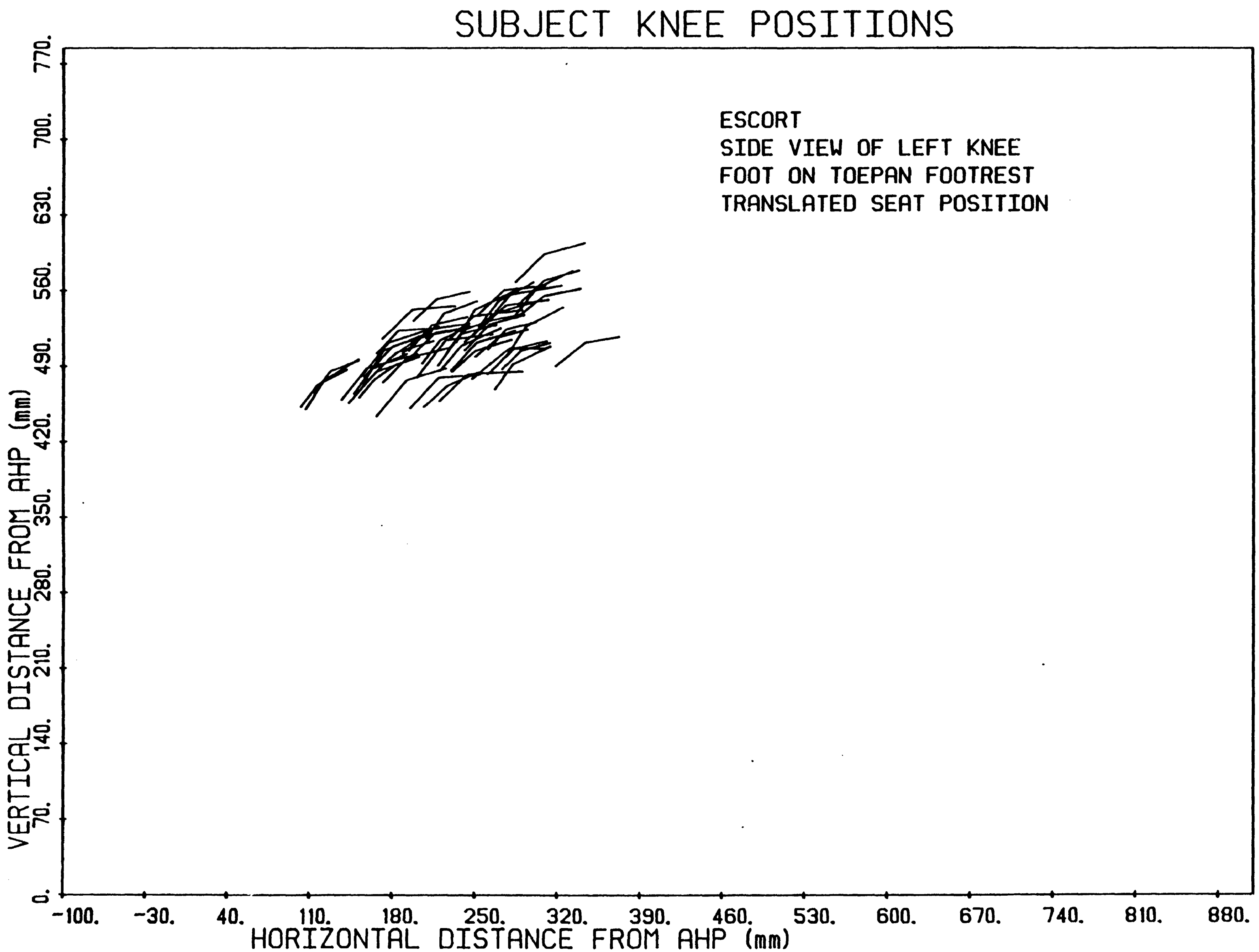
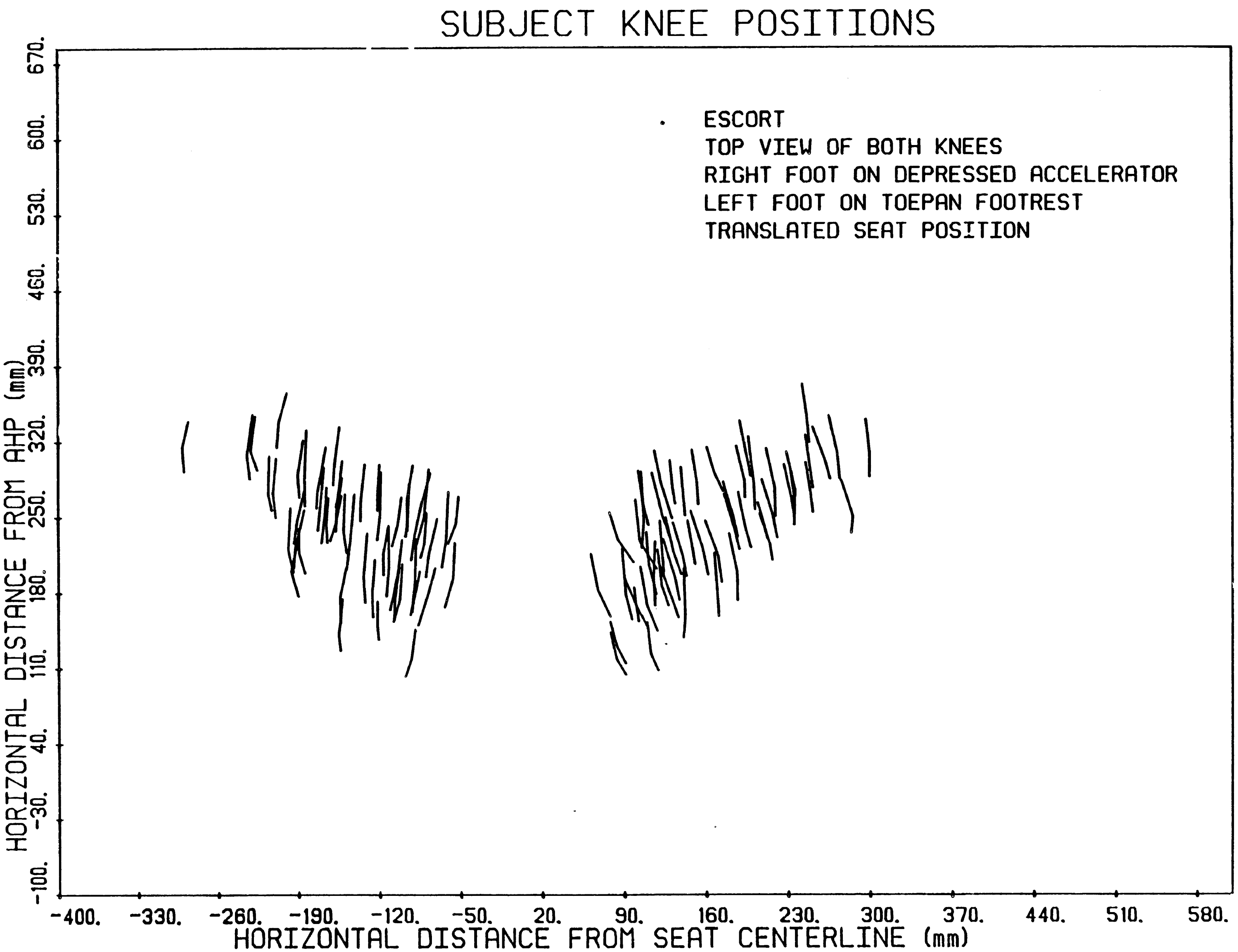
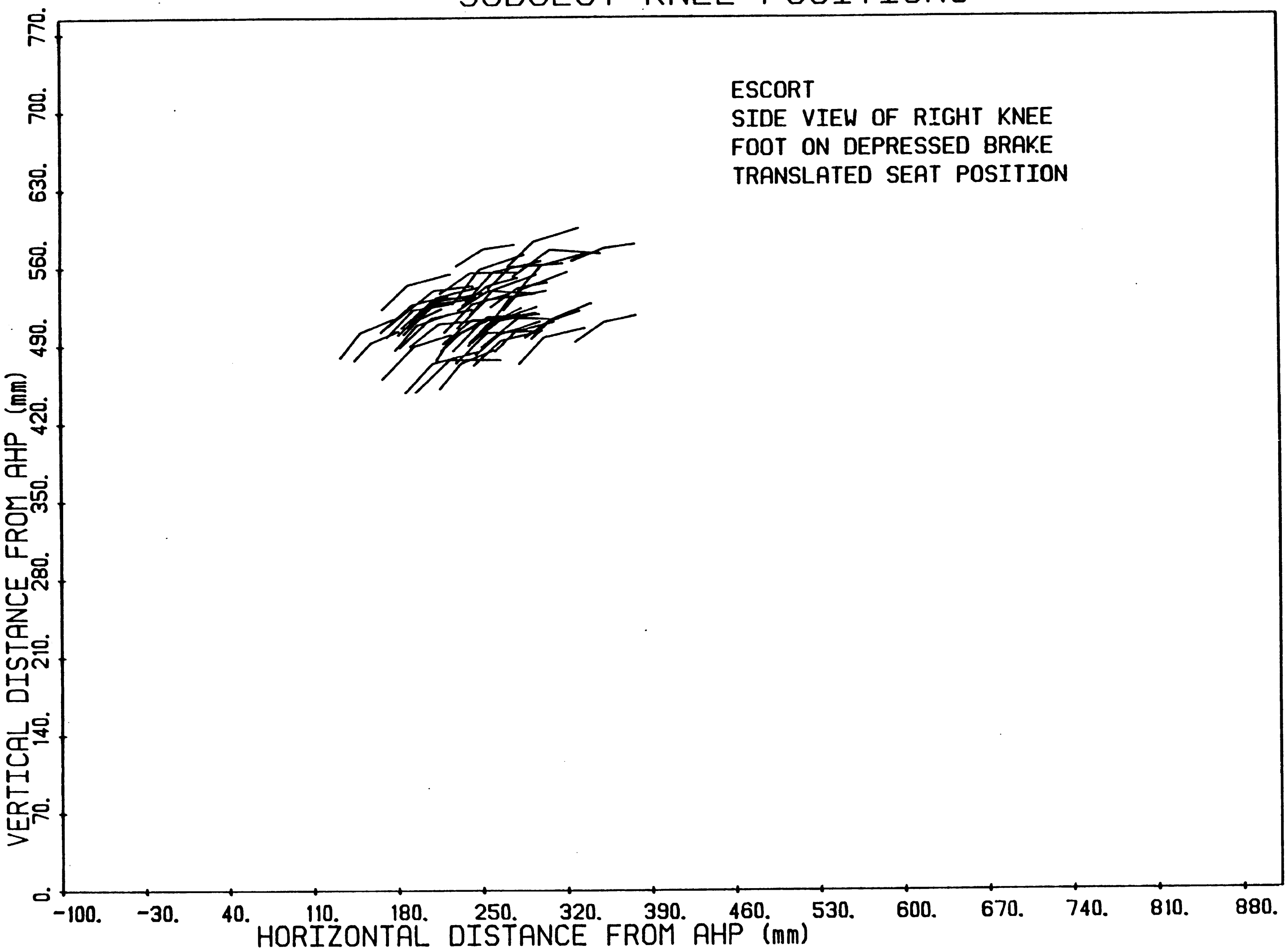
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

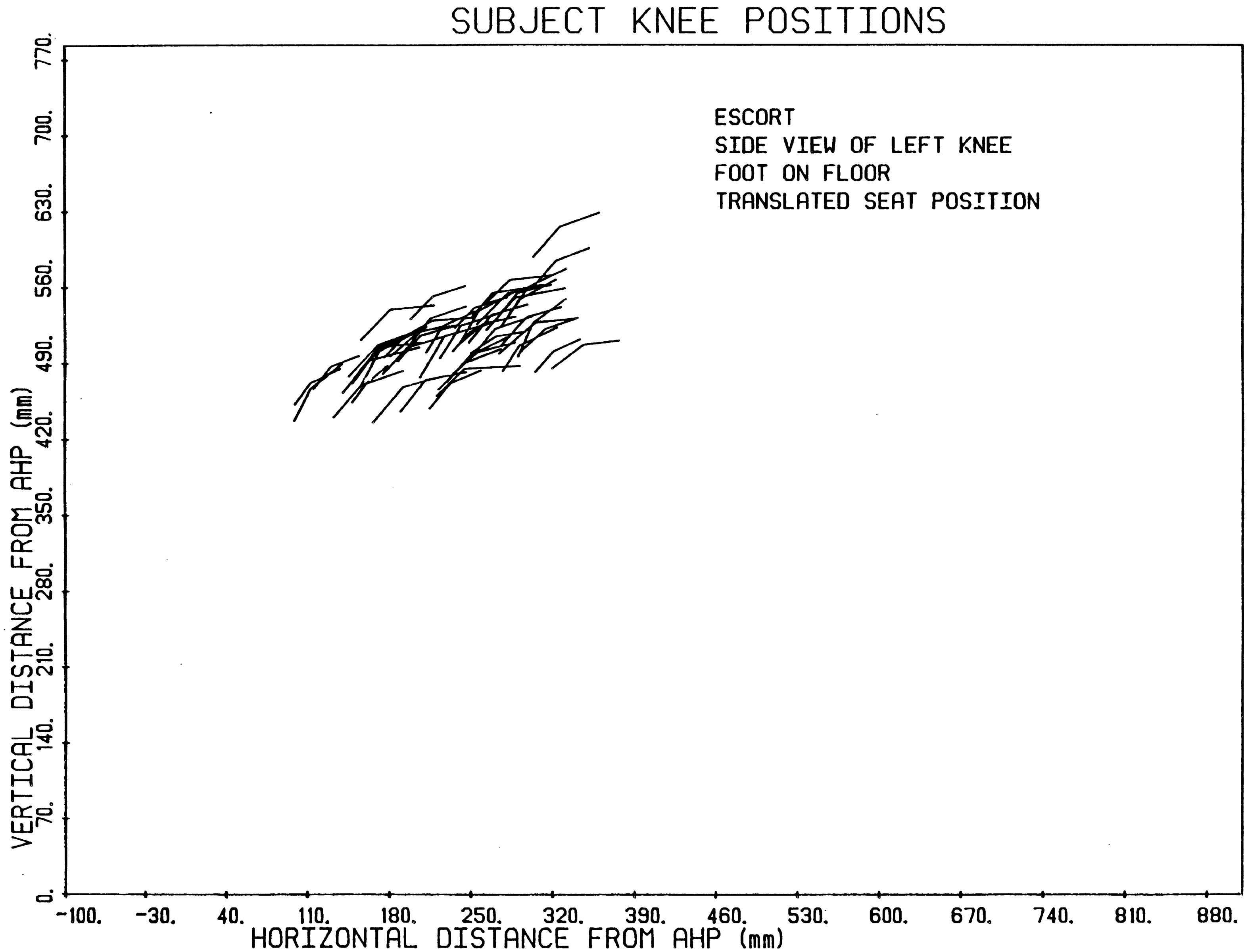

SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)



SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
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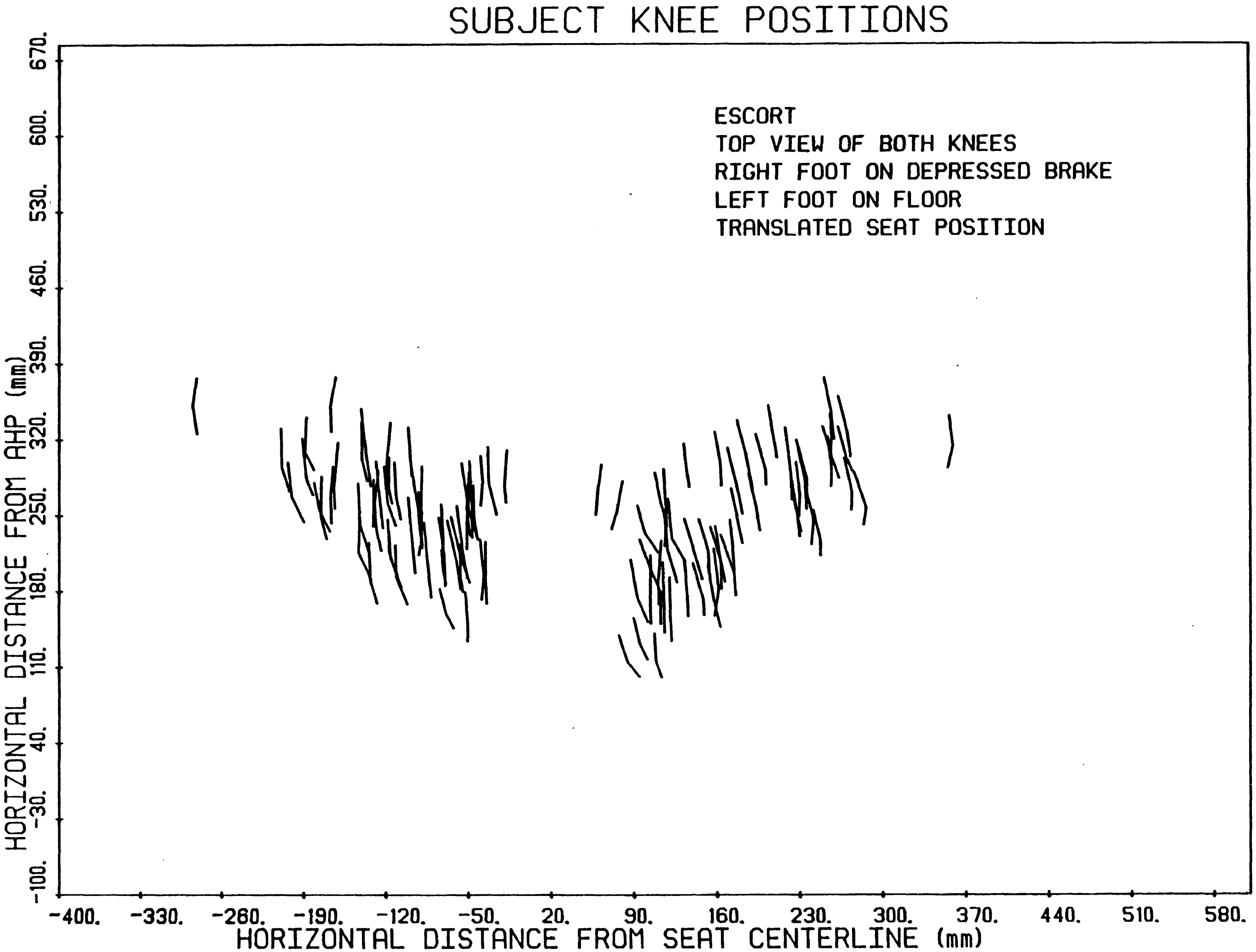
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
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250.
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110.
40.
-30.
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-400.
-330.
-260.
-190.
-120.
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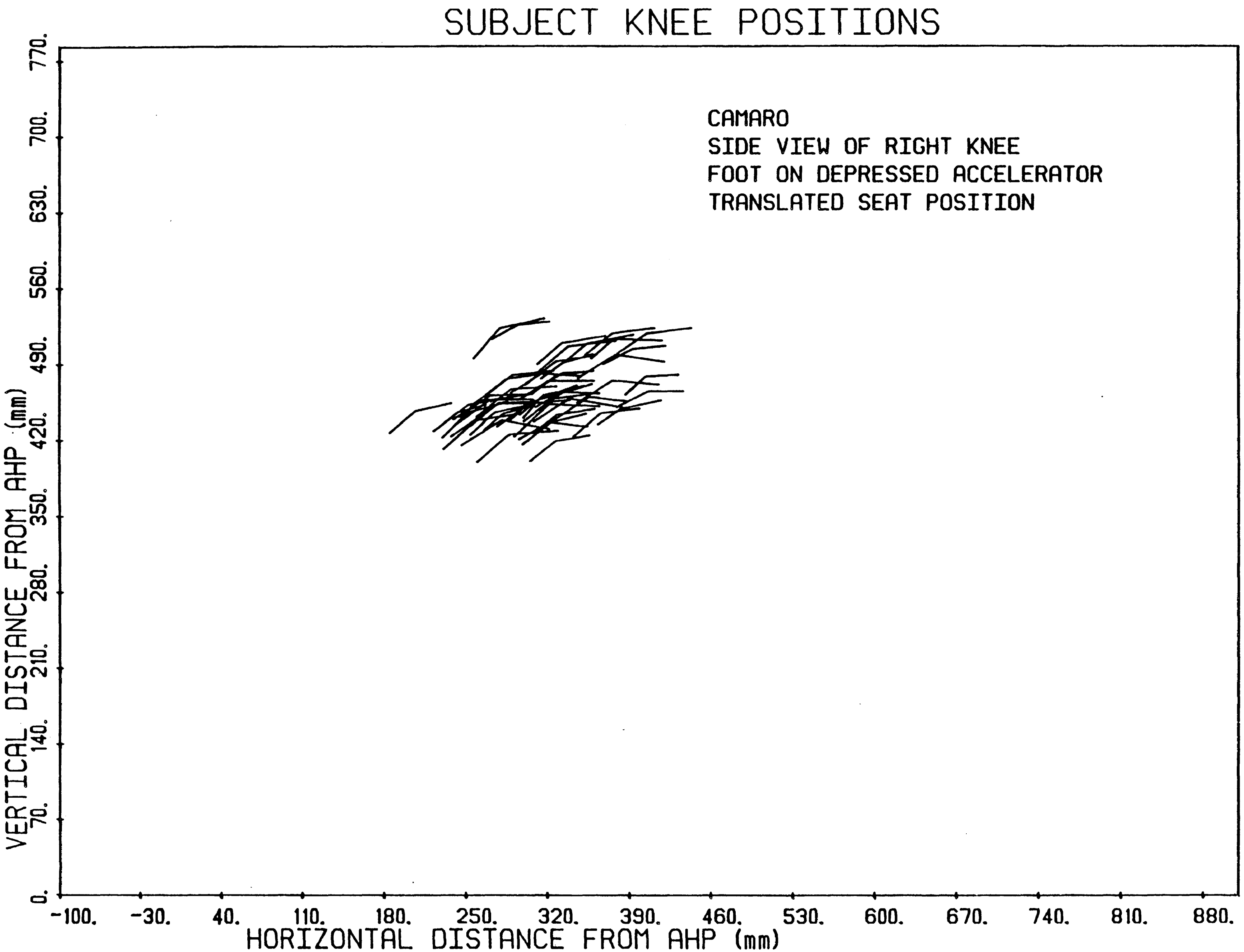
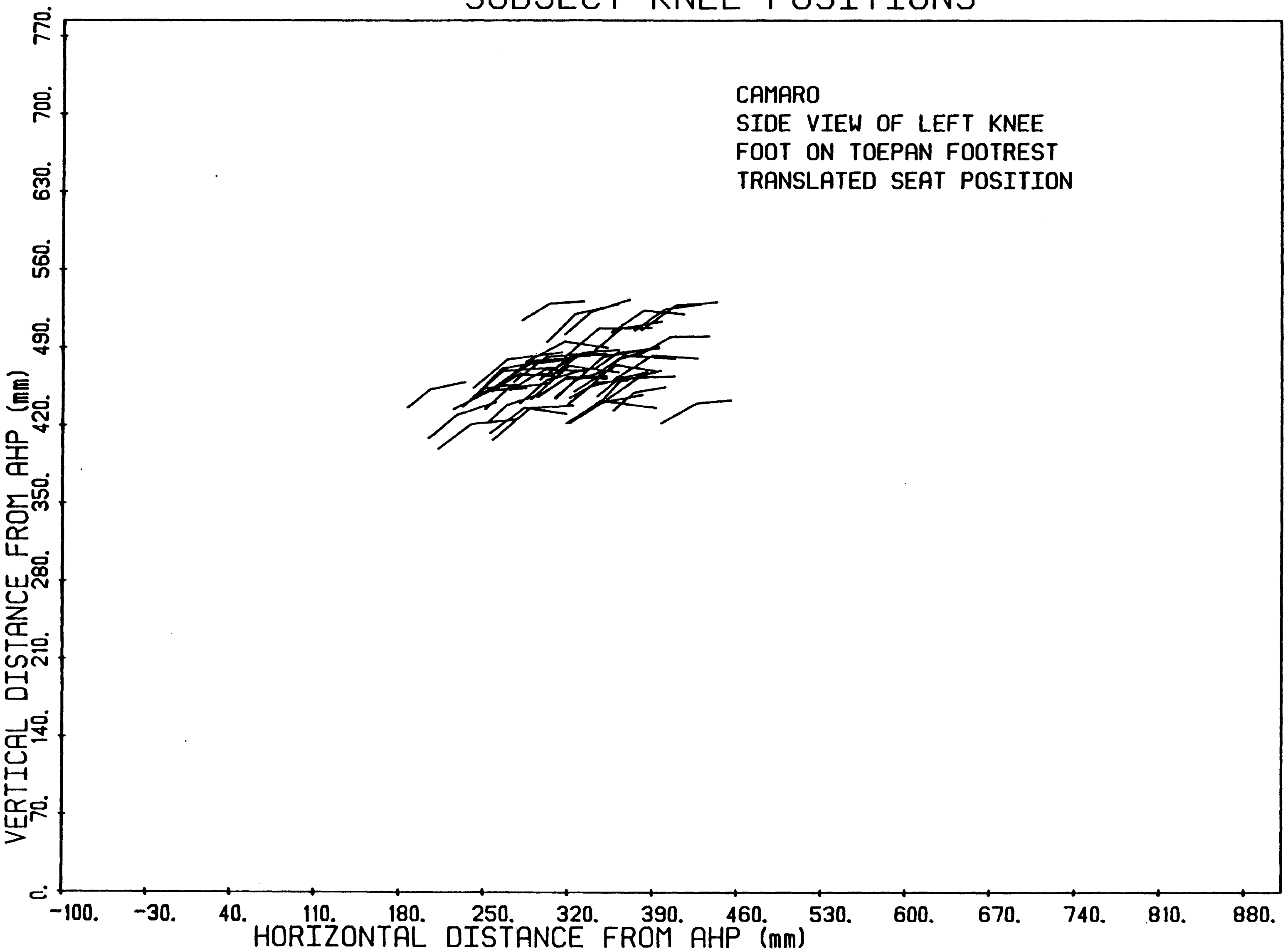
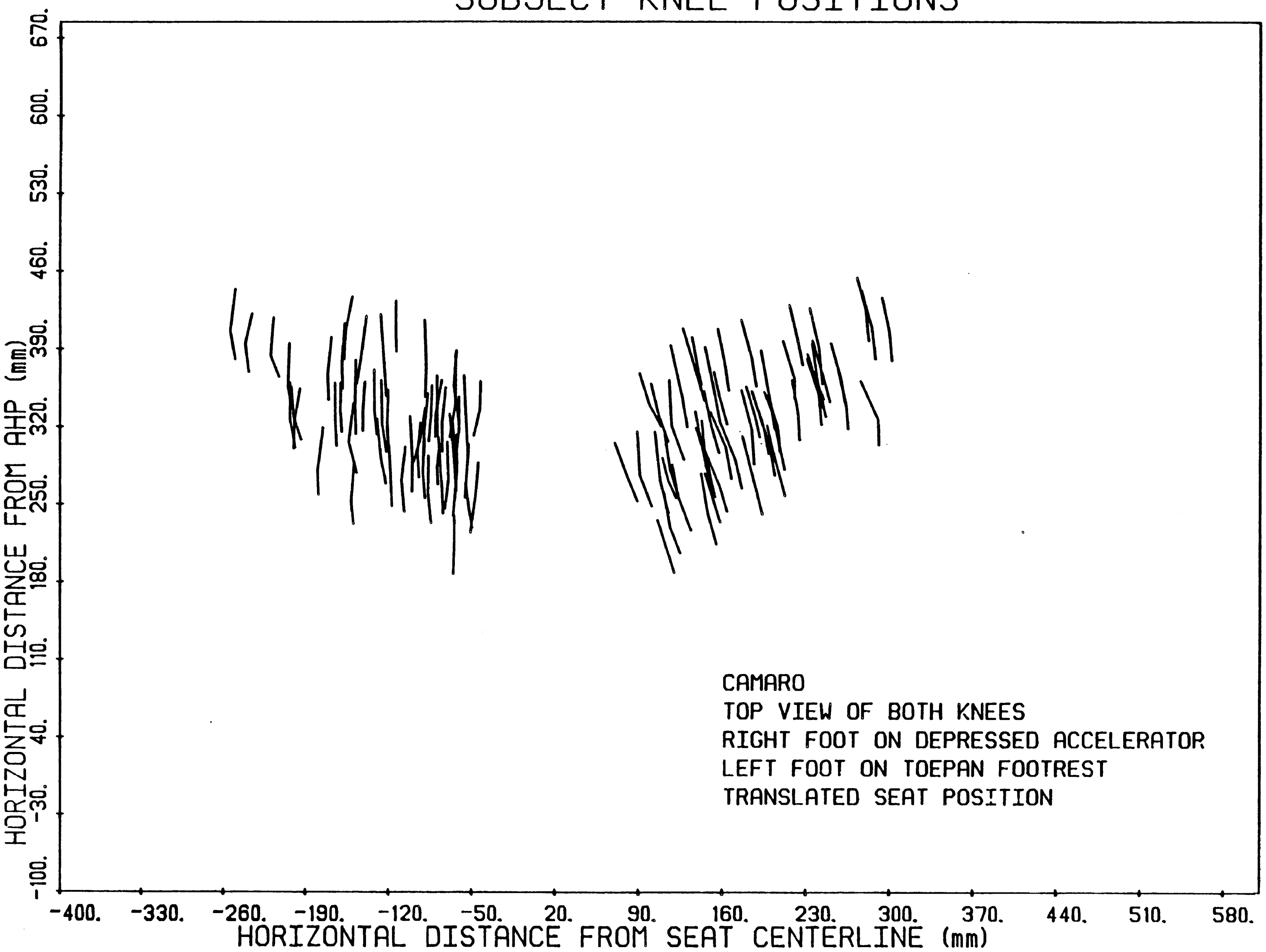
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

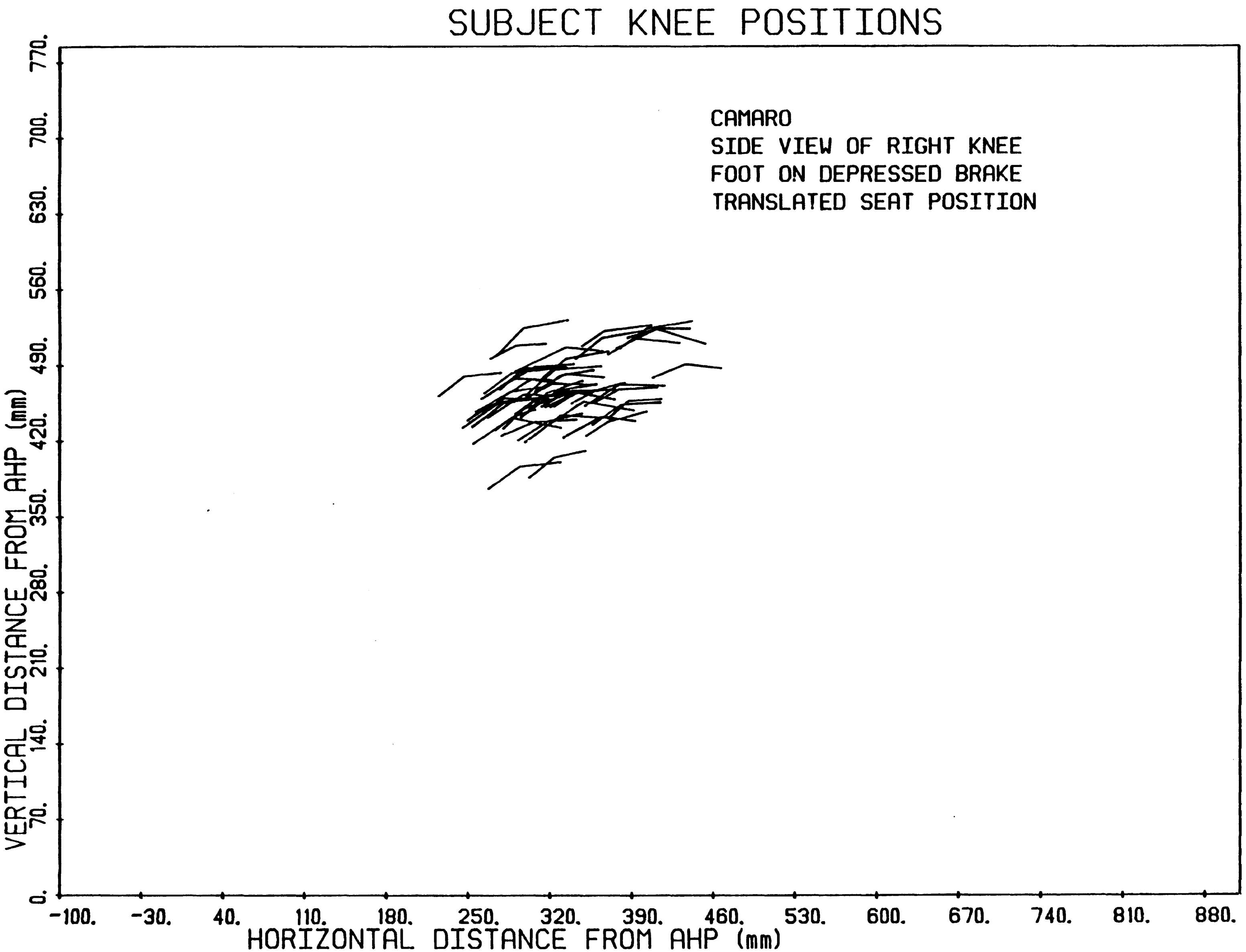

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

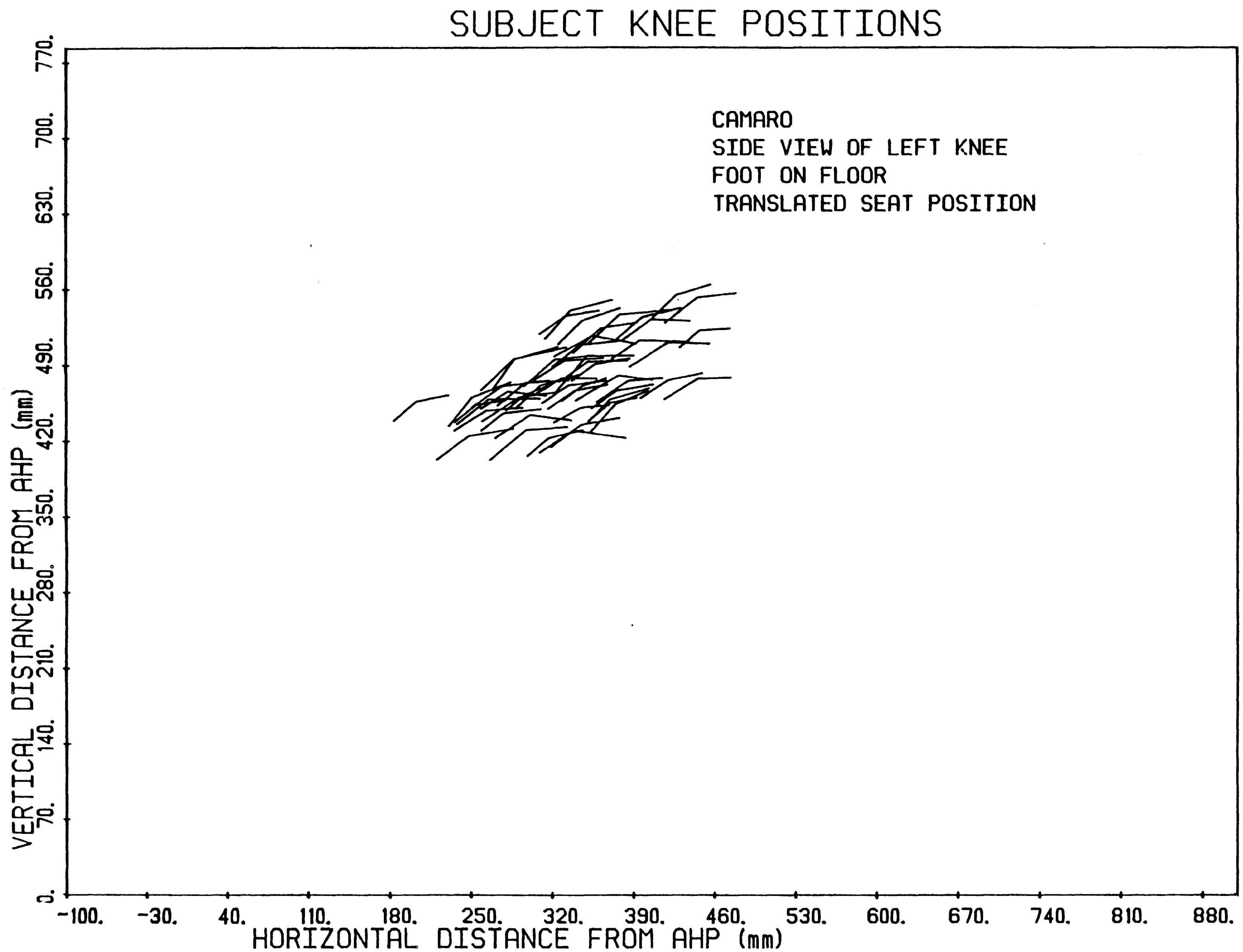
SUBJECT KNEE POSITIONS

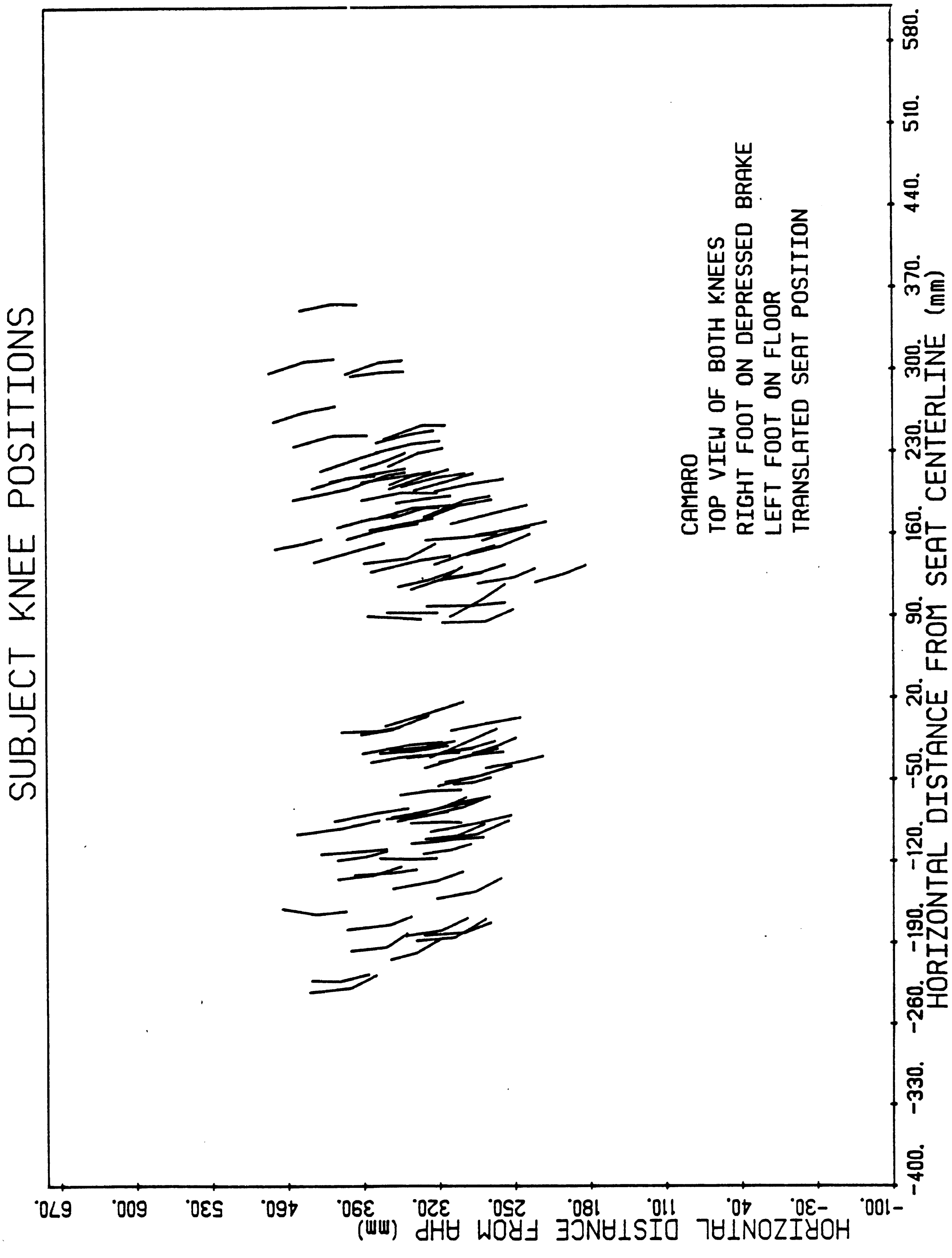


SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED BRAKE
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

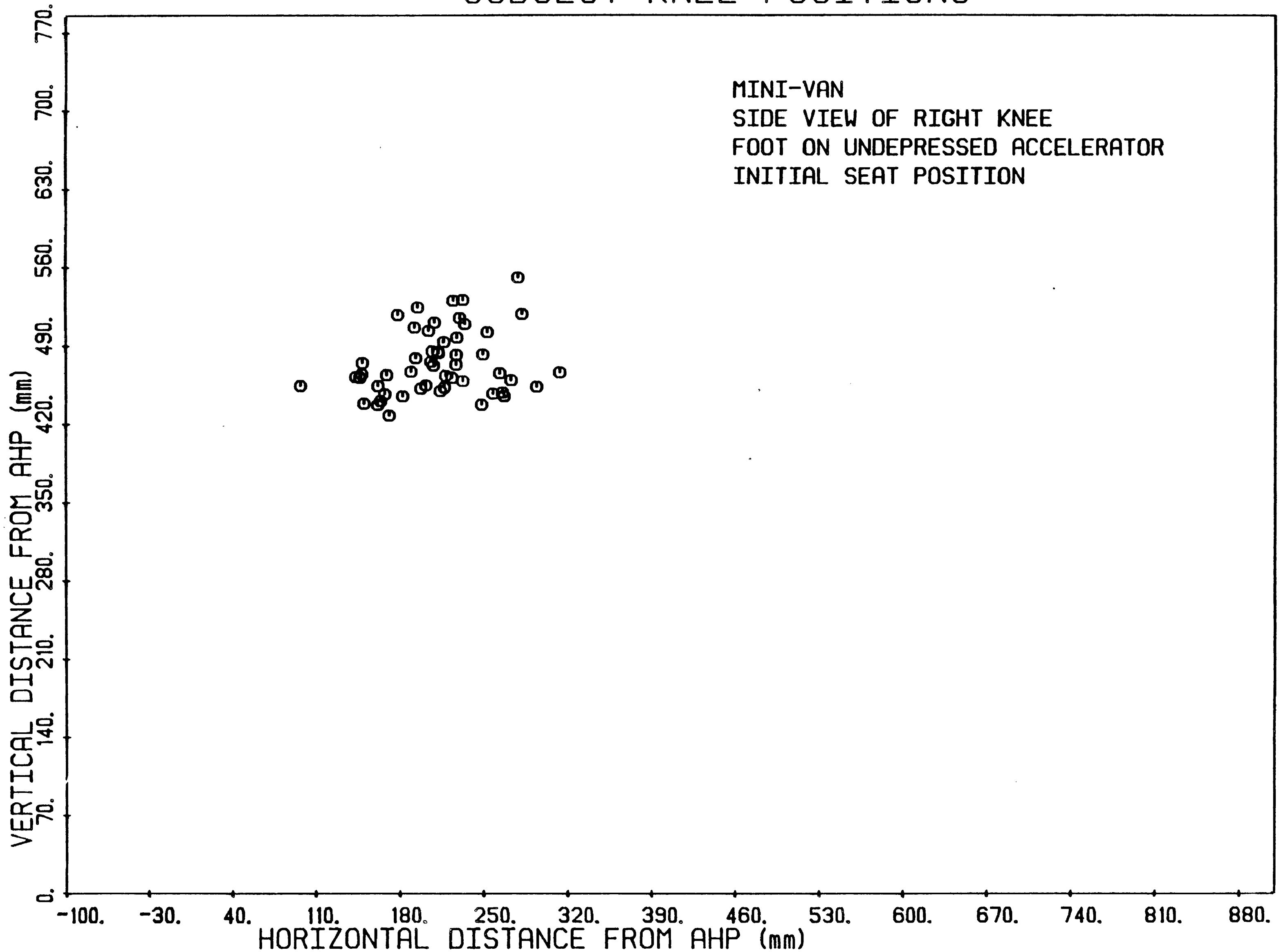

SUBJECT KNEE POSITIONS
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM AHP (mm)

APPENDIX D

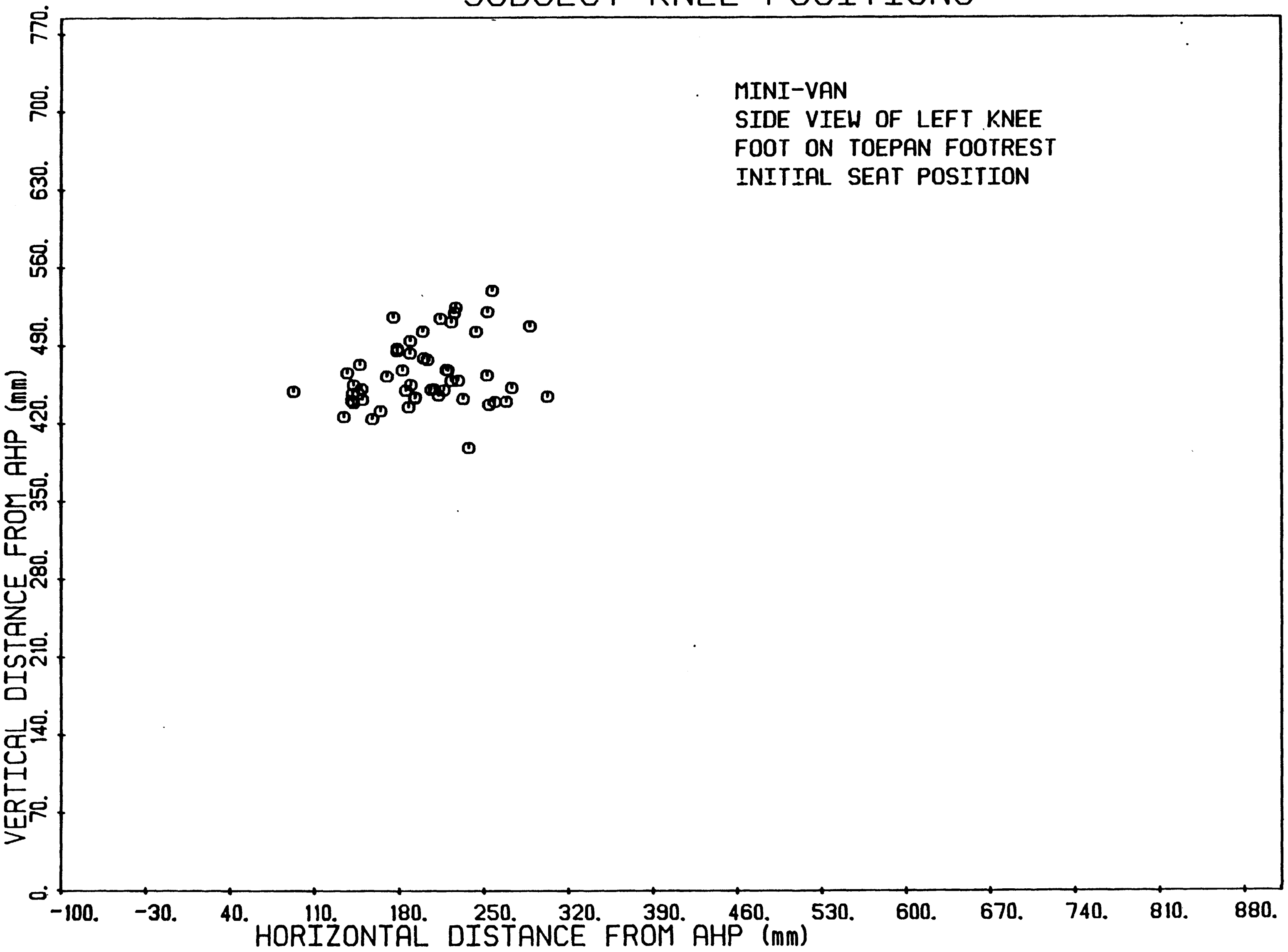
PLOTS OF KNEE LOCATIONS BY SUBJECT USING LOWER MARGIN OF PATELLA TARGET ON EACH LEG

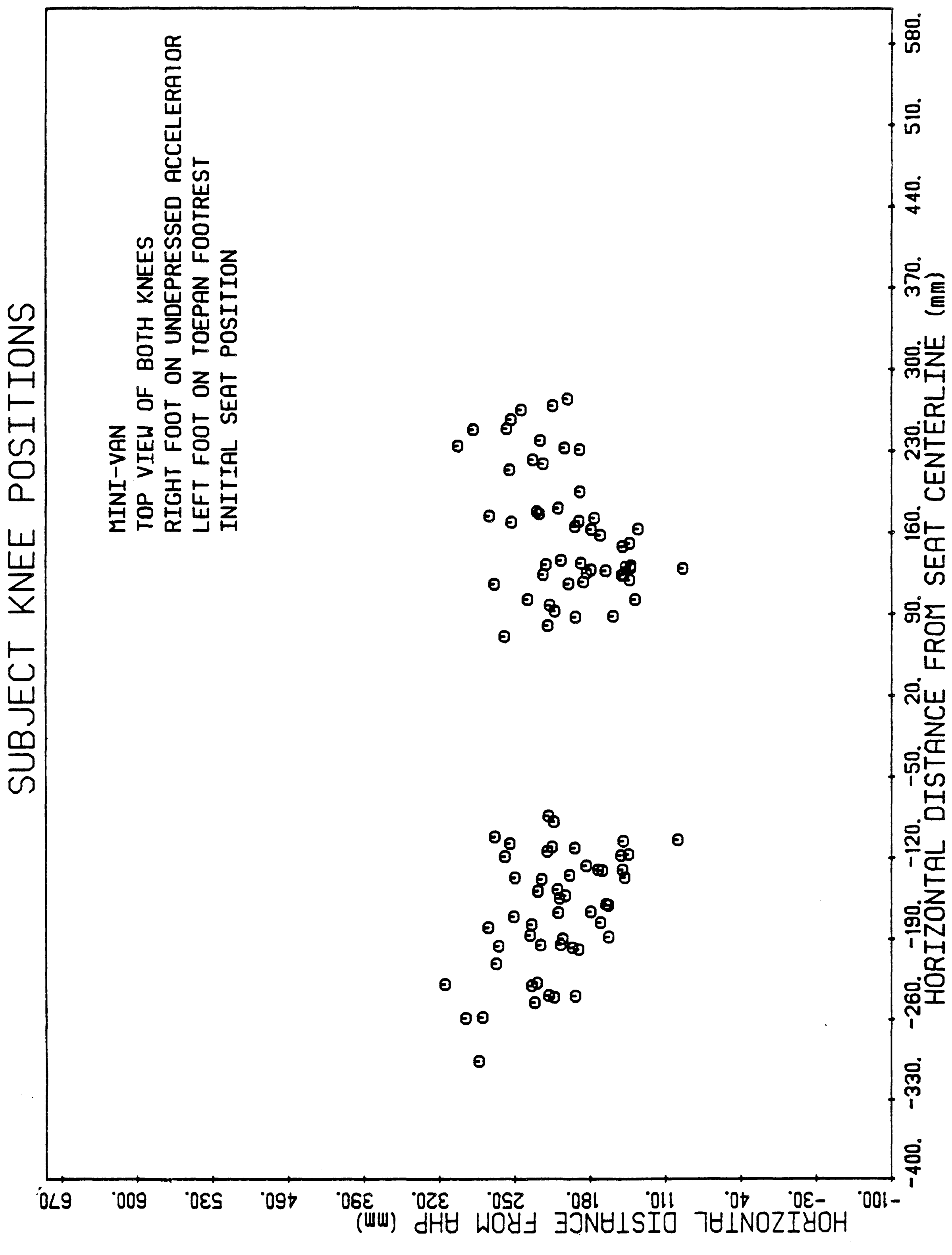
UNTRANSLATED SEAT CONDITIONS

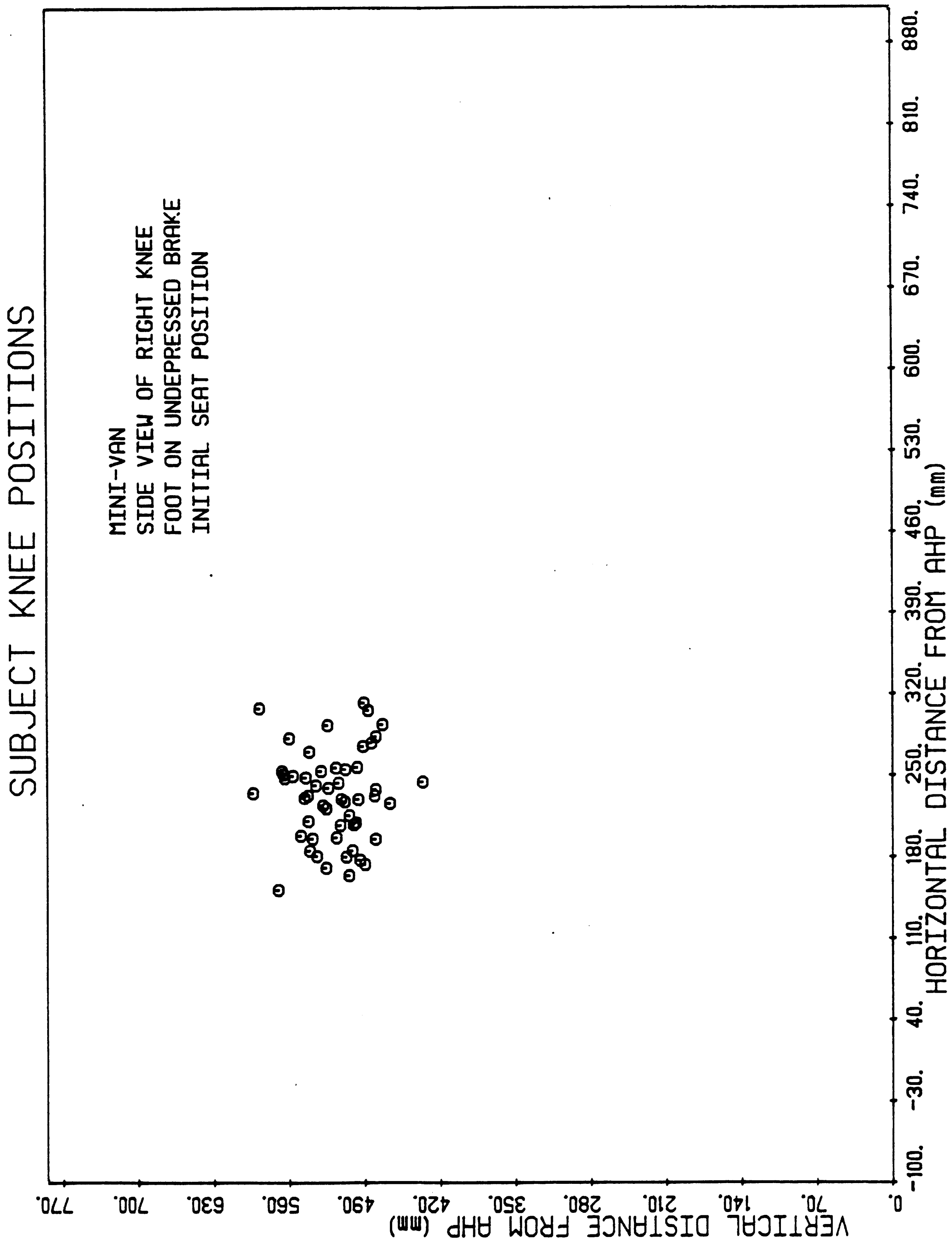
SUBJECT KNEE POSITIONS

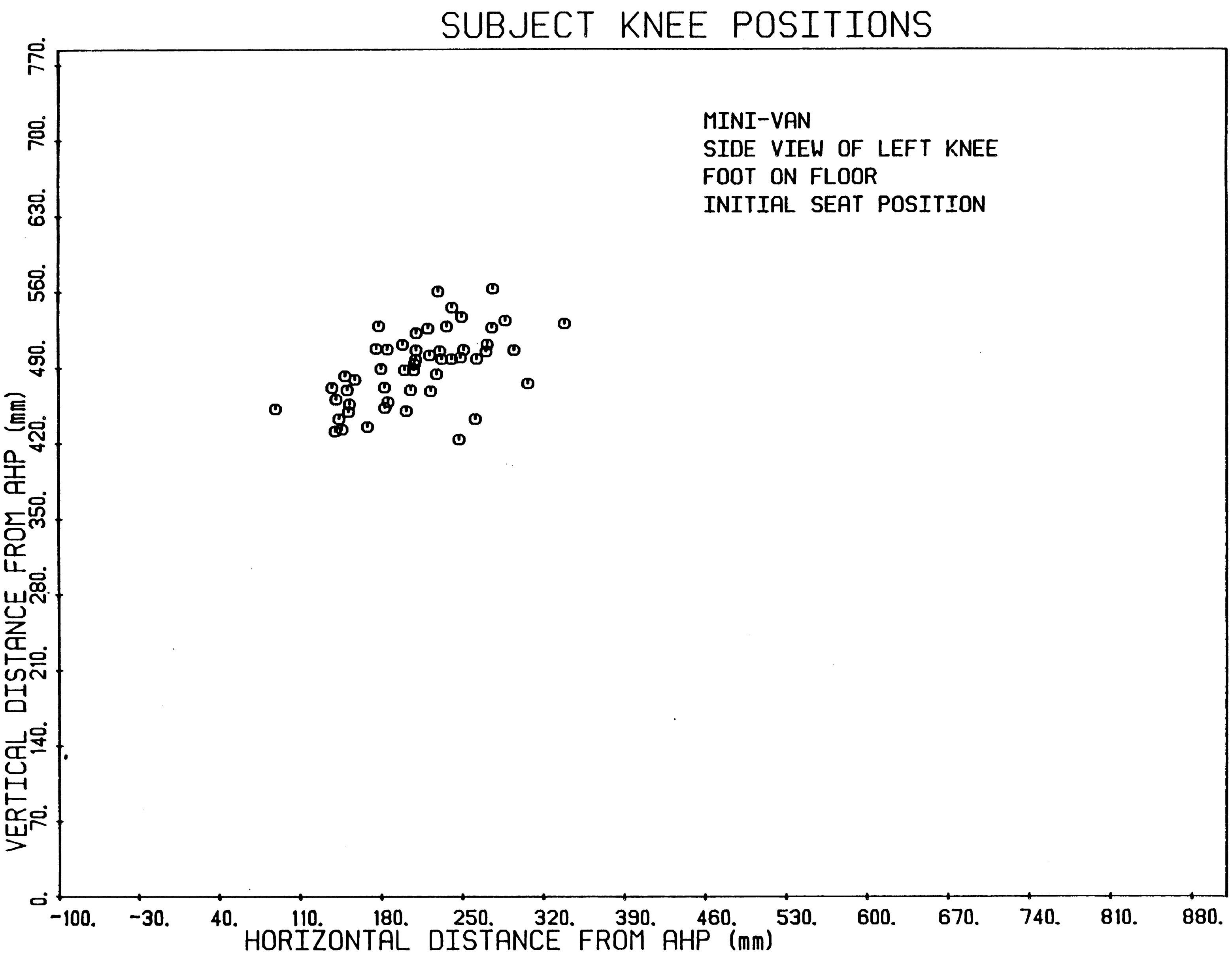


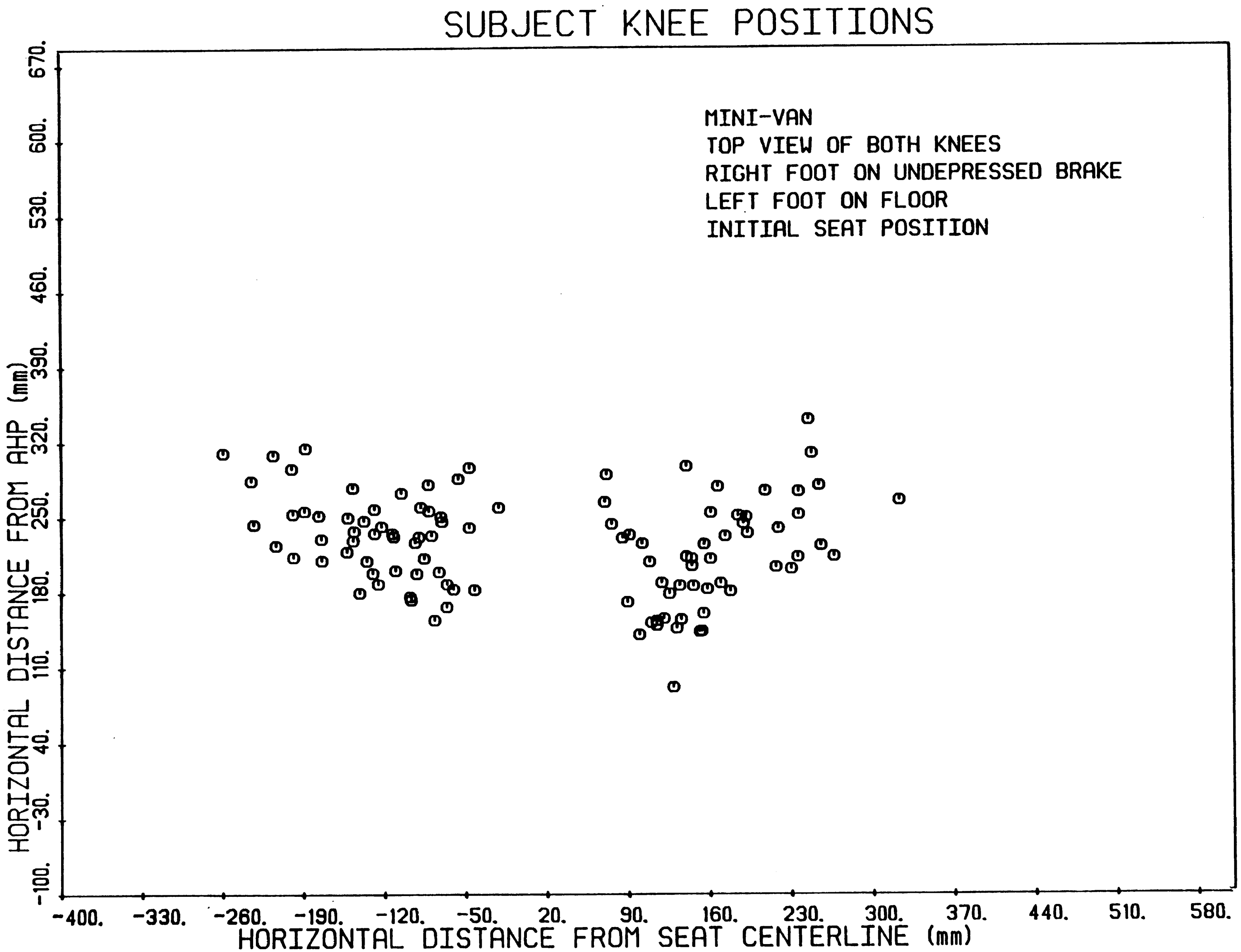
SUBJECT KNEE POSITIONS

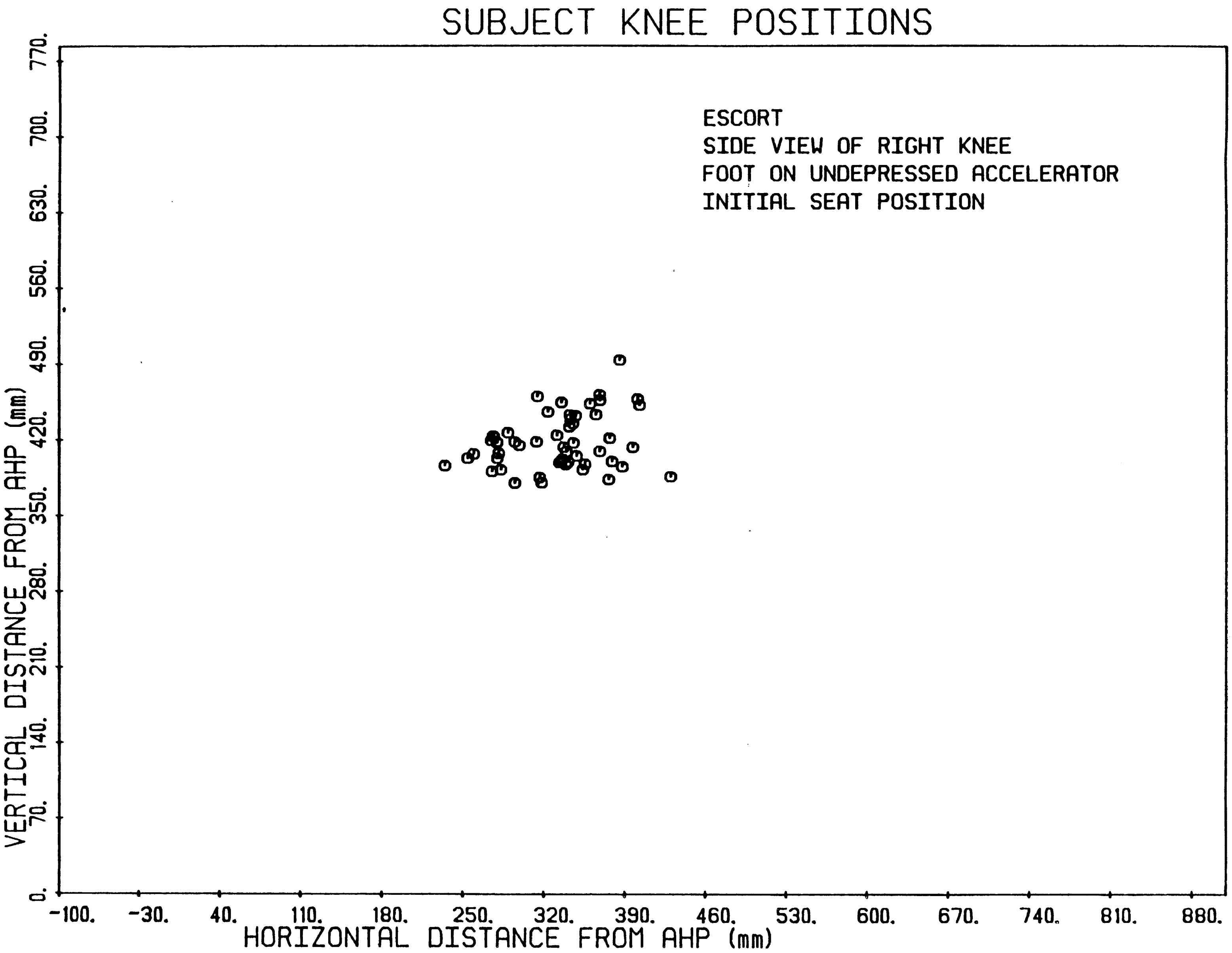


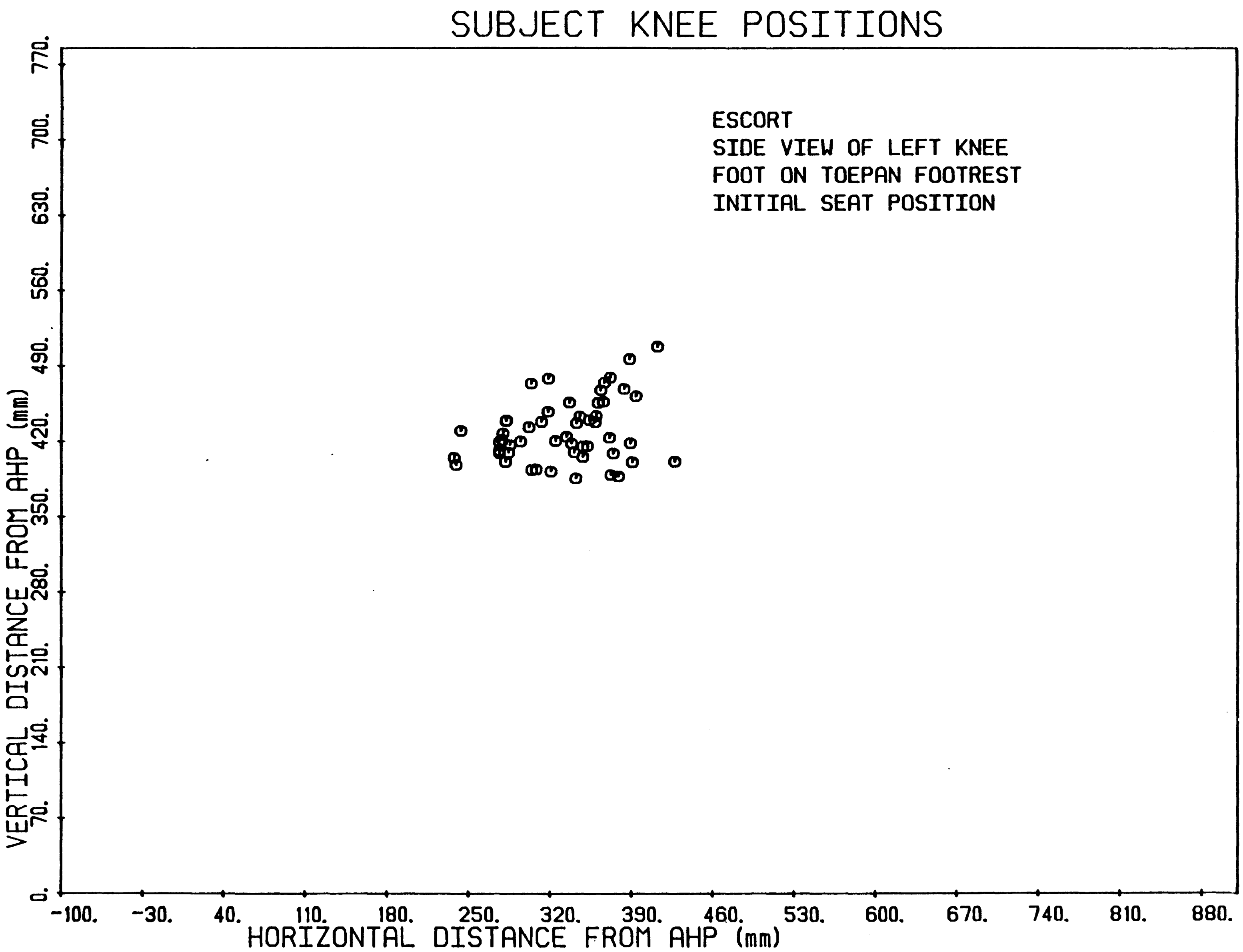

SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED BRAKE
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.

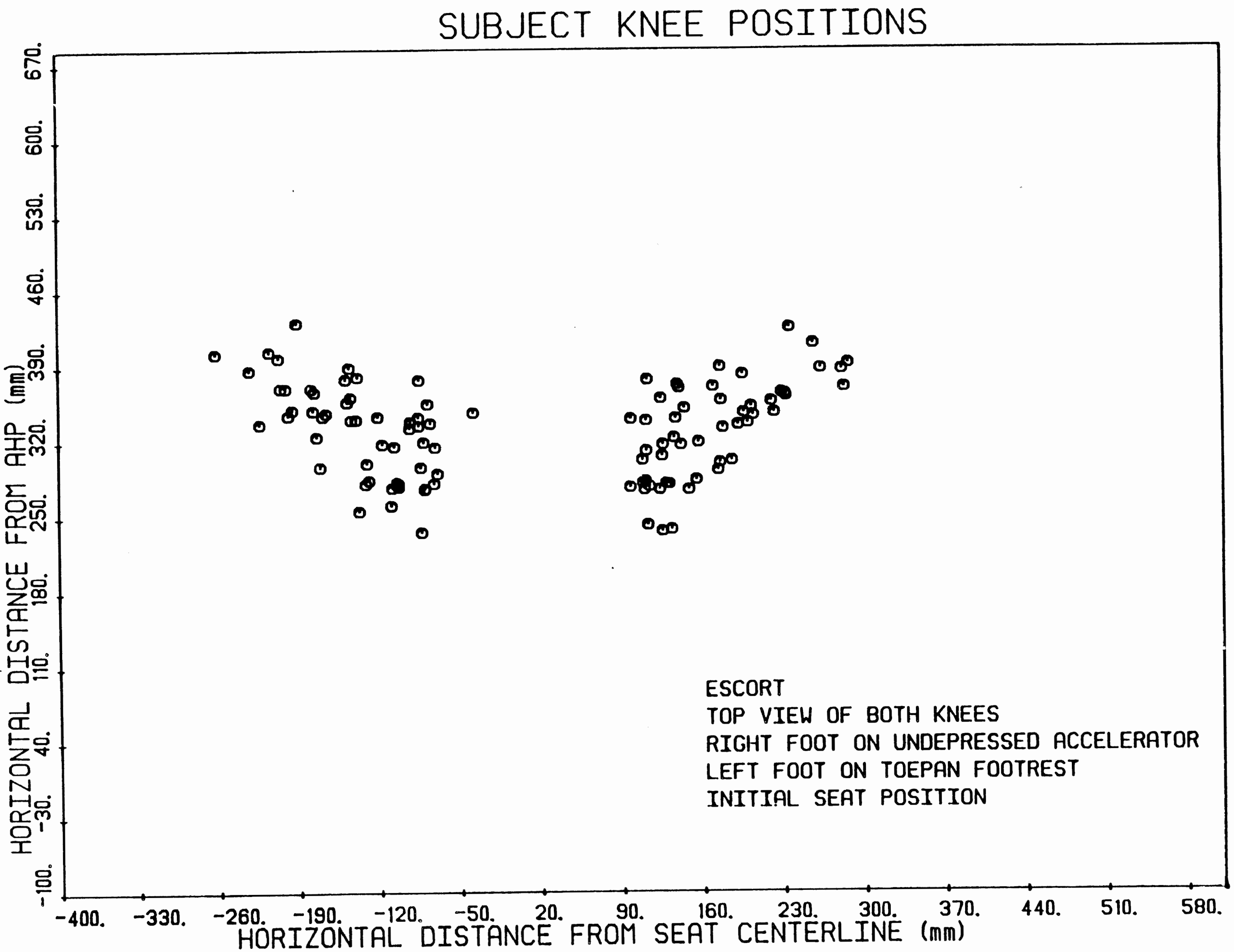

SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

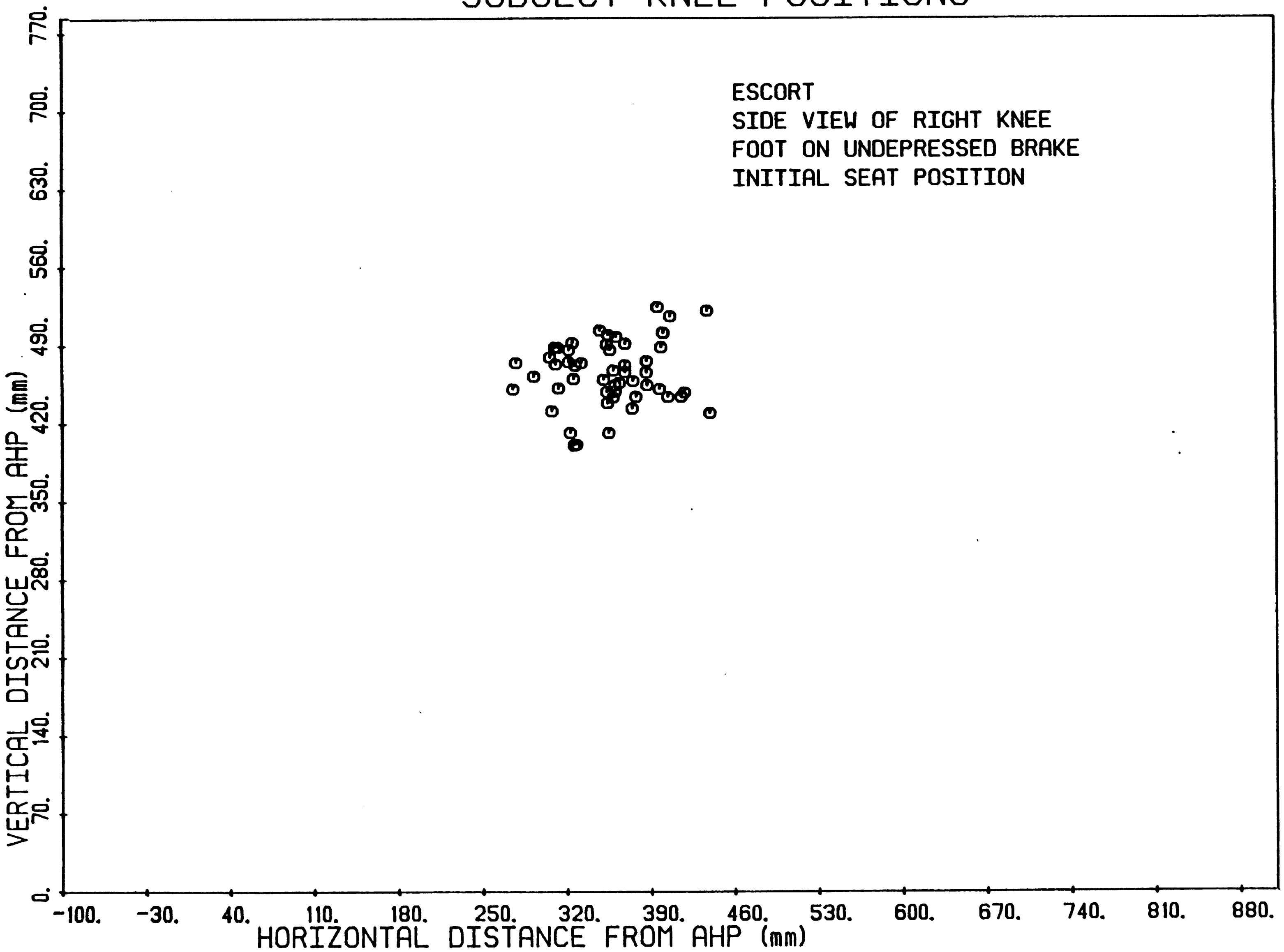

SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

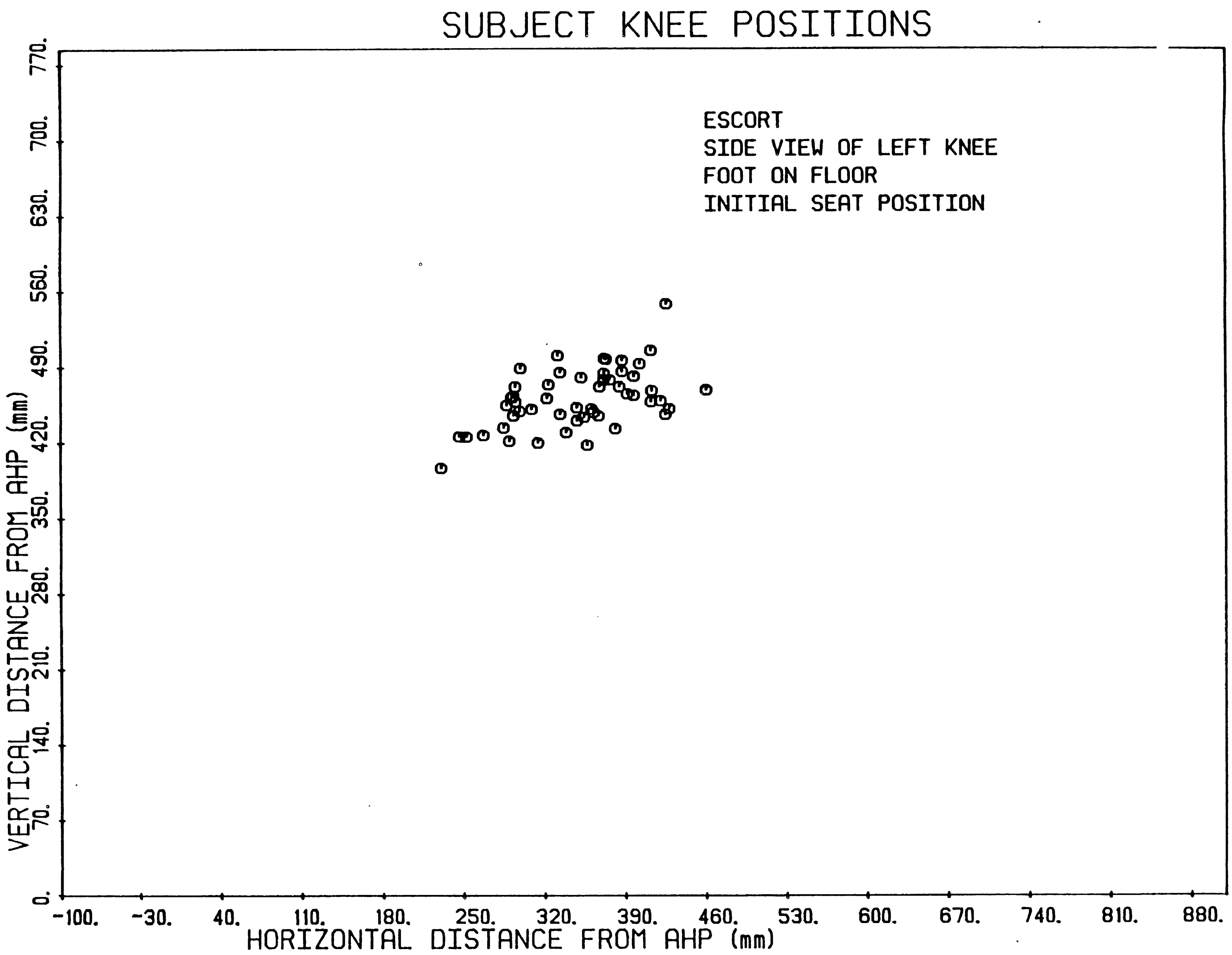


SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

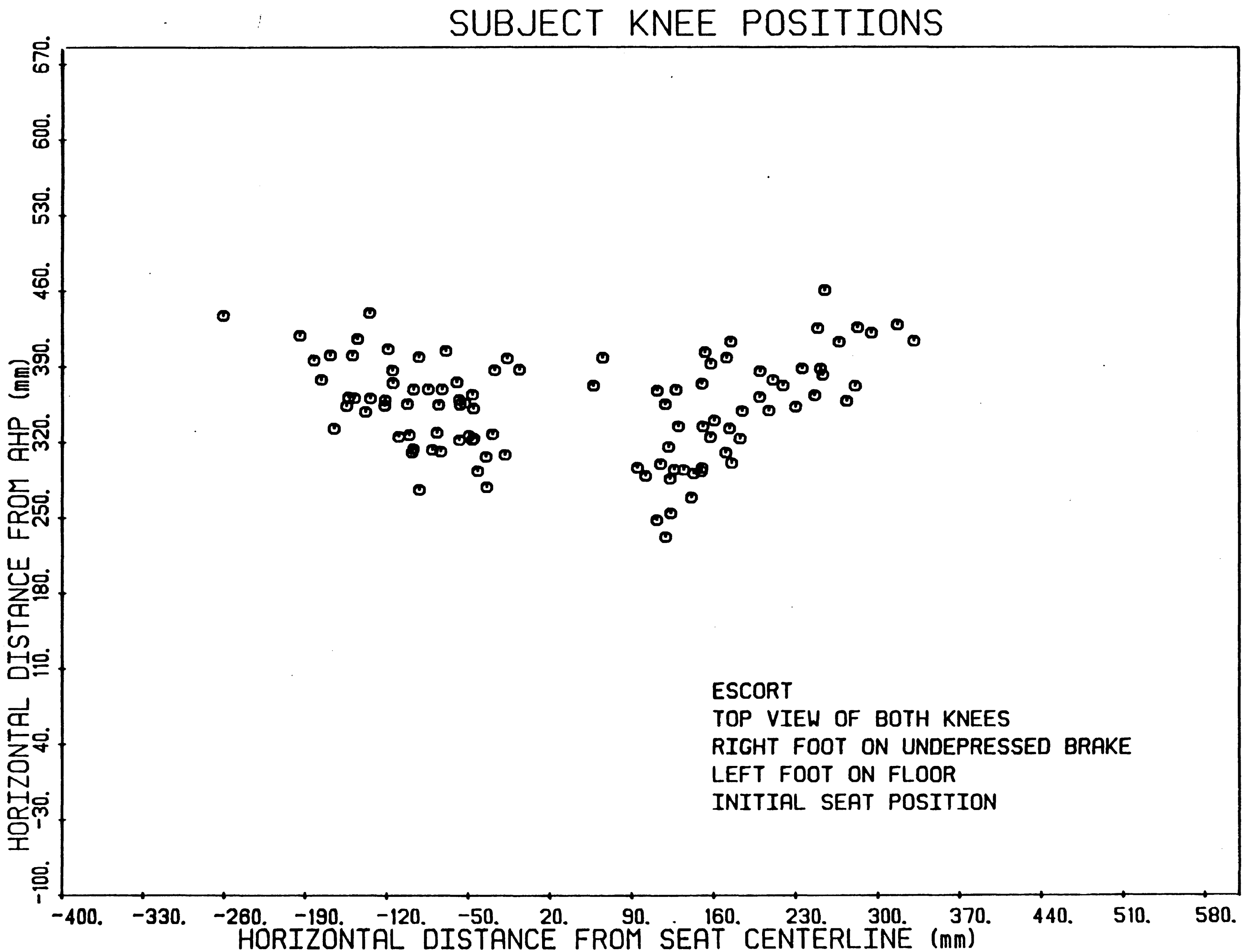

SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION

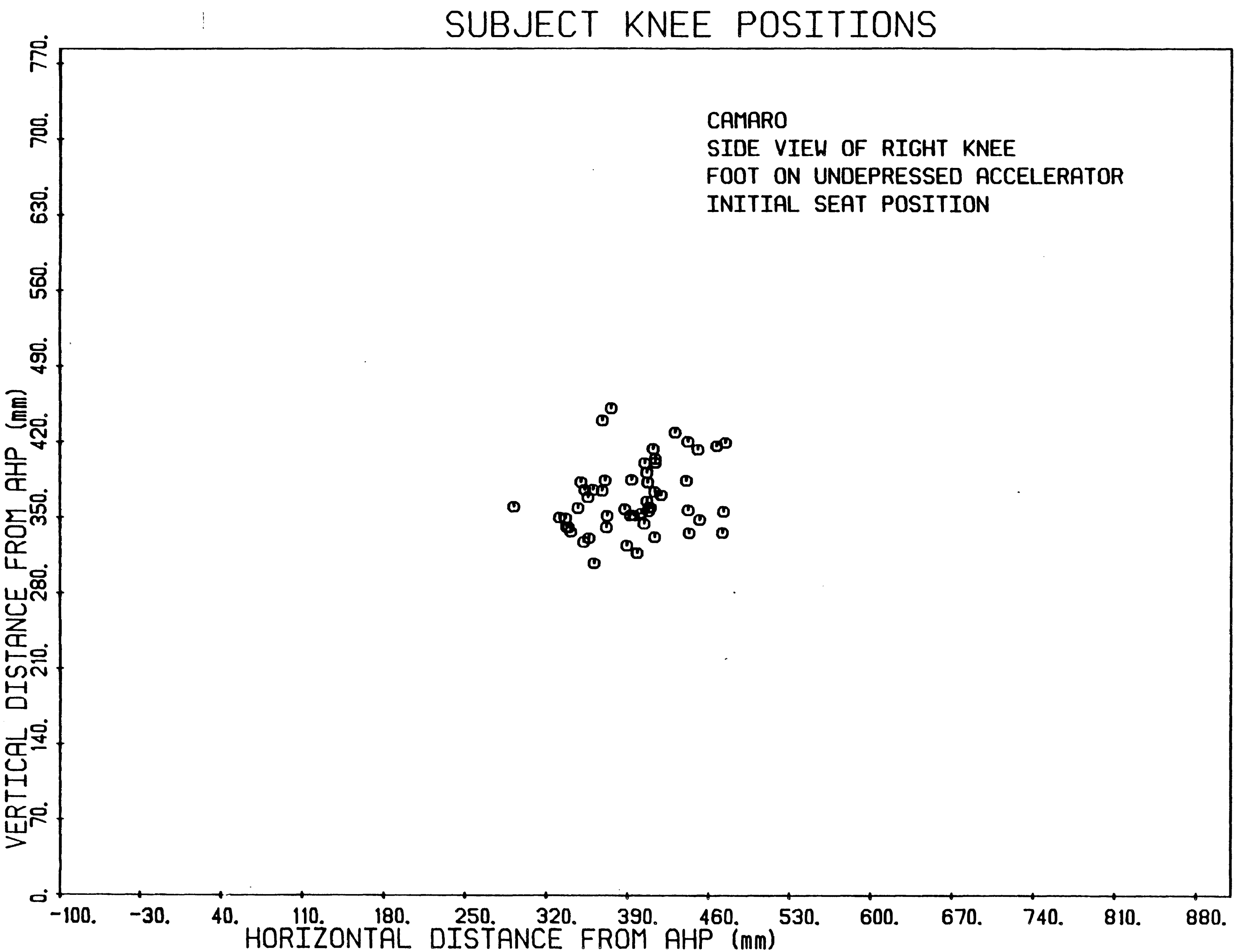
SUBJECT KNEE POSITIONS

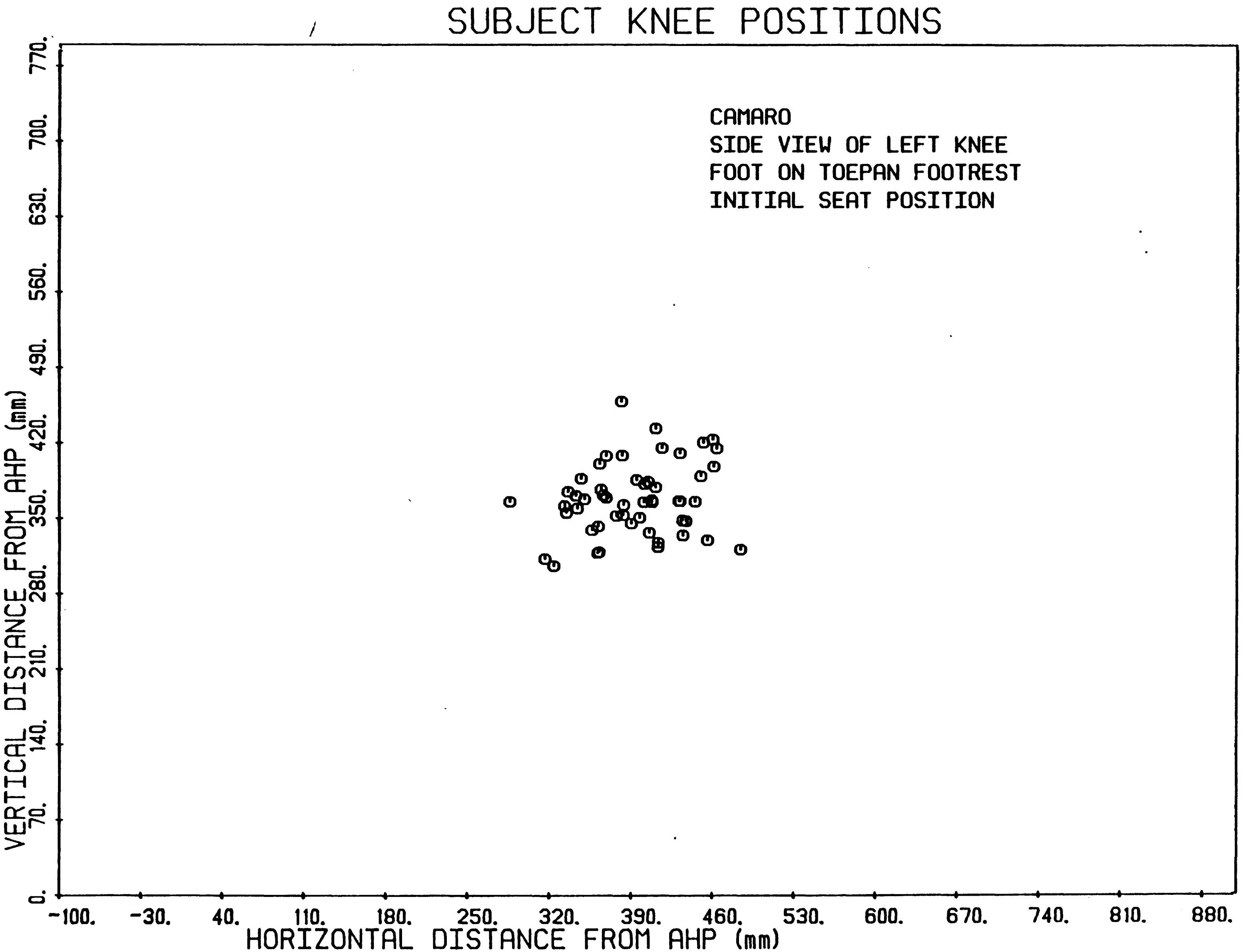




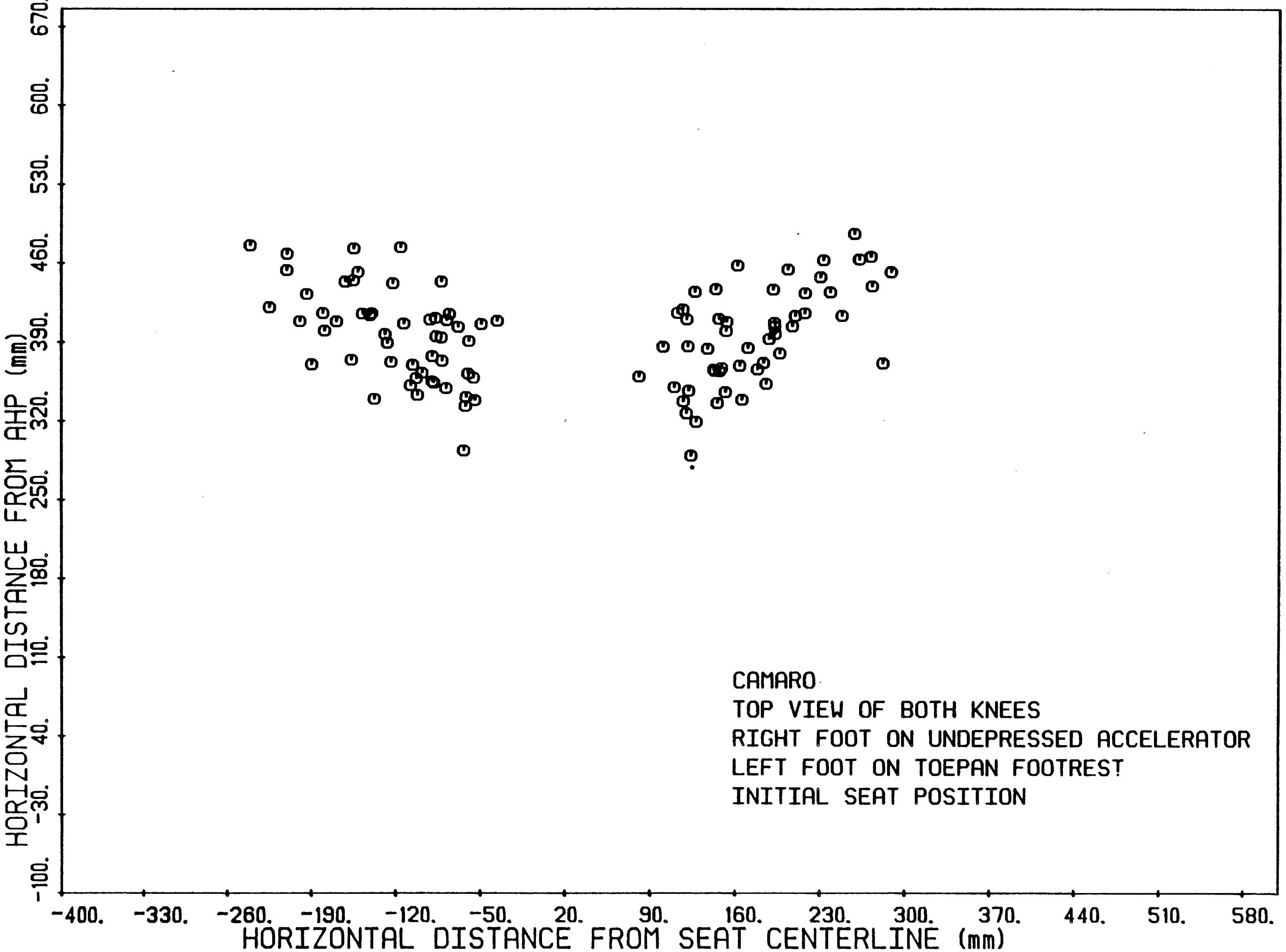
SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

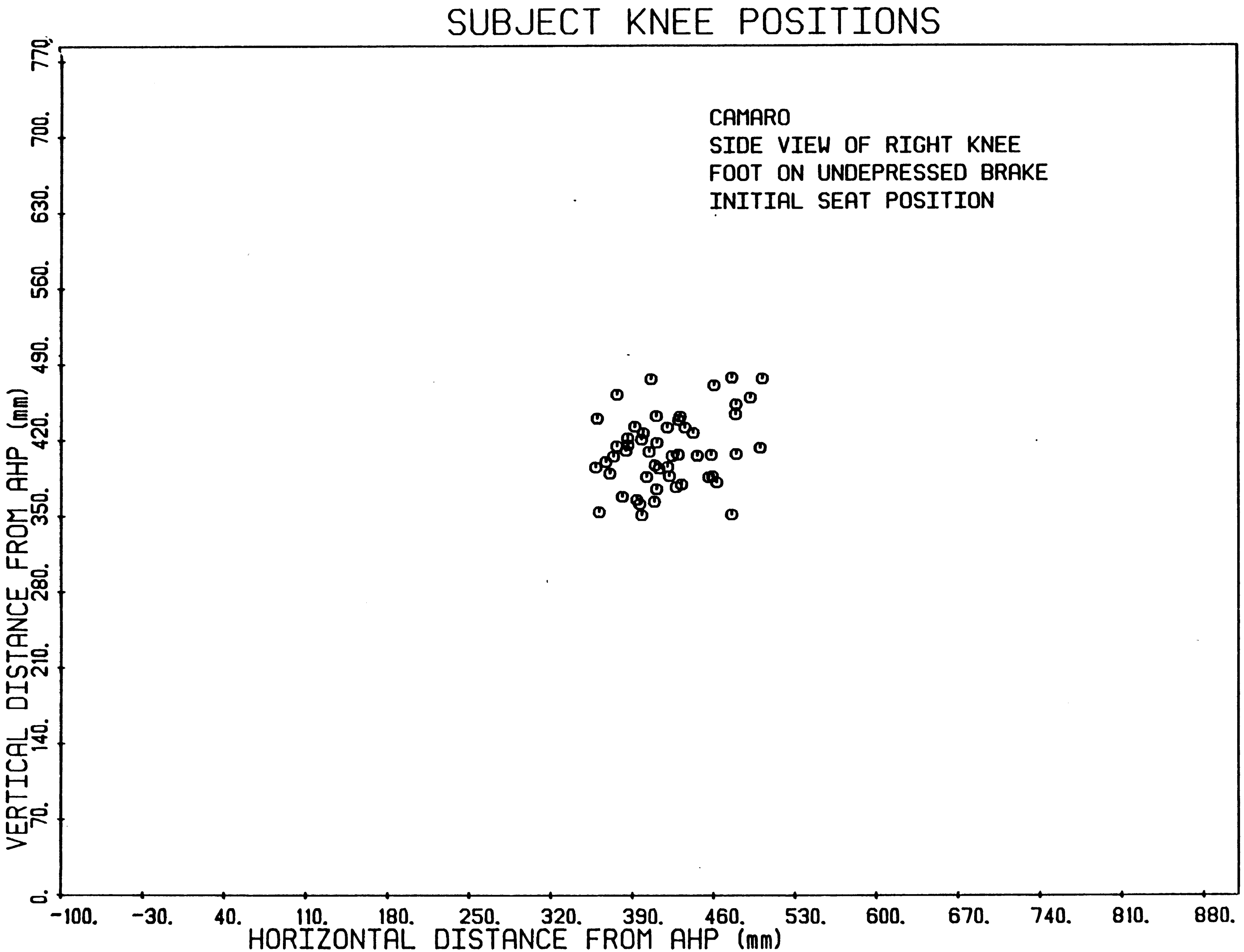

SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
INITIAL SEAT POSITION


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED ACCELERATOR
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

SUBJECT KNEE POSITIONS




SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON UNDEPRESSED BRAKE
INITIAL SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
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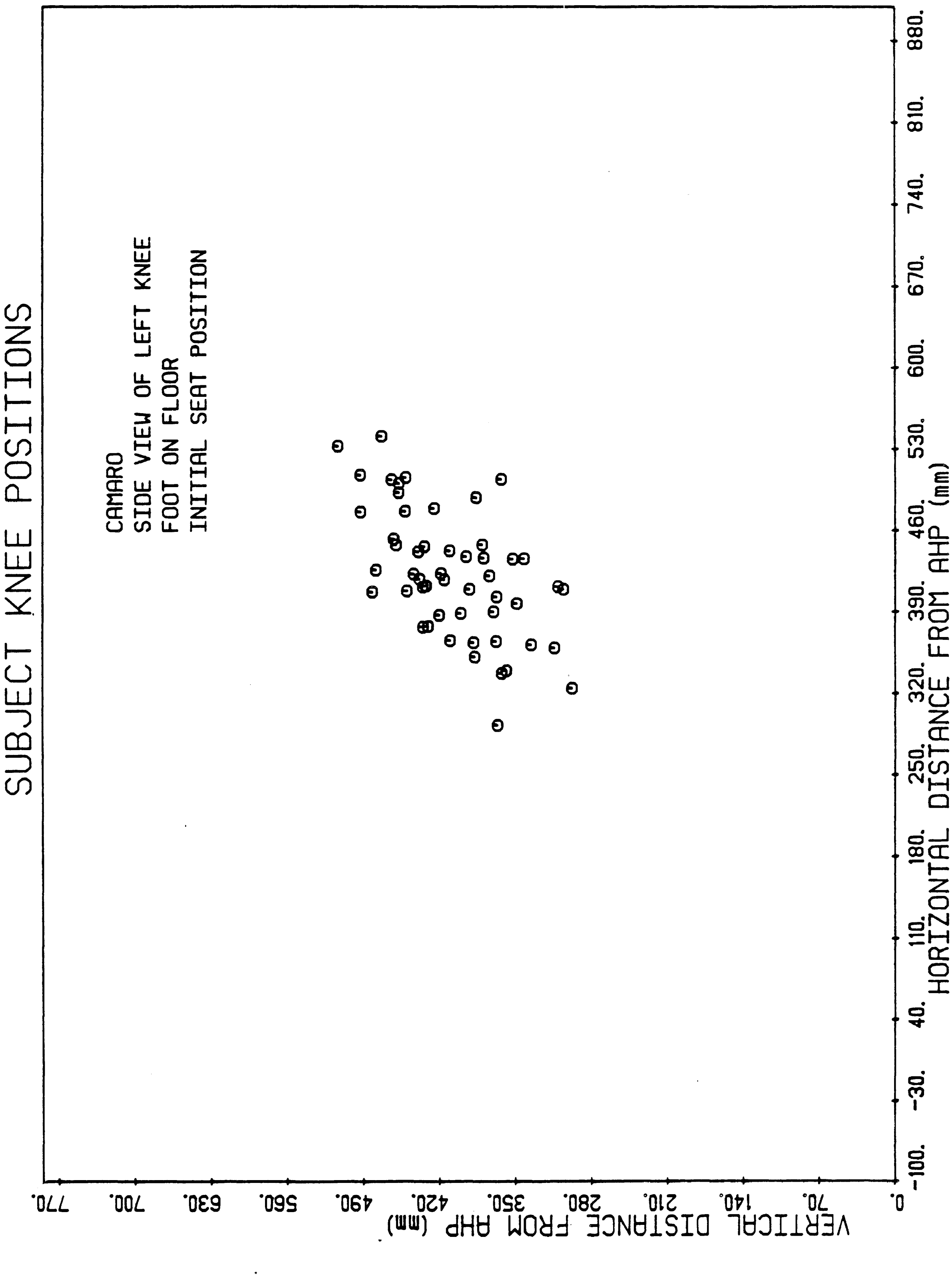
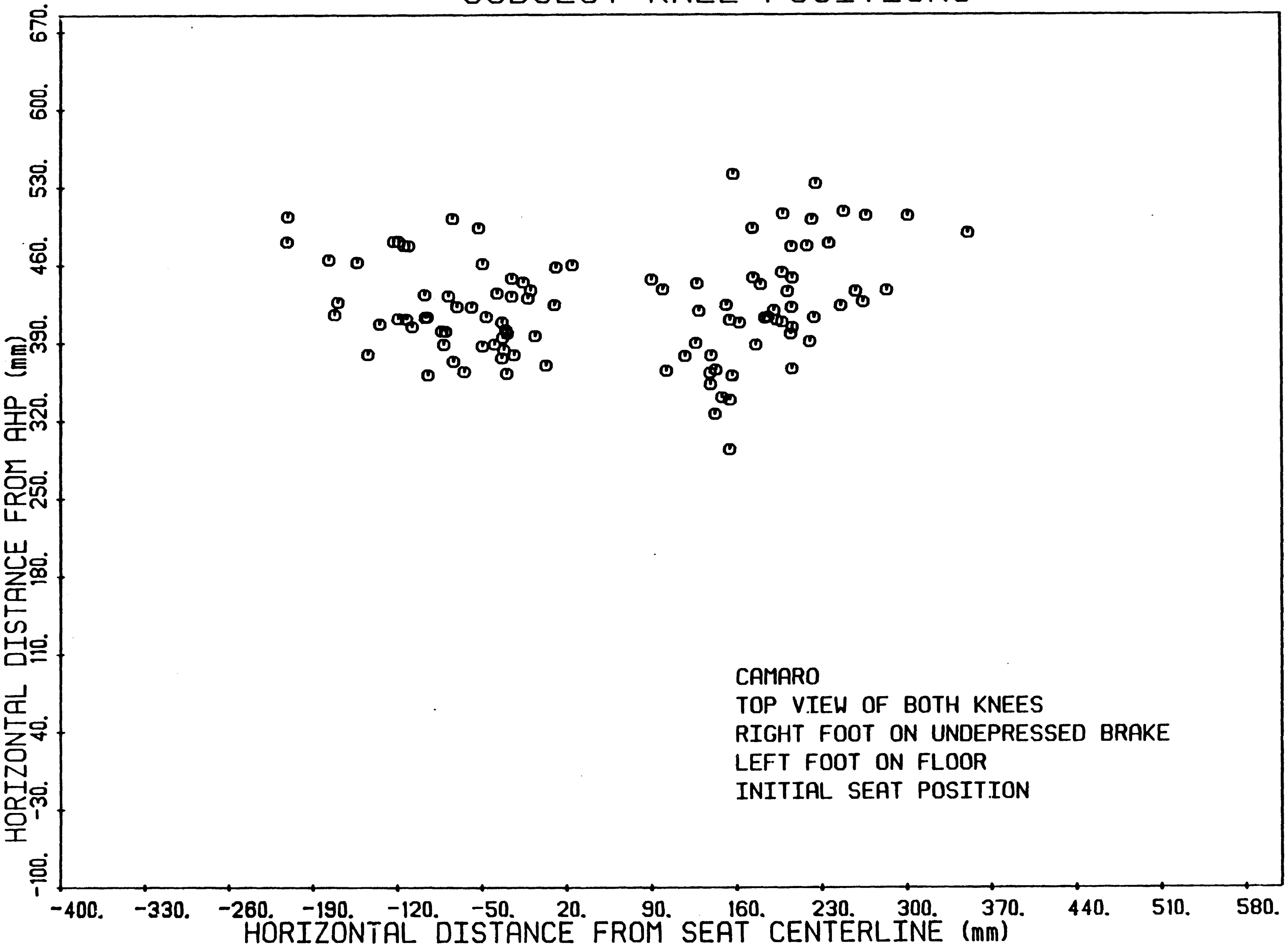
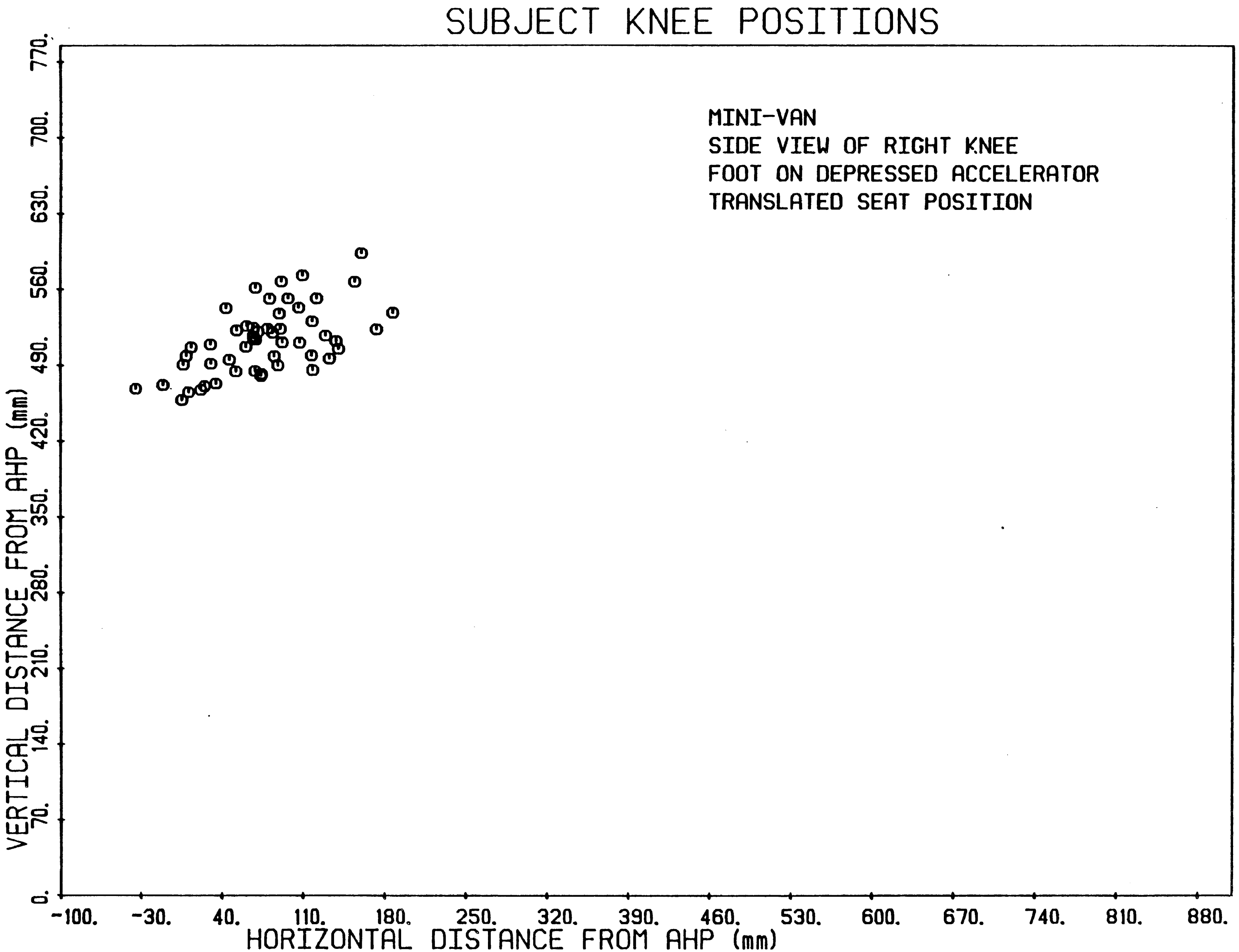
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

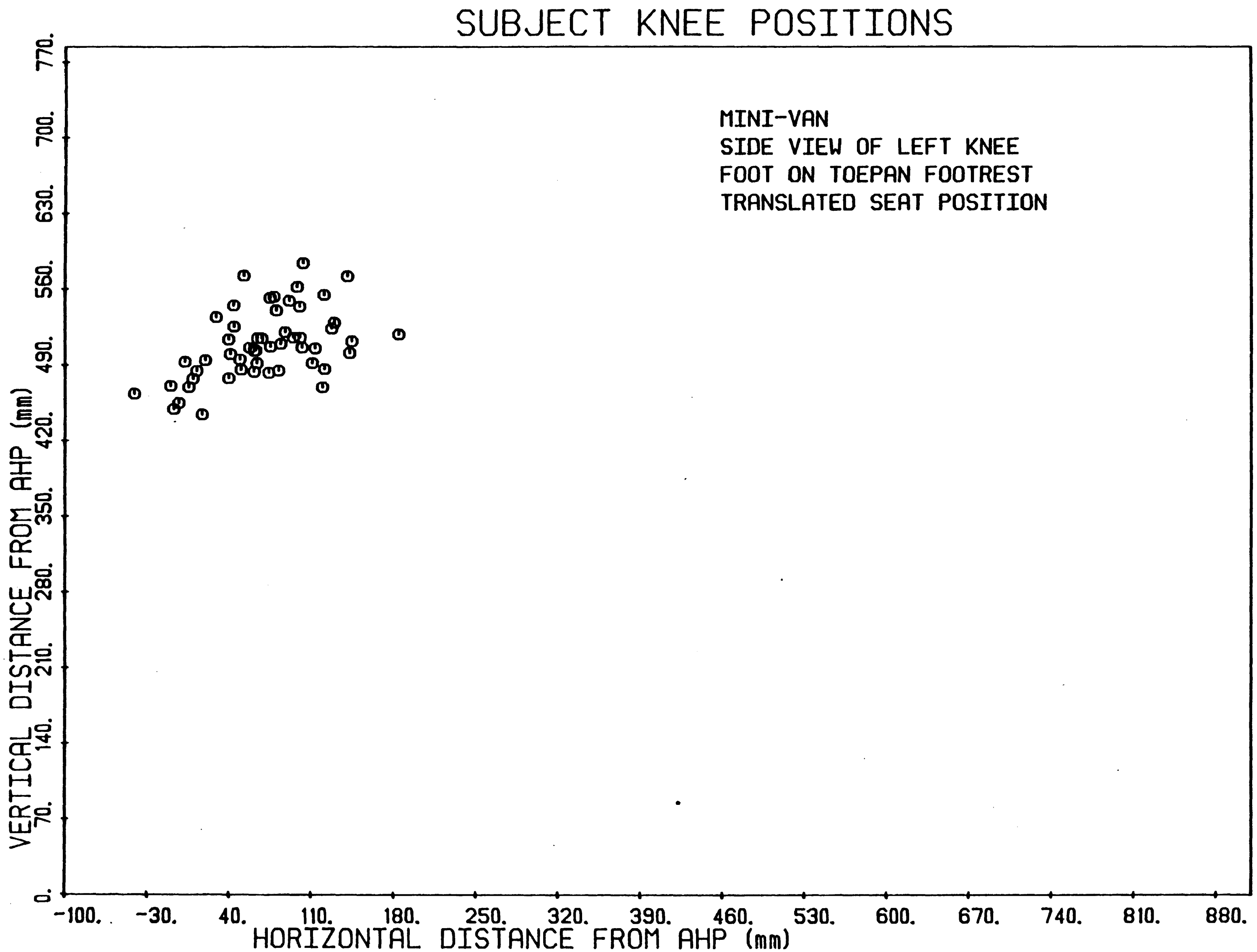

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
INITIAL SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
VERTICAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.

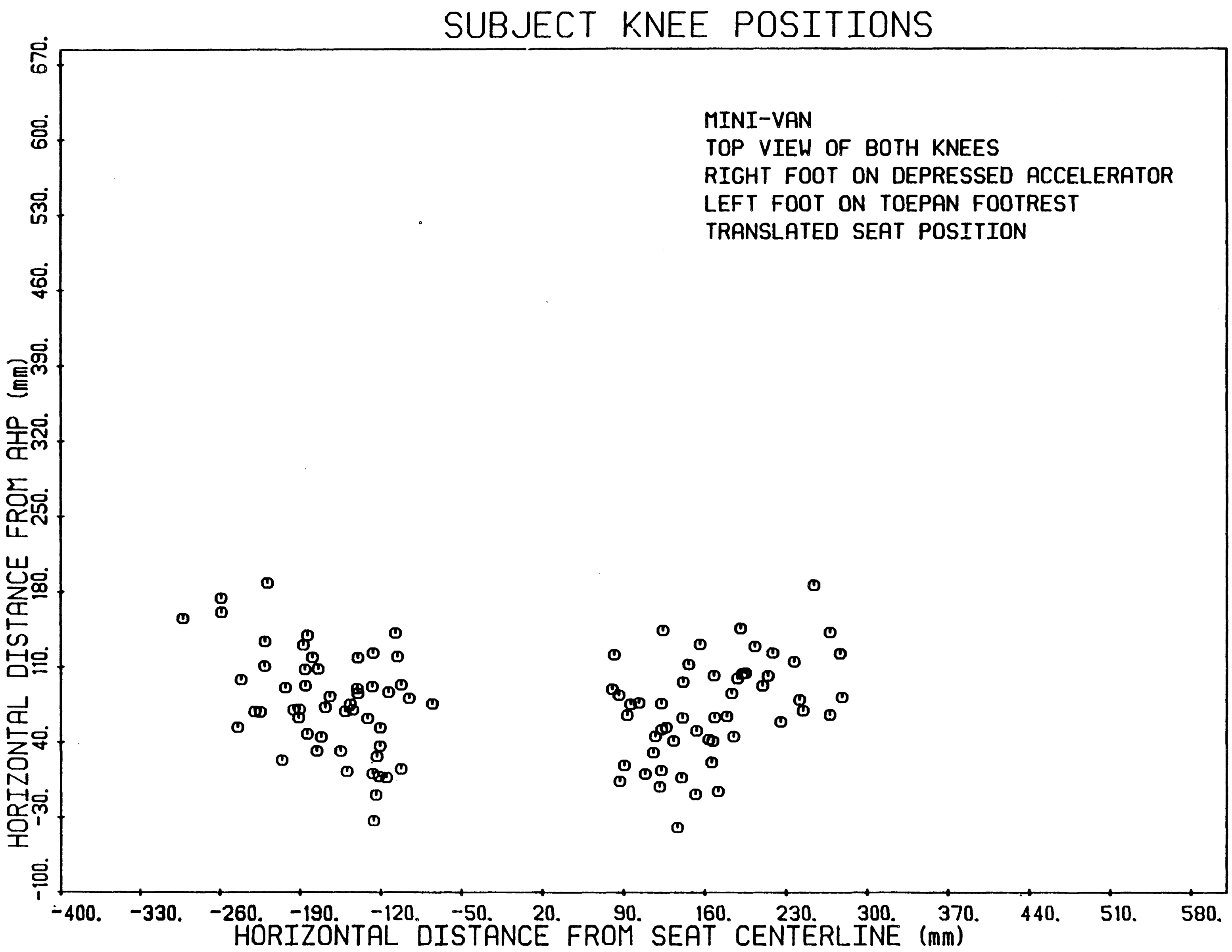
SUBJECT KNEE POSITIONS



TRANSLATED SEAT CONDITIONS


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
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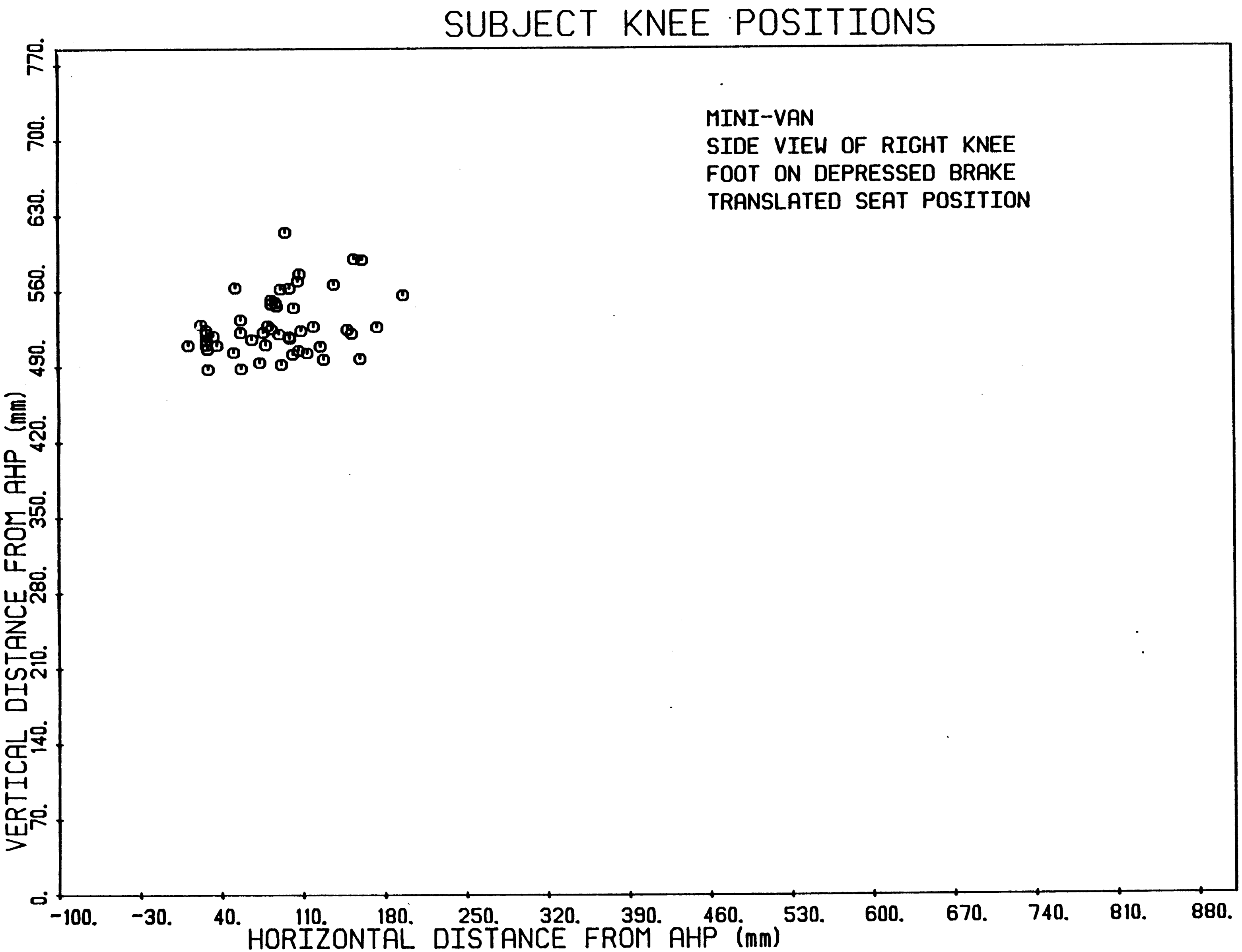
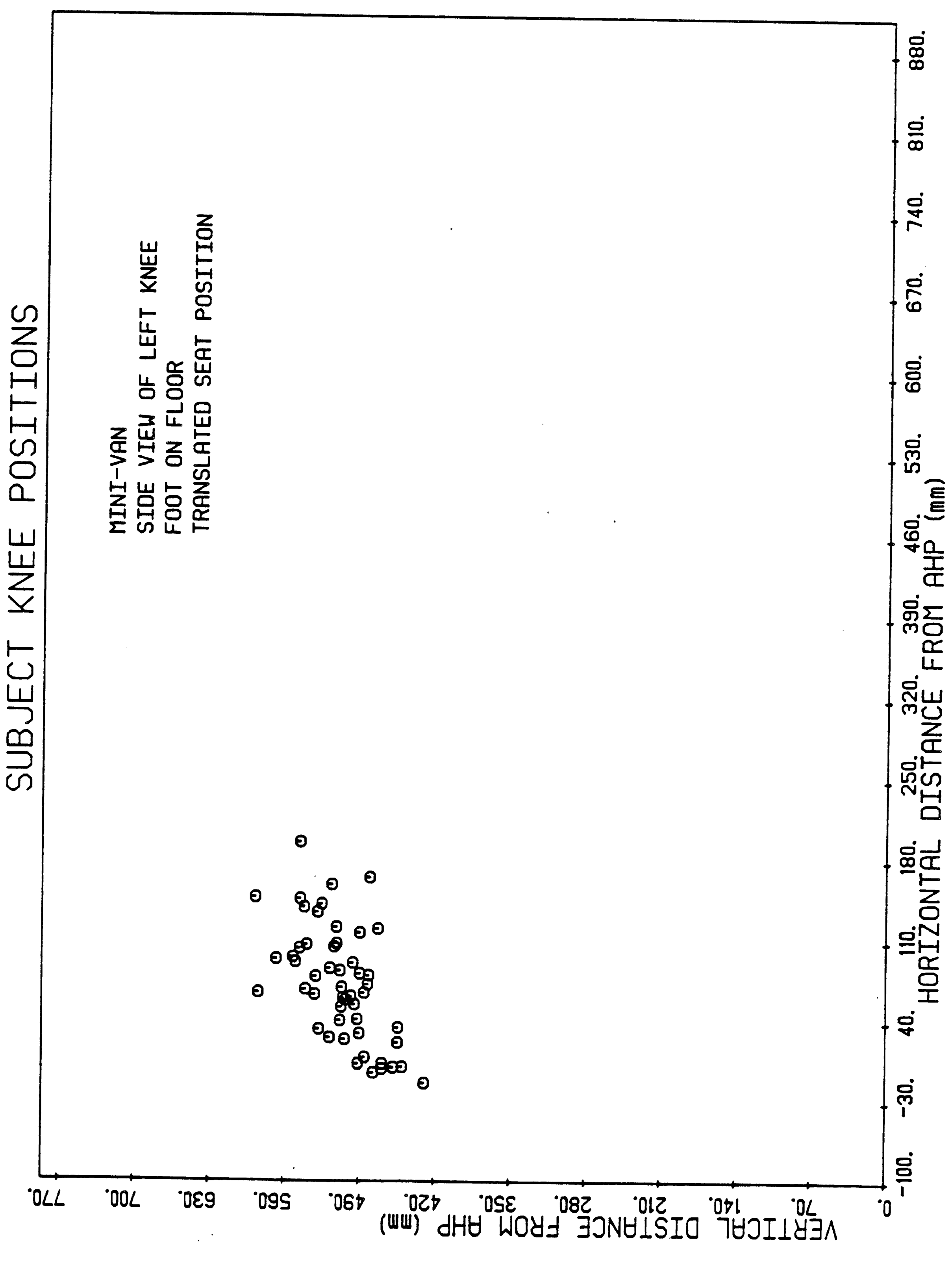
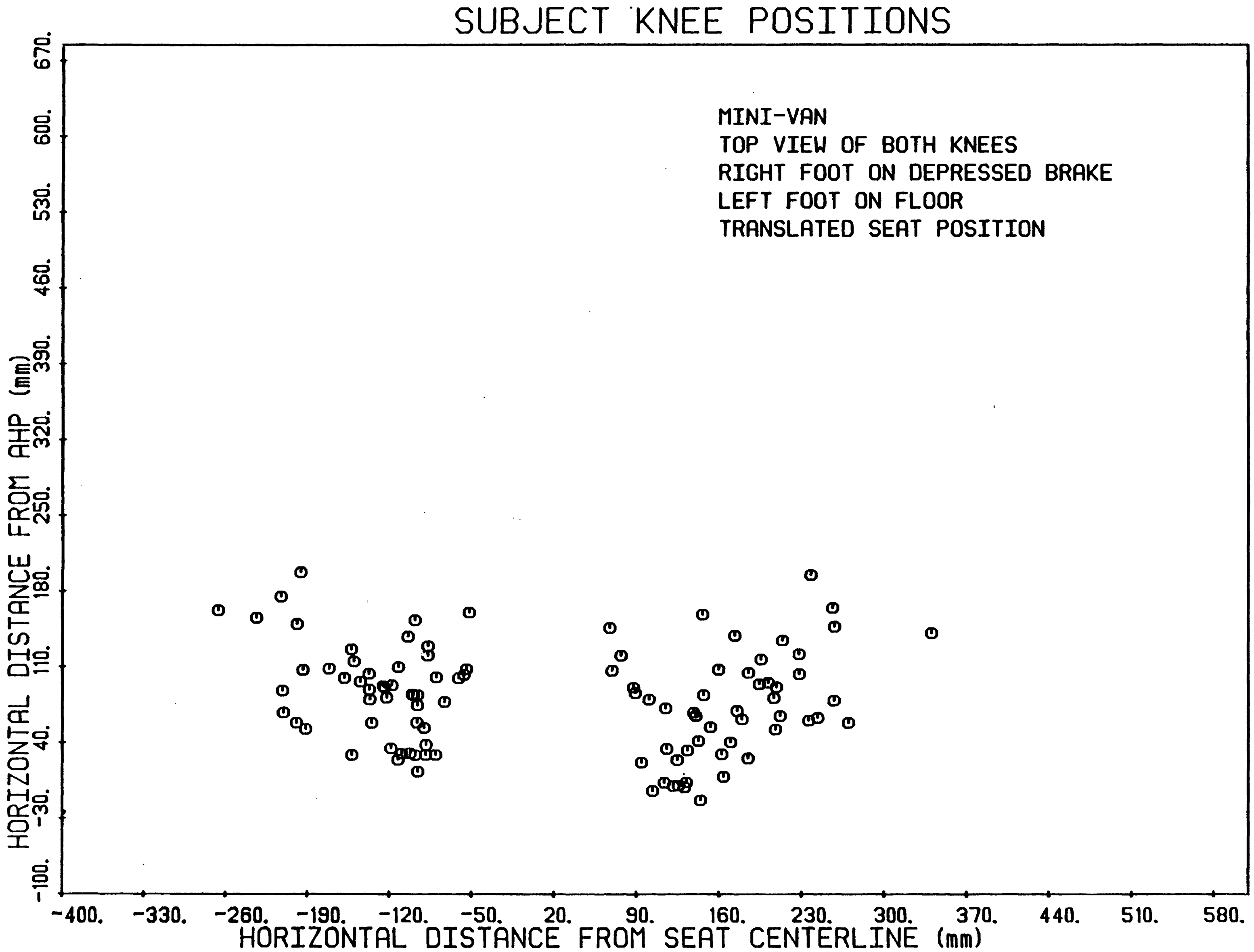
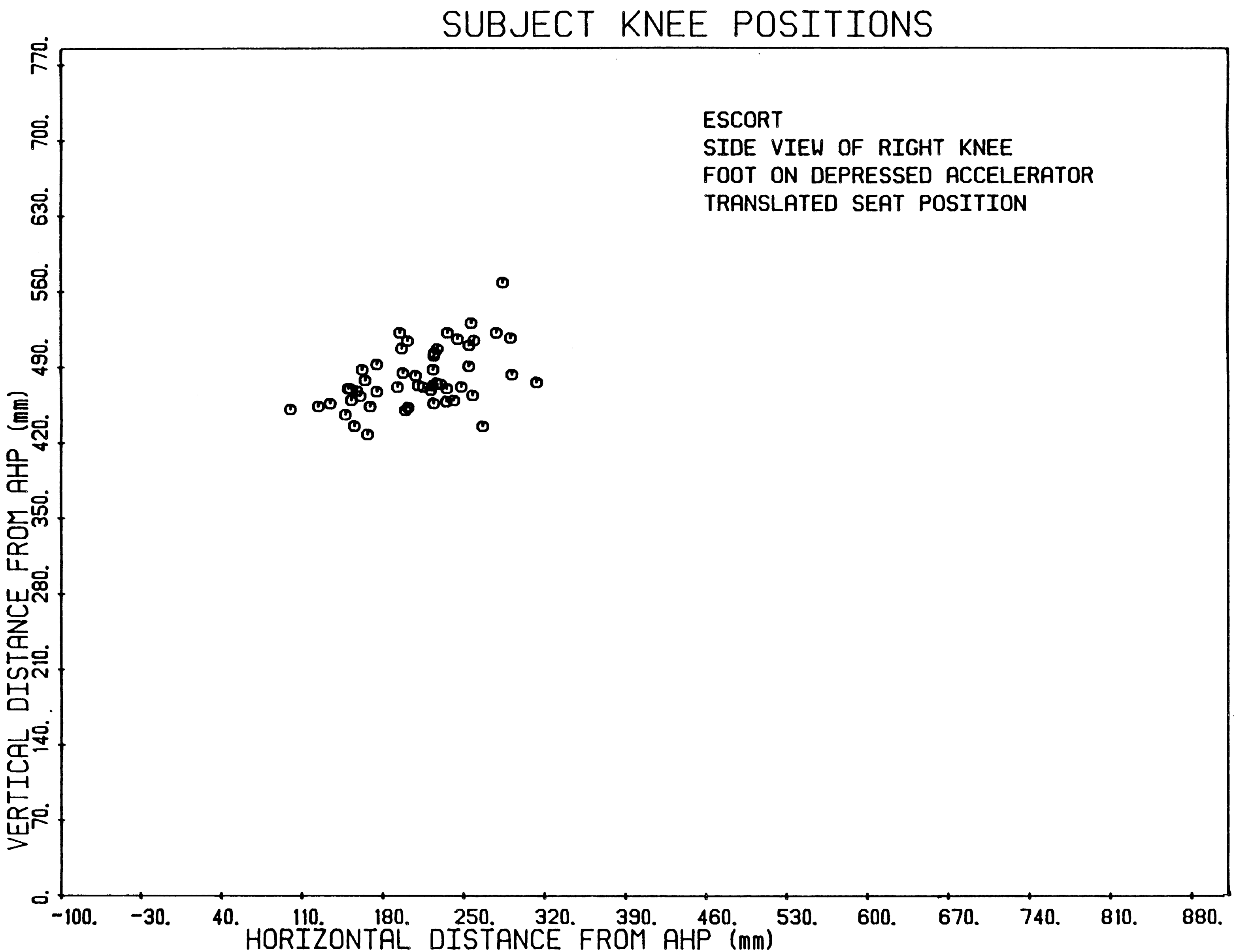
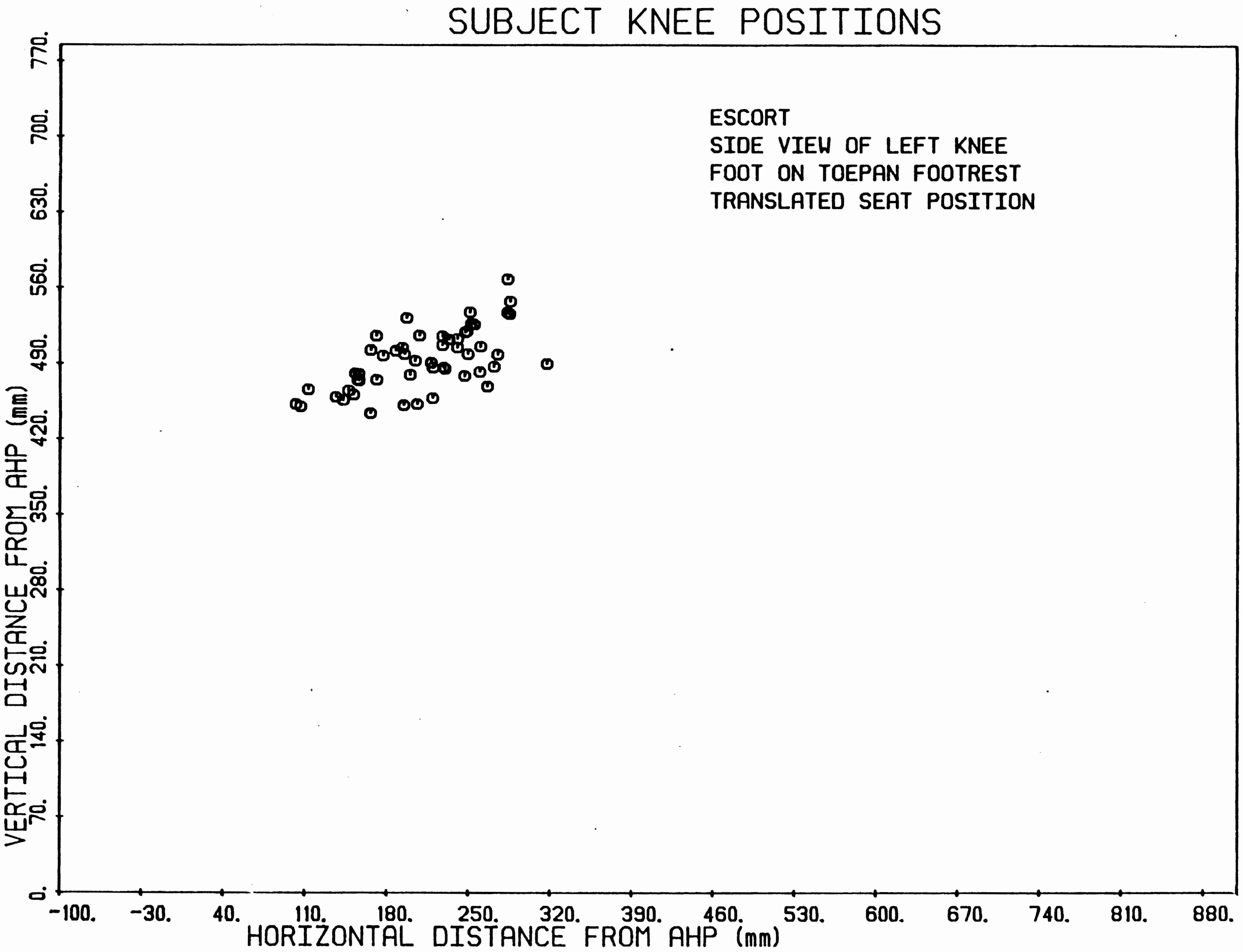
370.
440.
510.
580.


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED BRAKE
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
MINI-VAN
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.


SUBJECT KNEE POSITIONS
MINI-VAN
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.


SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
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180.
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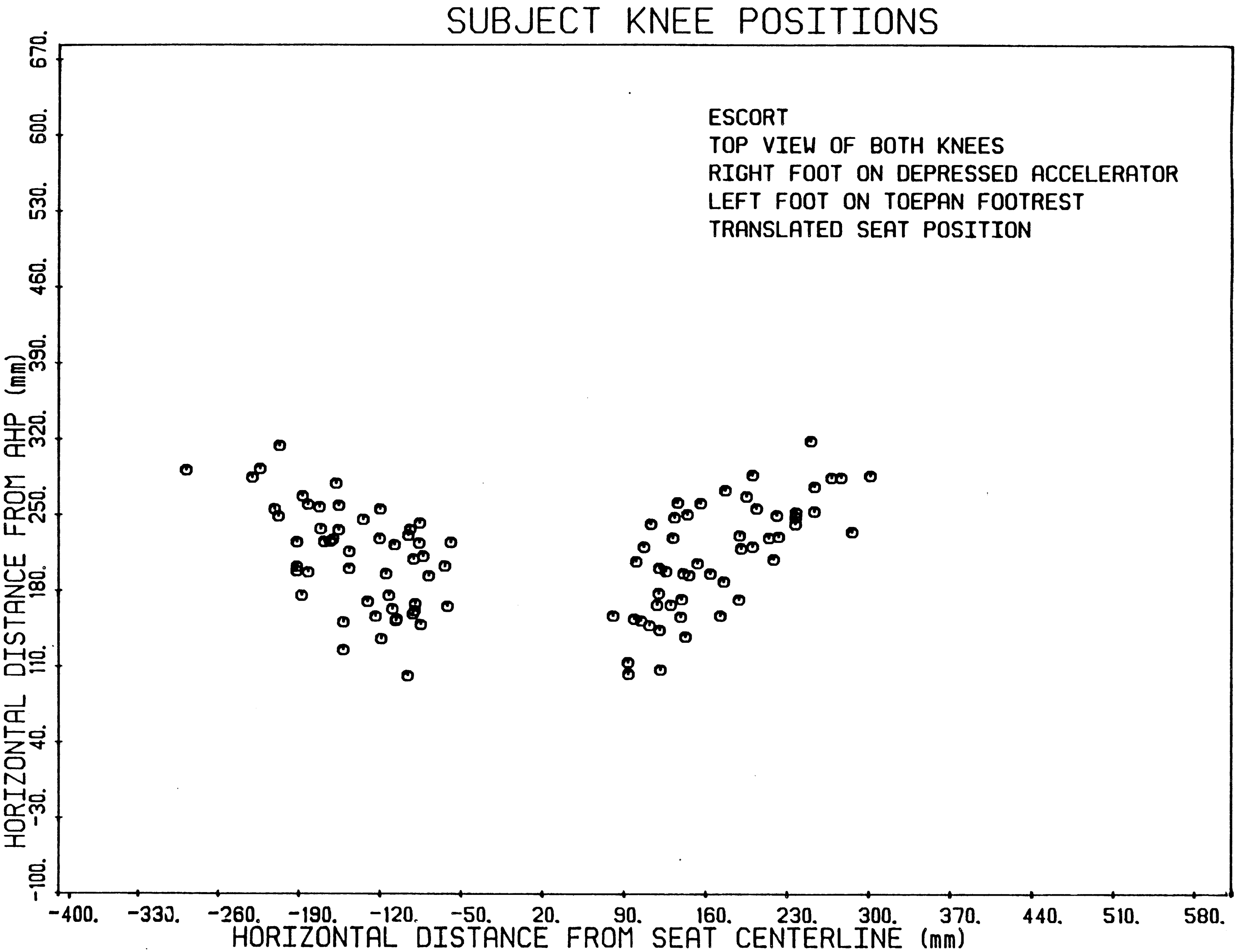
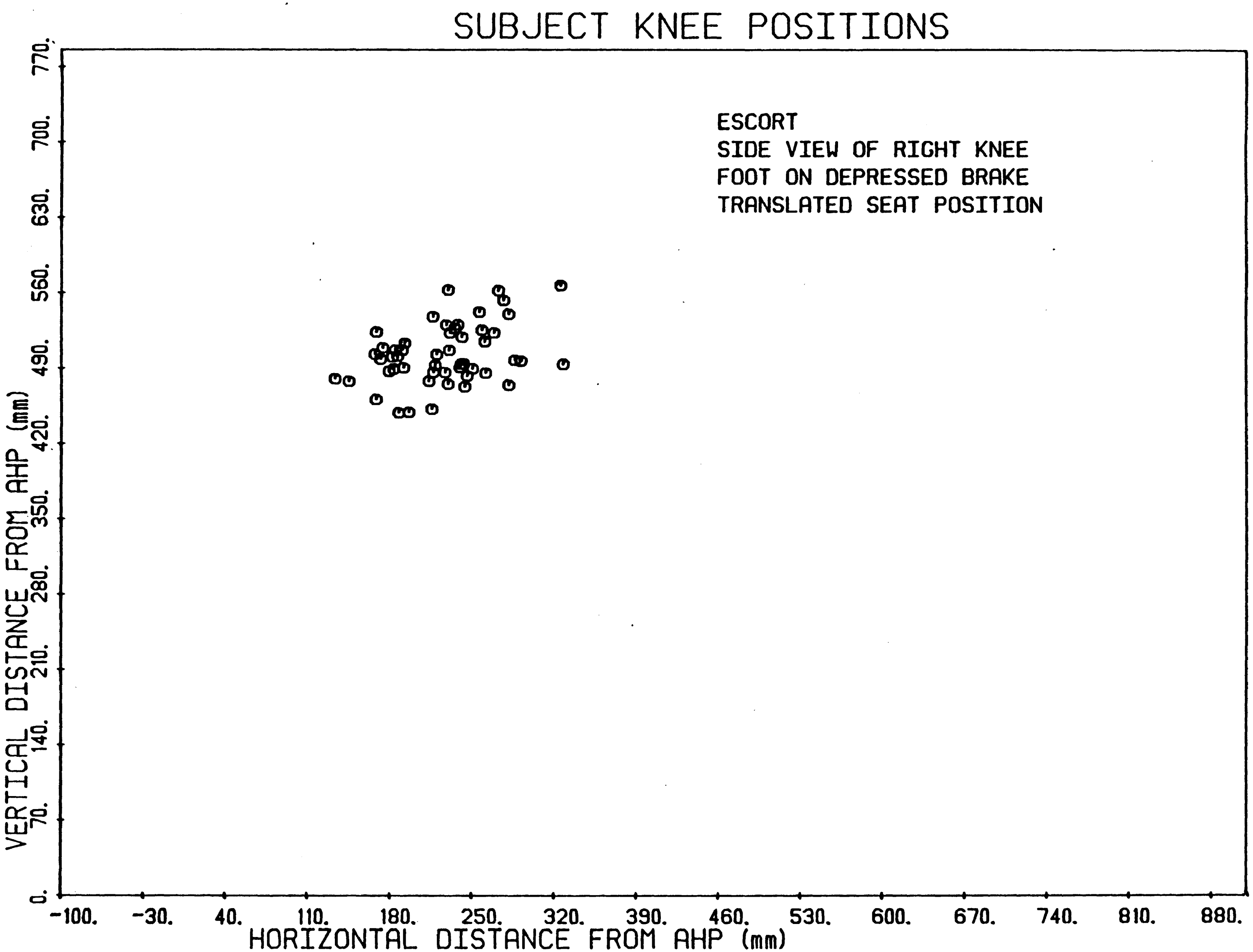
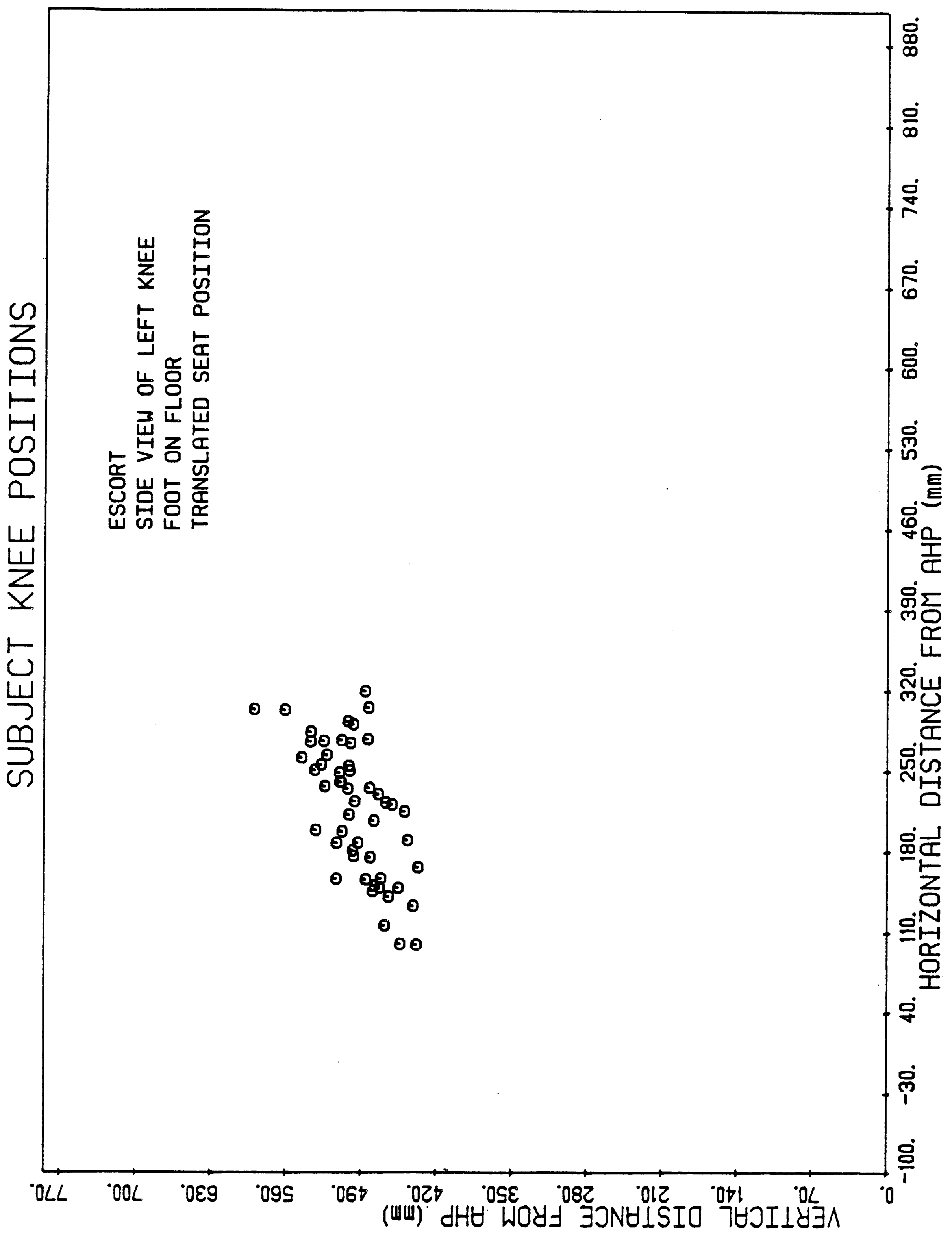
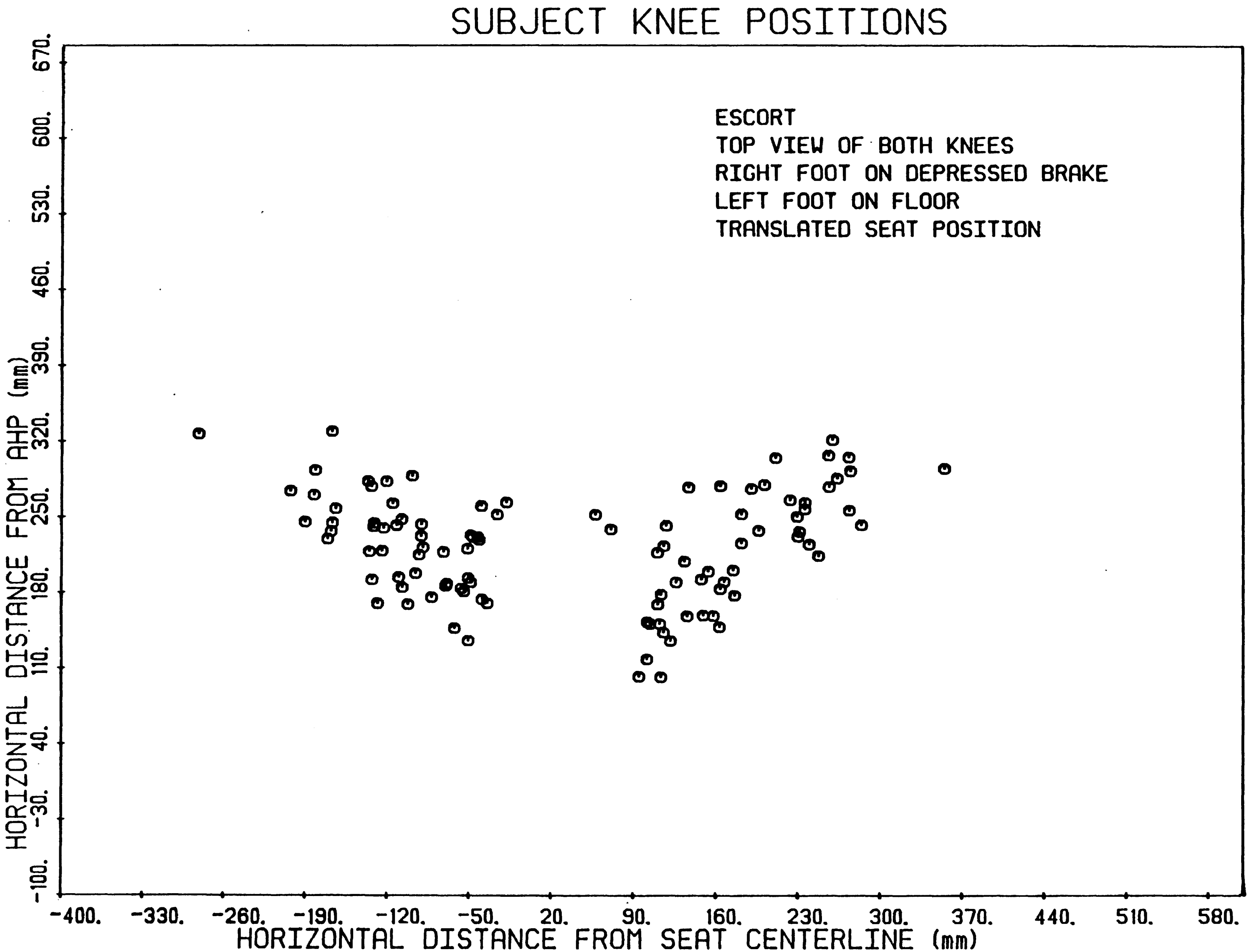
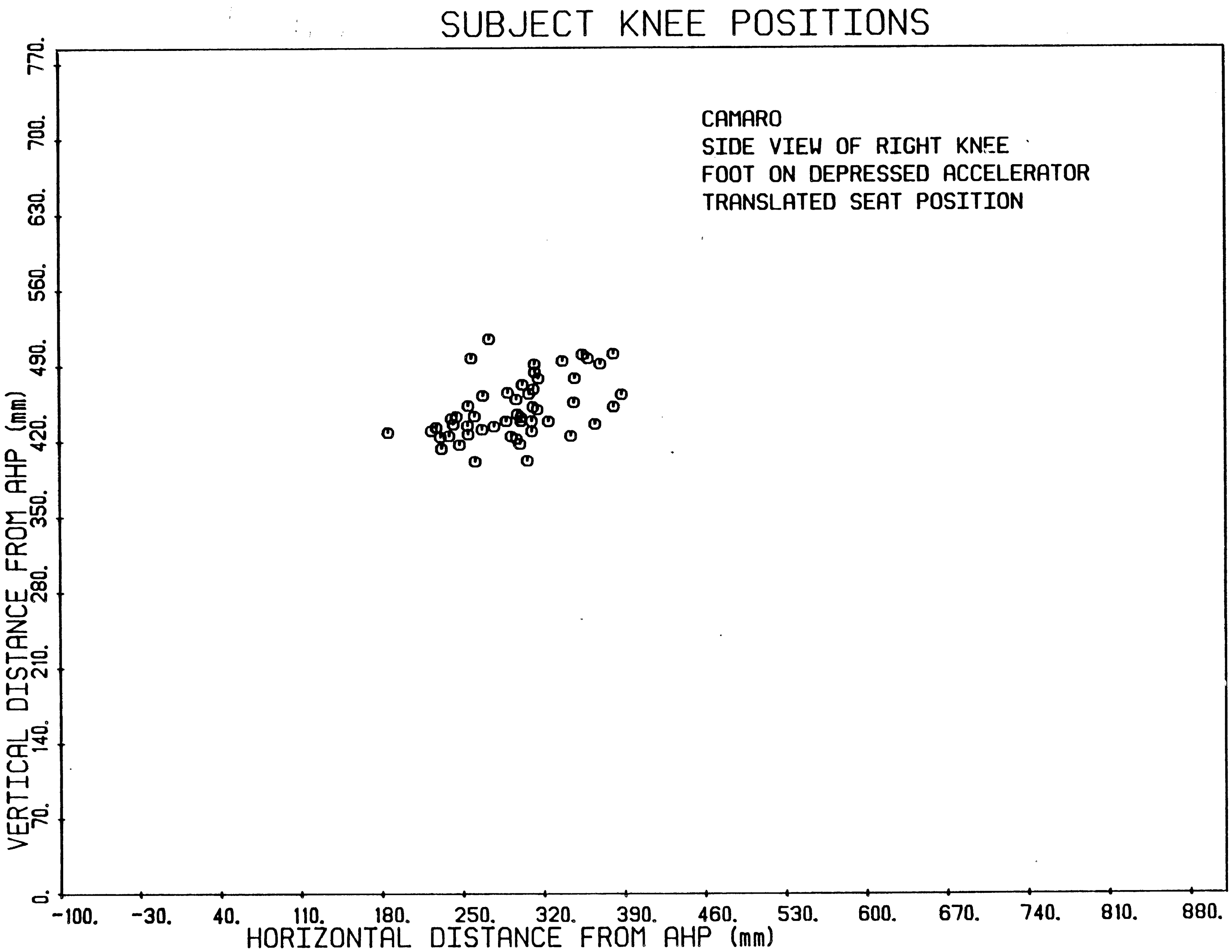
670.
740.
810.
880.

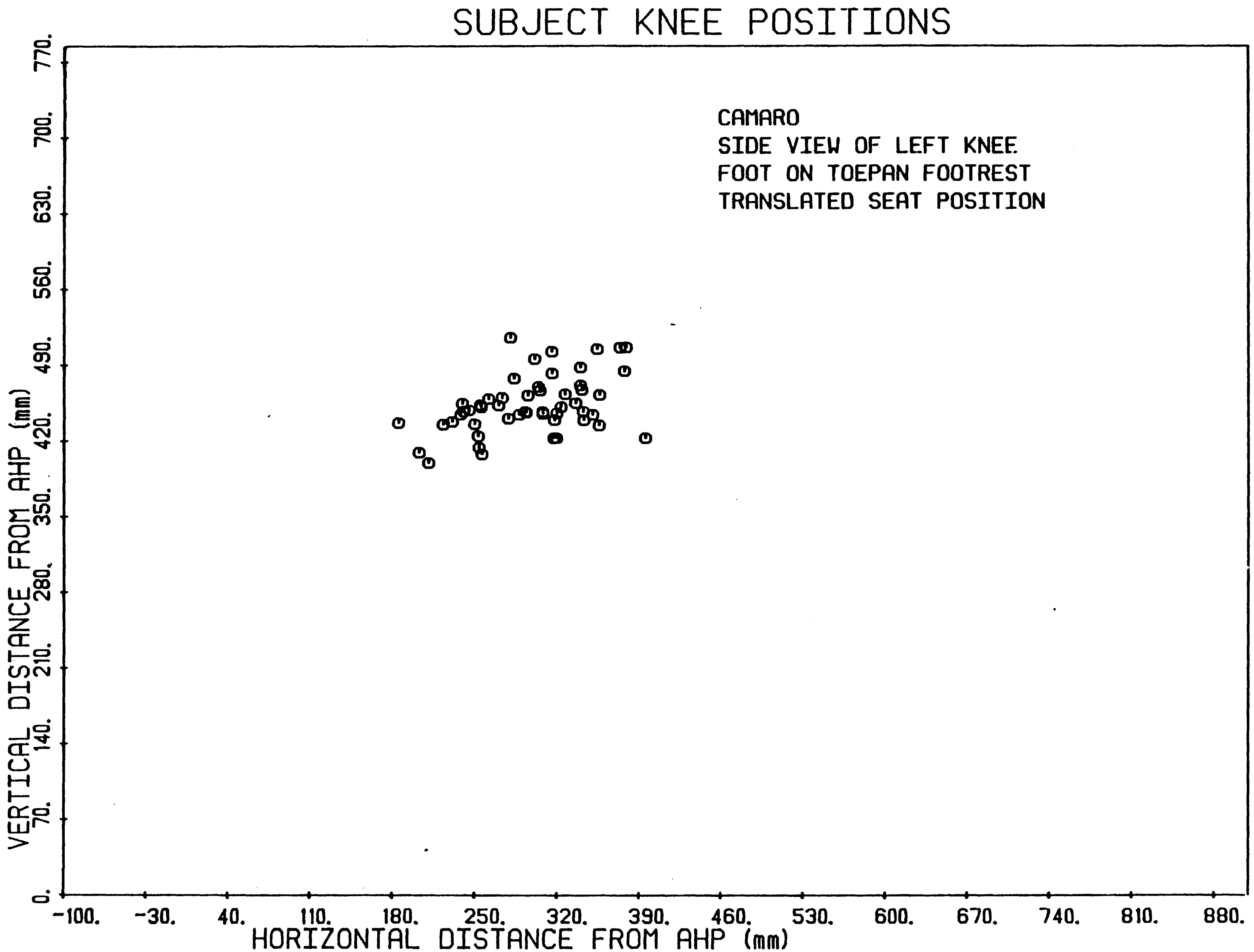

SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

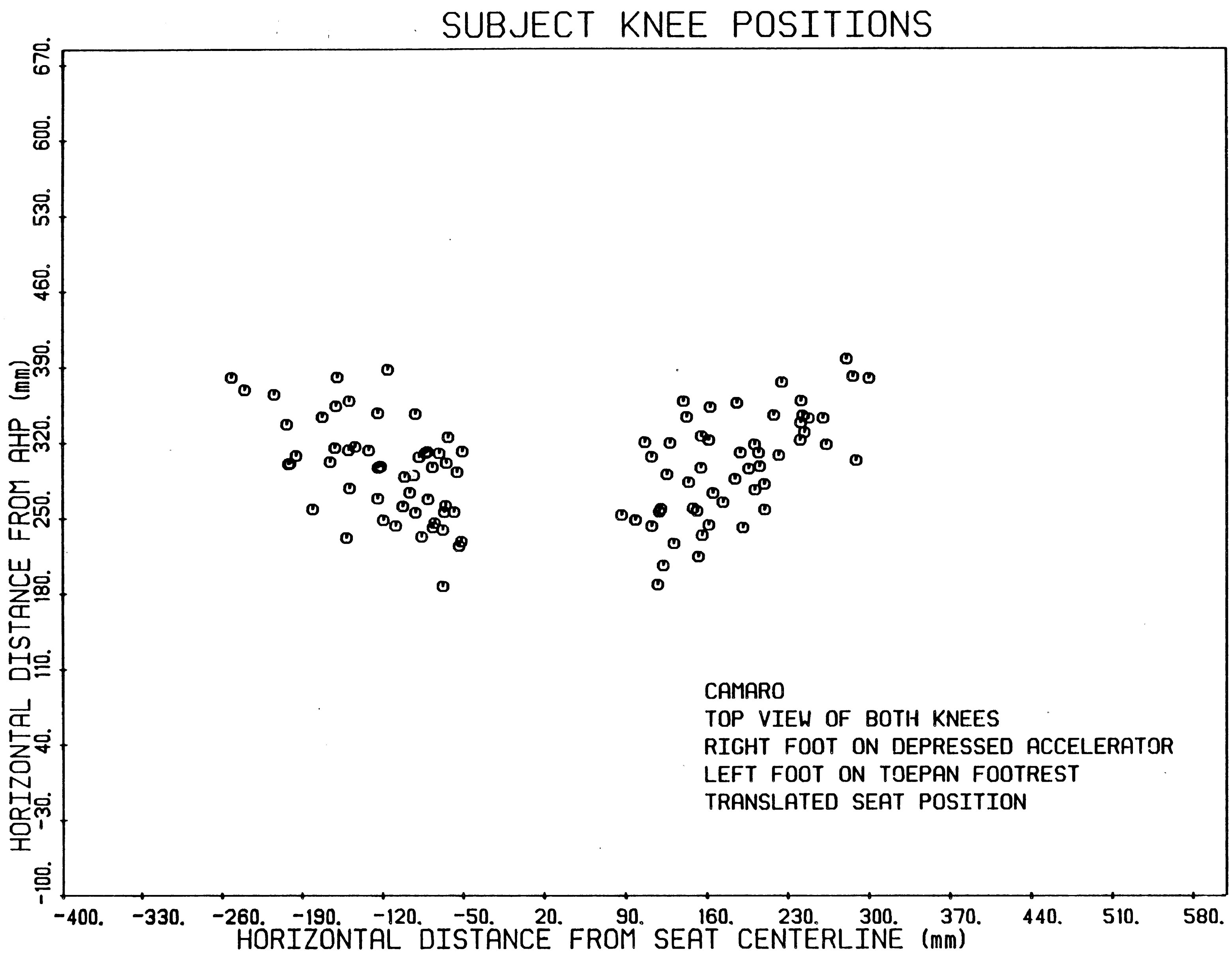

SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED BRAKE
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
ESCORT
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
VERTICAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.

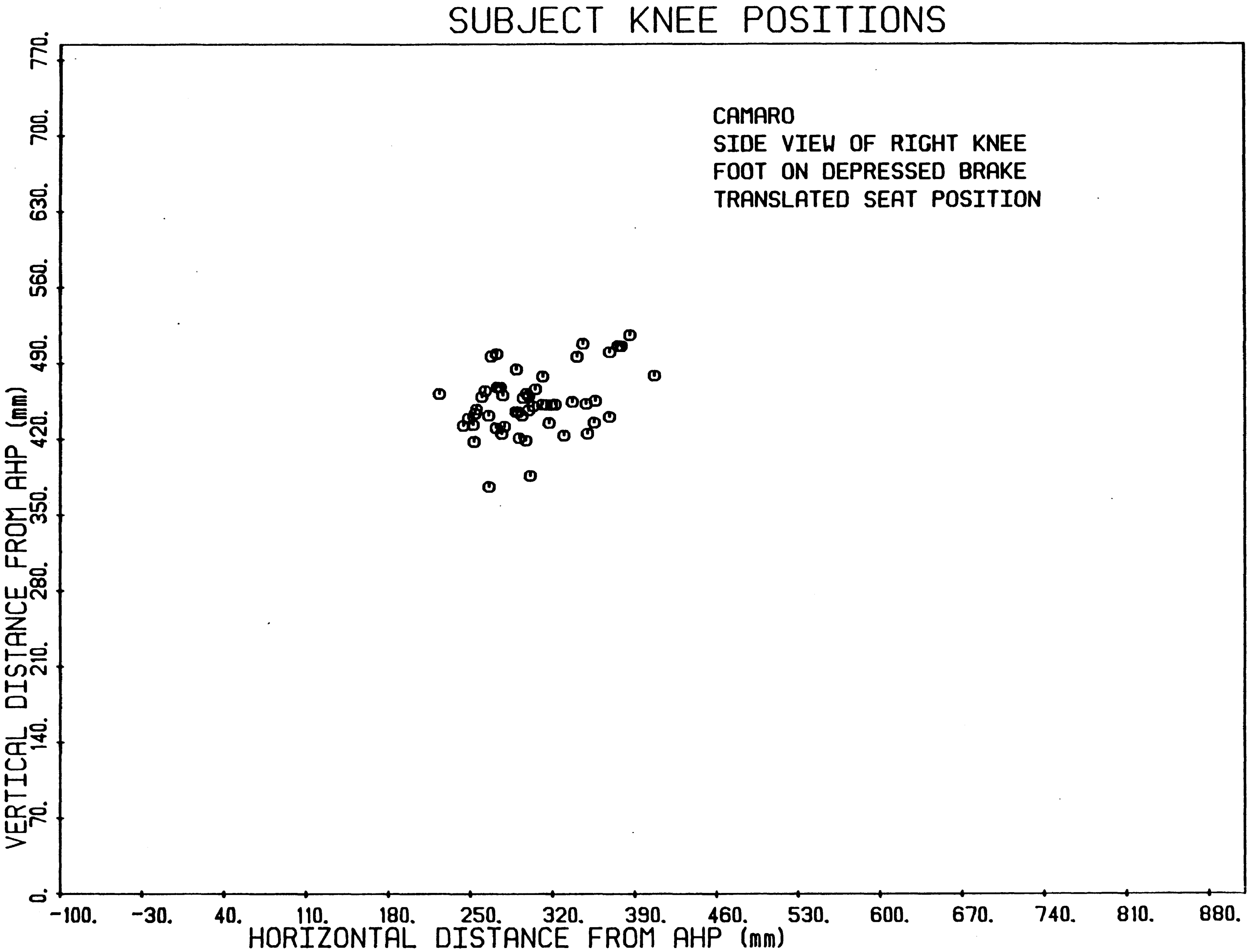

SUBJECT KNEE POSITIONS
ESCORT
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

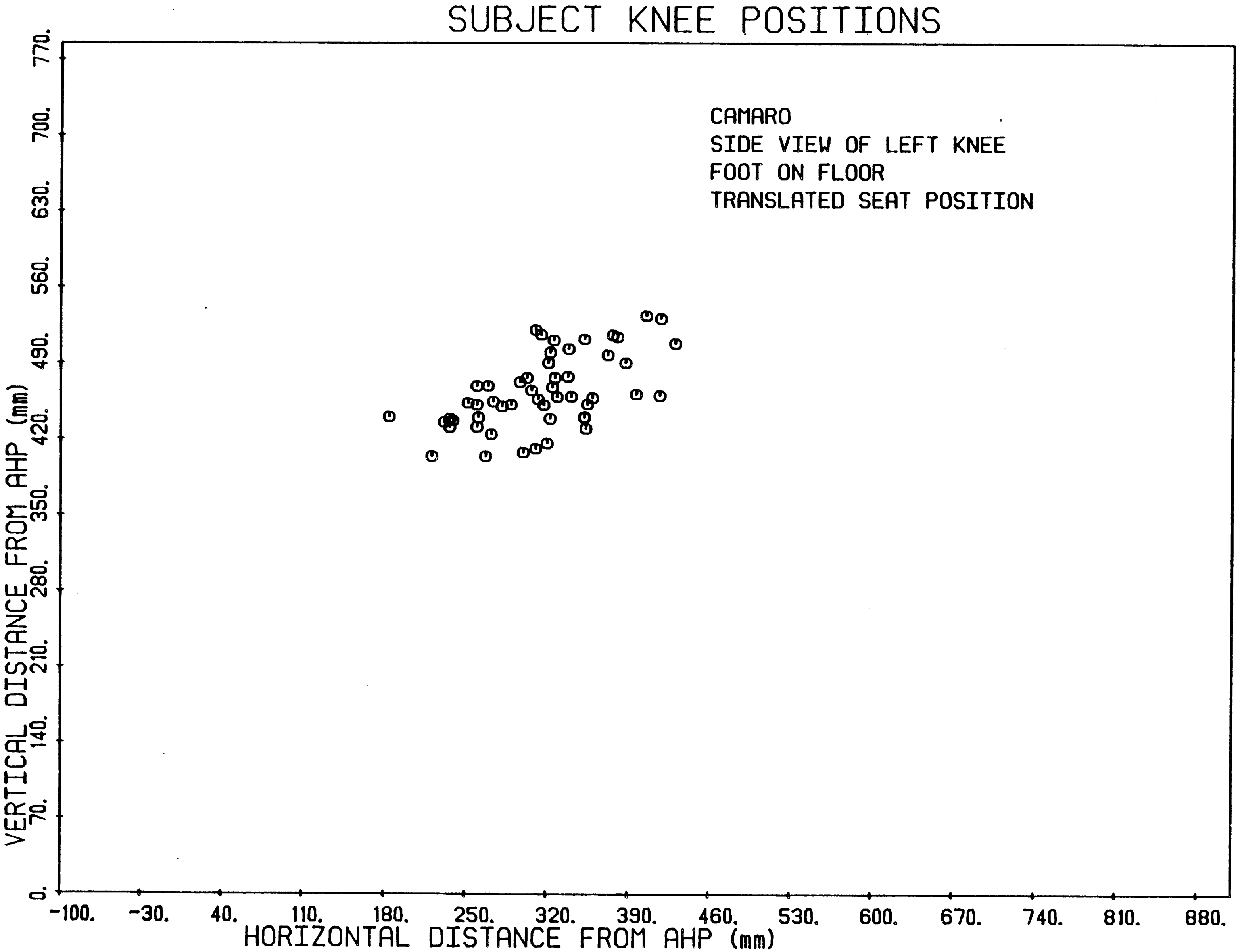

SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED ACCELERATOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

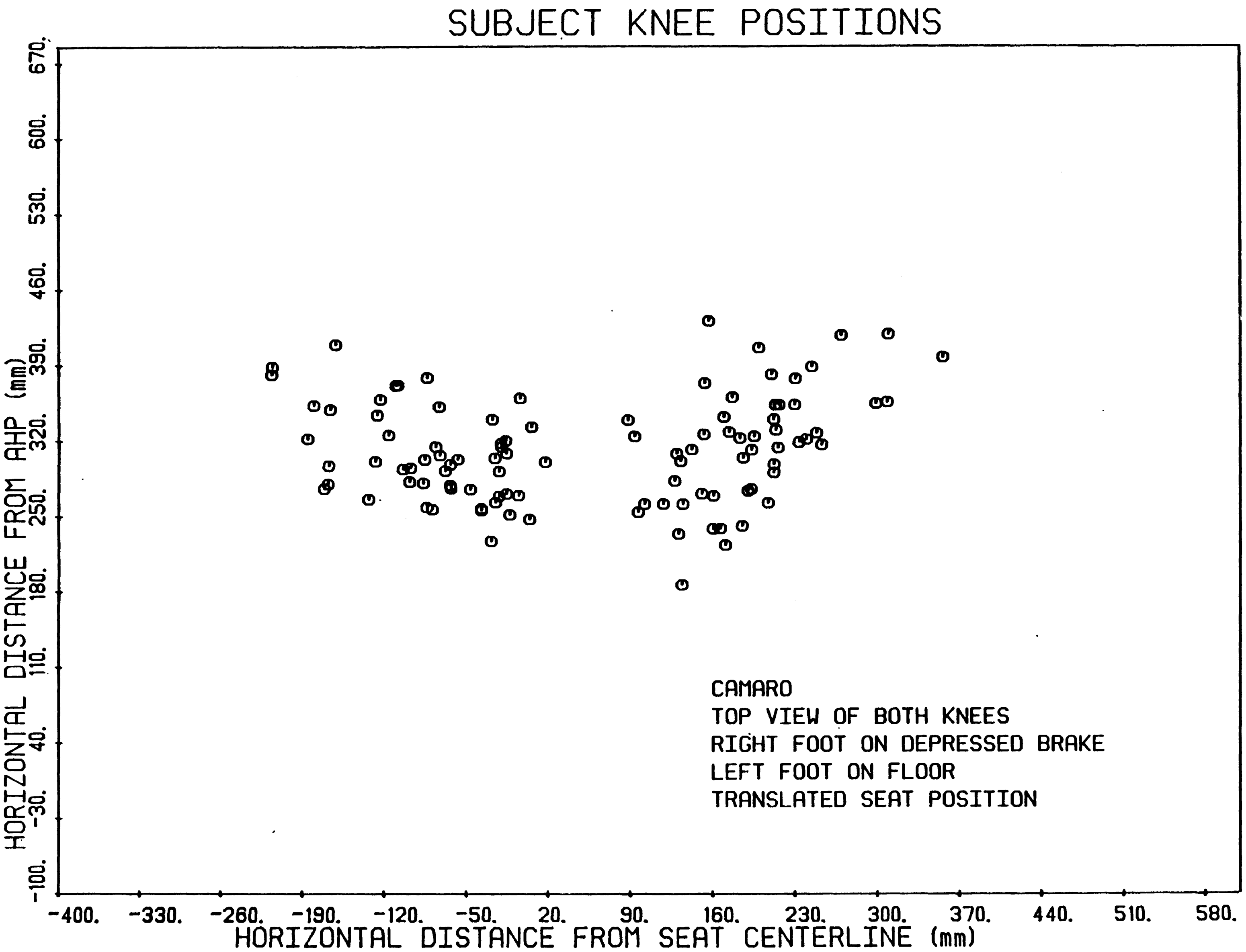


SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON TOEPAN FOOTREST
TRANSLATED SEAT POSITION


SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF RIGHT KNEE
FOOT ON DEPRESSED BRAKE
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.



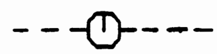
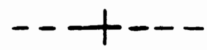
SUBJECT KNEE POSITIONS
CAMARO
SIDE VIEW OF LEFT KNEE
FOOT ON FLOOR
TRANSLATED SEAT POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


SUBJECT KNEE POSITIONS
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
CAMARO
TOP VIEW OF BOTH KNEES
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
TRANSLATED SEAT POSITION

APPENDIX E

PLOTS OF GROUP MEAN KNEE CONTOURS FOR INITIAL SEAT CONDITION

Key to Group Mean Knee Contour Plots:

Group #	Contour Line/Symbol
1	
2	
3	
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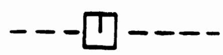
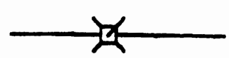
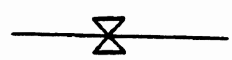
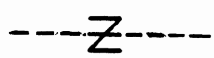
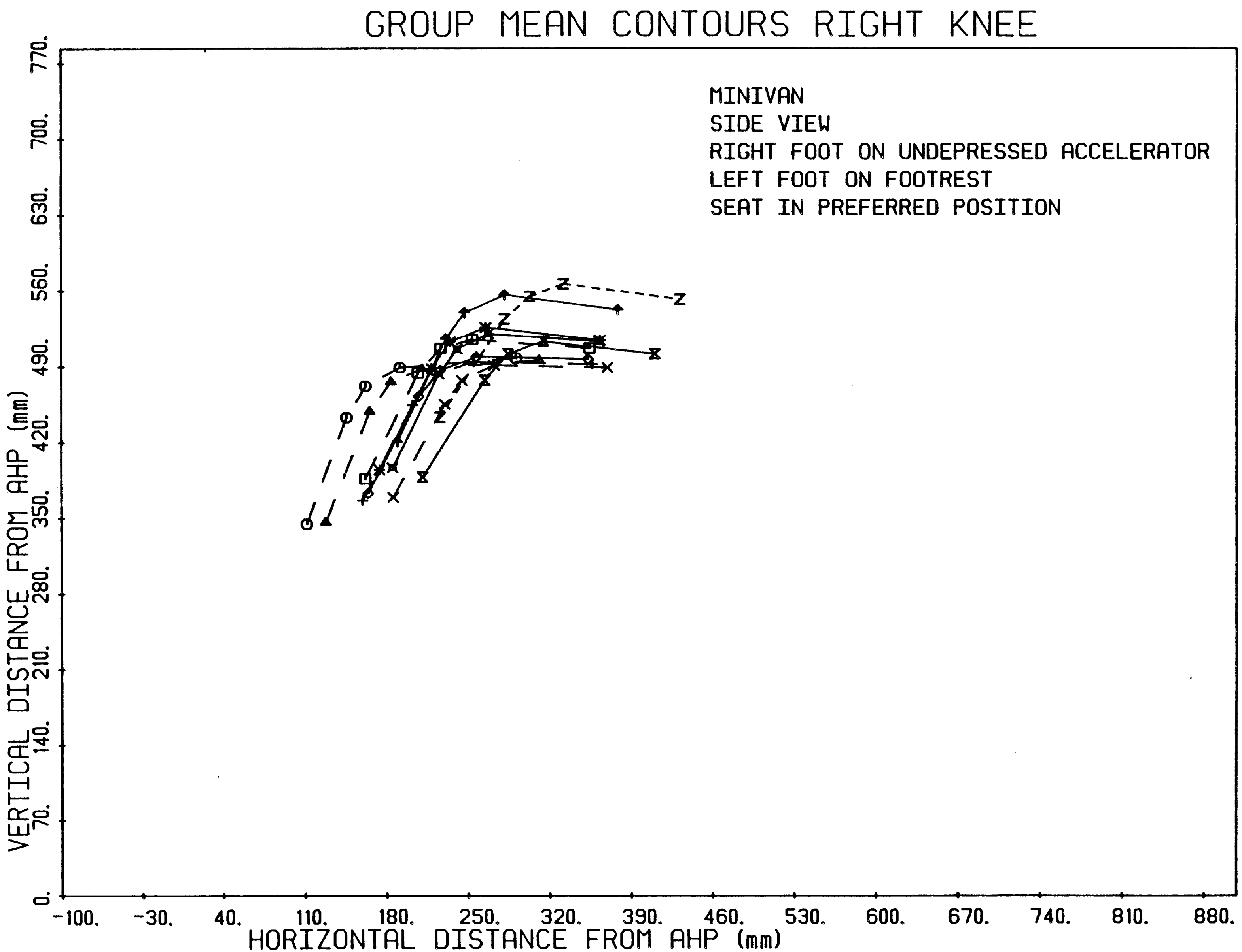
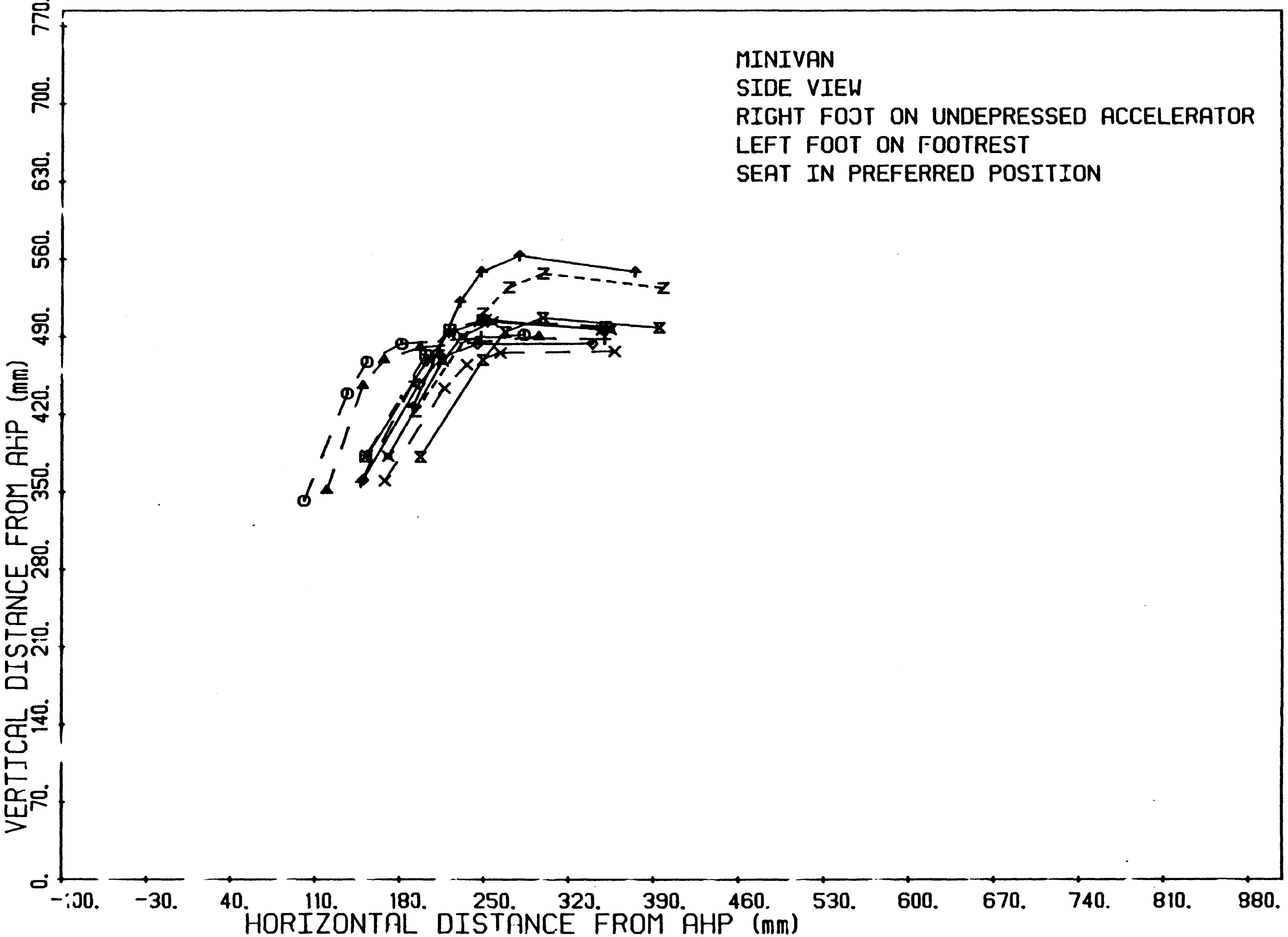
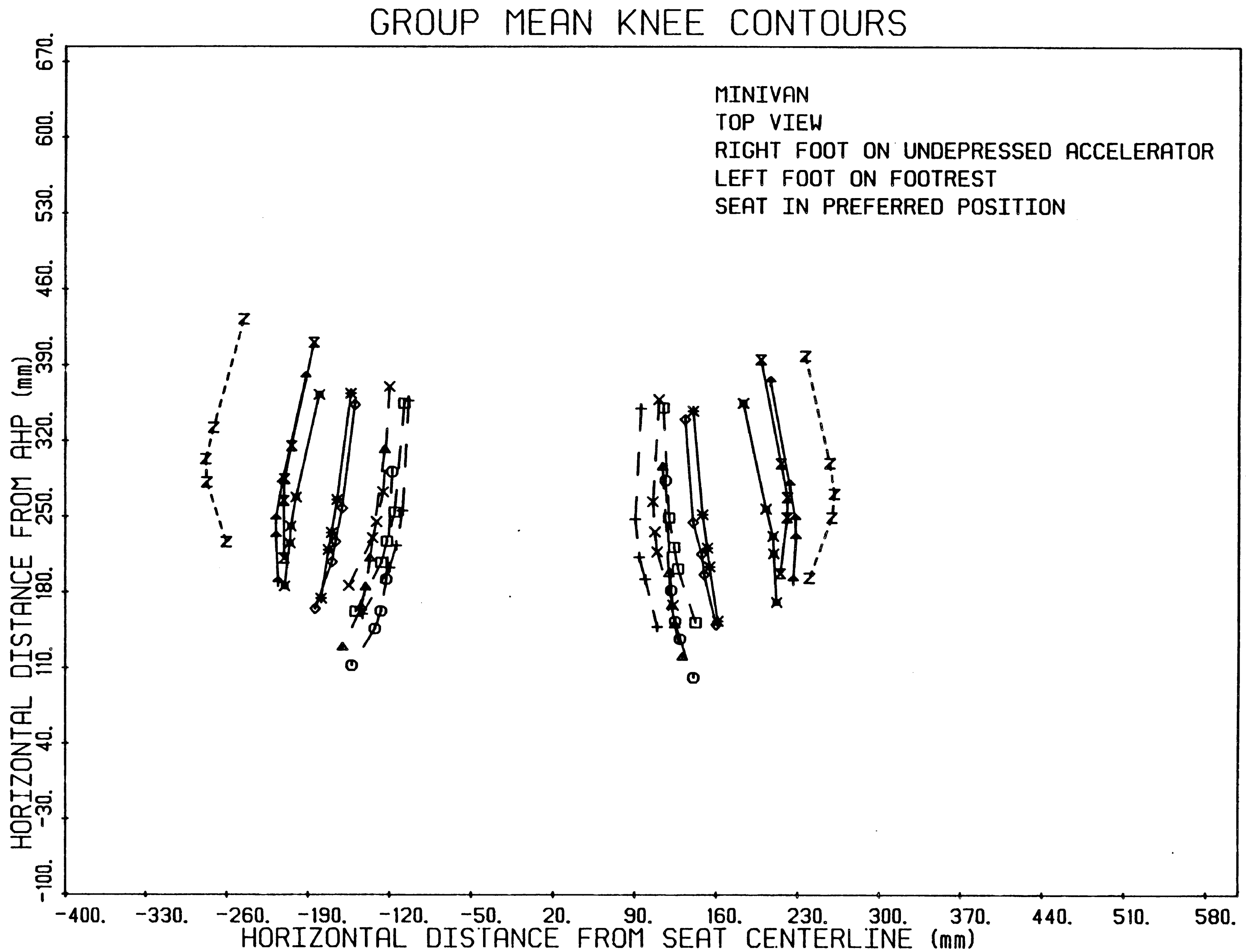
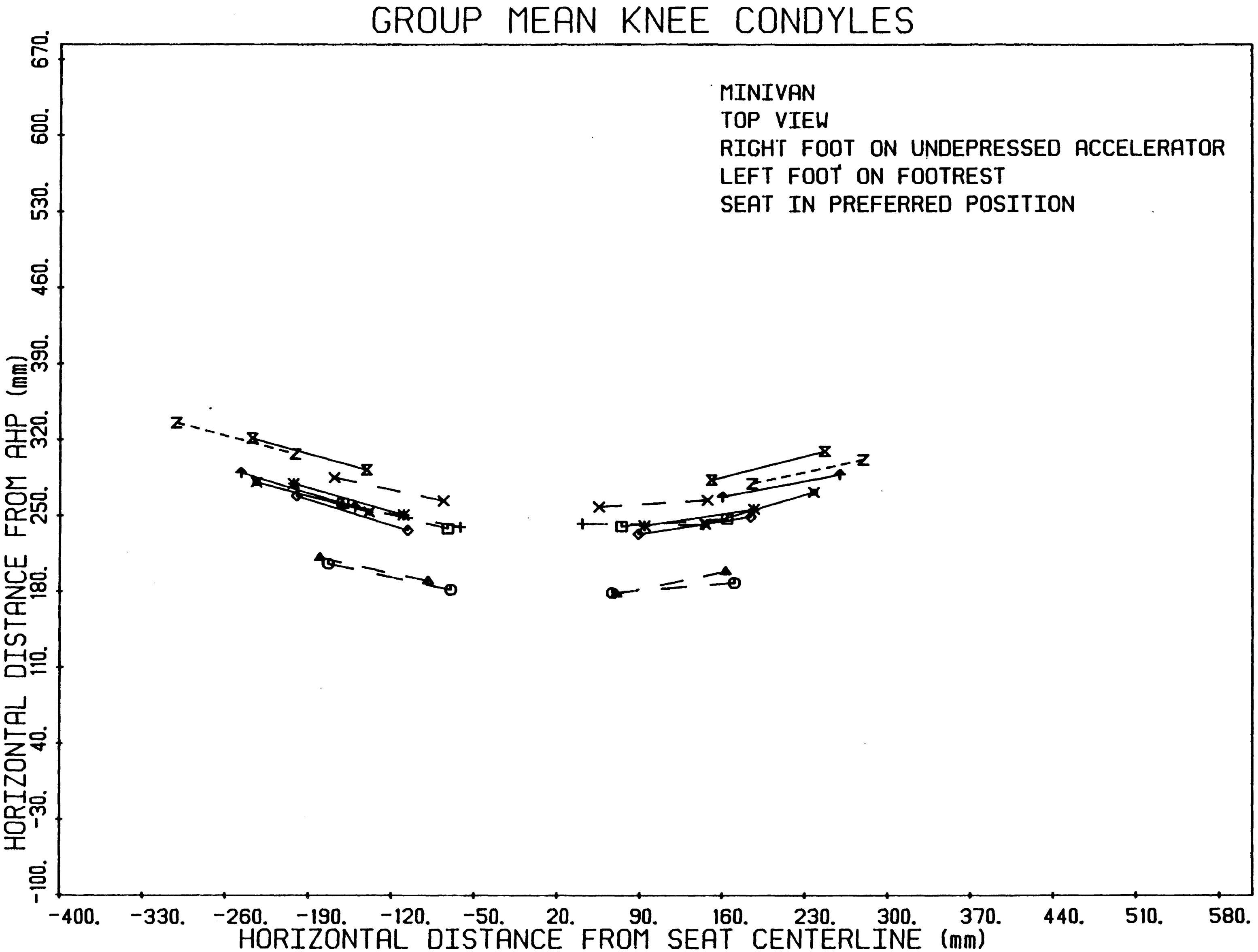
5	
6	
7	
8	
9	
10	
11	

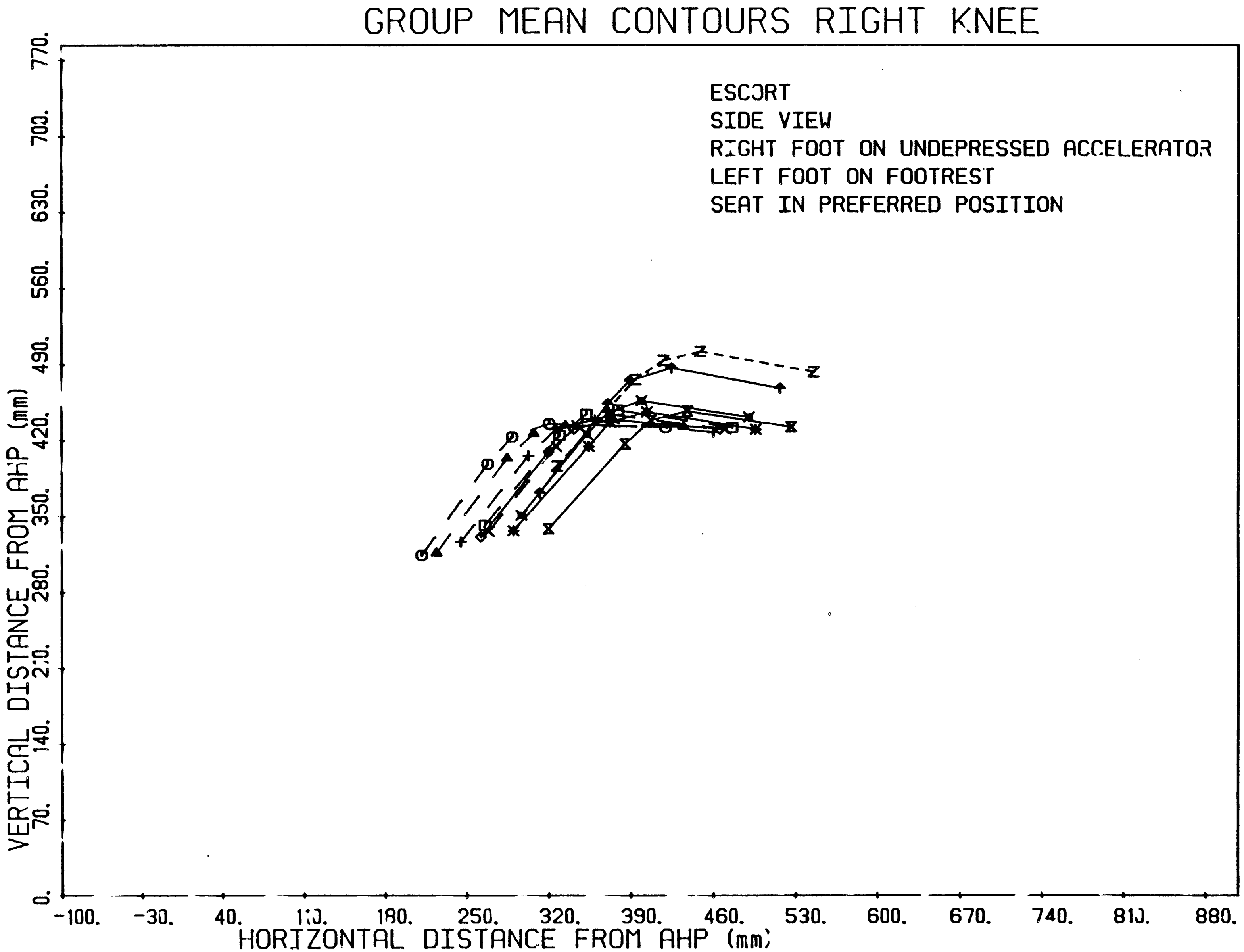

GROUP MEAN CONTOURS RIGHT KNEE
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

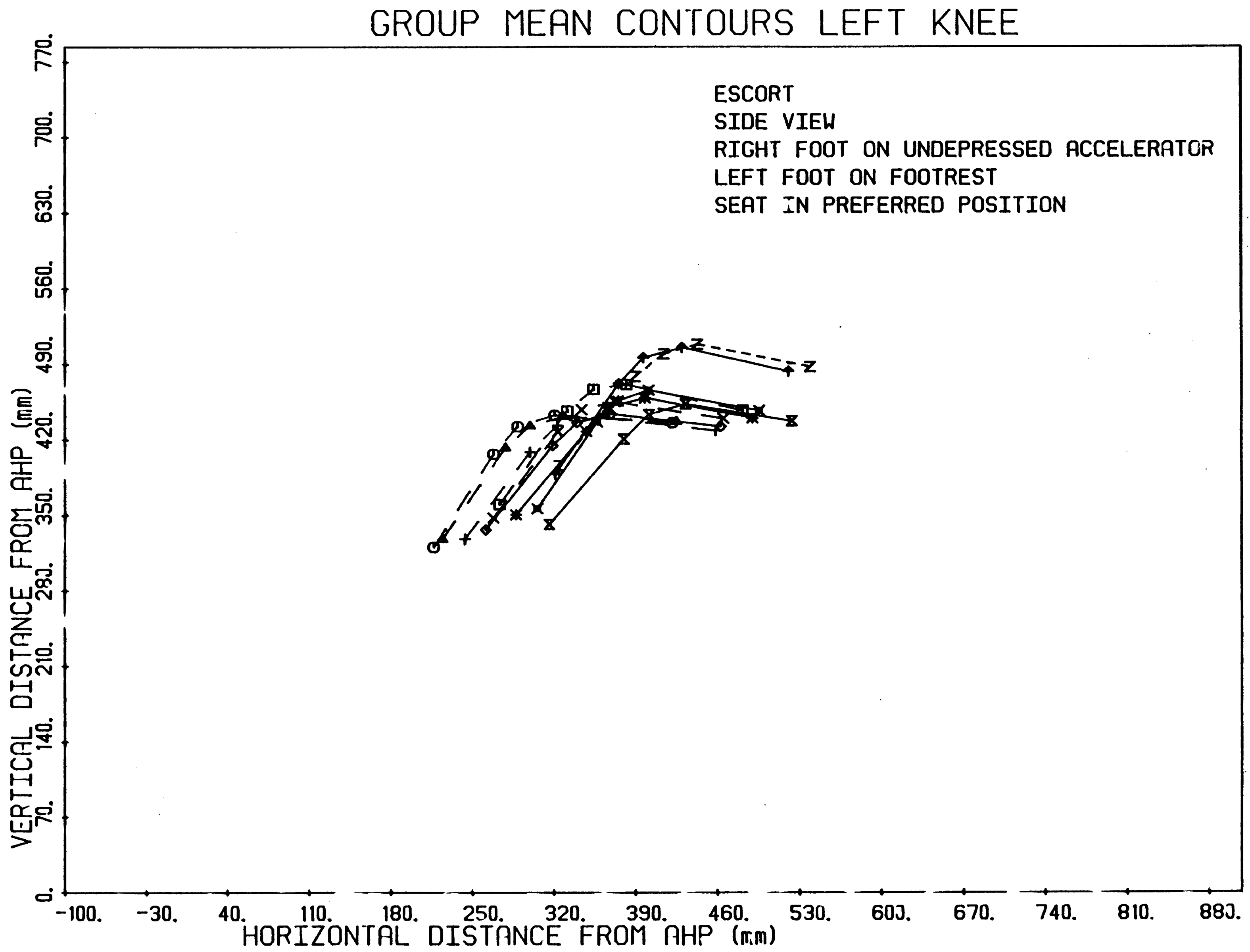
GROUP MEAN CONTOURS LEFT KNEE



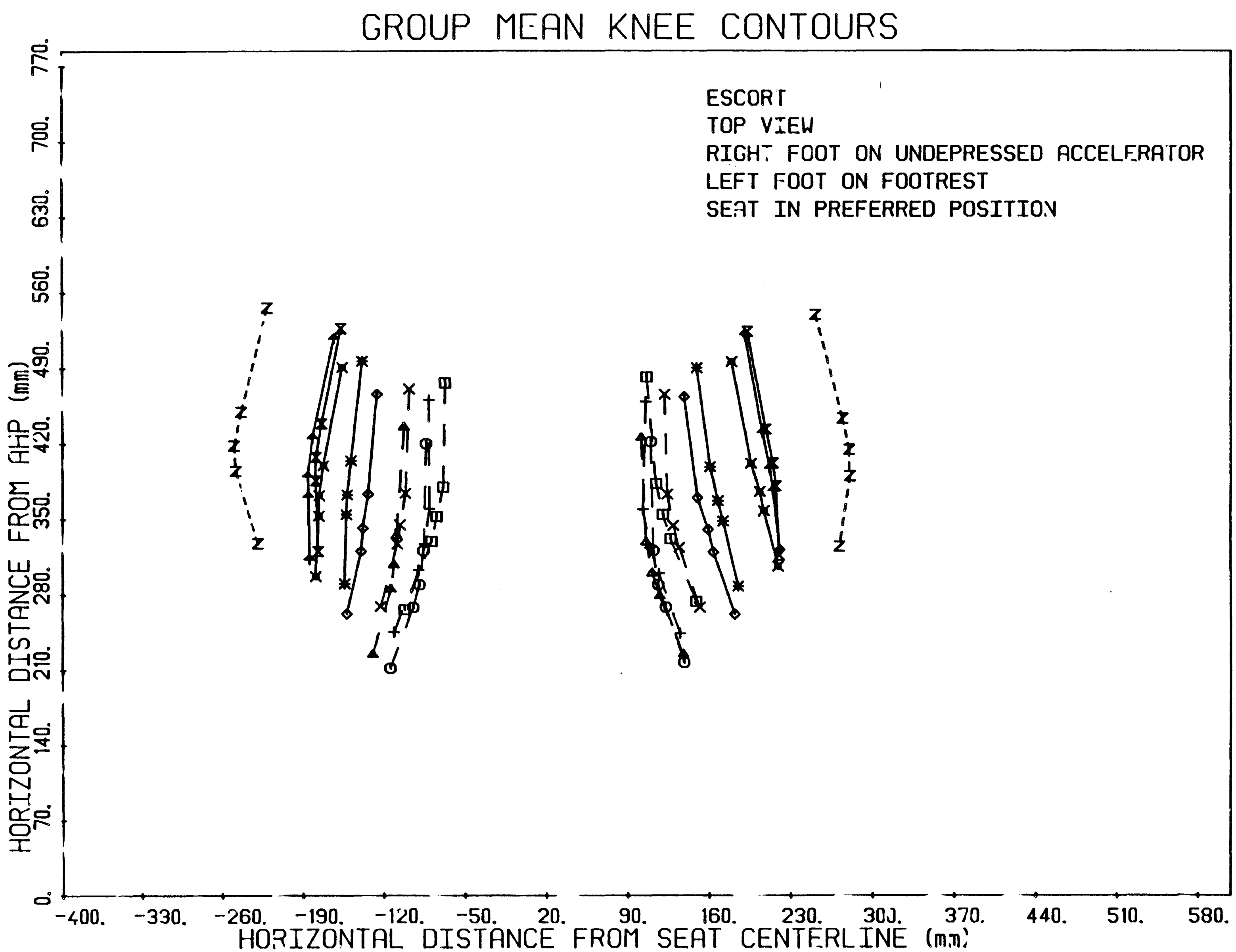

GROUP MEAN KNEE CONTOURS
MINIVAN
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

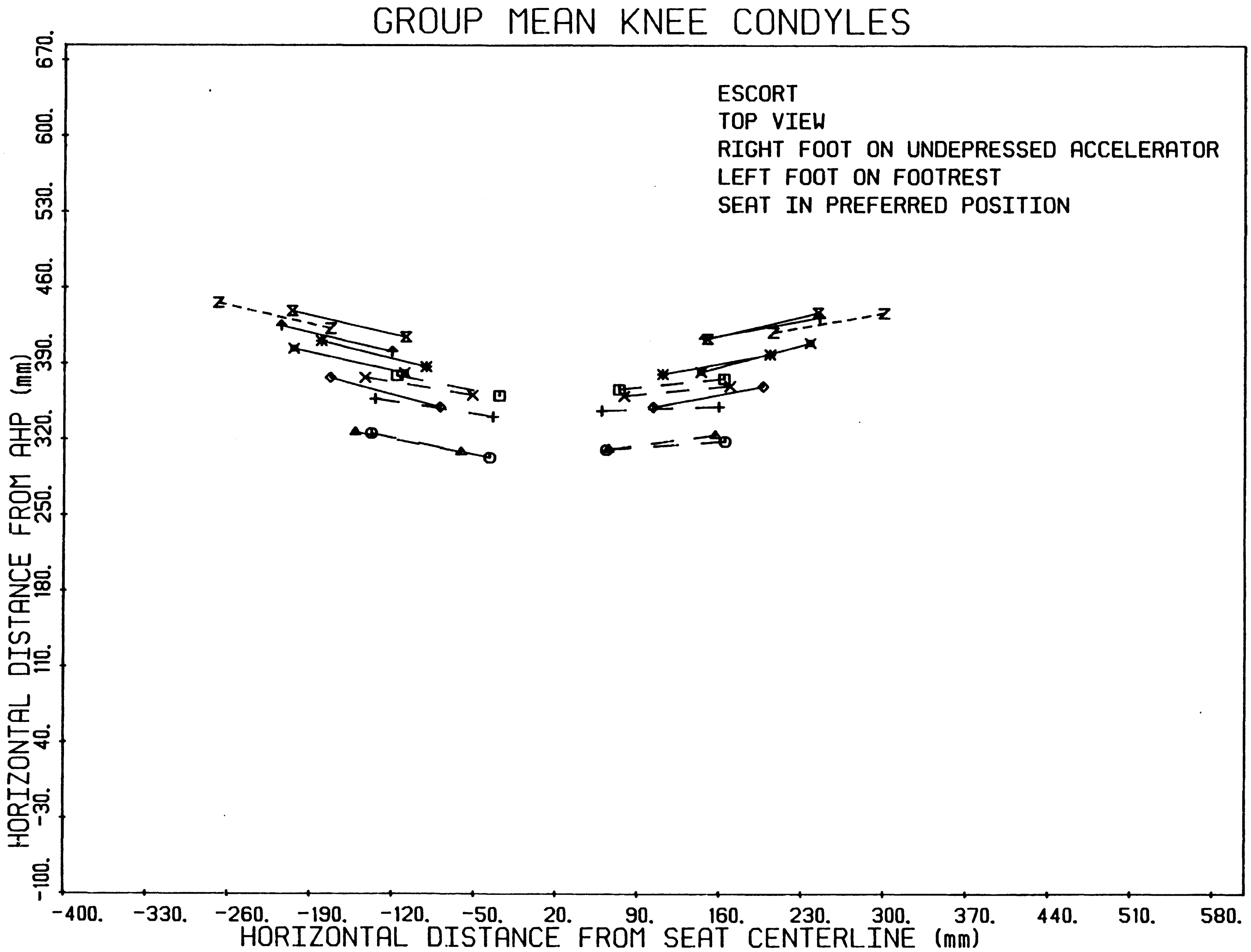

GROUP MEAN KNEE CONDYLES
MINIVAN
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.


GROUP MEAN CONTOURS RIGHT KNEE
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

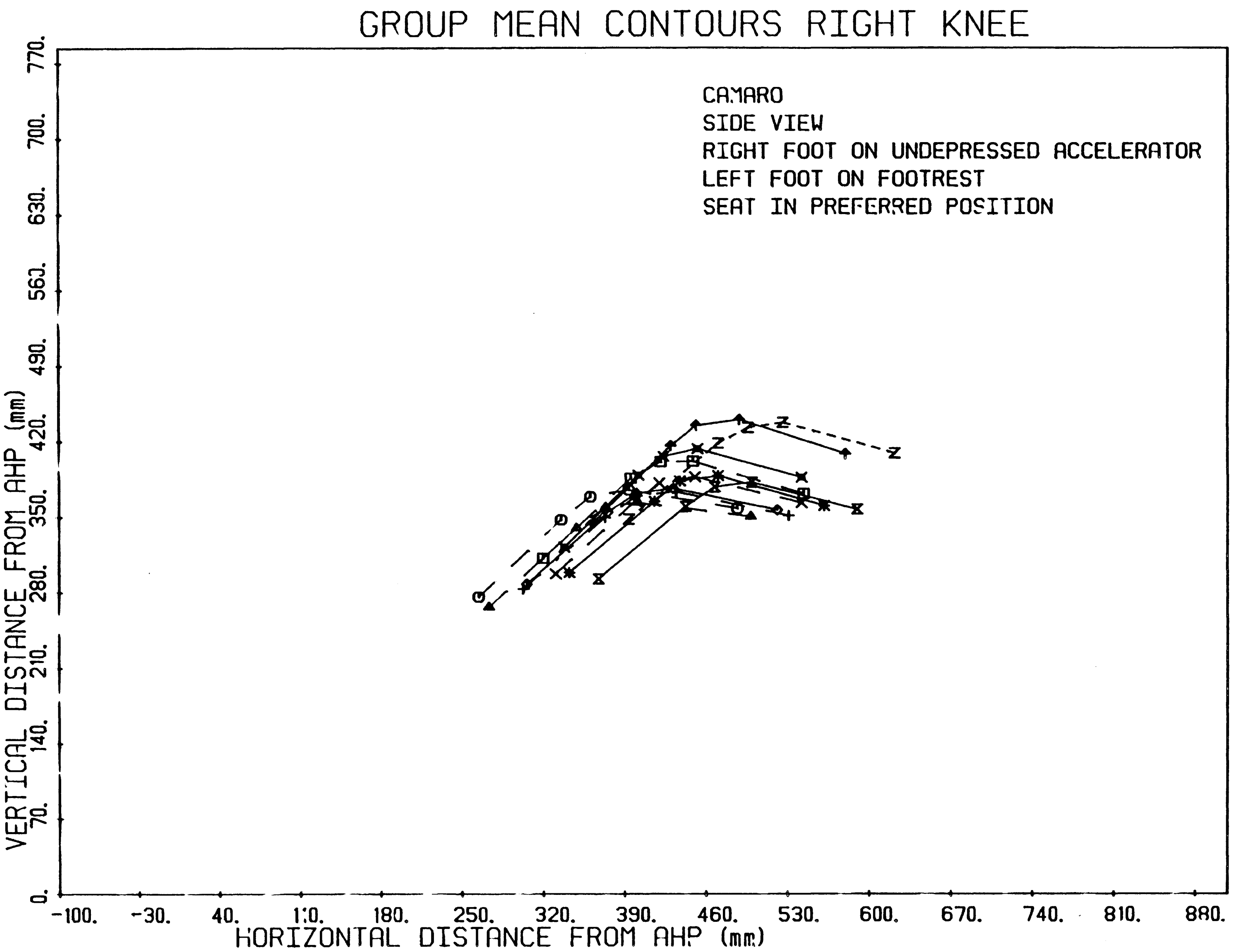


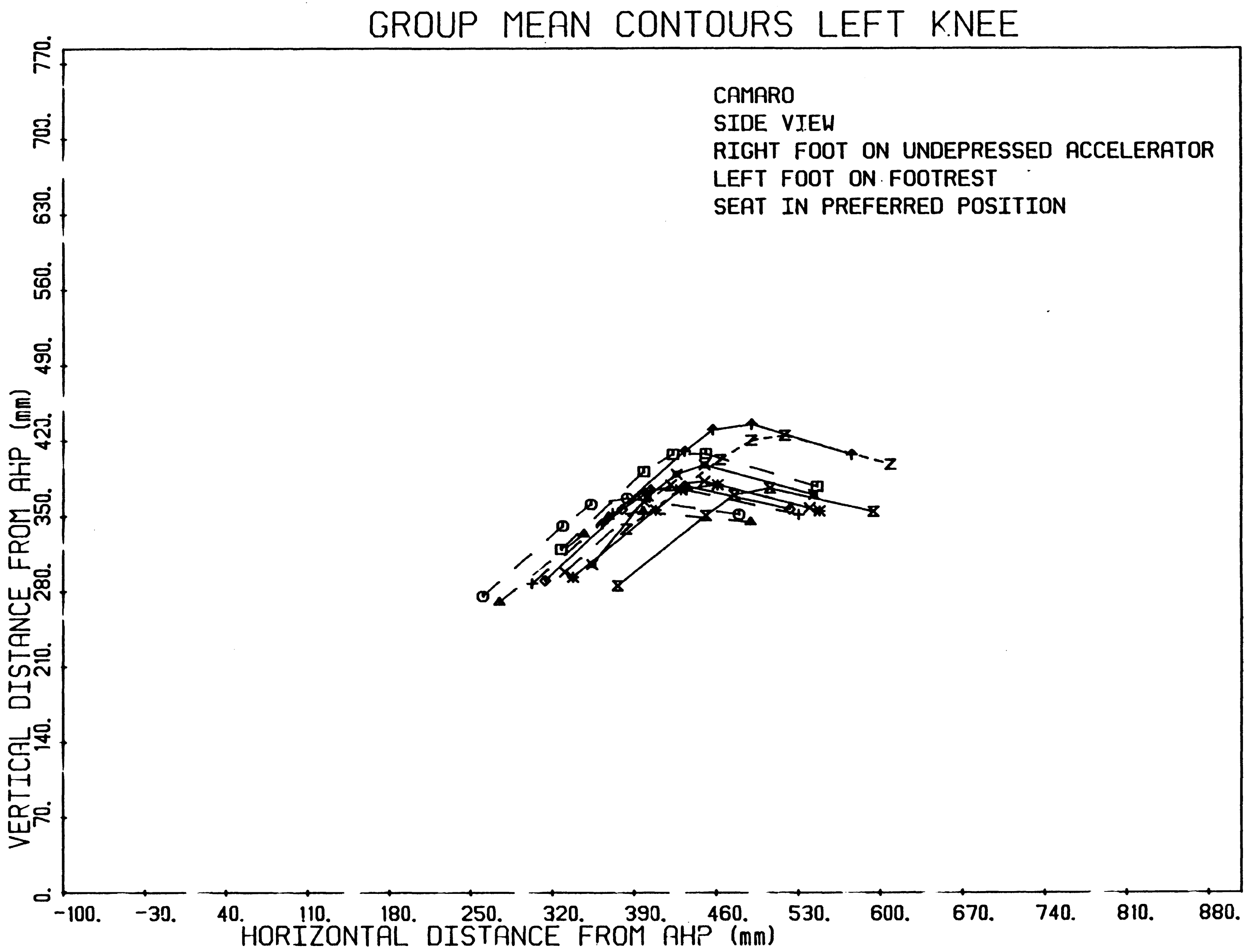
GROUP MEAN CONTOURS LEFT KNEE
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

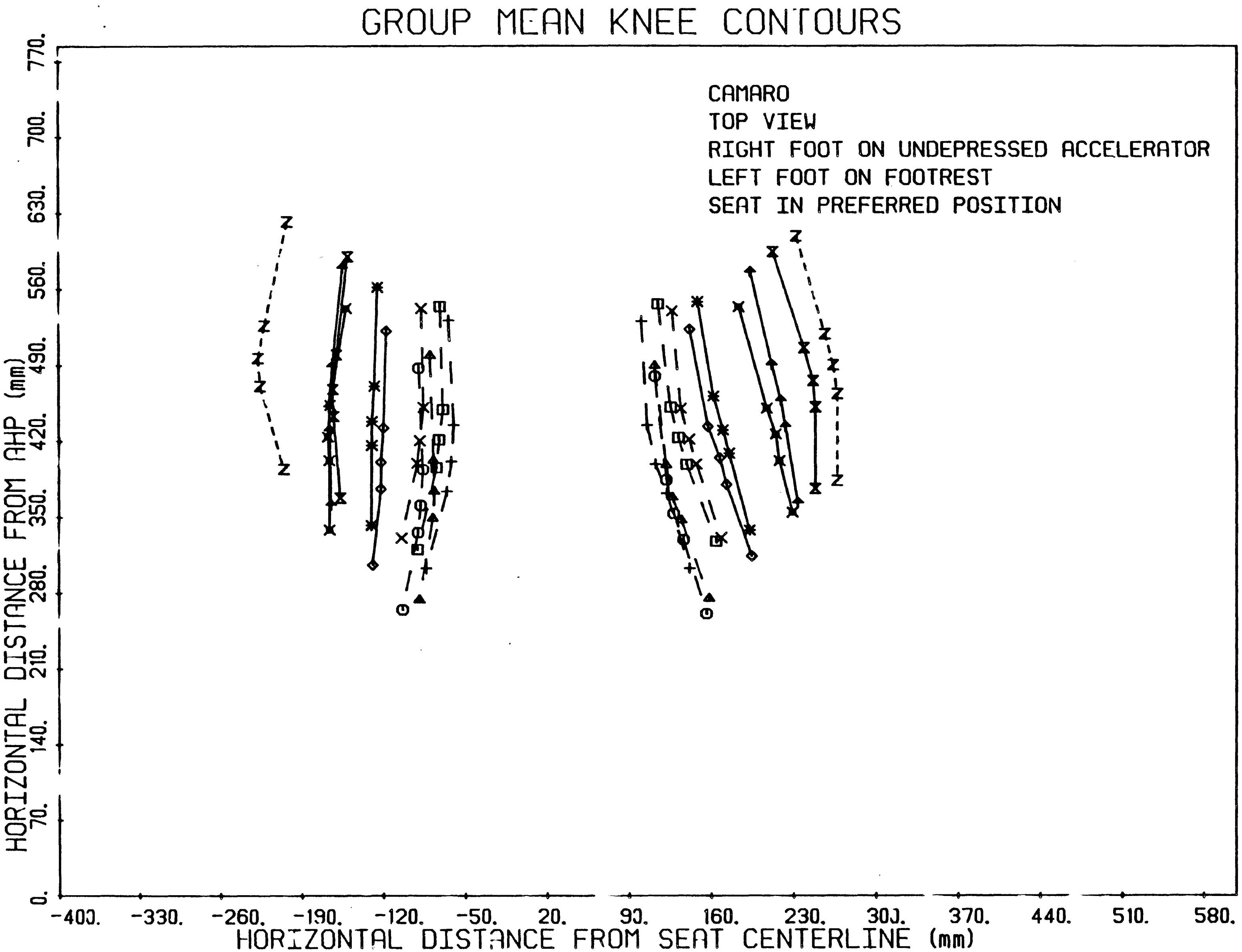

GROUP MEAN KNEE CONTOURS
ESCORT
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.

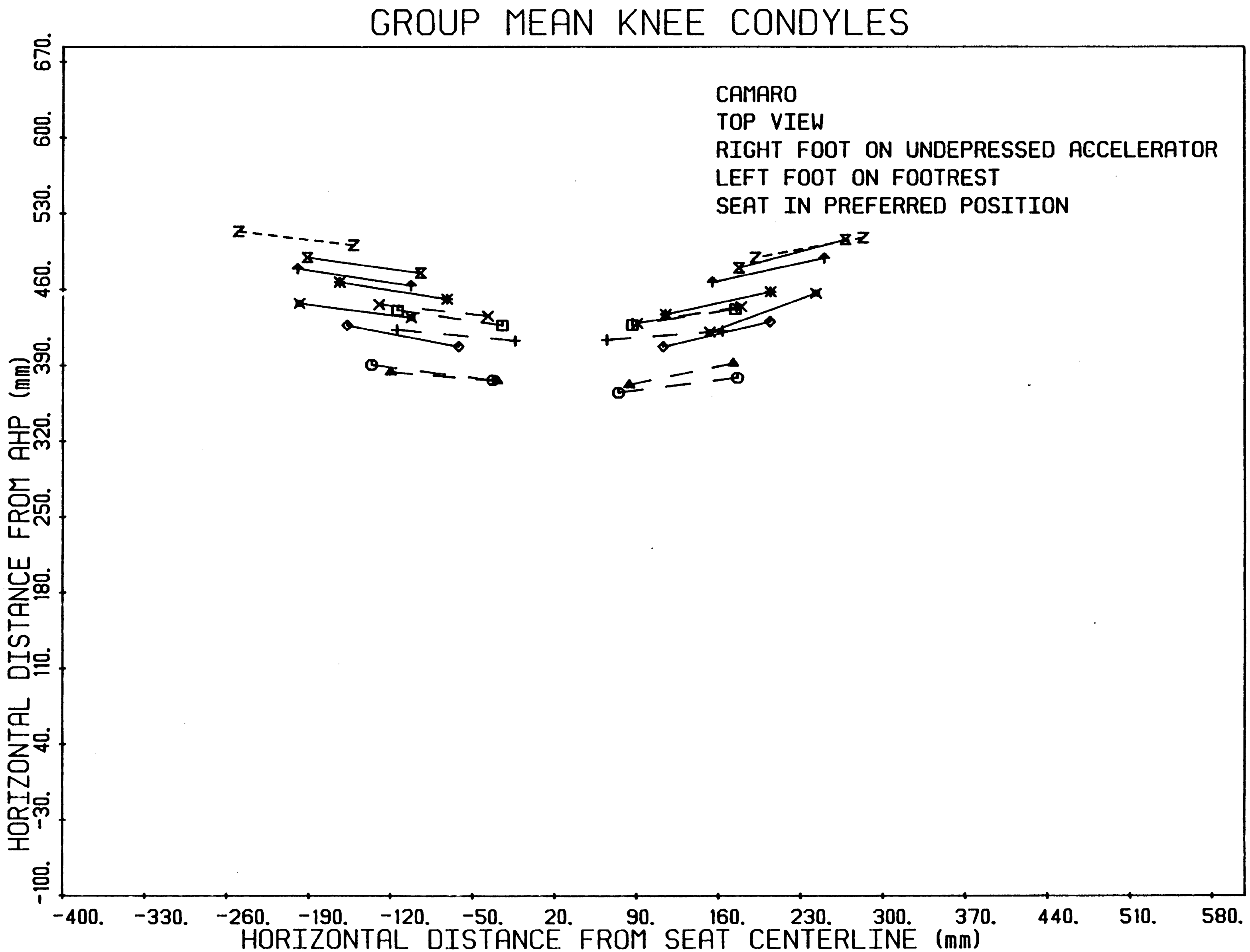


GROUP MEAN KNEE CONDYLES
ESCORT
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


GROUP MEAN CONTOURS RIGHT KNEE
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
HORIZONTAL DISTANCE FROM AHP (mm)


GROUP MEAN CONTOURS LEFT KNEE
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


GROUP MEAN KNEE CONTOURS
CAMARO
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


GROUP MEAN KNEE CONDYLES
CAMARO
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

APPENDIX F

PLOTS OF GROUP MEAN KNEE POSITIONS IN THE X, Y, AND Z-DIRECTIONS FOR ALL SEATING CONDITIONS

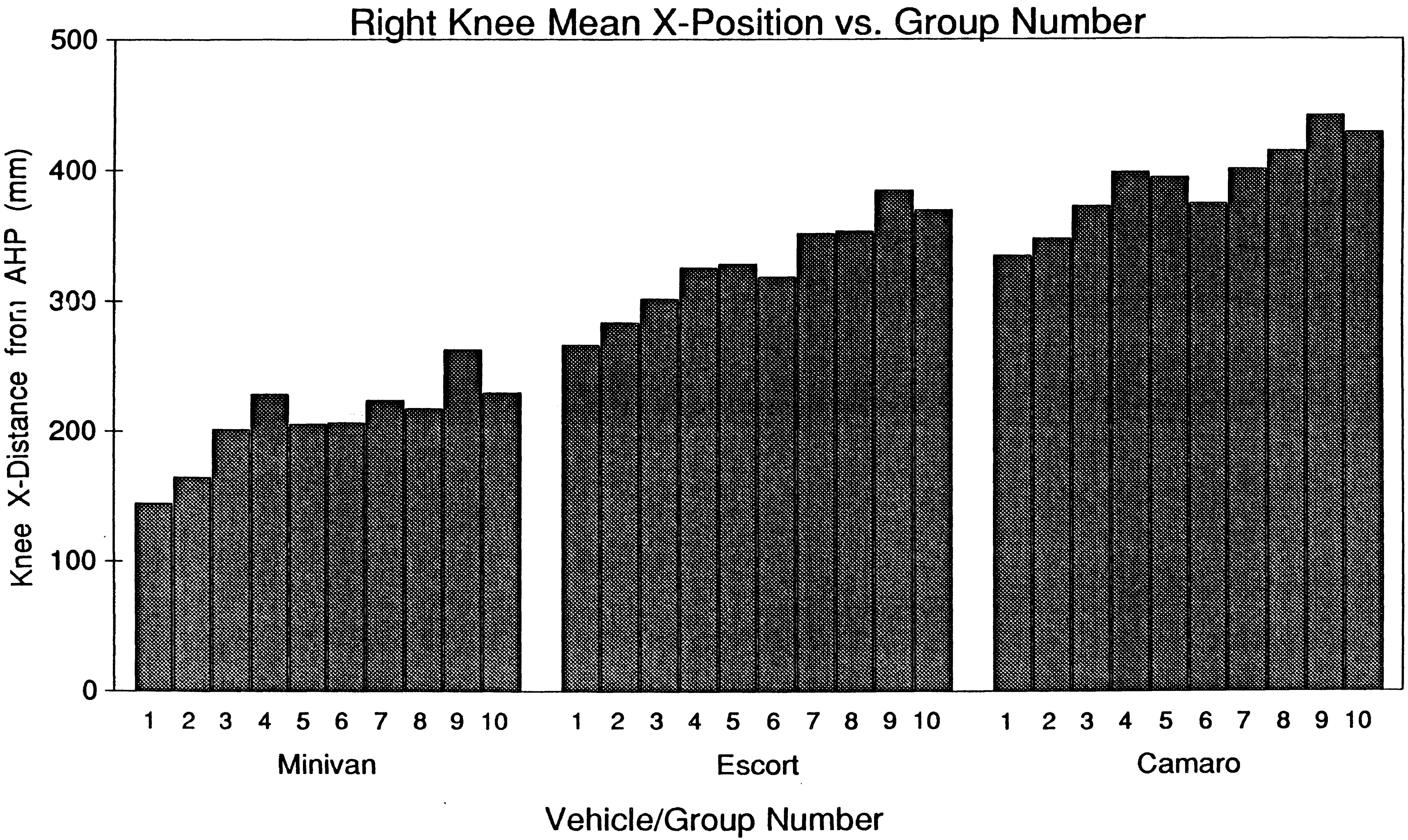


Figure F-1a. Comparison of group mean knee X-positions with foot on undepressed accelerator pedal and seat in preferred position.

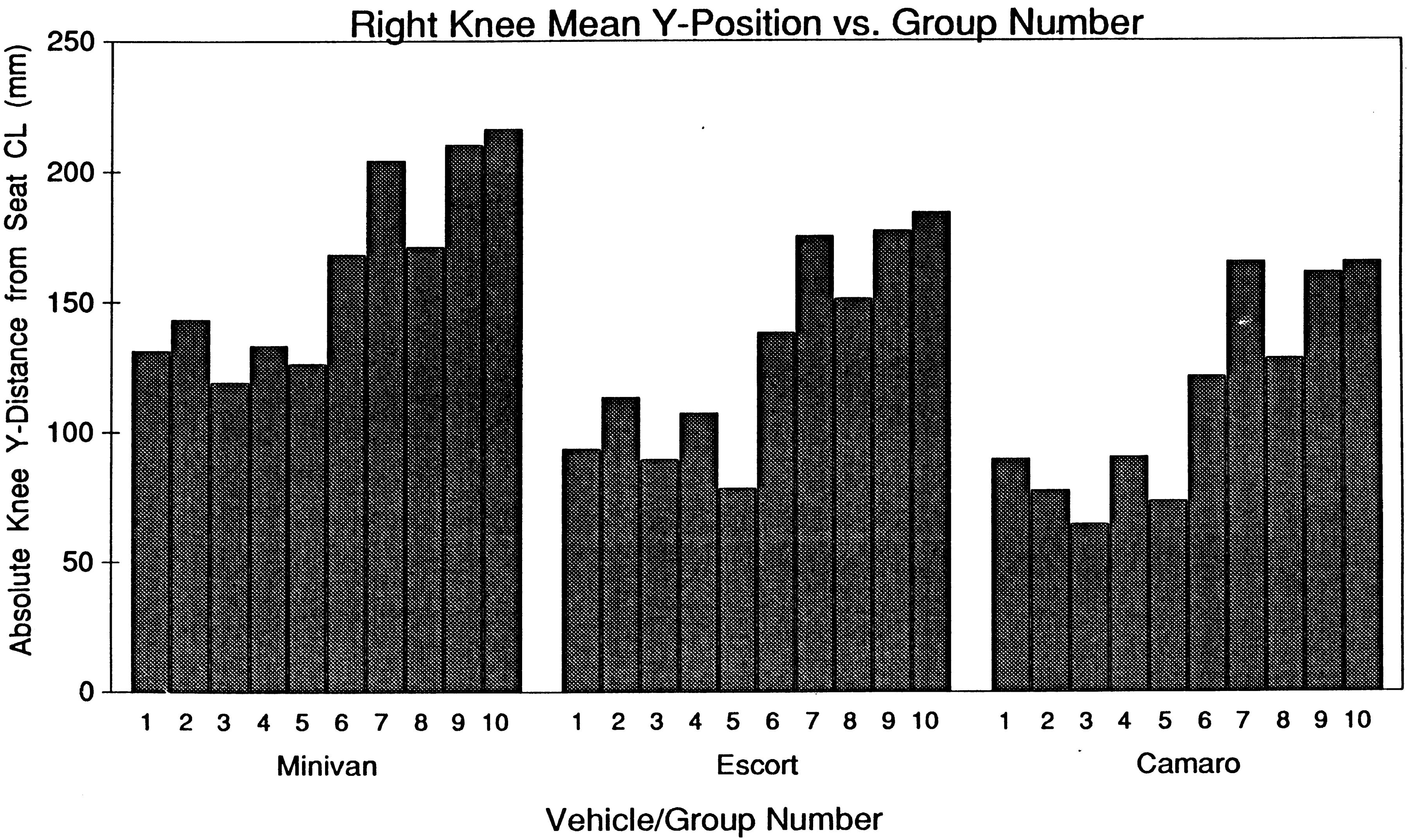


Figure F-1b. Comparison of group mean knee Y-positions with foot on undepressed accelerator pedal and seat in preferred position.

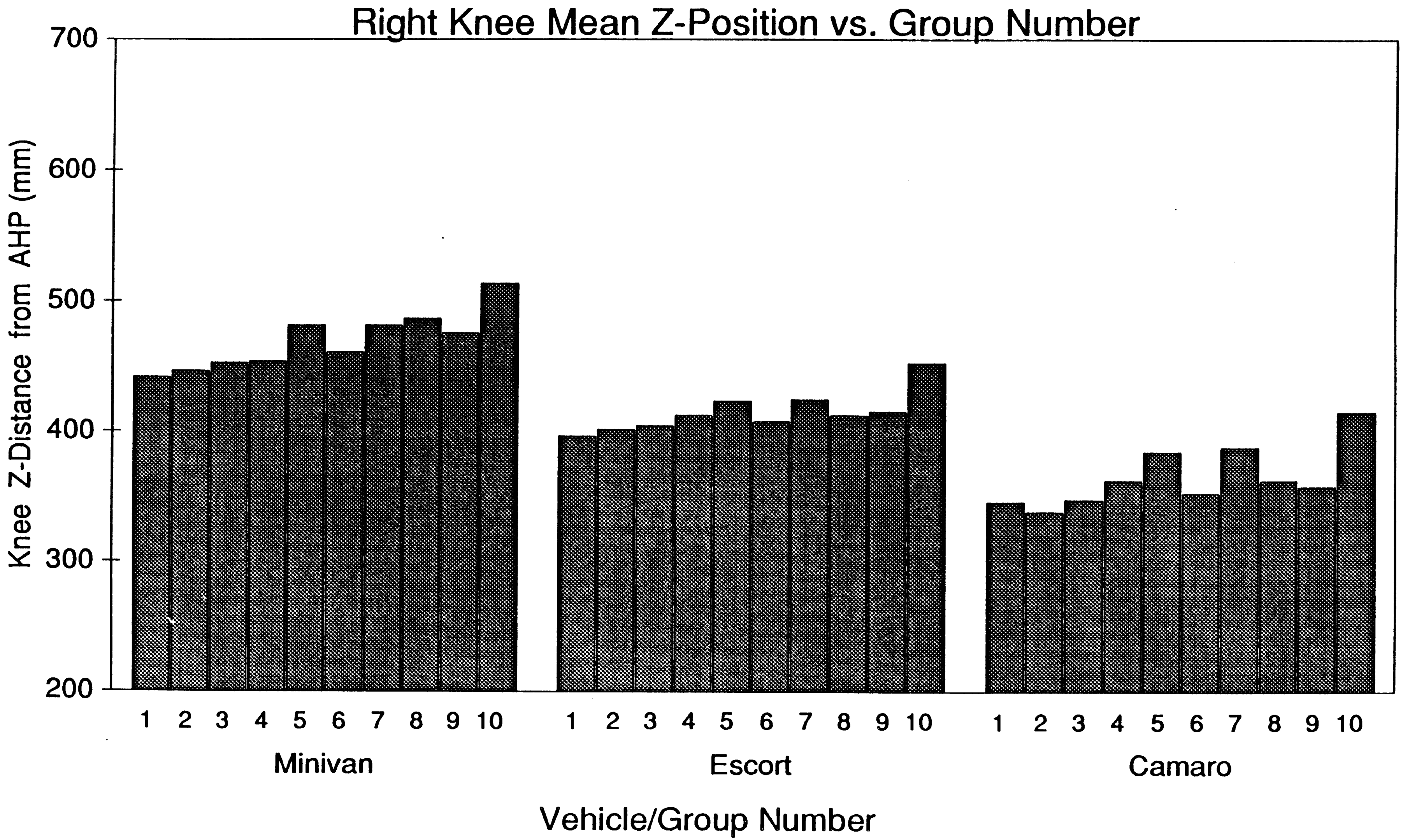


Figure F-1c. Comparison of group mean knee Z-positions with foot on undepressed accelerator pedal and seat in preferred position.

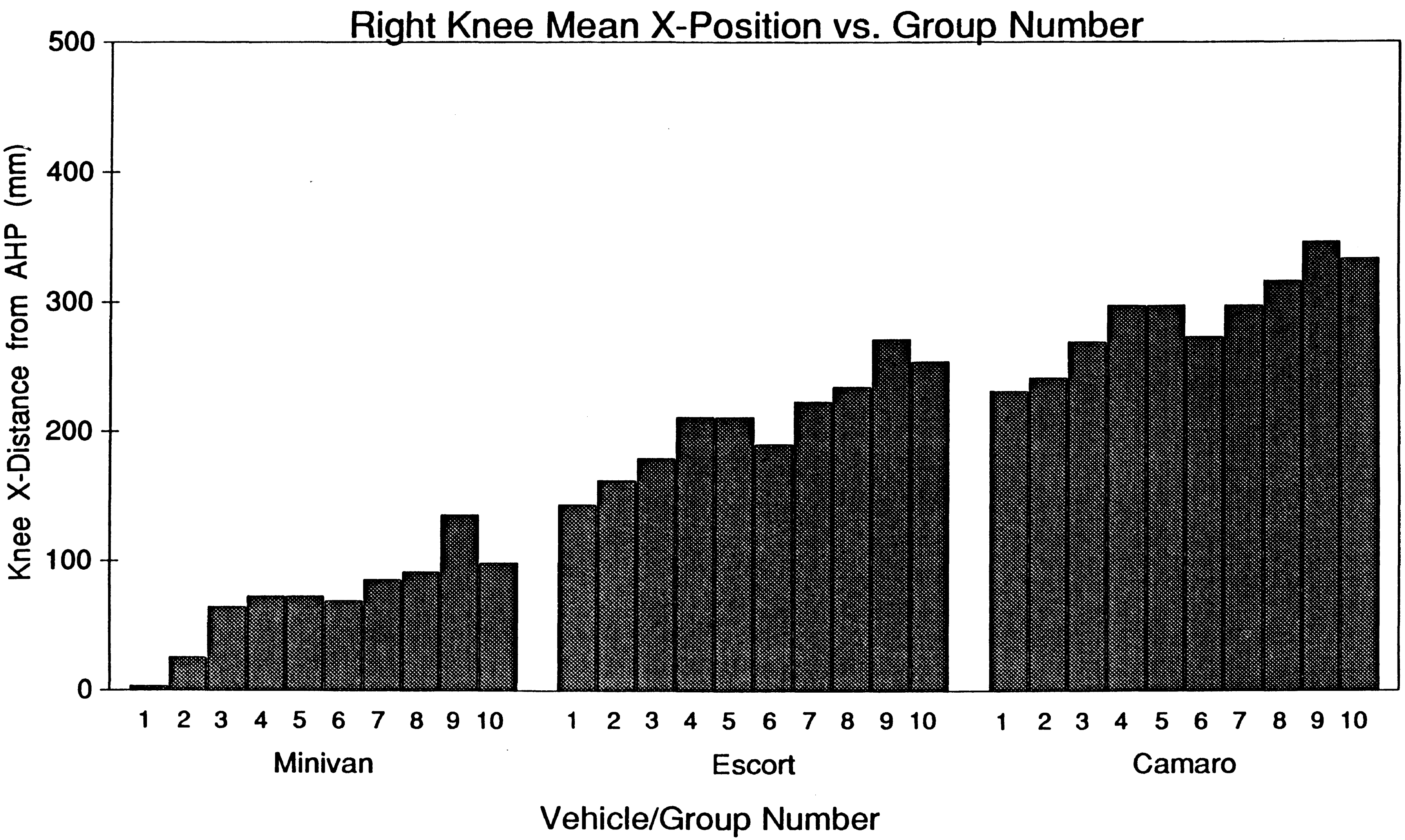


Figure F-2a. Comparison of group mean right knee X-positions with foot on depressed accelerator pedal and seat translated forward six inches.

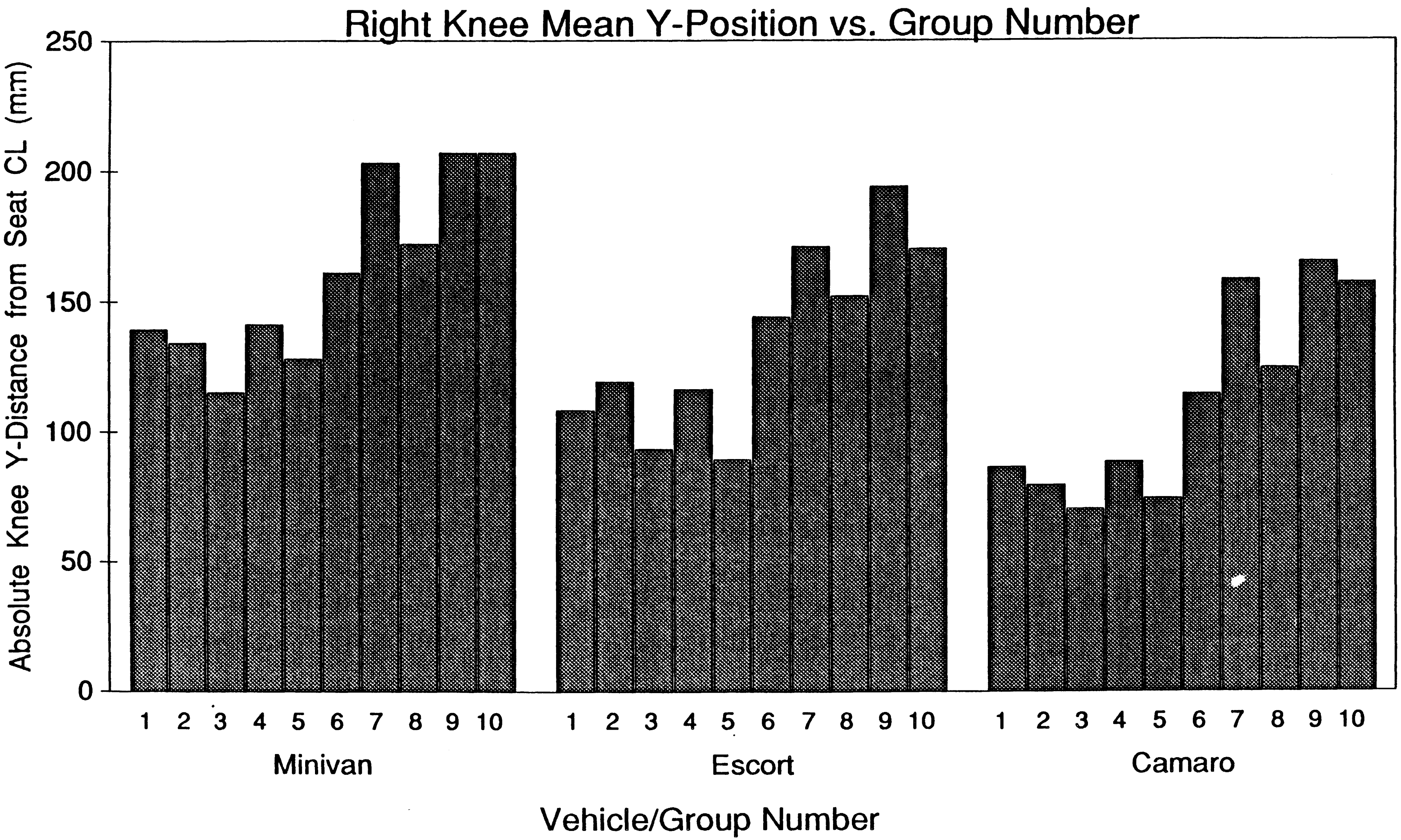


Figure F-2b. Comparison of group mean right knee Y-positions with foot on depressed accelerator pedal and seat translated forward six inches.

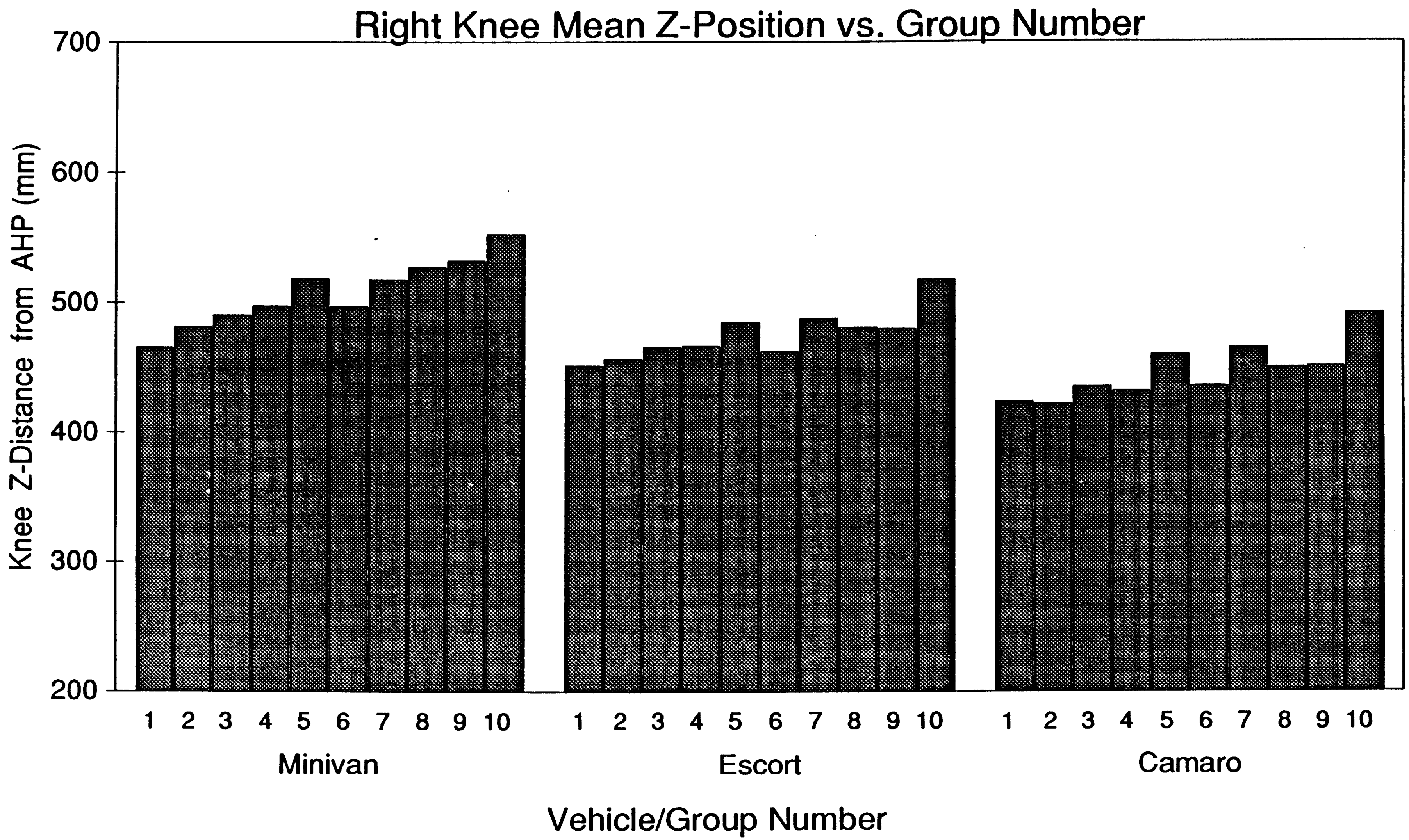


Figure F-2c. Comparison of group mean right knee Z-positions with foot on depressed accelerator pedal and seat translated forward six inches.

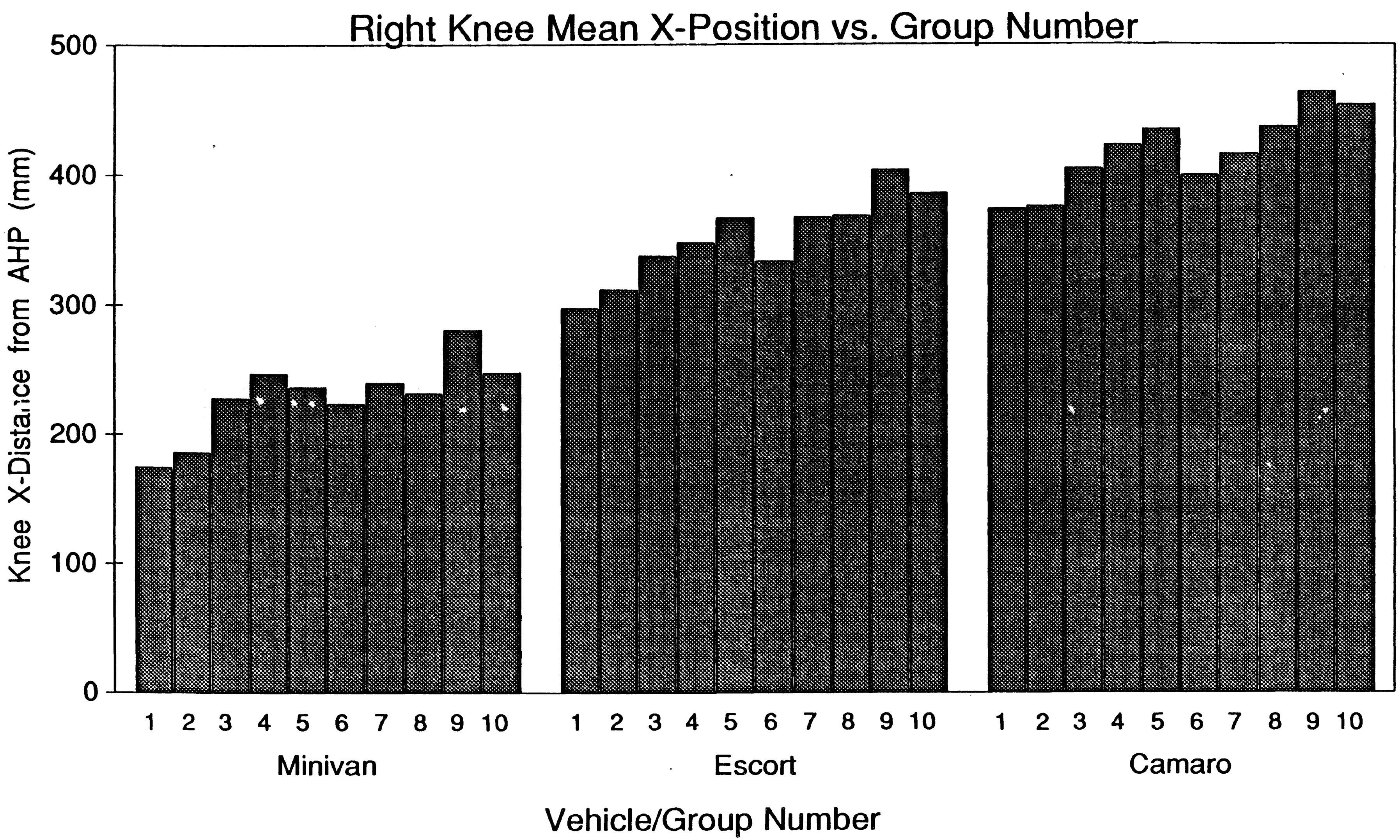


Figure F-3a. Comparison of group mean right knee X-positions with foot on undepressed brake pedal and seat in preferred position.

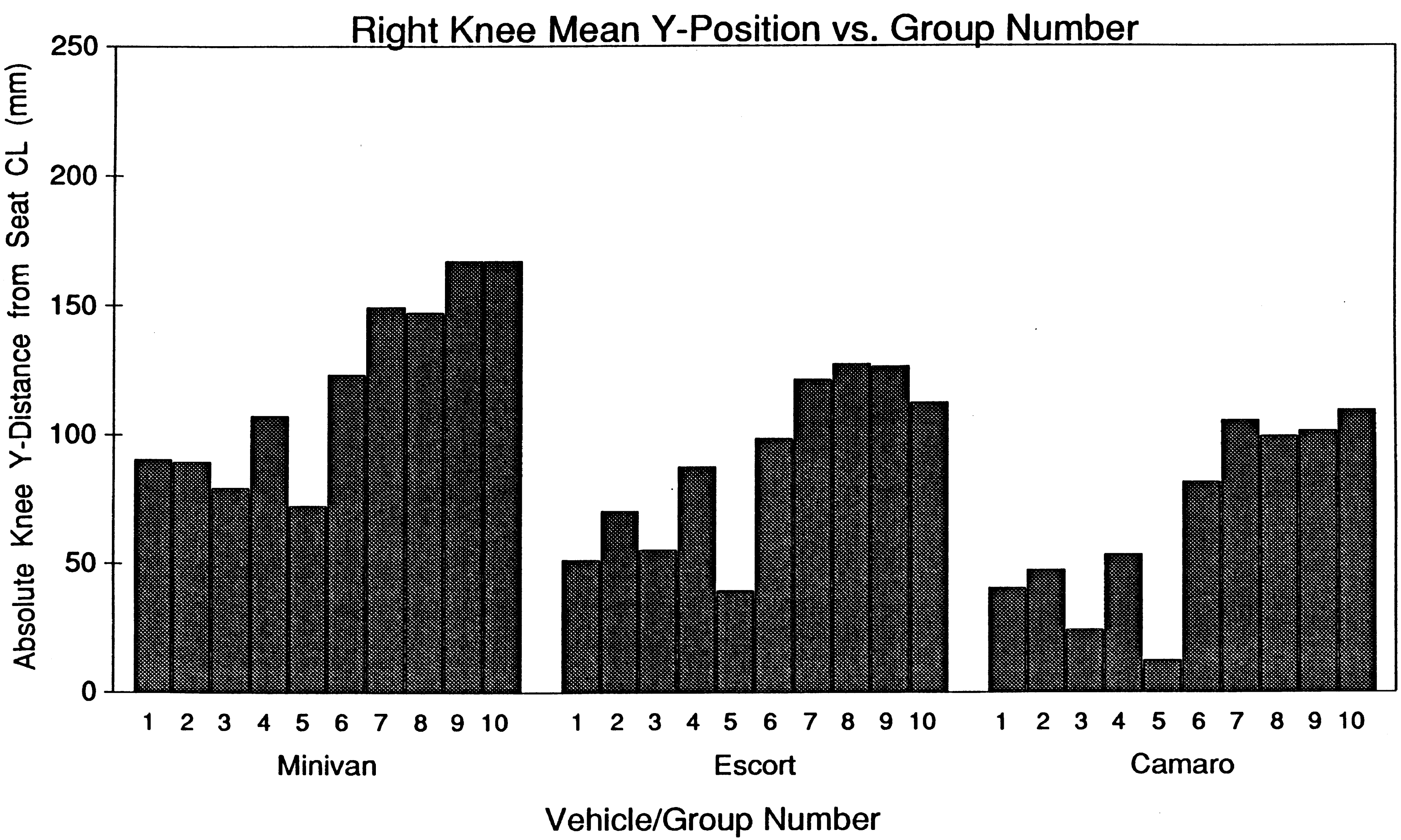


Figure F-3b. Comparison of group mean right knee Y-positions with foot on undepressed brake pedal and seat in preferred position.

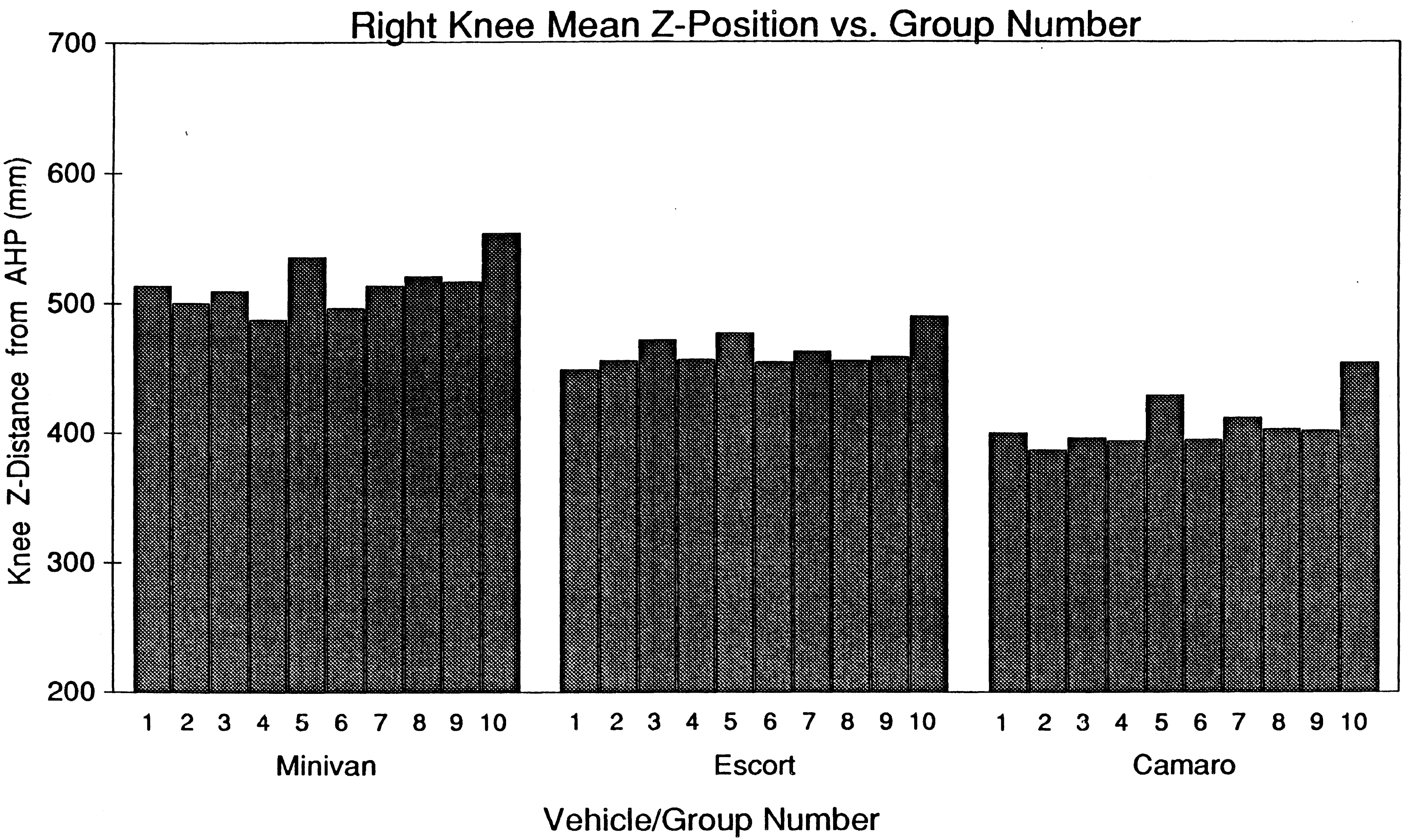


Figure F-3c. Comparison of group mean right knee Z-positions with foot on undepressed brake pedal and seat in preferred positions.

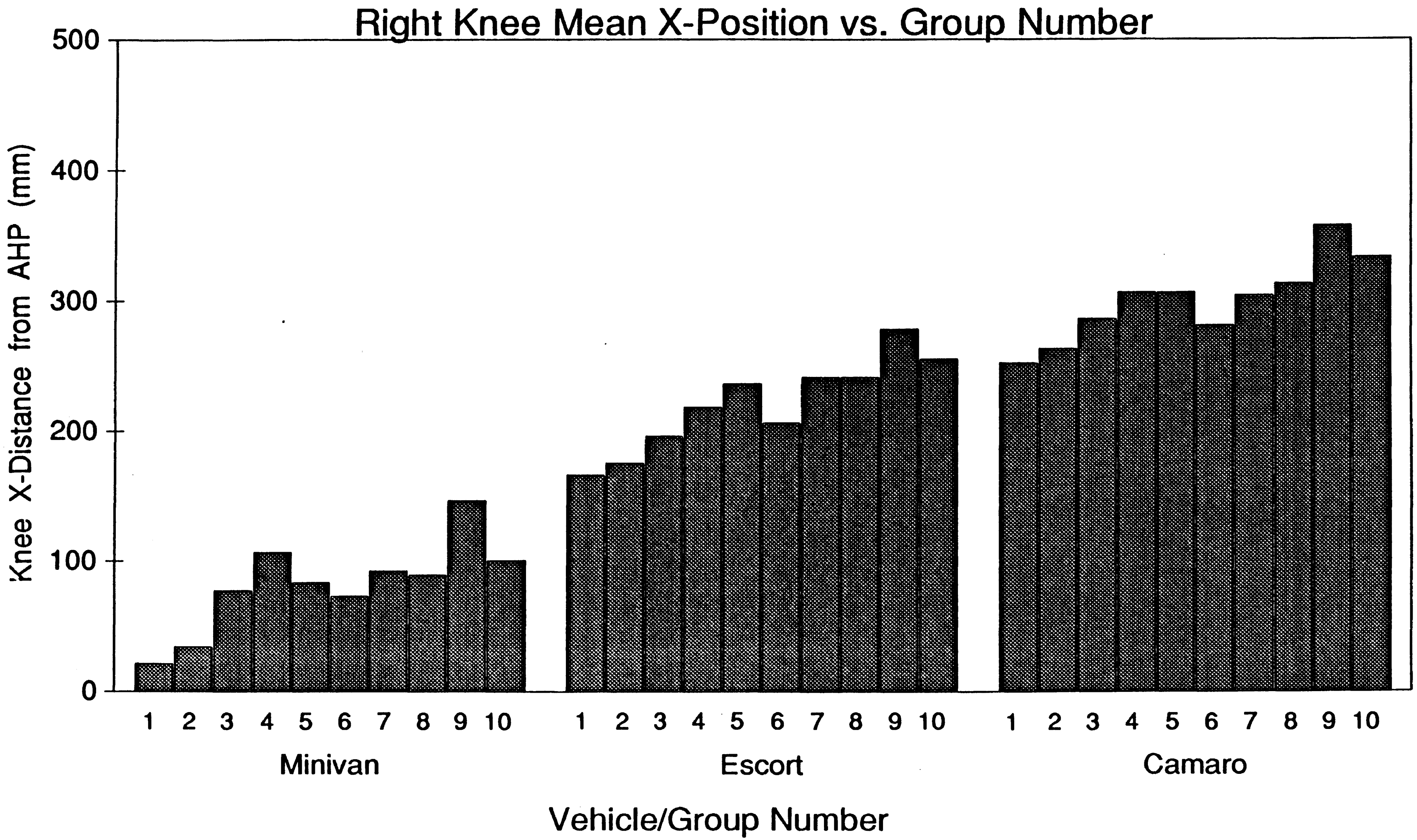


Figure F-4a. Comparison of group mean right knee X-positions with foot on depressed brake pedal and seat translated forward six inches.

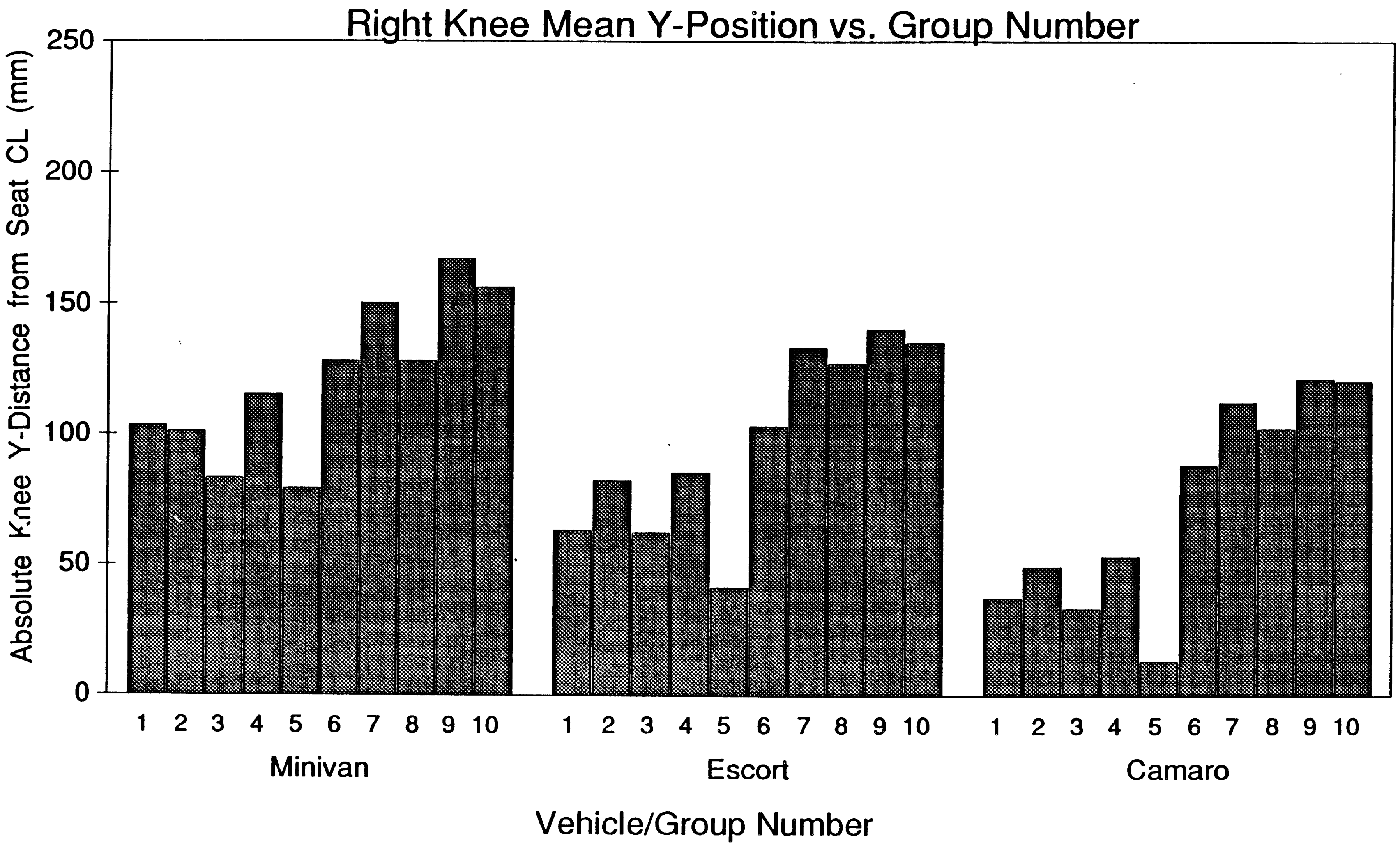


Figure F-4b. Comparison of group mean right knee Y-positions with foot on depressed brake pedal and seat translated forward six inches.

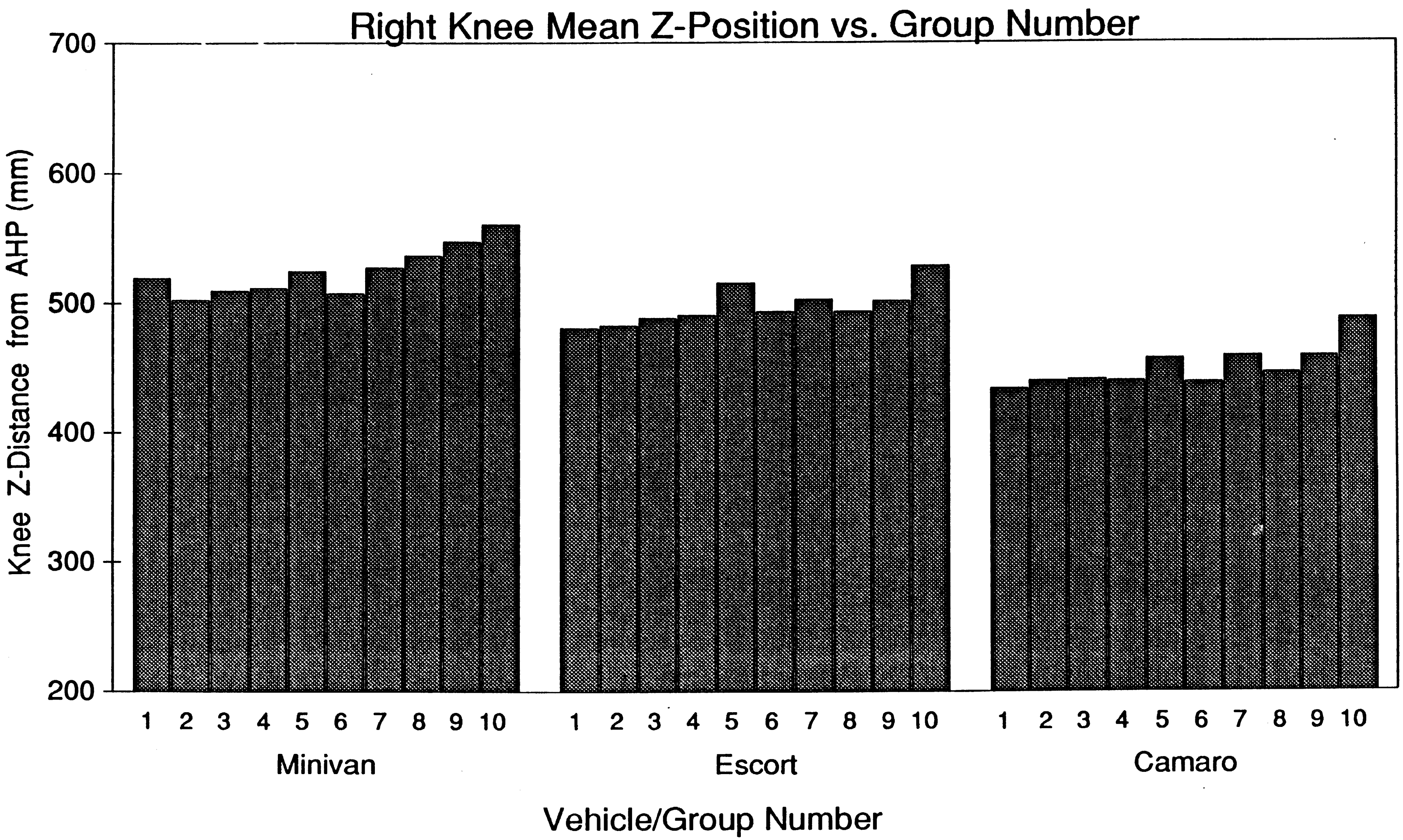


Figure F-4c. Comparison of group mean right knee Z-positions with foot on depressed brake pedal and seat translated forward six inches.

APPENDIX G

TABLES OF 95th AND 99th PERCENTILE KNEE ELLIPSES AND PLOTS OF 95th PERCENTILE ELLIPSES USING LOWER MARGIN OF PATELLA TARGET

TABLE G-1

95%ILE AND 99%ILE DRIVER KNEE ELLIPSES
(RIGHT FOOT ON UNDEPRESSED ACCELERATOR/LEFT FOOT ON FOOTREST/SEAT NORMAL)

	Minivan		Escort		Camaro	
	Right Patella	Left Patella	Right Patella	Left Patella	Right Patella	Left Patella
Mean X	209.99	199.11	329.66	328.15	392.07	391.90
Mean Y	-163.12	155.21	-131.43	159.27	-114.27	171.97
Mean Z	471.05	462.82	416.60	427.33	366.83	362.05
X Std. Dev.	42.65	44.66	42.64	44.60	39.10	42.21
Y Std. Dev.	45.97	52.70	46.66	48.18	47.31	50.02
Z Std. Dev.	26.59	29.63	22.53	27.93	31.66	33.06
95% X*	140.75	147.38	140.71	147.18	129.03	139.29
95% Y	151.70	173.91	153.98	158.99	155.53	165.07
95% Z	87.75	97.78	74.35	92.17	104.48	109.10
99% X*	198.75	208.12	198.70	207.84	182.21	196.70
99% Y	214.22	245.58	217.44	224.52	220.46	233.09
99% Z	123.91	138.08	104.99	130.15	147.54	154.06
X/Z Slope	0.14	0.22	0.12	0.24	0.39	0.29
X/Y Slope	-2.75	2.86	-2.44	2.03	-2.11	1.95
Y/Z Slope	-0.33	0.39	-0.28	0.36	-0.35	0.32
X/Z Correlation	0.14	0.20	0.17	0.25	0.19	0.16
X/Y Correlation	-0.37	0.36	-0.52	0.63	-0.47	0.55
Y/Z Correlation	-0.43	0.56	-0.47	0.48	-0.33	0.30

Coordinate values are in mm.
* 95%ile and 99%ile accommodation centrally distributed about the mean.

TABLE G-2

95%ILE AND 99%ILE DRIVER KNEE ELLIPSES
(RIGHT FOOT ON DEPRESSED ACCELERATOR/LEFT FOOT ON FOOTREST/SEAT TRANSLATED)

	Minivan		Escort		Camaro	
	Right Patella	Left Patella	Right Patella	Left Patella	Right Patella	Left Patella
Mean X	74.86	68.53	209.22	210.06	291.49	295.53
Mean Y	-161.68	158.17	-136.64	161.94	-112.48	179.64
Mean Z	509.70	506.79	476.69	491.00	447.86	451.22
X Std. Dev.	46.16	46.06	45.62	50.51	43.82	47.01
Y Std. Dev.	44.15	52.00	44.33	53.49	46.96	51.58
Z Std. Dev.	28.23	31.17	25.10	26.04	26.68	25.64
95% X*	152.33	152.00	150.55	166.68	144.61	155.13
95% Y	145.70	171.60	146.29	176.52	154.97	170.21
95% Z	93.16	102.86	82.83	85.93	88.04	84.61
99% X*	215.11	214.64	212.59	235.38	204.20	219.07
99% Y	205.74	242.32	206.58	249.26	218.83	240.36
99% Z	131.55	145.25	116.97	121.35	124.33	119.48
X/Z Slope	0.42	0.45	0.30	0.36	0.35	0.28
X/Y Slope	-2.76	2.72	-2.45	2.12	-2.43	2.32
Y/Z Slope	-0.43	0.34	-0.25	0.33	-0.28	0.24
X/Z Correlation	0.52	0.45	0.42	0.59	0.41	0.39
X/Y Correlation	-0.35	0.36	-0.48	0.67	-0.46	0.56
Y/Z Correlation	-0.49	0.41	-0.31	0.59	-0.36	0.38

Coordinate values are in mm.
* 95%ile and 99%ile accommodation centrally distributed about the mean.

TABLE G-3
95%ILE AND 99%ILE DRIVER KNEE ELLIPSES
(RIGHT FOOT ON UNDEPRESSED BRAKE/LEFT FOOT ON FLOOR/SEAT NORMAL)

	Minivan		Escort		Camaro	
	Right Patella	Left Patella	Right Patella	Left Patella	Right Patella	Left Patella
Mean X	230.71	210.43	353.39	346.05	419.47	420.61
Mean Y	-120.05	156.79	-89.66	173.72	-68.10	182.15
Mean Z	516.23	488.24	464.45	458.67	408.21	406.83
X Std. Dev.	37.80	50.64	37.32	51.73	36.38	53.88
Y Std. Dev.	51.74	52.44	47.03	61.00	50.73	46.17
Z Std. Dev.	31.10	33.12	27.06	25.02	32.59	52.83
95% X*	124.74	167.11	123.16	170.71	120.05	177.80
95% Y	170.74	173.05	155.20	201.30	167.41	152.36
95% Z	102.63	109.30	89.30	82.57	107.55	174.34
99% X*	176.15	235.98	173.91	241.06	169.53	251.08
99% Y	241.11	244.37	219.16	284.26	236.40	215.15
99% Z	144.93	154.33	126.10	116.59	151.87	246.19
X/Z Slope	-0.36	0.47	0.05	0.28	0.59	0.97
X/Y Slope	-3.74	2.67	-2.74	2.43	-5.13	0.81
Y/Z Slope	-0.17	0.39	-0.08	0.08	-0.12	2.09
X/Z Correlation	-0.16	0.54	0.03	0.48	0.20	0.60
X/Y Correlation	-0.26	0.35	-0.39	0.59	-0.17	0.44
Y/Z Correlation	-0.18	0.43	-0.09	0.15	-0.12	0.17

Coordinate values are in mm.
* 95%ile and 99%ile accommodation centrally distributed about the mean.

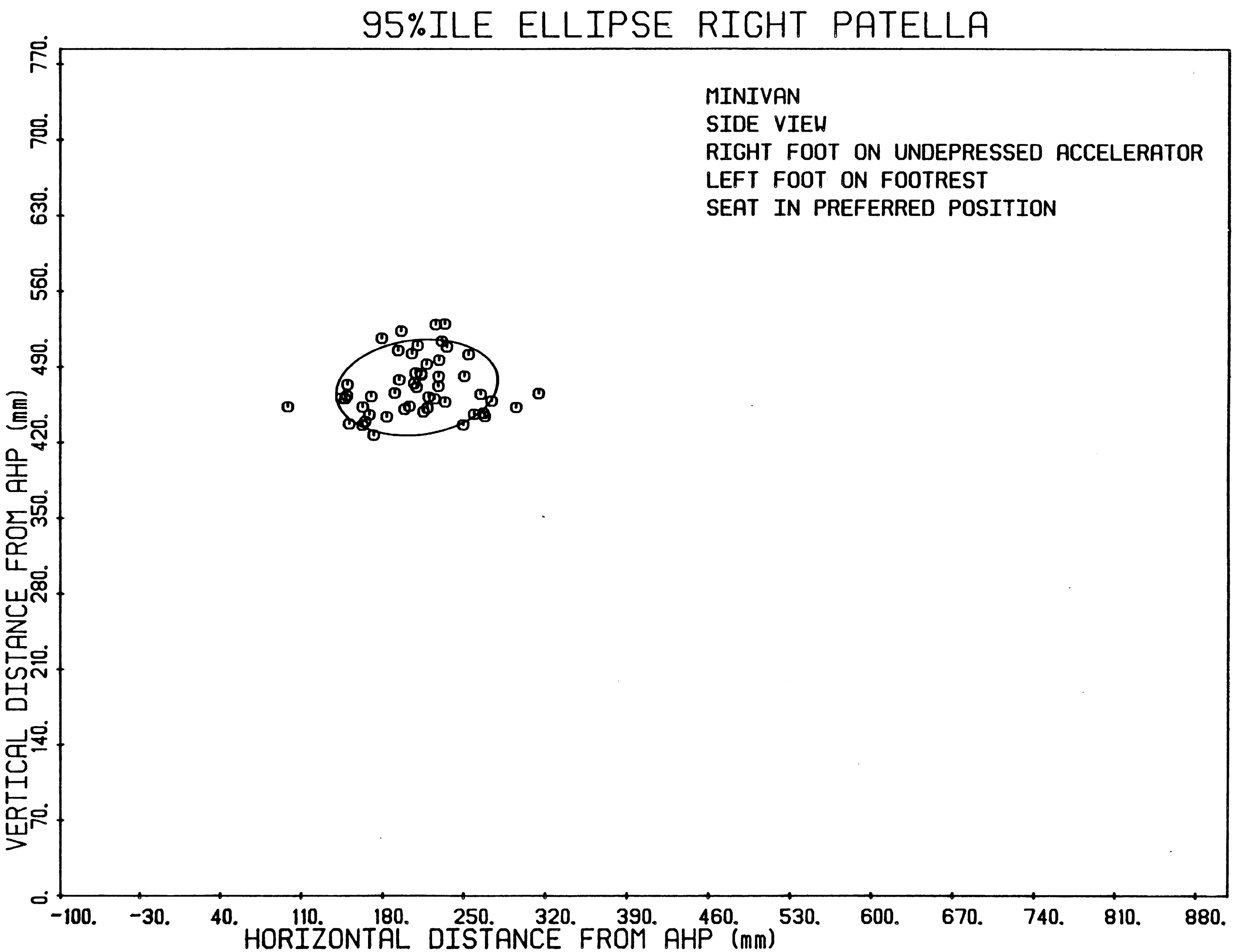
TABLE G-4

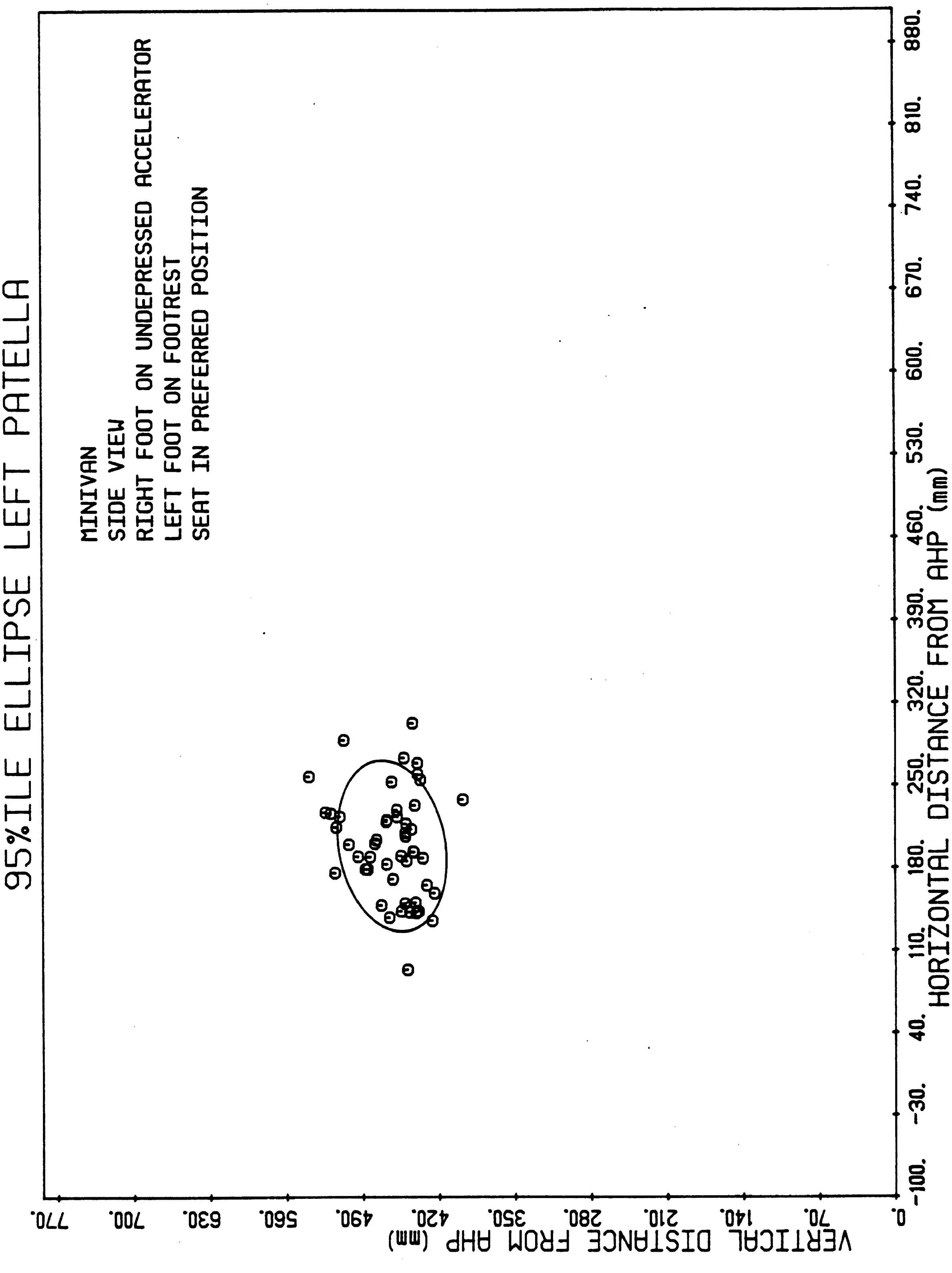
95%ILE AND 99%ILE DRIVER KNEE ELLIPSES
(RIGHT FOOT ON DEPRESSED BRAKE/LEFT FOOT ON FLOOR/SEAT NORMAL)

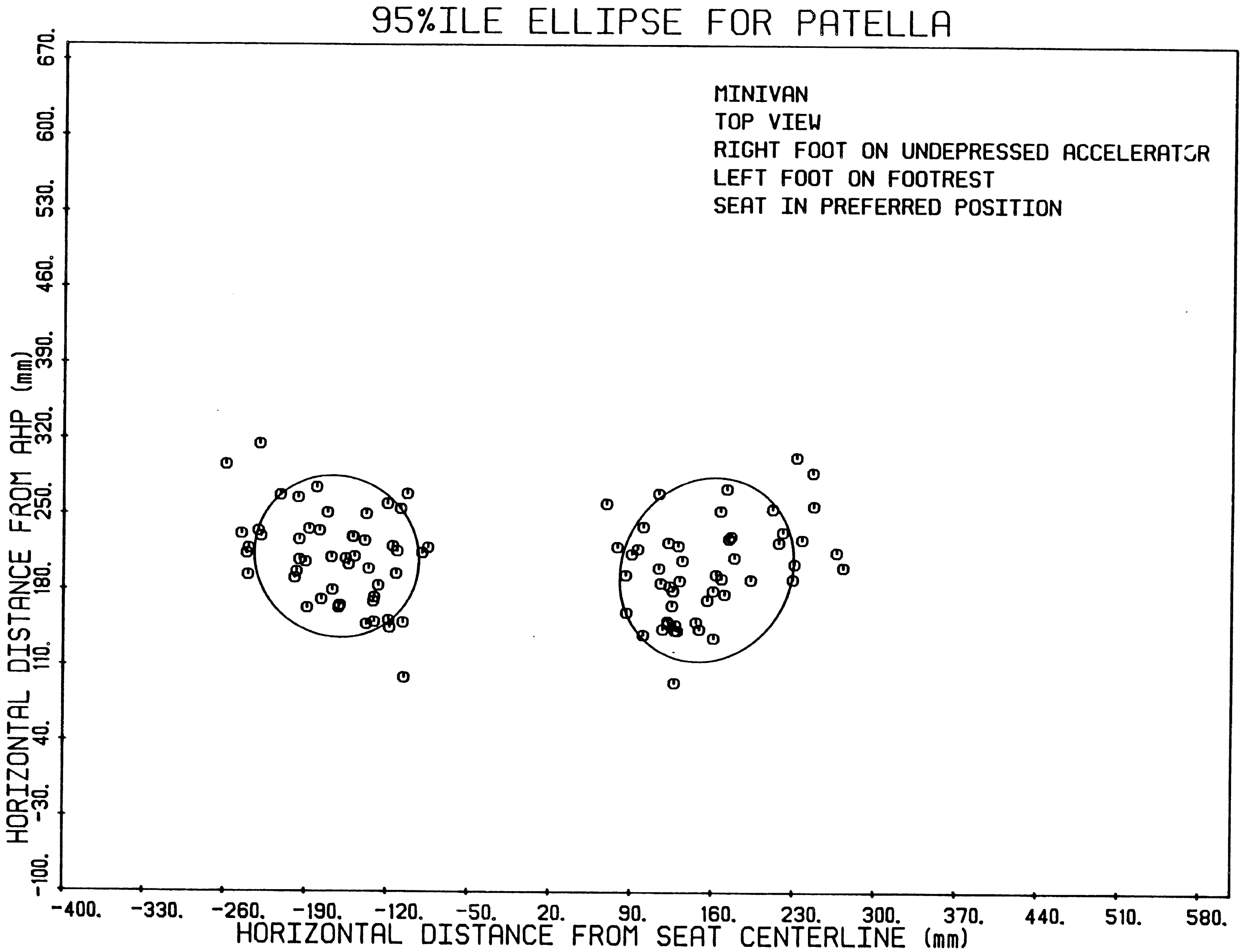
	Minivan		Escort		Camaro	
	Right Patella	Left Patella	Right Patella	Left Patella	Right Patella	Left Patella
Mean X	85.33	68.69	223.25	214.45	302.05	311.57
Mean Y	-122.35	161.31	-97.99	171.31	-73.79	183.81
Mean Z	526.29	503.08	499.14	492.56	451.13	461.55
X Std. Dev.	44.93	49.97	40.92	56.25	39.43	52.52
Y Std. Dev.	44.46	52.93	46.66	60.39	55.84	50.83
Z Std. Dev.	26.25	32.58	25.30	29.31	27.39	33.48
95% X*	148.27	164.90	135.04	185.63	130.12	173.32
95% Y	146.72	174.67	153.98	199.29	184.27	167.74
95% Z	86.63	107.51	83.49	96.72	90.39	110.48
99% X*	209.37	232.86	190.69	262.13	183.74	244.74
99% Y	207.18	246.65	217.44	281.42	260.21	236.87
99% Z	122.33	151.82	117.90	136.58	127.64	156.02
X/Z Slope	0.17	0.49	0.26	0.38	0.34	0.47
X/Y Slope	-3.78	3.05	-2.53	2.16	-3.60	2.27
Y/Z Slope	-0.27	0.34	-0.21	0.25	-0.19	0.24
X/Z Correlation	0.18	0.56	0.27	0.62	0.29	0.56
X/Y Correlation	-0.23	0.30	-0.45	0.65	-0.34	0.46
Y/Z Correlation	-0.31	0.39	-0.28	0.42	-0.30	0.22

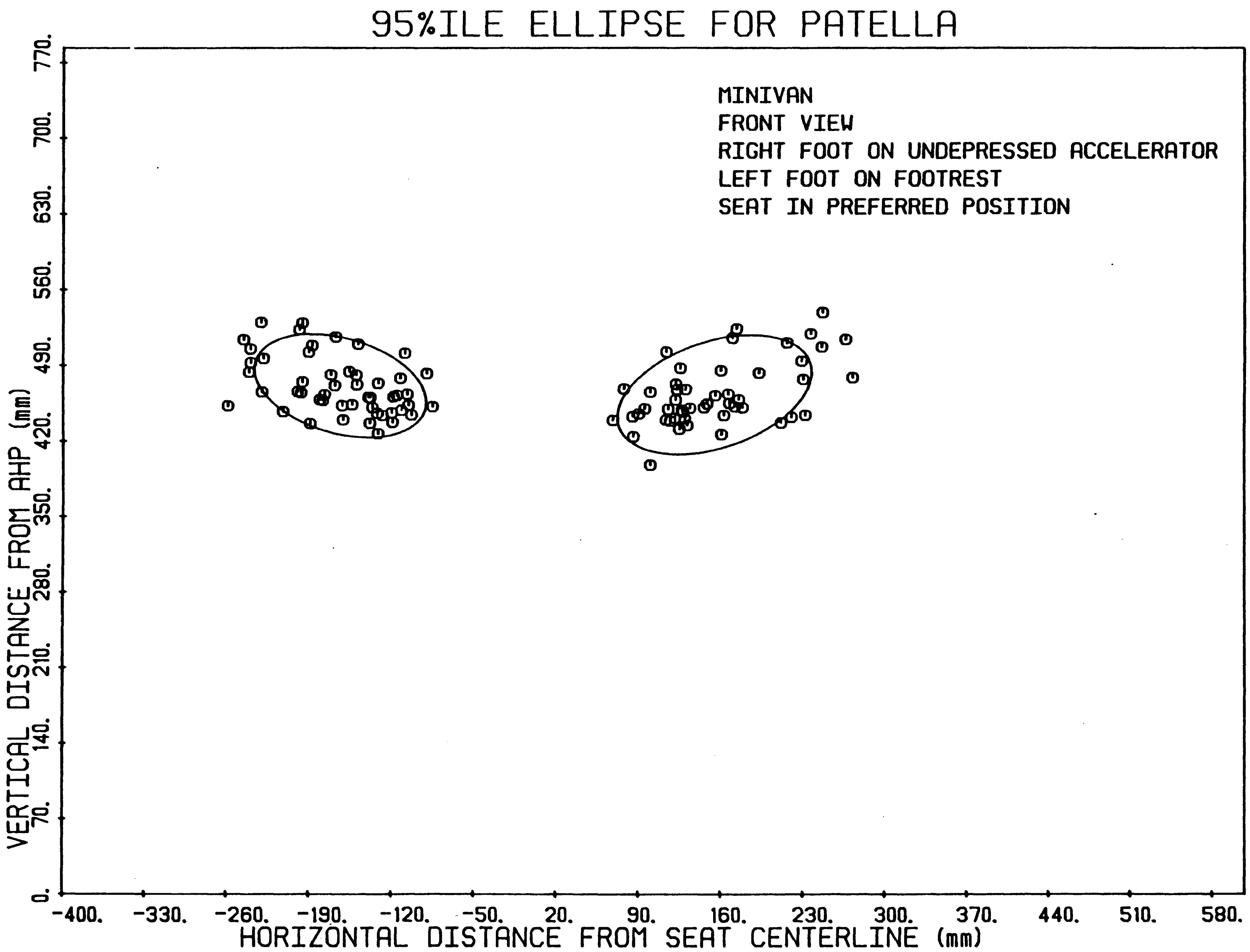
Coordinate values are in mm.
* 95%ile and 99%ile accommodation centrally distributed about the mean.

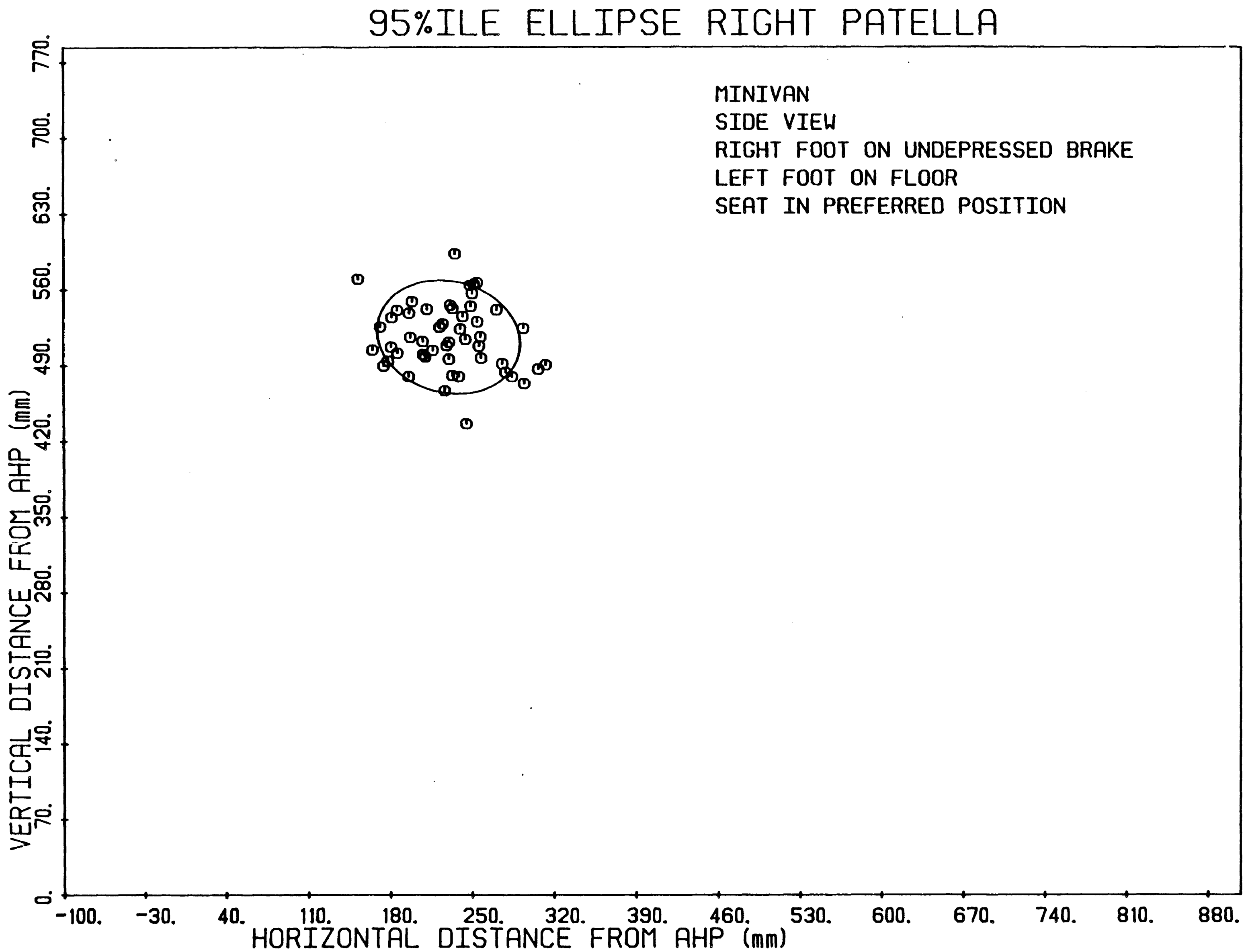
UNTRANSLATED SEAT CONDITIONS


95%ILE ELLIPSE RIGHT PATELLA
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
770.
700.
630.
560.
490.
420.
350.
280.
210.
140.
70.
0.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

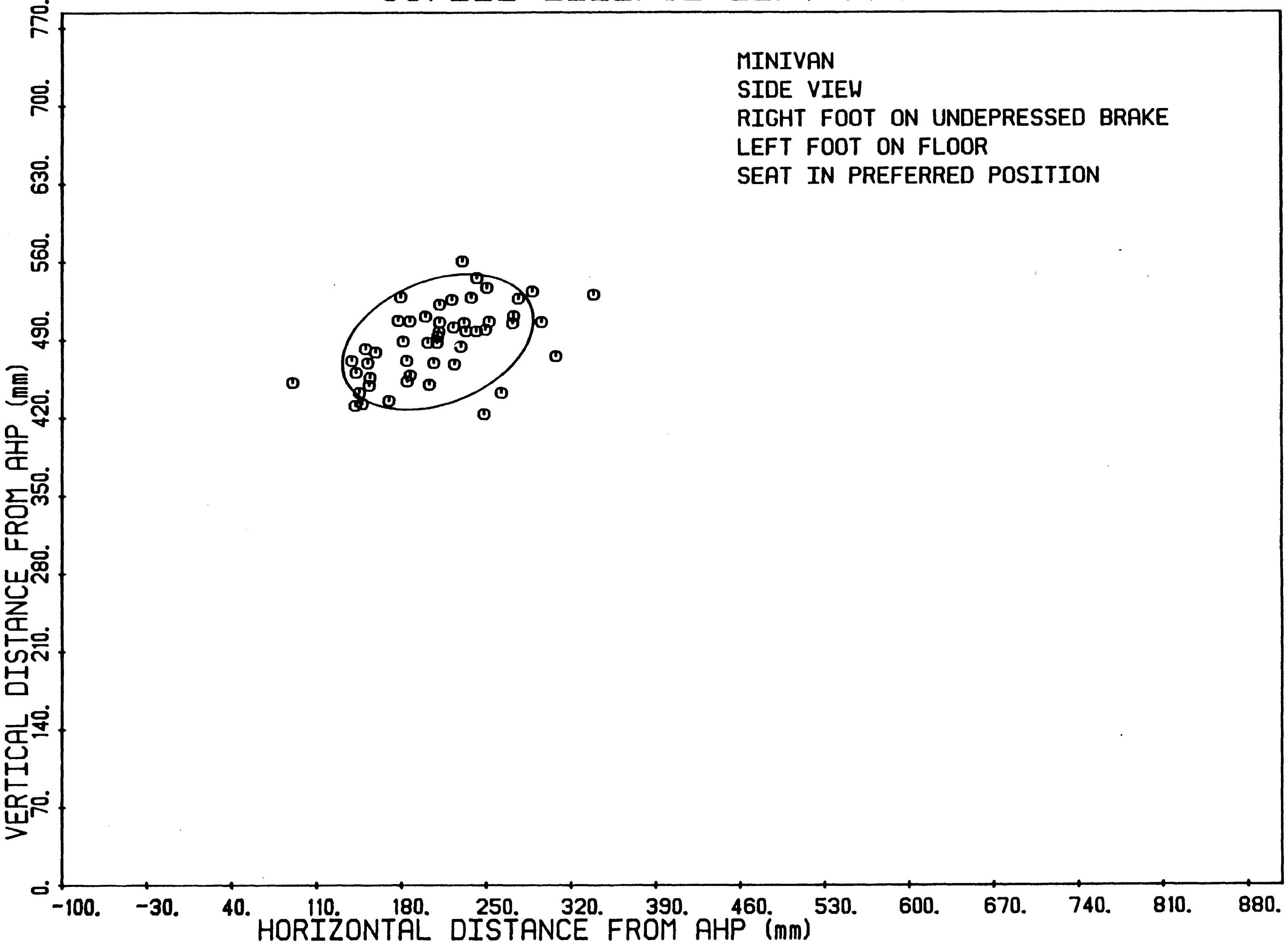

95%ILE ELLIPSE LEFT PATELLA
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.

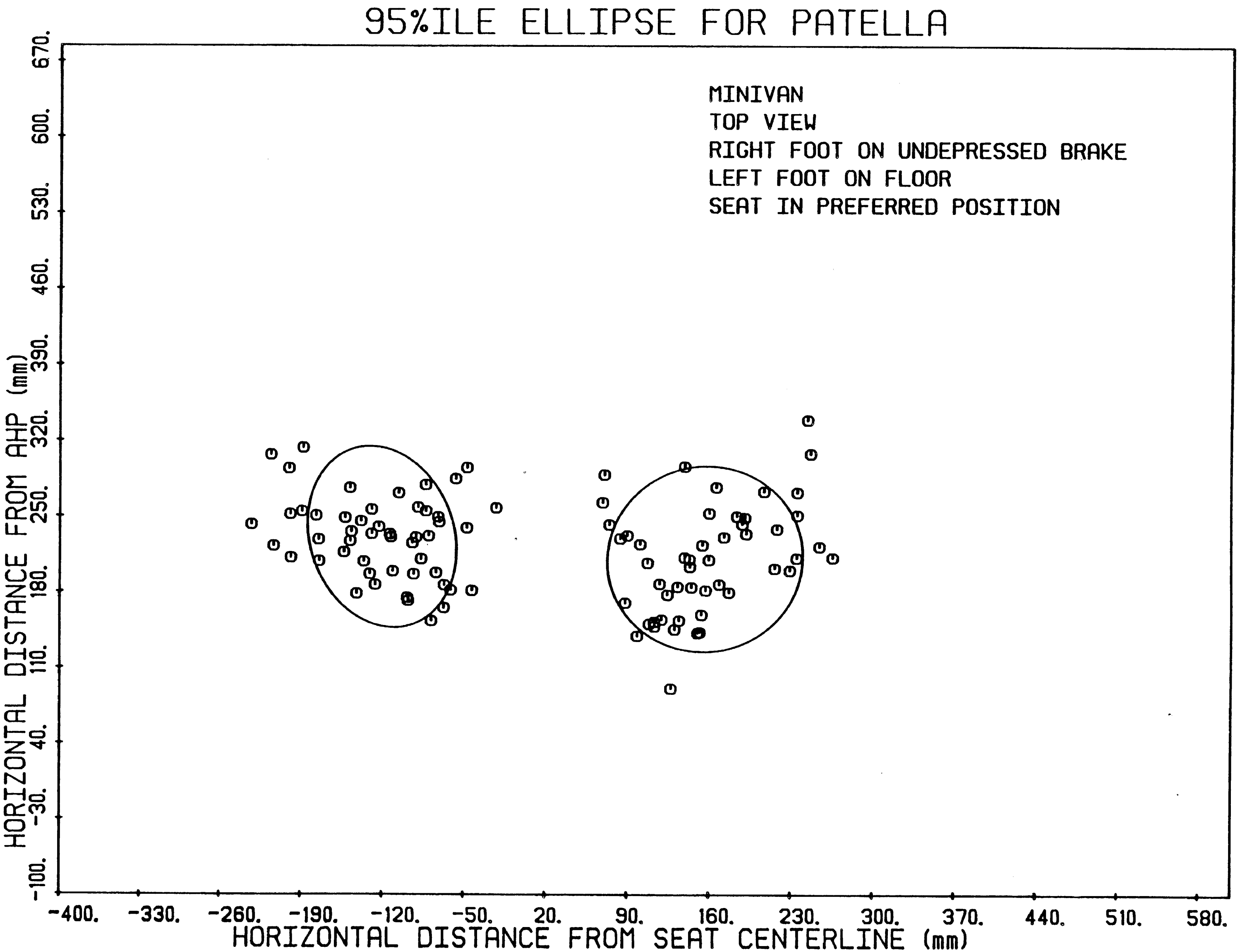

95%ILE ELLIPSE FOR PATELLA
MINIVAN
TOP VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)

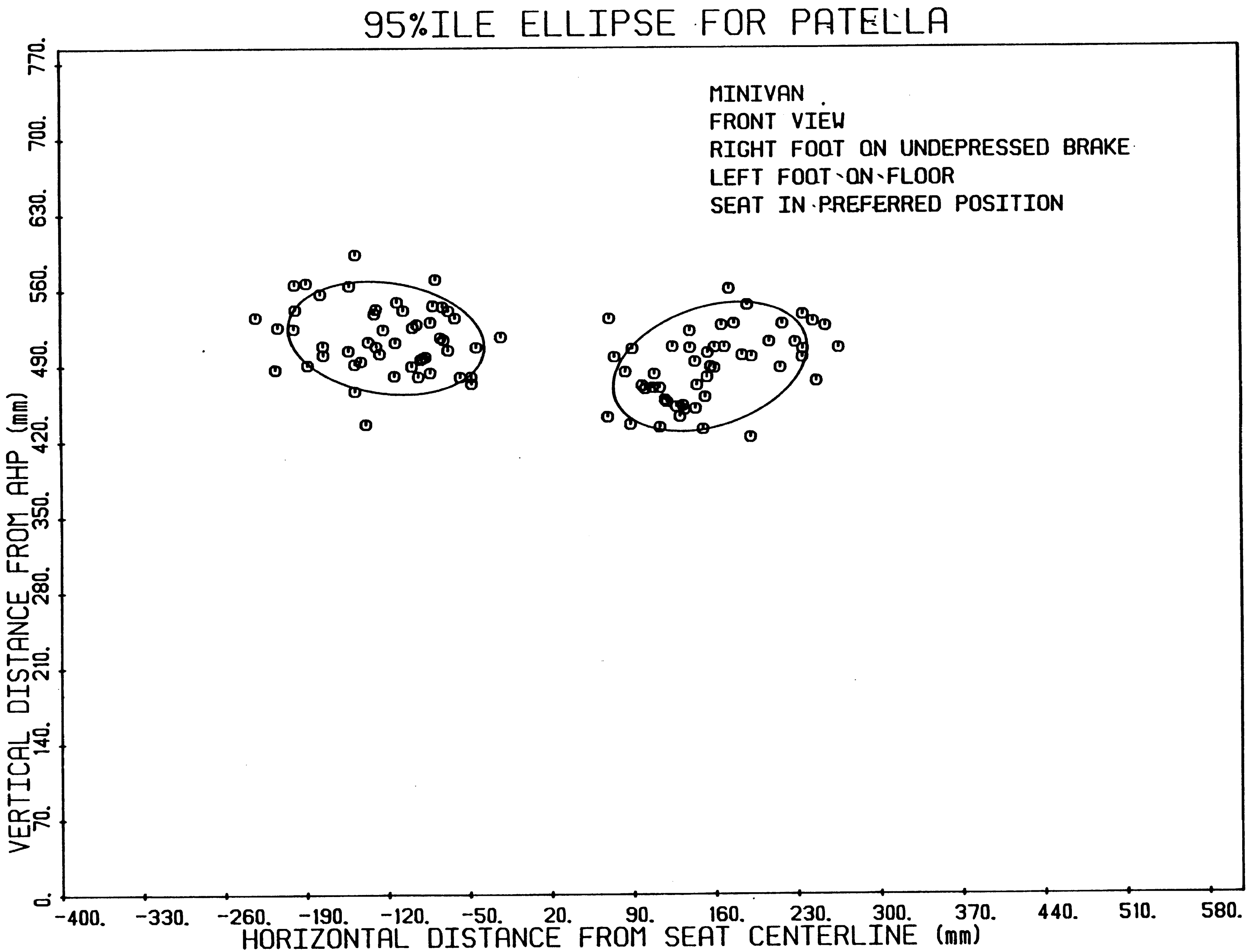

95%ILE ELLIPSE FOR PATELLA
MINIVAN
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


95%ILE ELLIPSE RIGHT PATELLA
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

95%ILE ELLIPSE LEFT PATELLA




95%ILE ELLIPSE FOR PATELLA
MINIVAN
TOP VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


95%ILE ELLIPSE FOR PATELLA
MINIVAN
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
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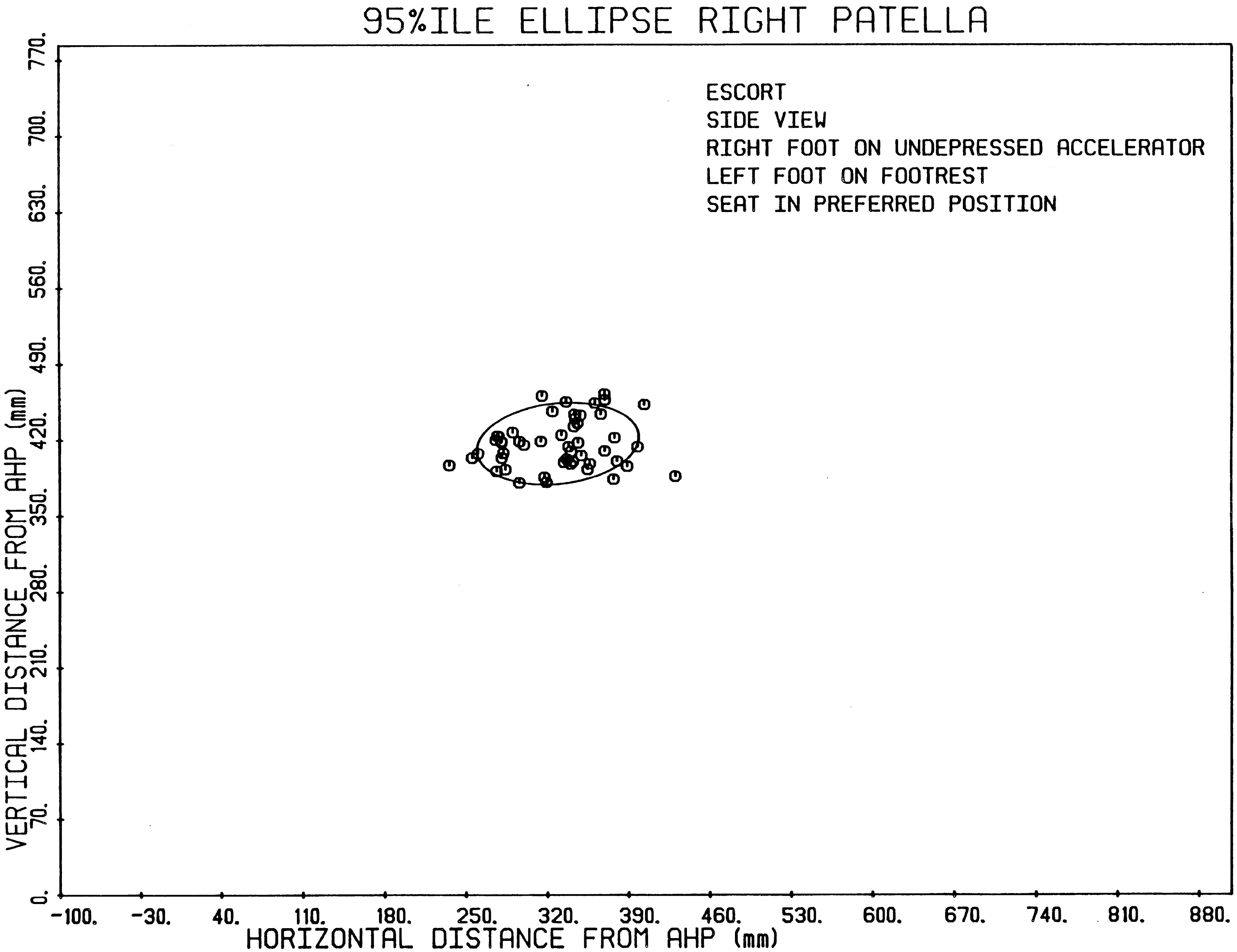
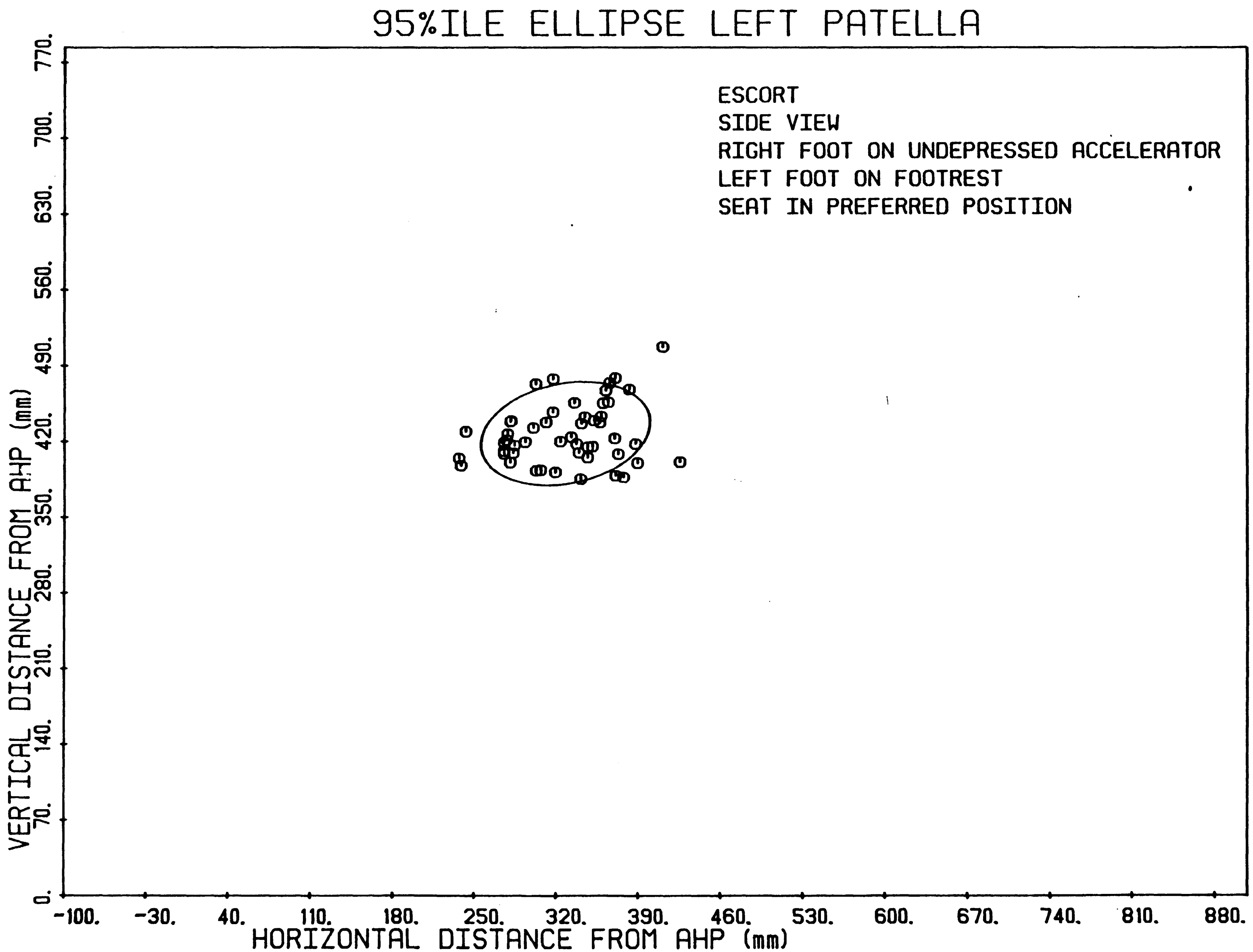
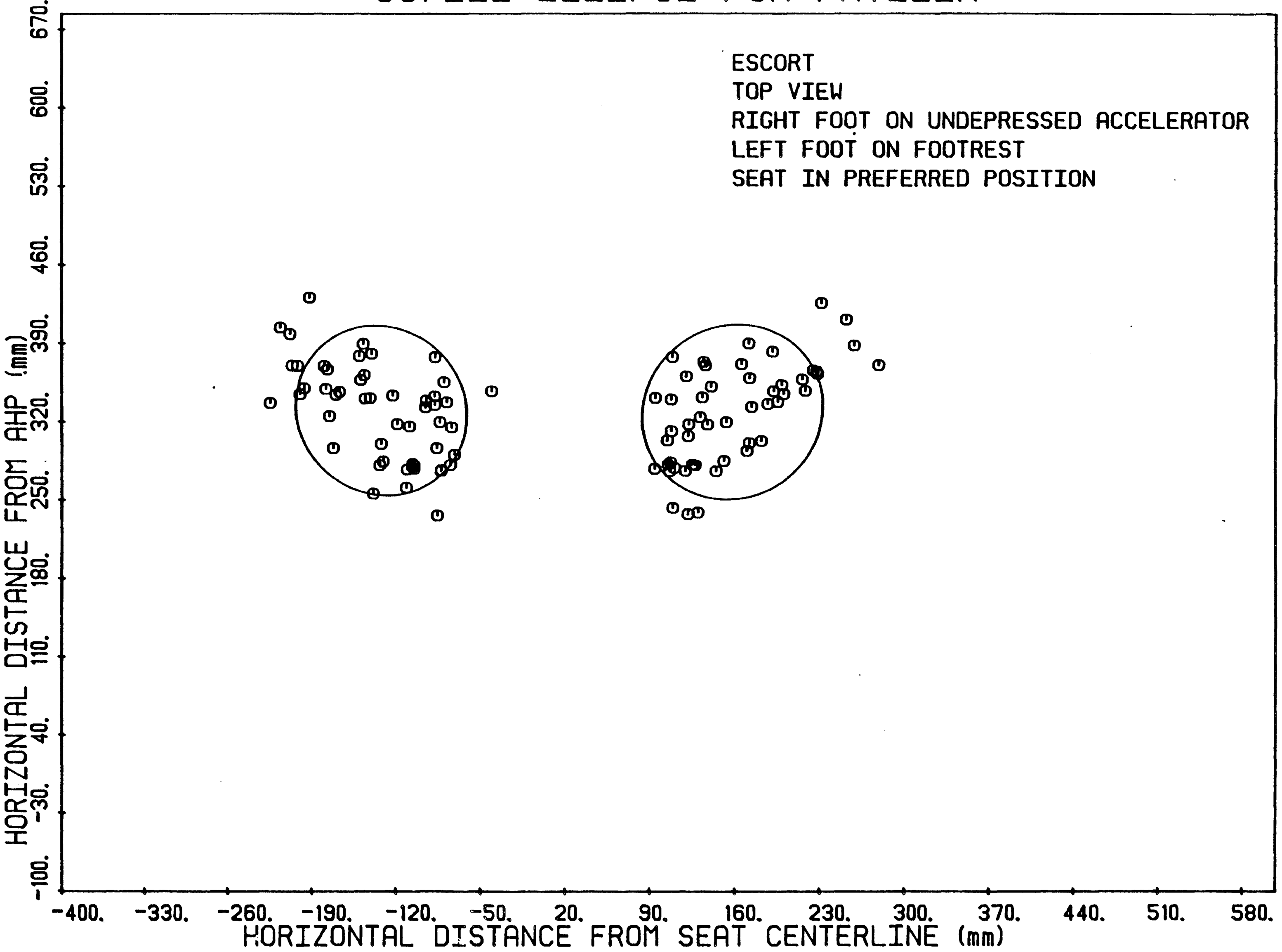
370.
440.
510.
580.

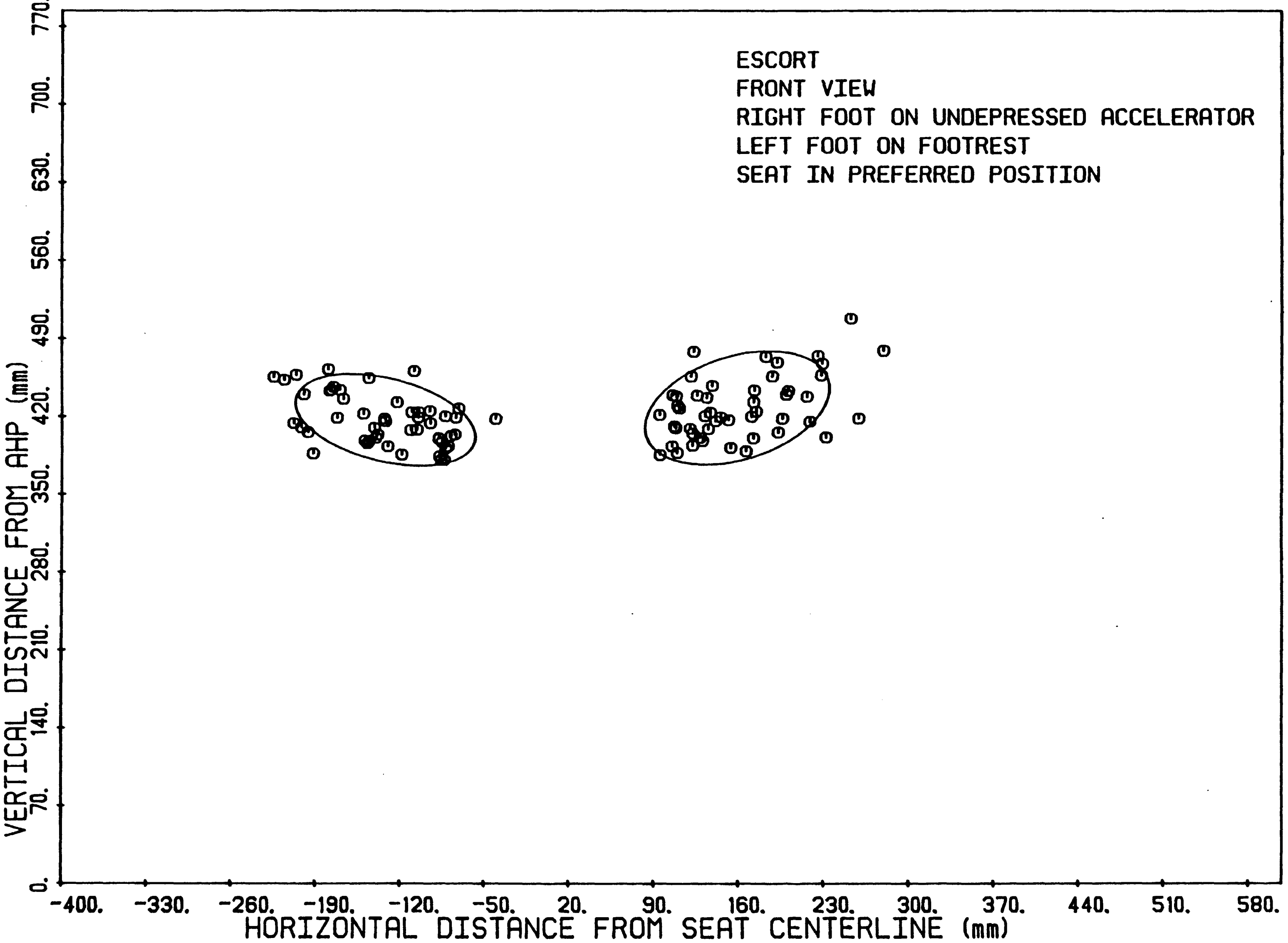

95%ILE ELLIPSE RIGHT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

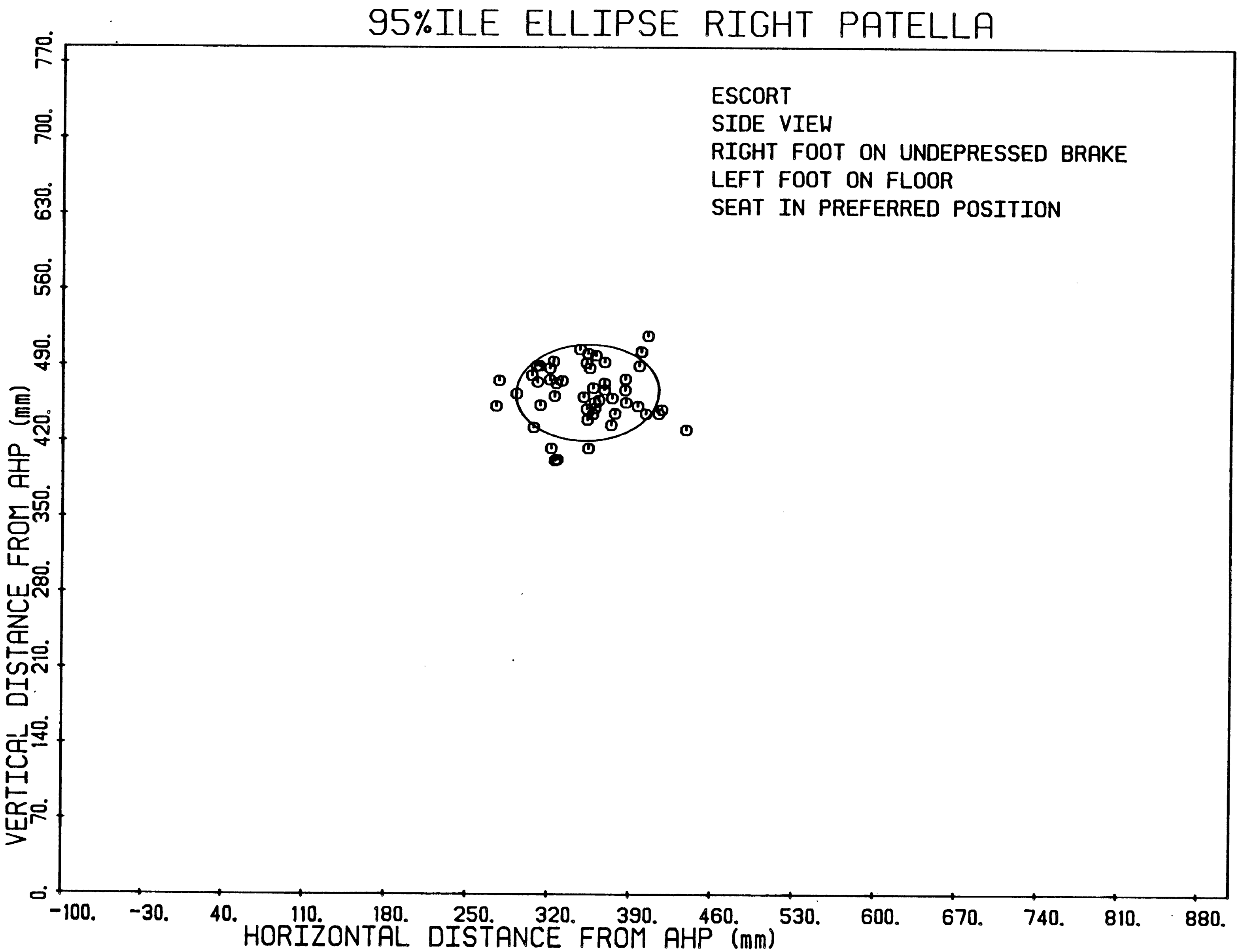

95%ILE ELLIPSE LEFT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

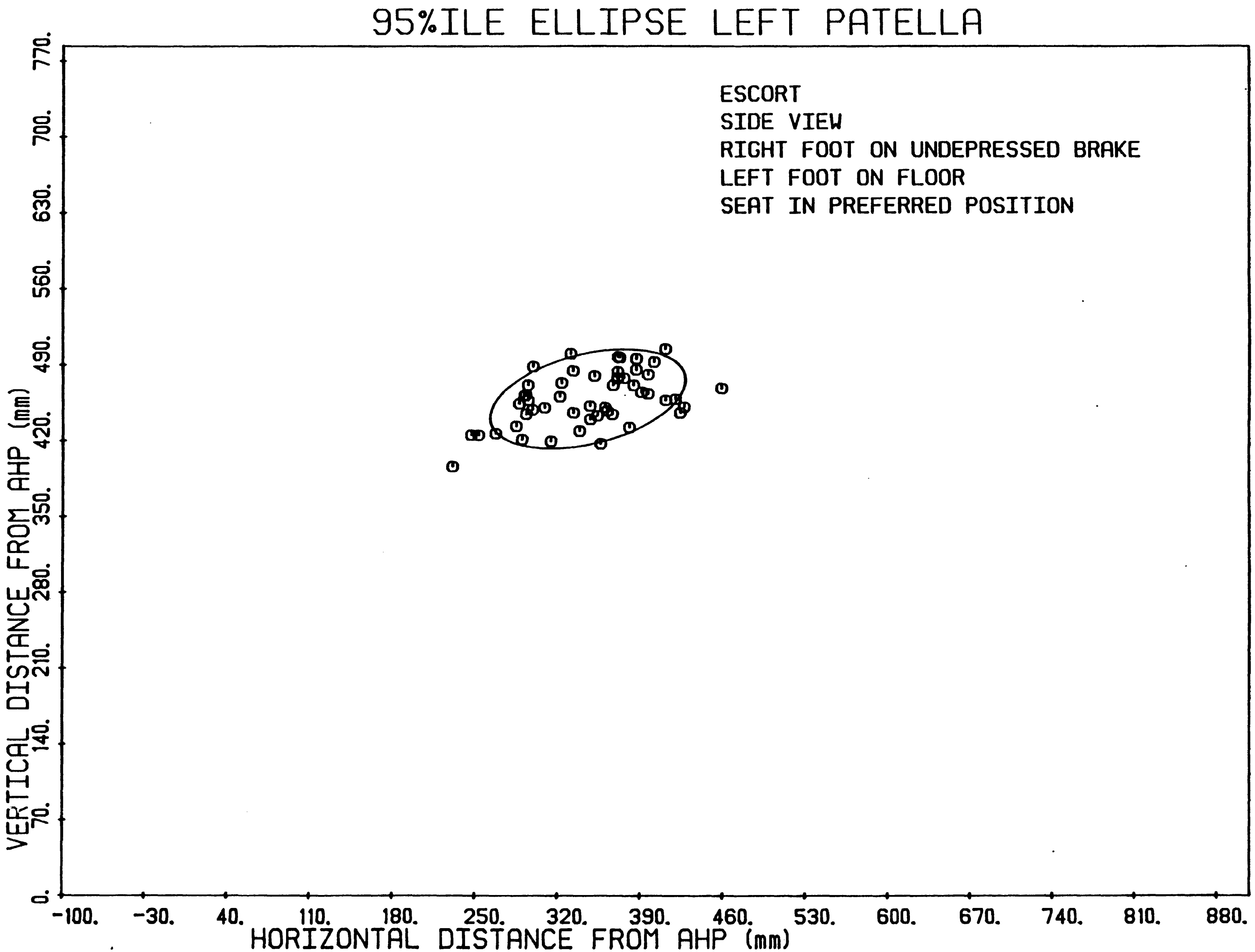
95%ILE ELLIPSE FOR PATELLA



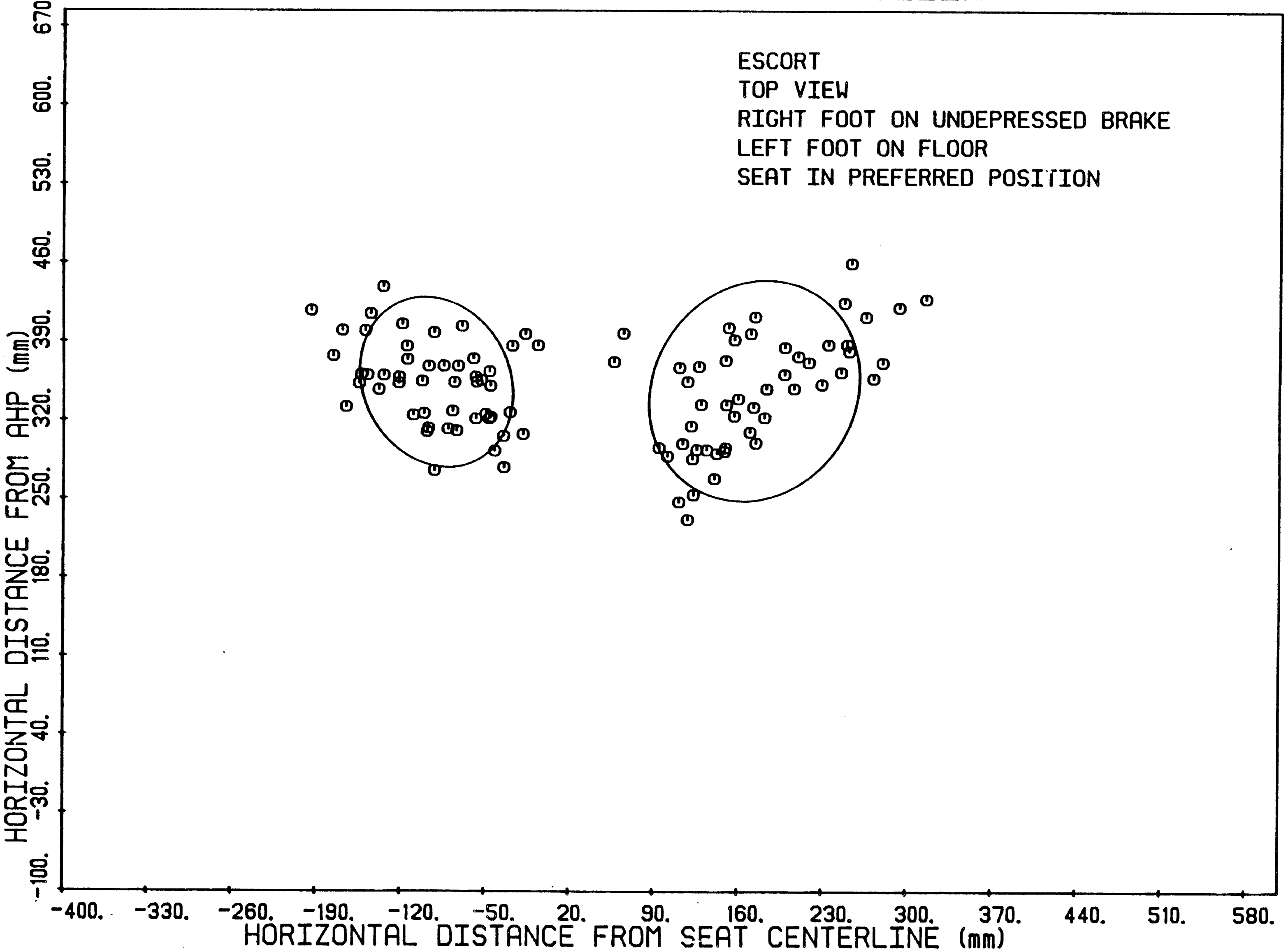
95%ILE ELLIPSE FOR PATELLA



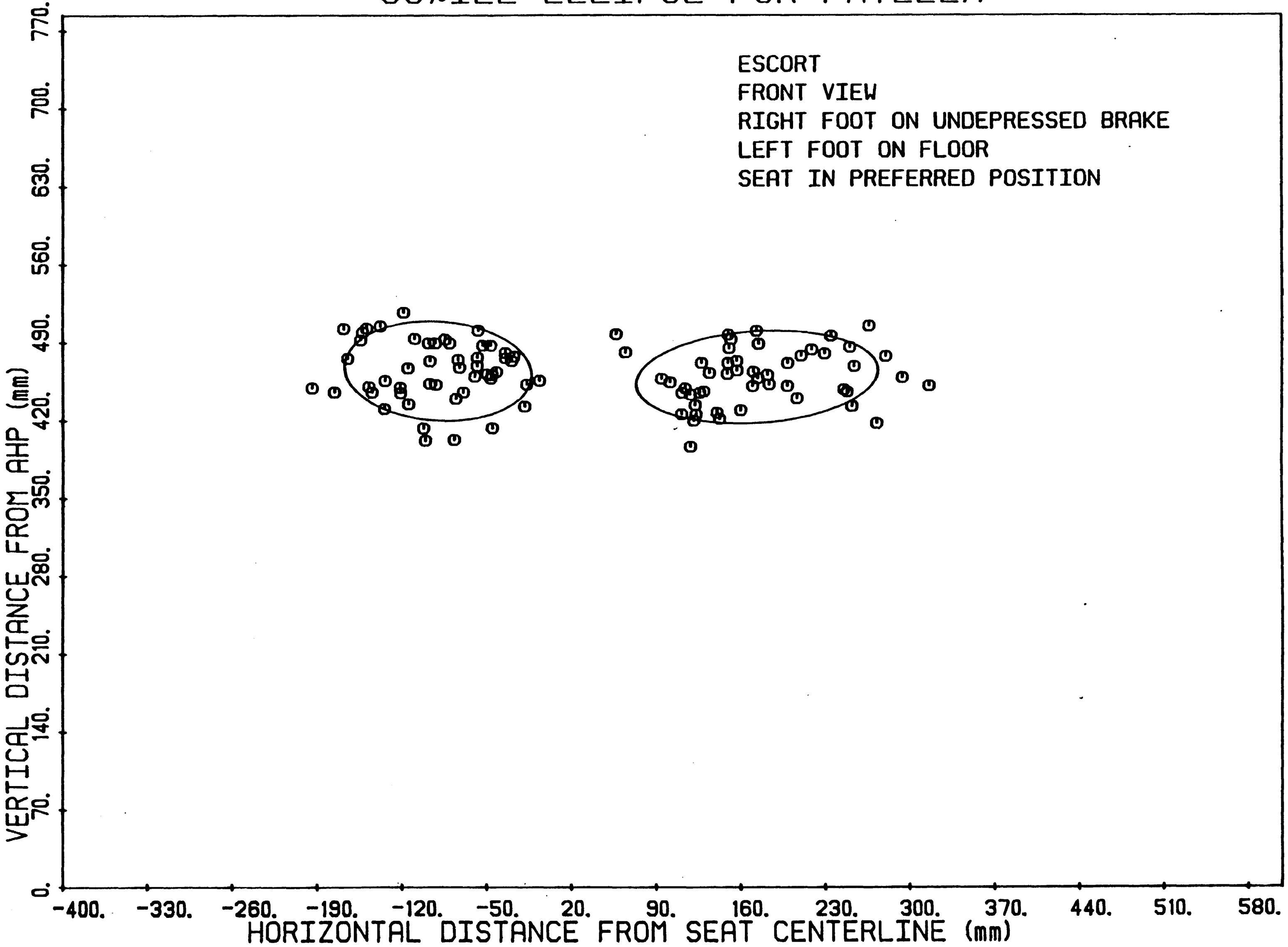

95%ILE ELLIPSE RIGHT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

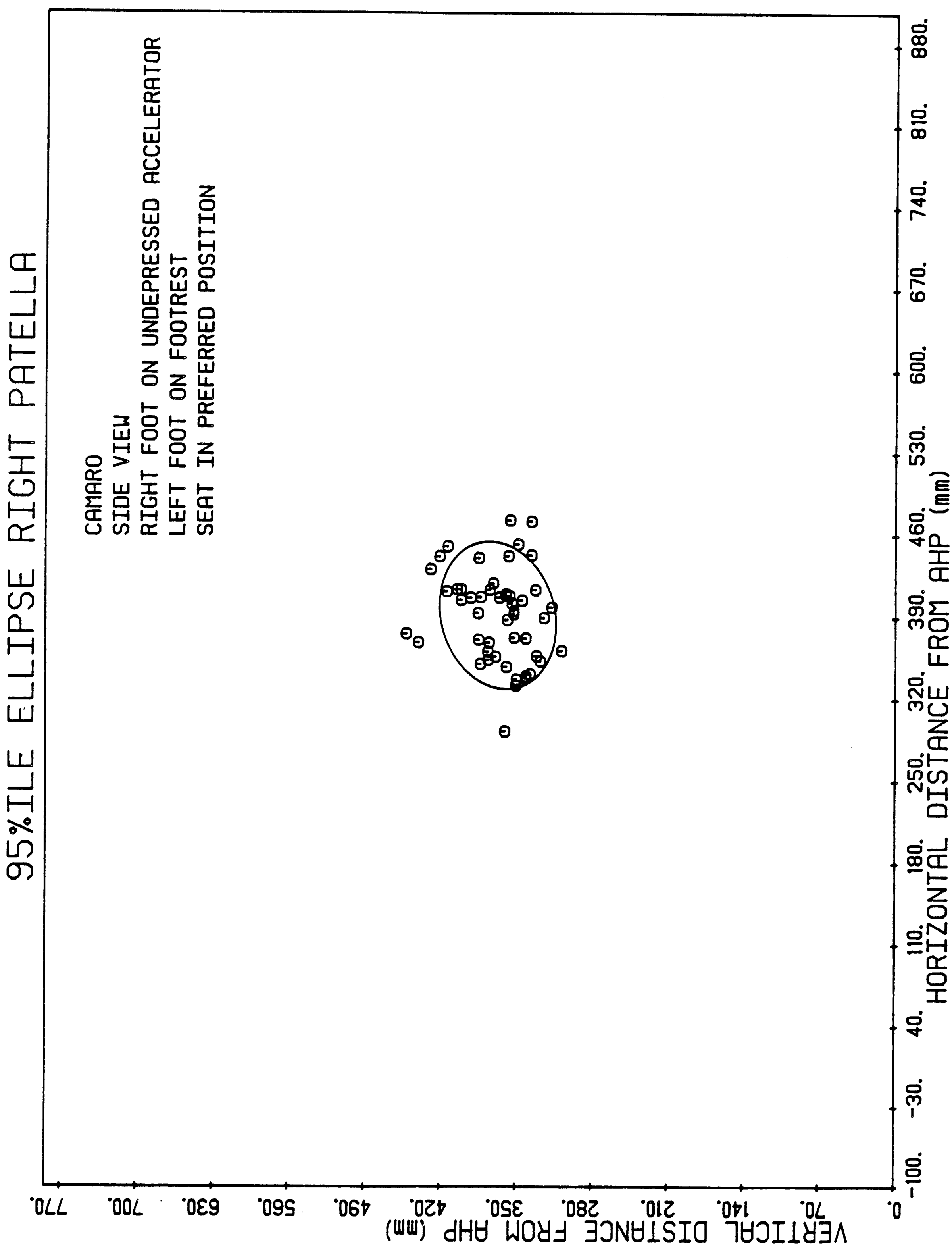

95%ILE ELLIPSE LEFT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.

95%ILE ELLIPSE FOR PATELLA

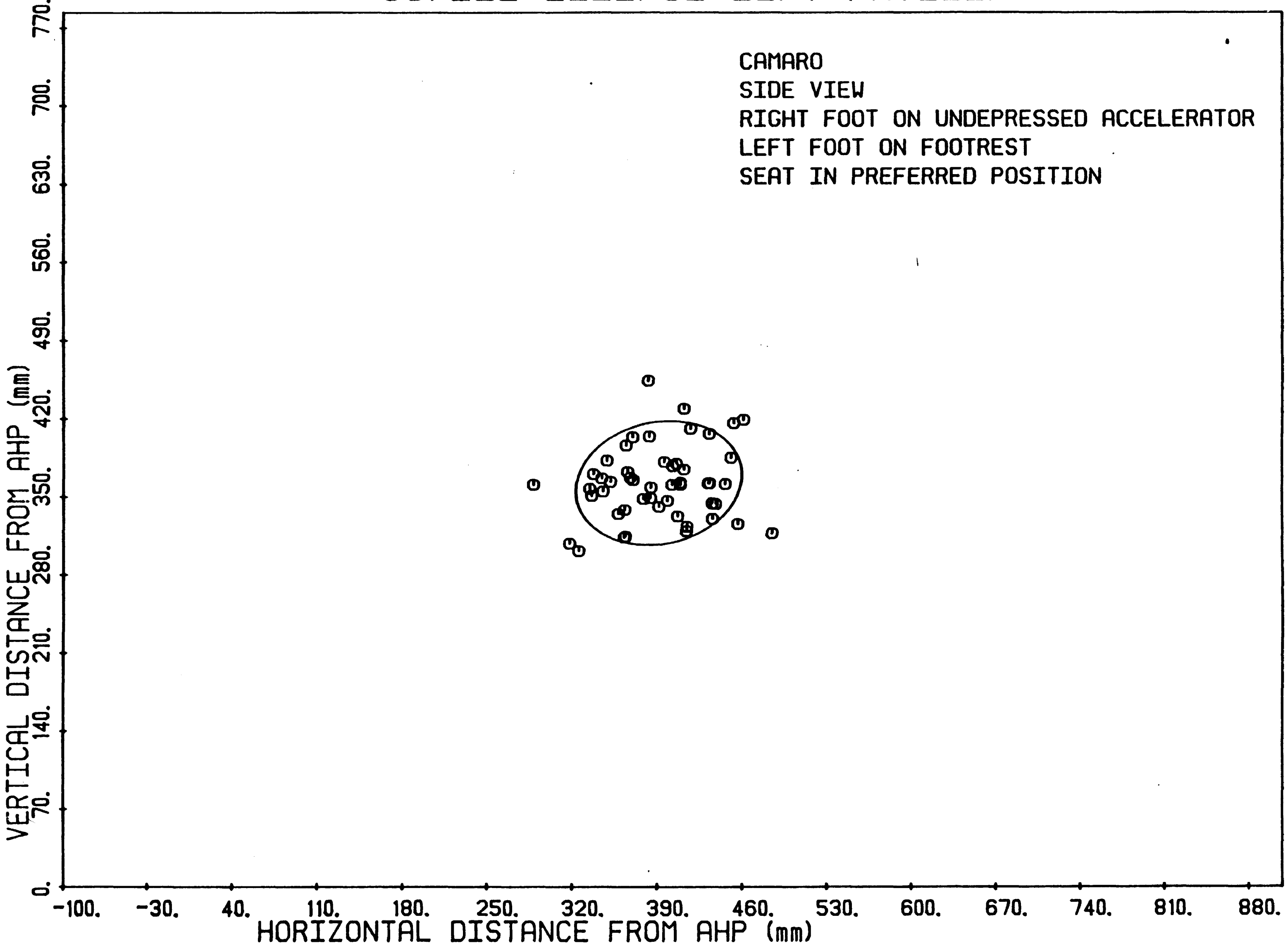


95%ILE ELLIPSE FOR PATELLA

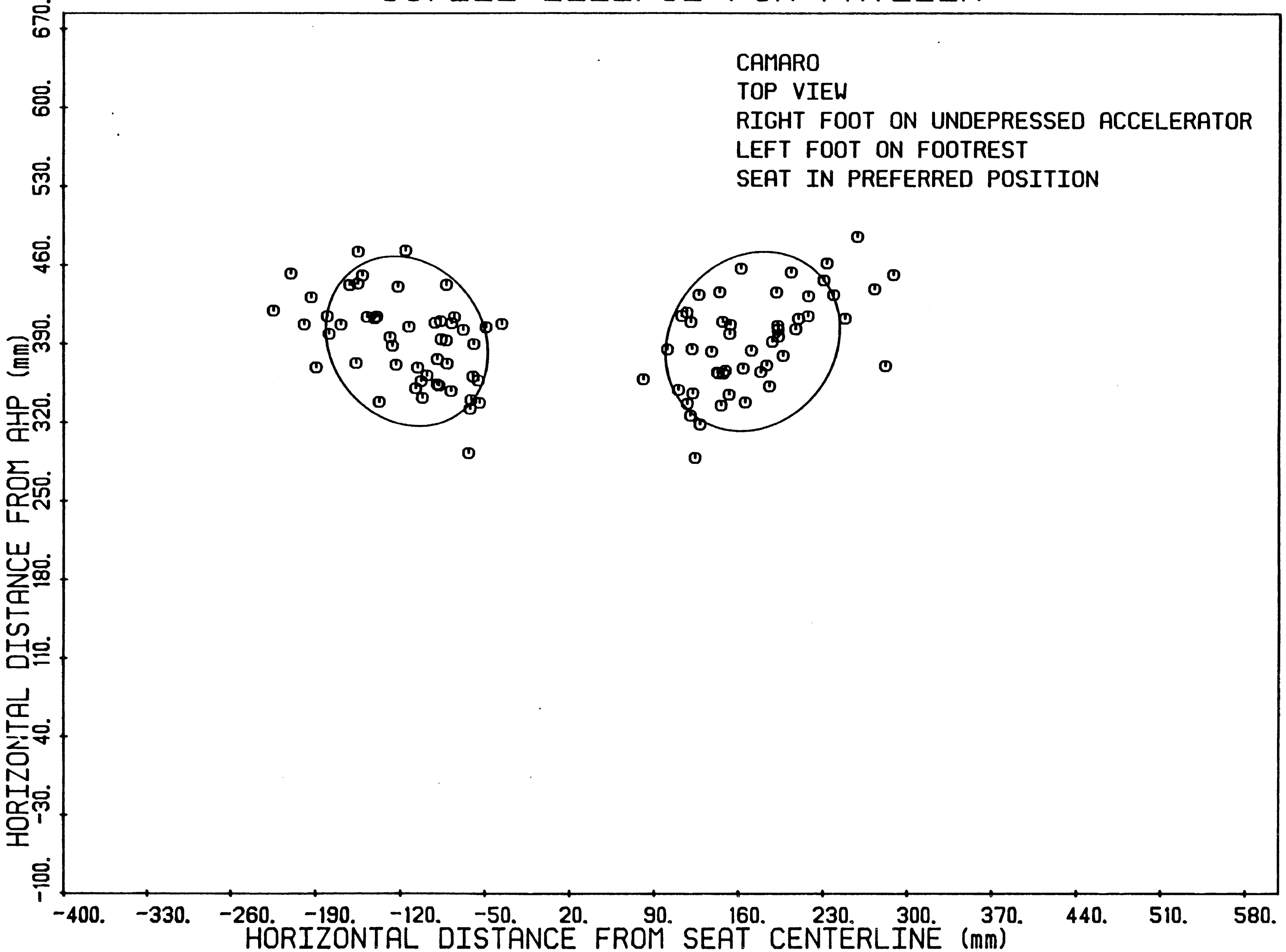



95%ILE ELLIPSE RIGHT PATELLA
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
VERTICAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.

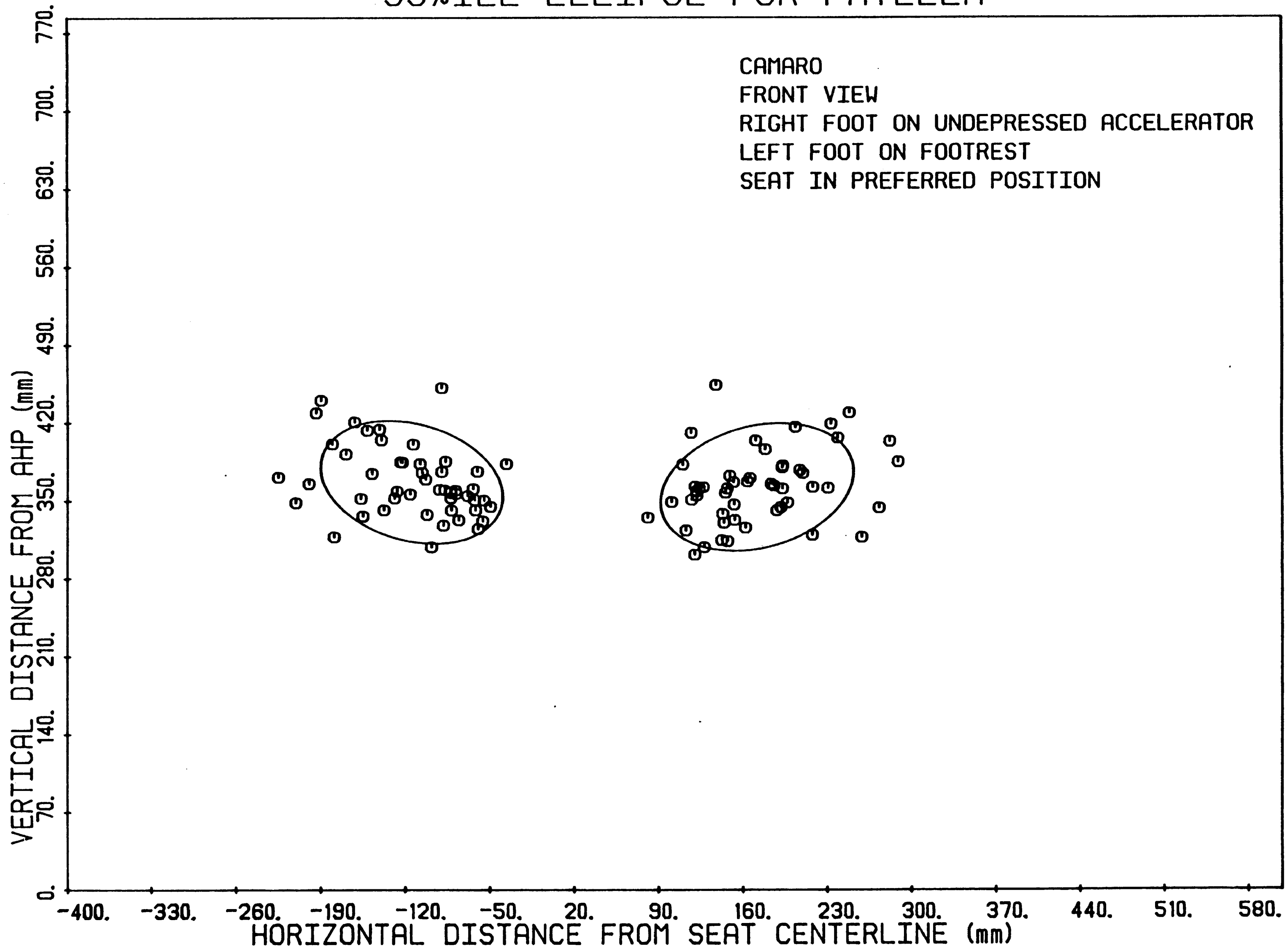
95%ILE ELLIPSE LEFT PATELLA

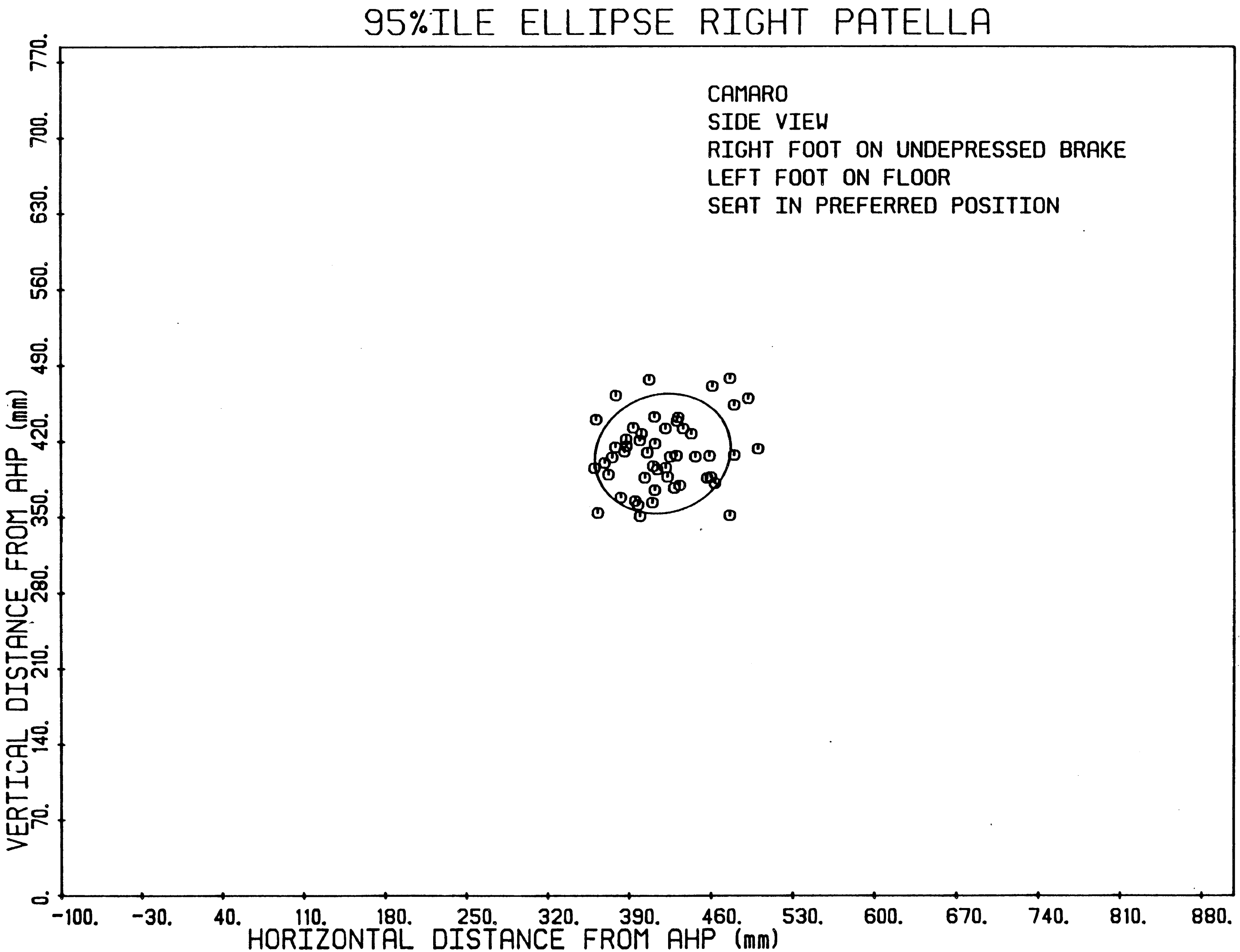


95%ILE ELLIPSE FOR PATELLA

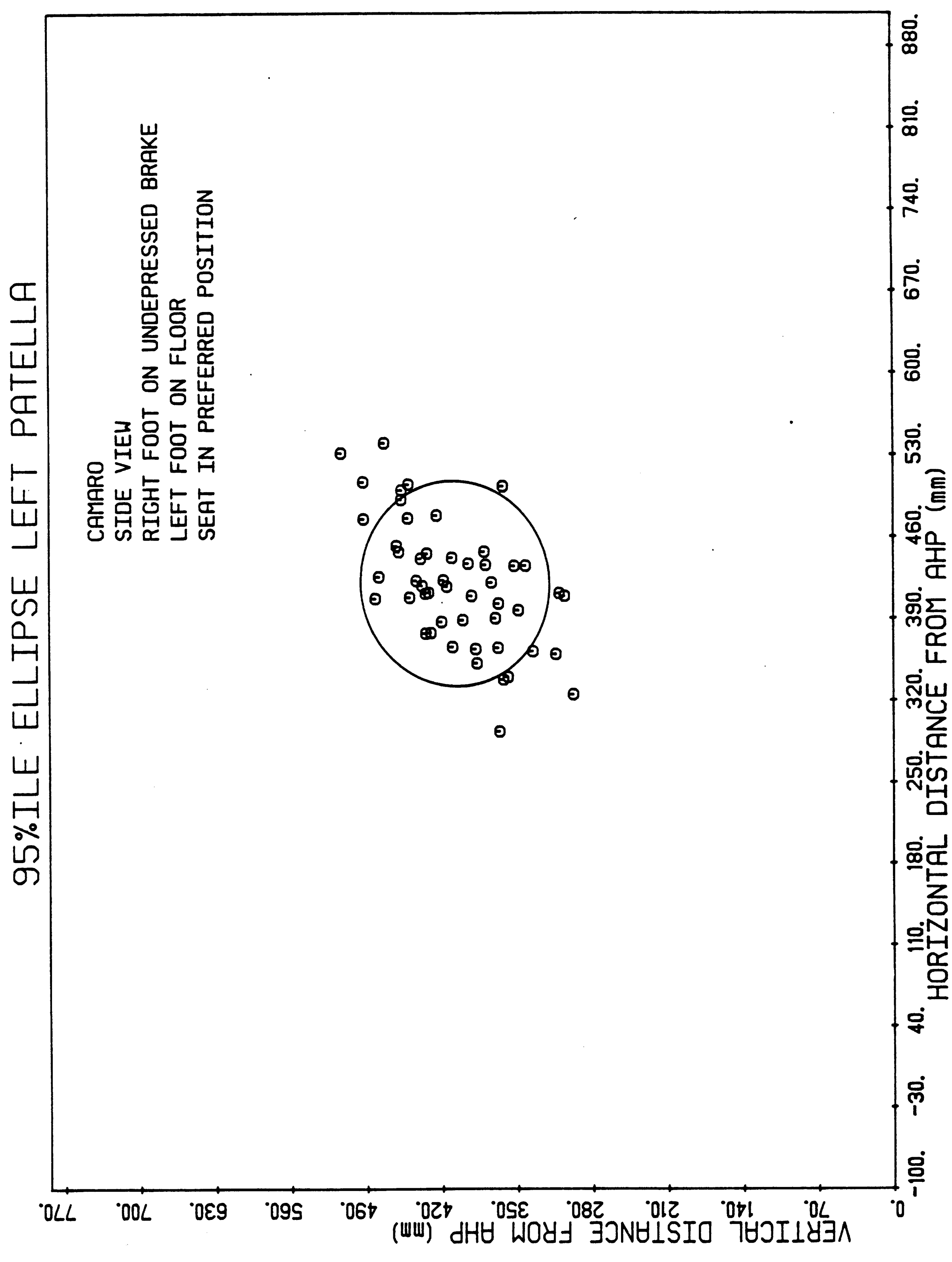


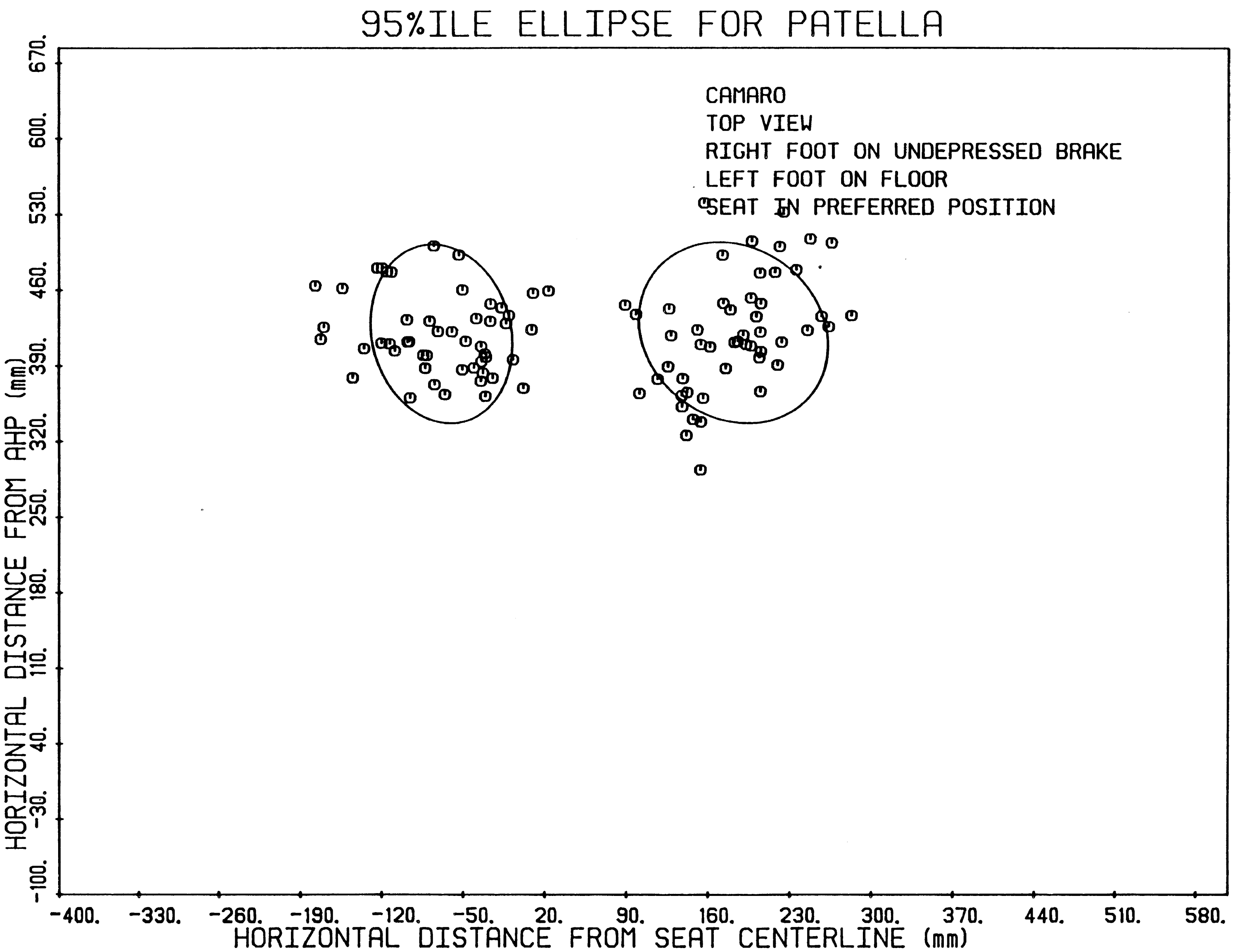
95%ILE ELLIPSE FOR PATELLA

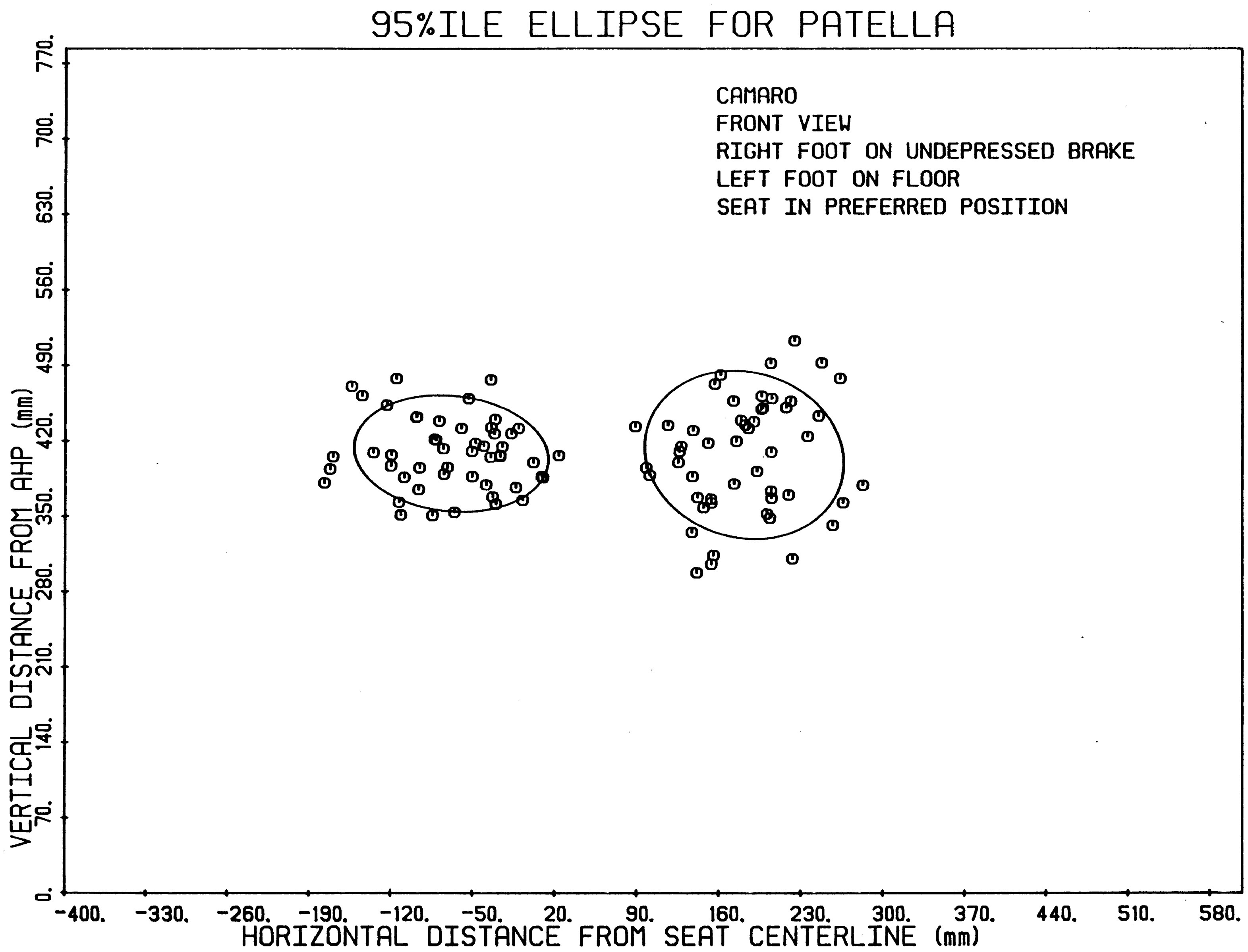




95%ILE ELLIPSE RIGHT PATELLA
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

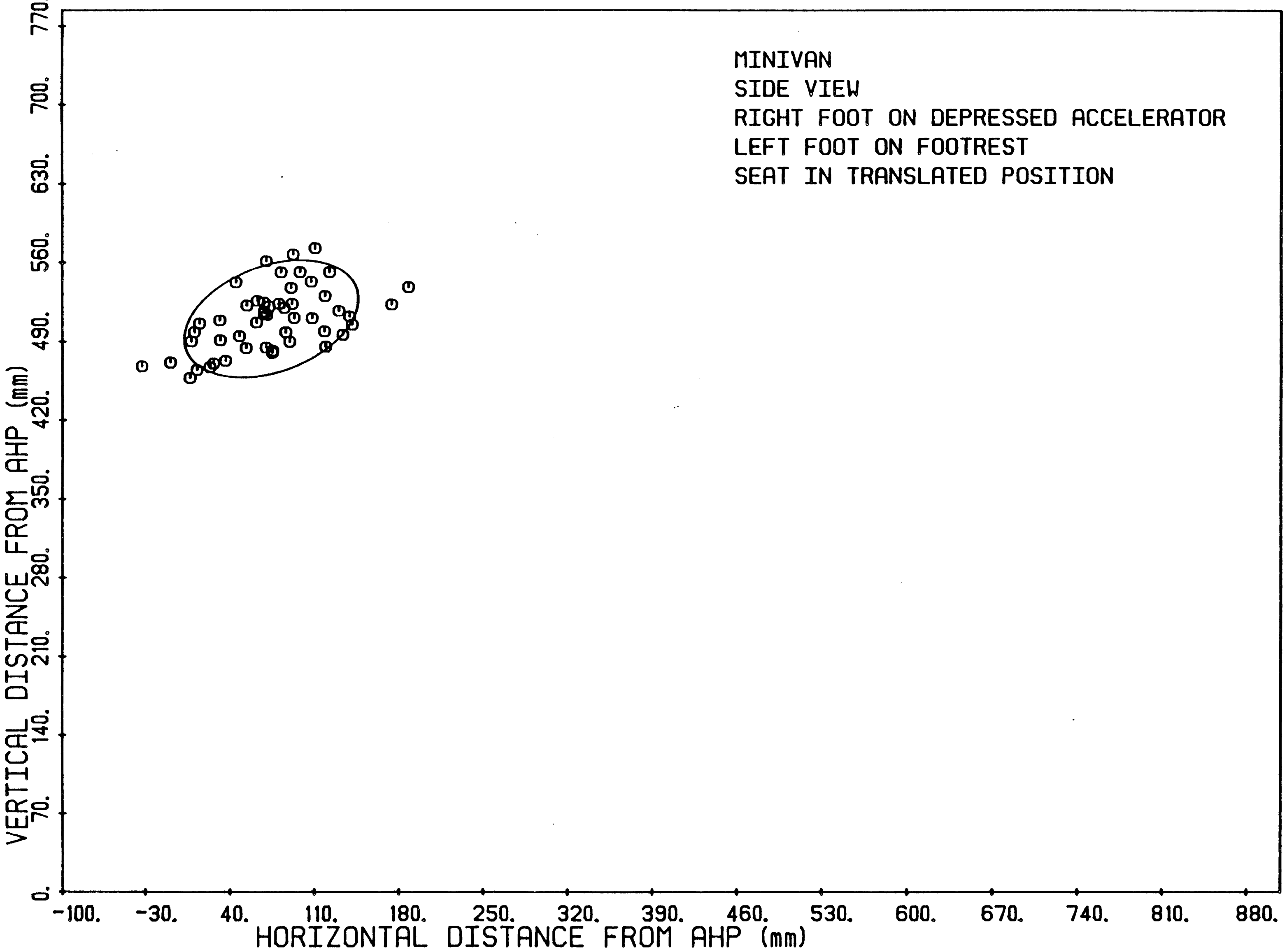

95%ILE ELLIPSE LEFT PATELLA
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.
HORIZONTAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
VERTICAL DISTANCE FROM AHP (mm)

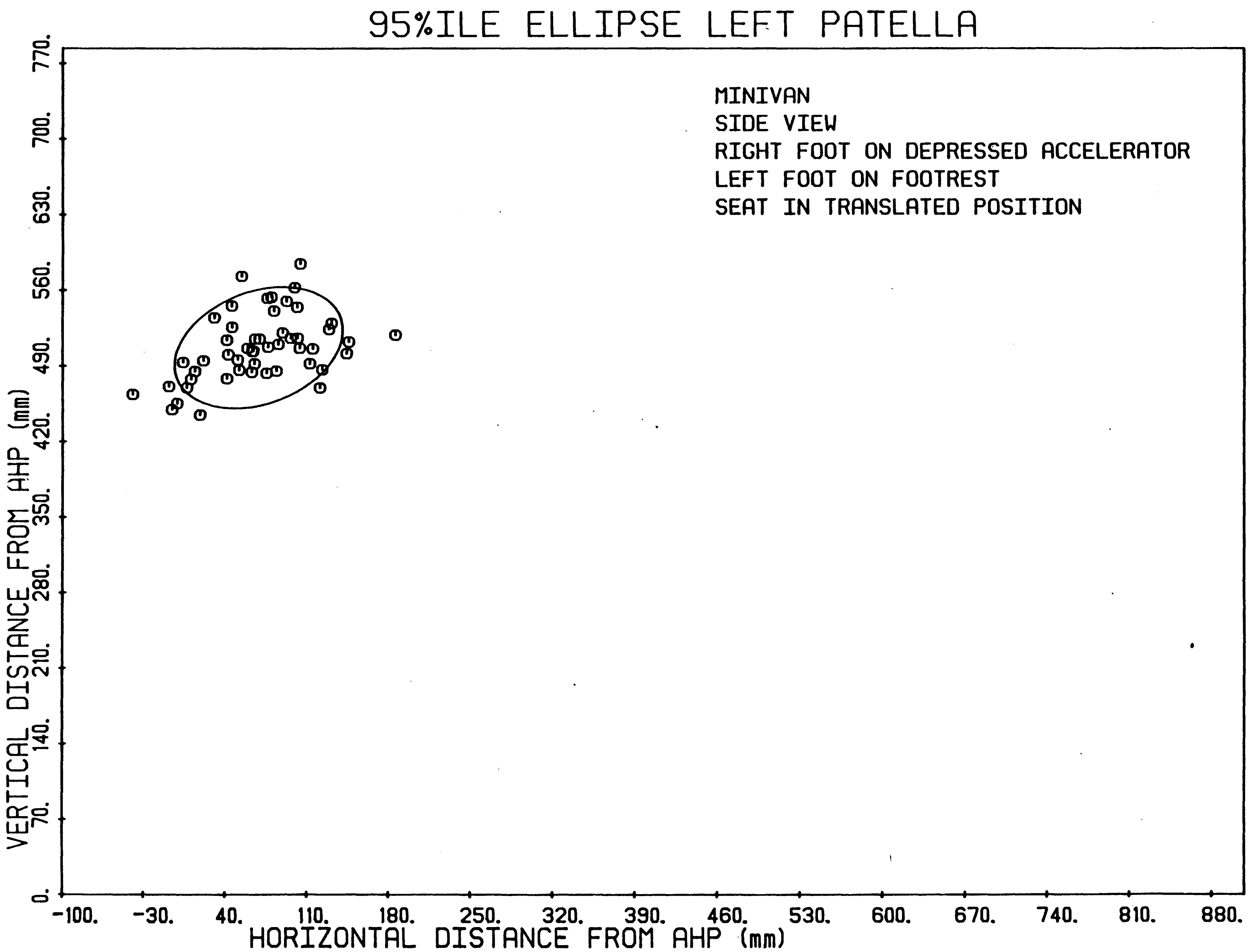

95%ILE ELLIPSE FOR PATELLA
CAMARO
TOP VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


95%ILE ELLIPSE FOR PATELLA
CAMARO
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.

TRANSLATED SEAT CONDITIONS

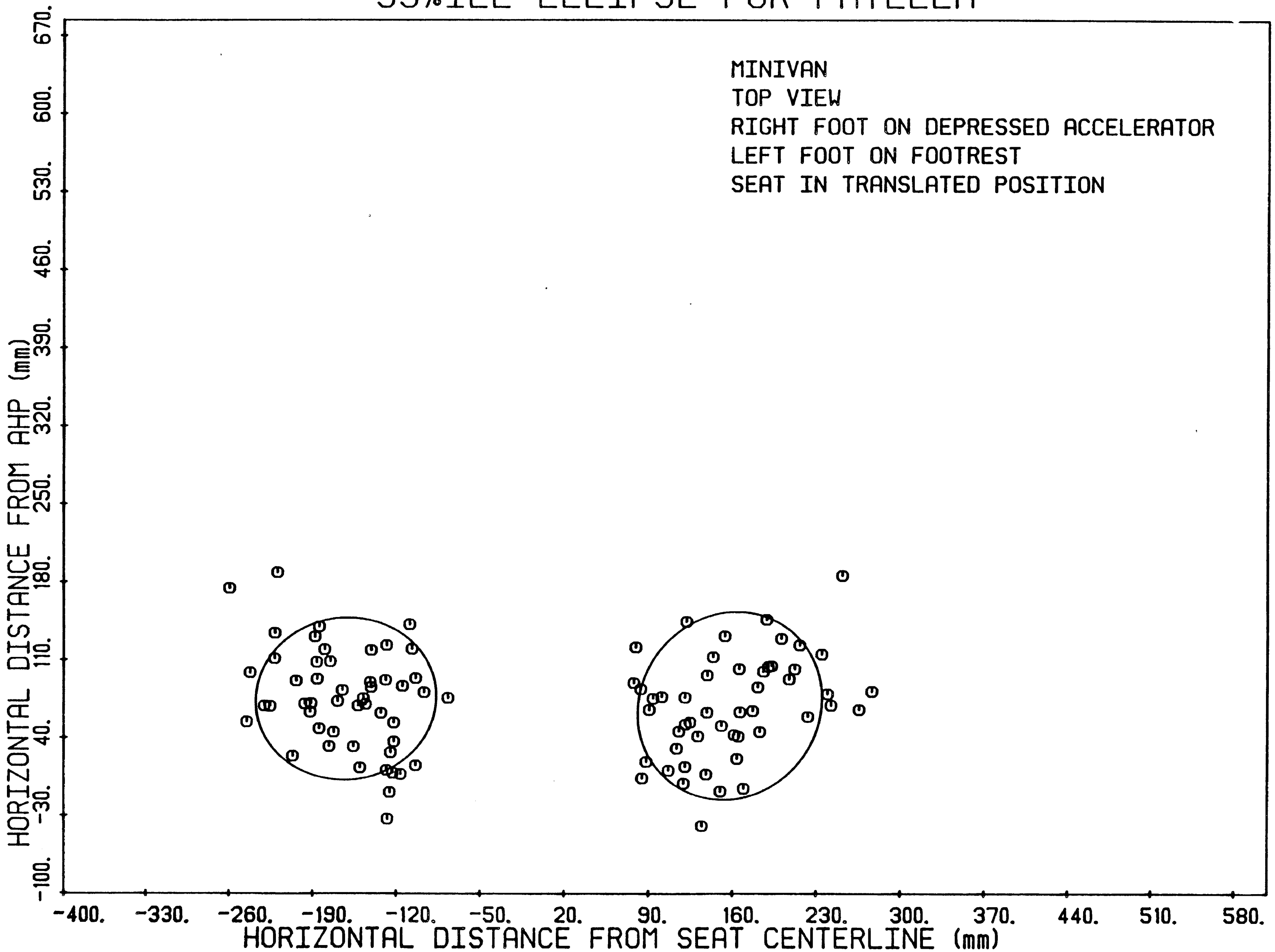
95%ILE ELLIPSE RIGHT PATELLA



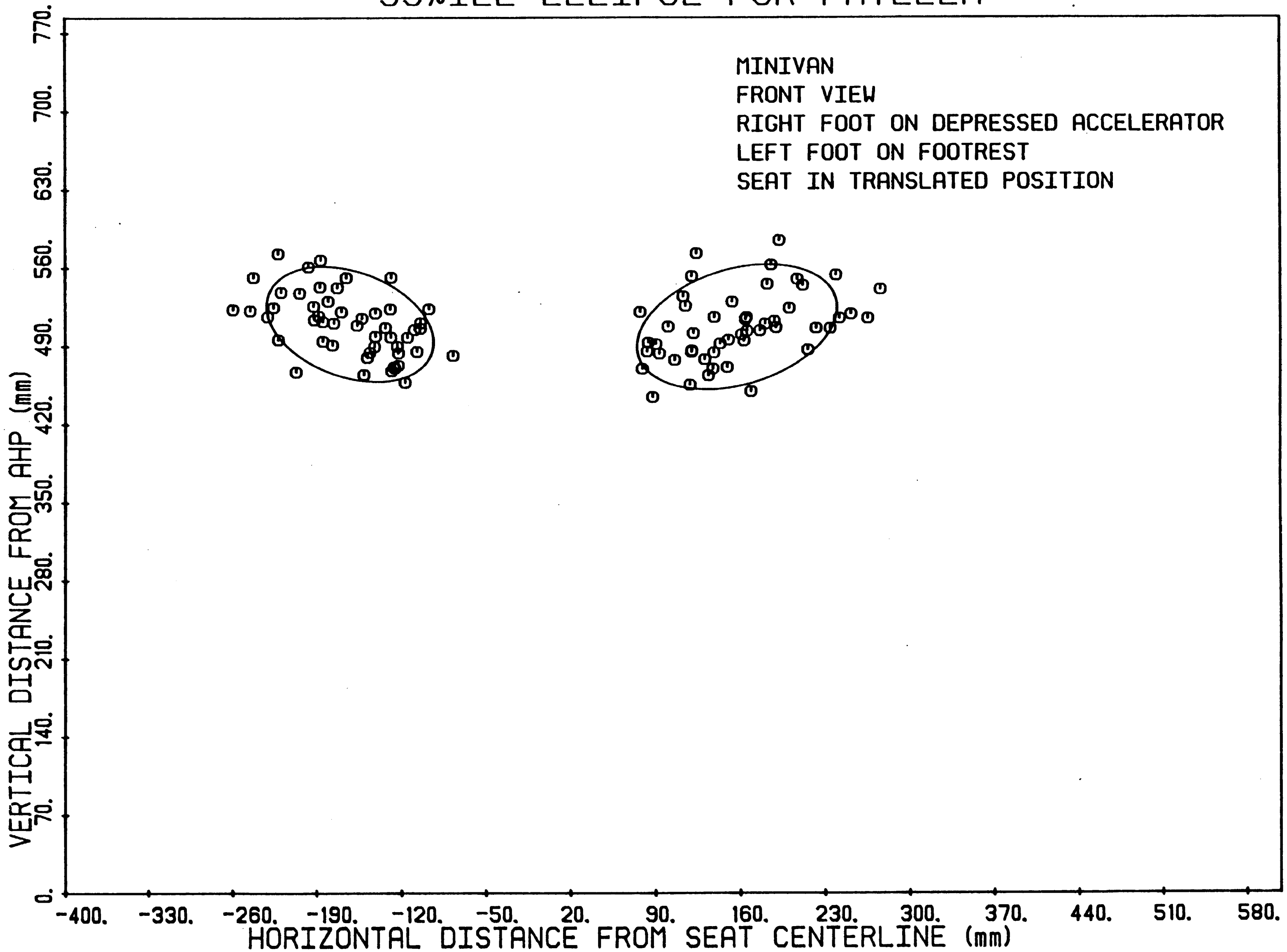


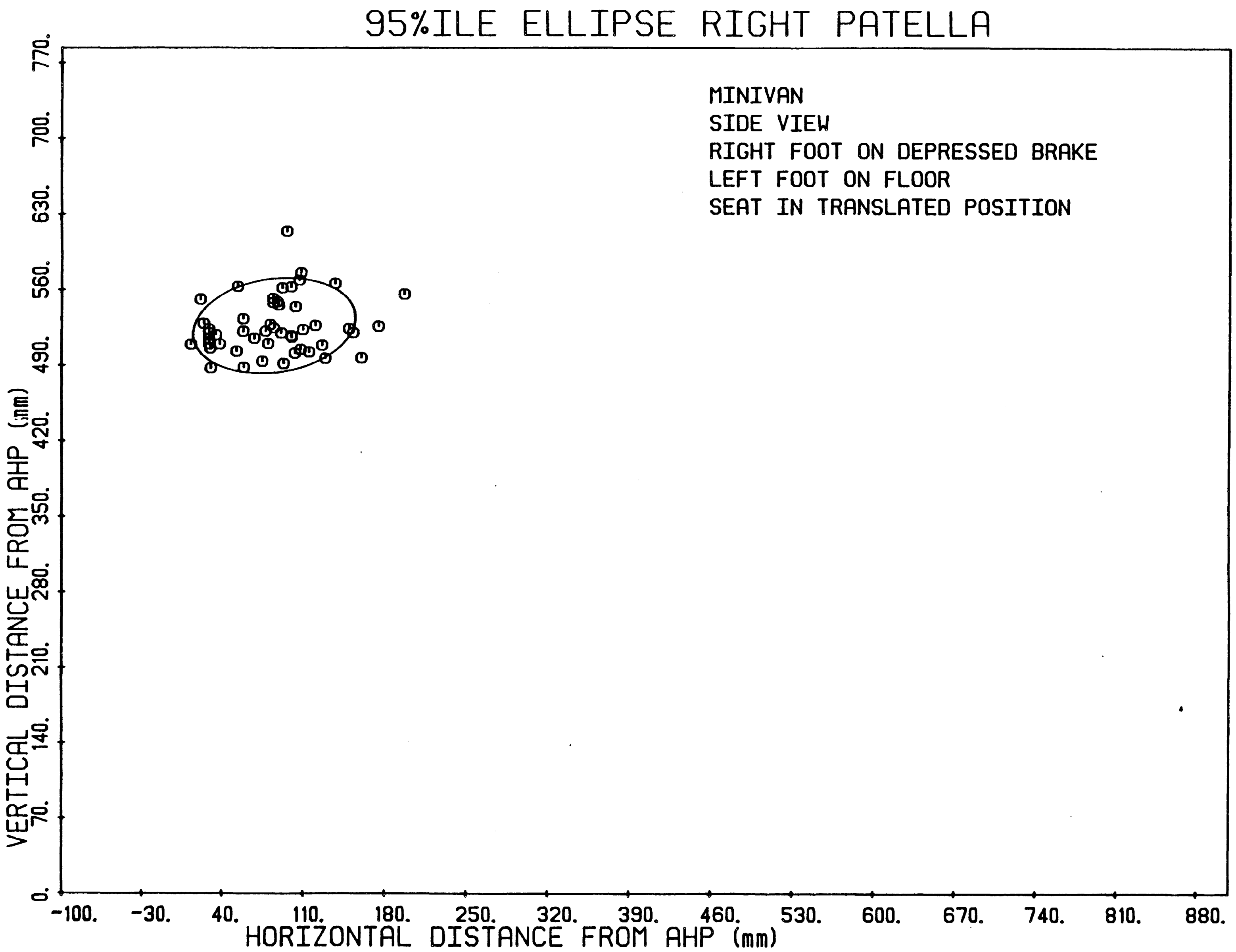
95%ILE ELLIPSE LEFT PATELLA
MINIVAN
SIDE VIEW
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.

95%ILE ELLIPSE FOR PATELLA

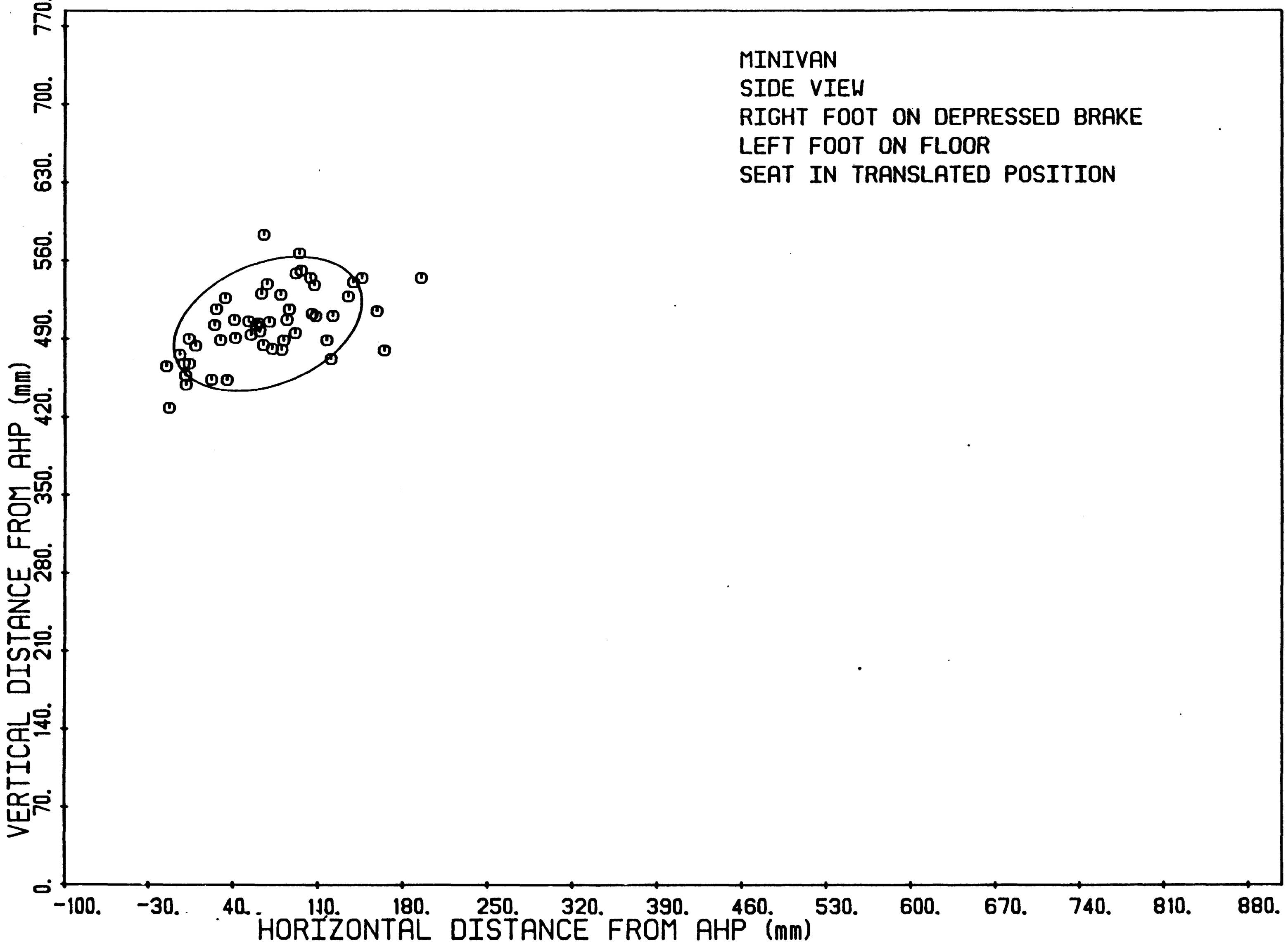


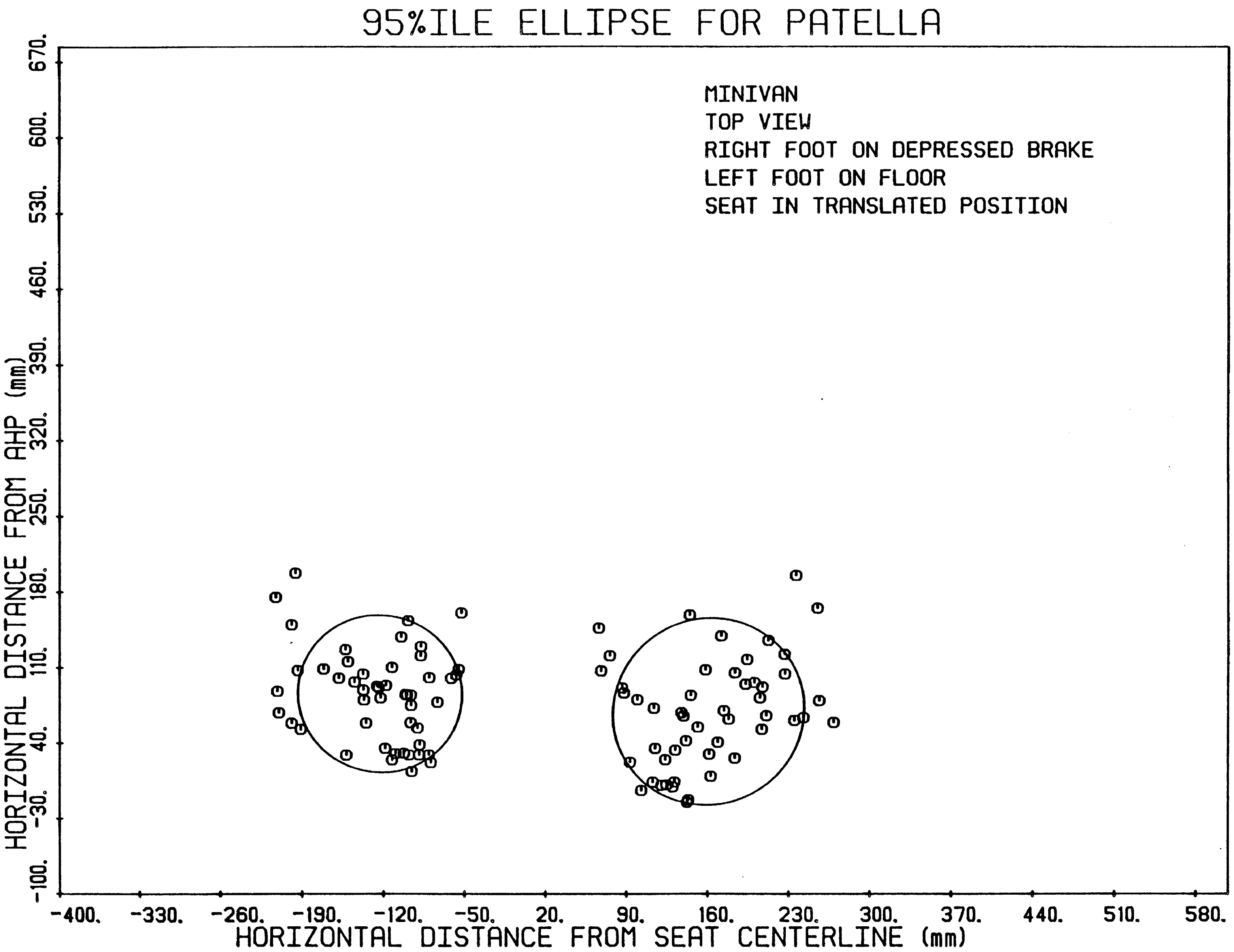
95%ILE ELLIPSE FOR PATELLA

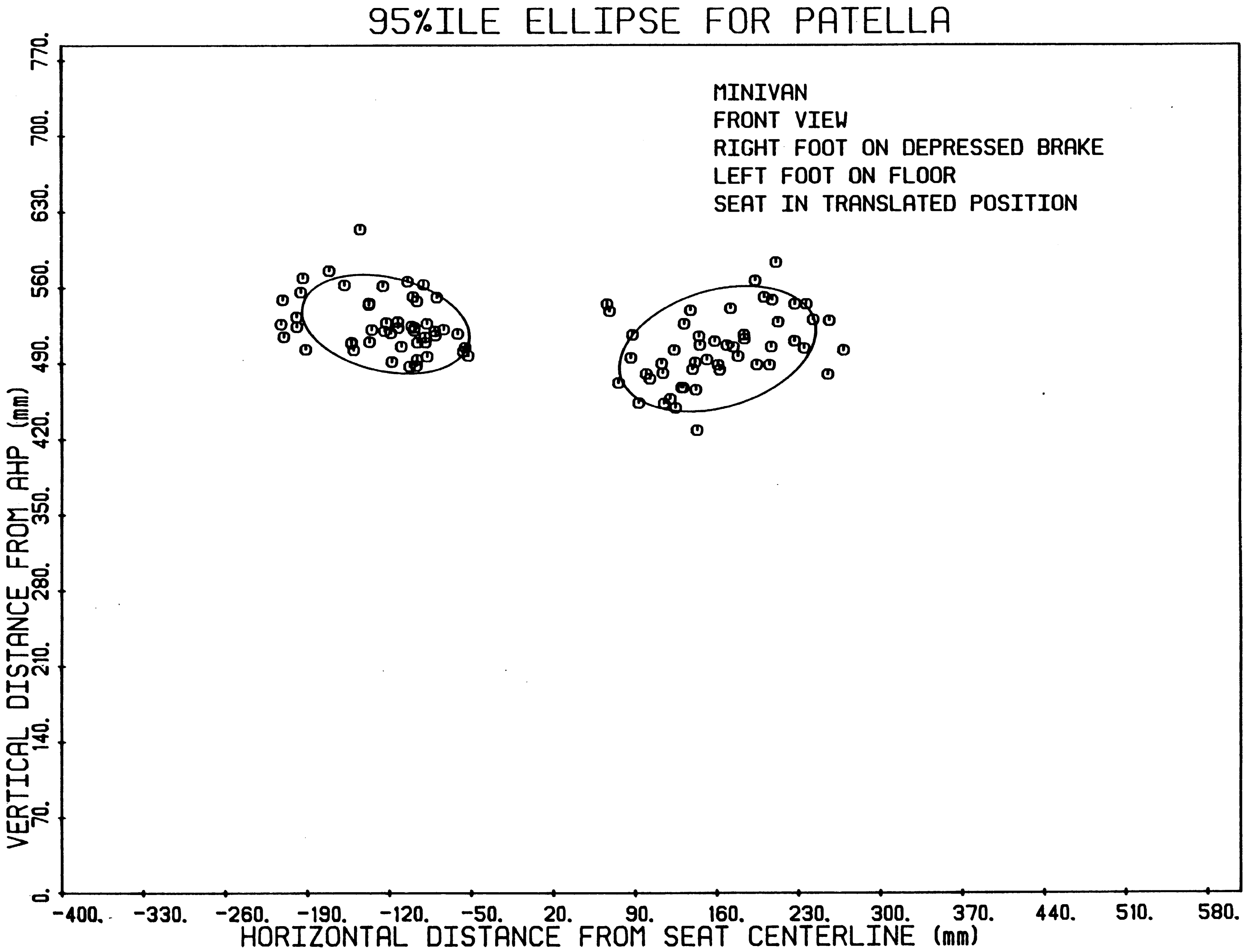



95%ILE ELLIPSE RIGHT PATELLA
MINIVAN
SIDE VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

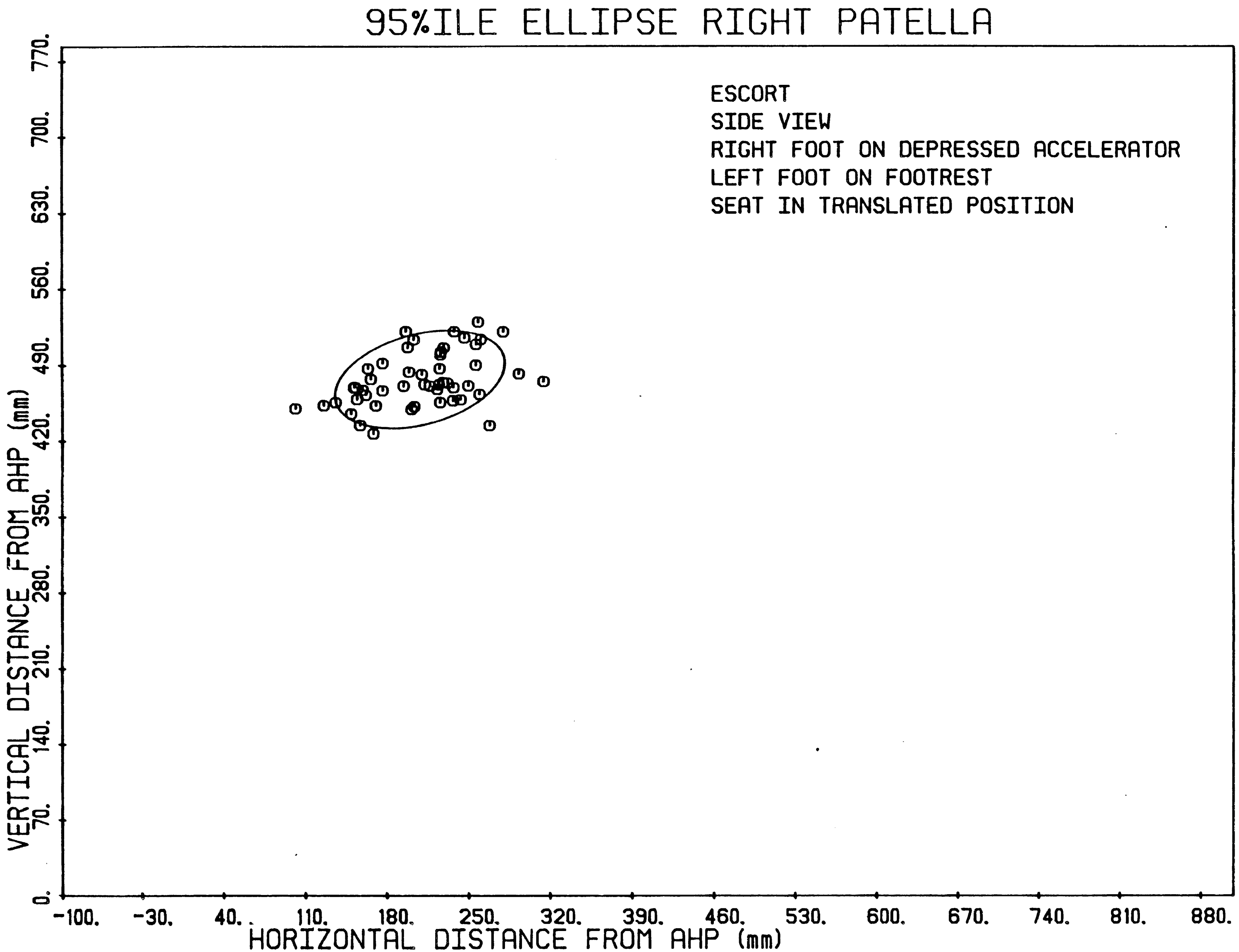
95%ILE ELLIPSE LEFT PATELLA



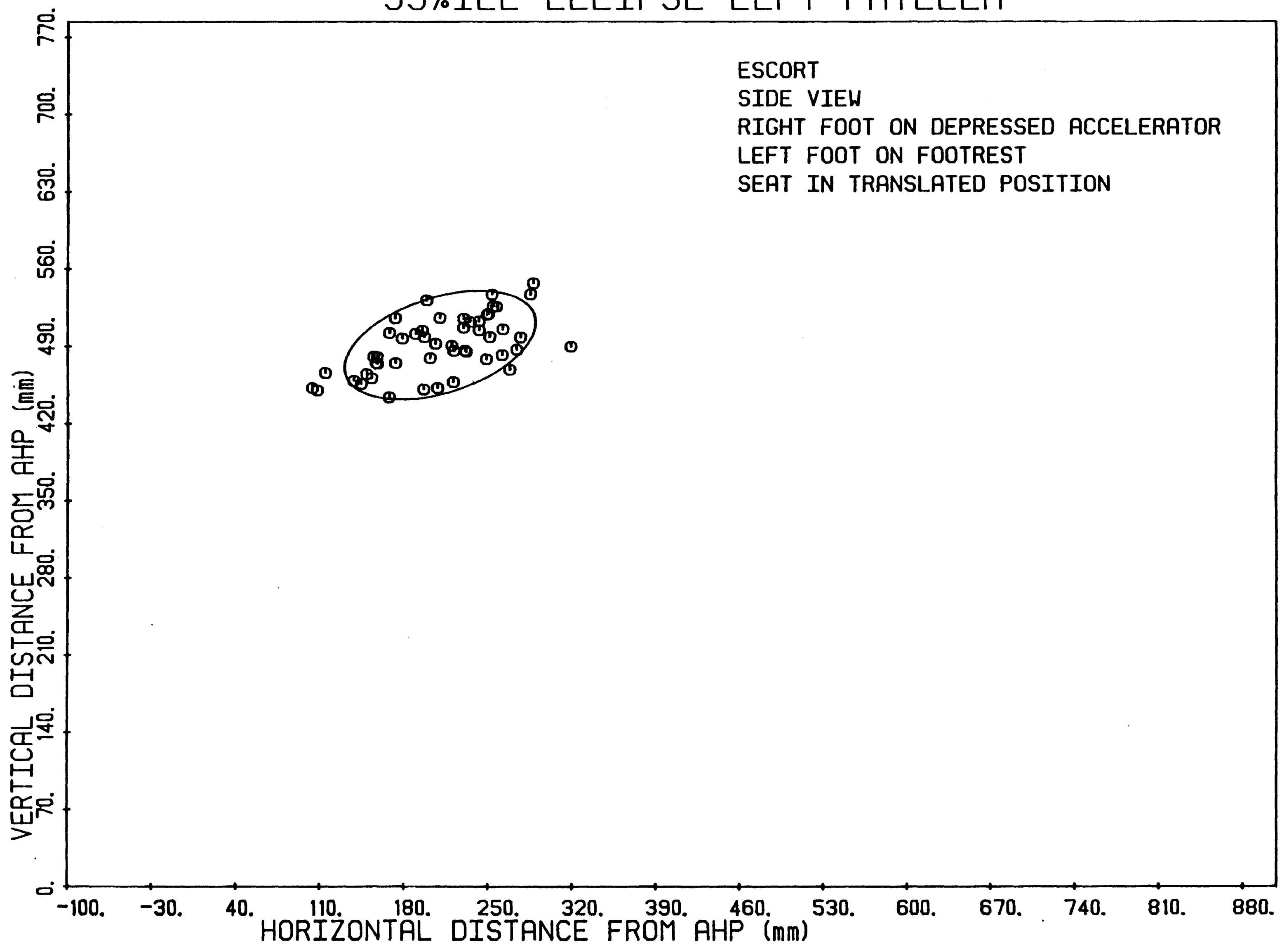

95%ILE ELLIPSE FOR PATELLA
MINIVAN
TOP VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.

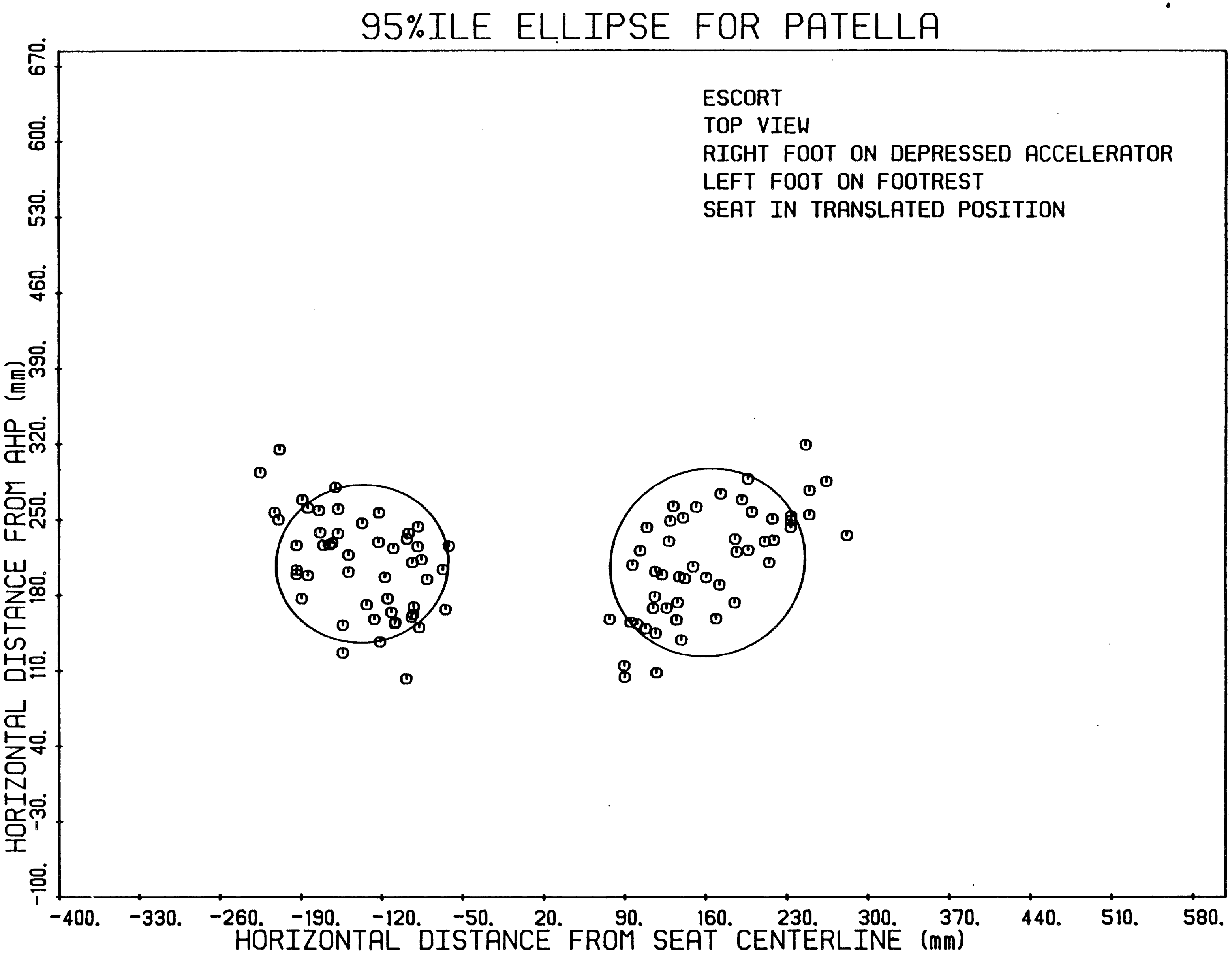


95%ILE ELLIPSE FOR PATELLA
MINIVAN
FRONT VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.

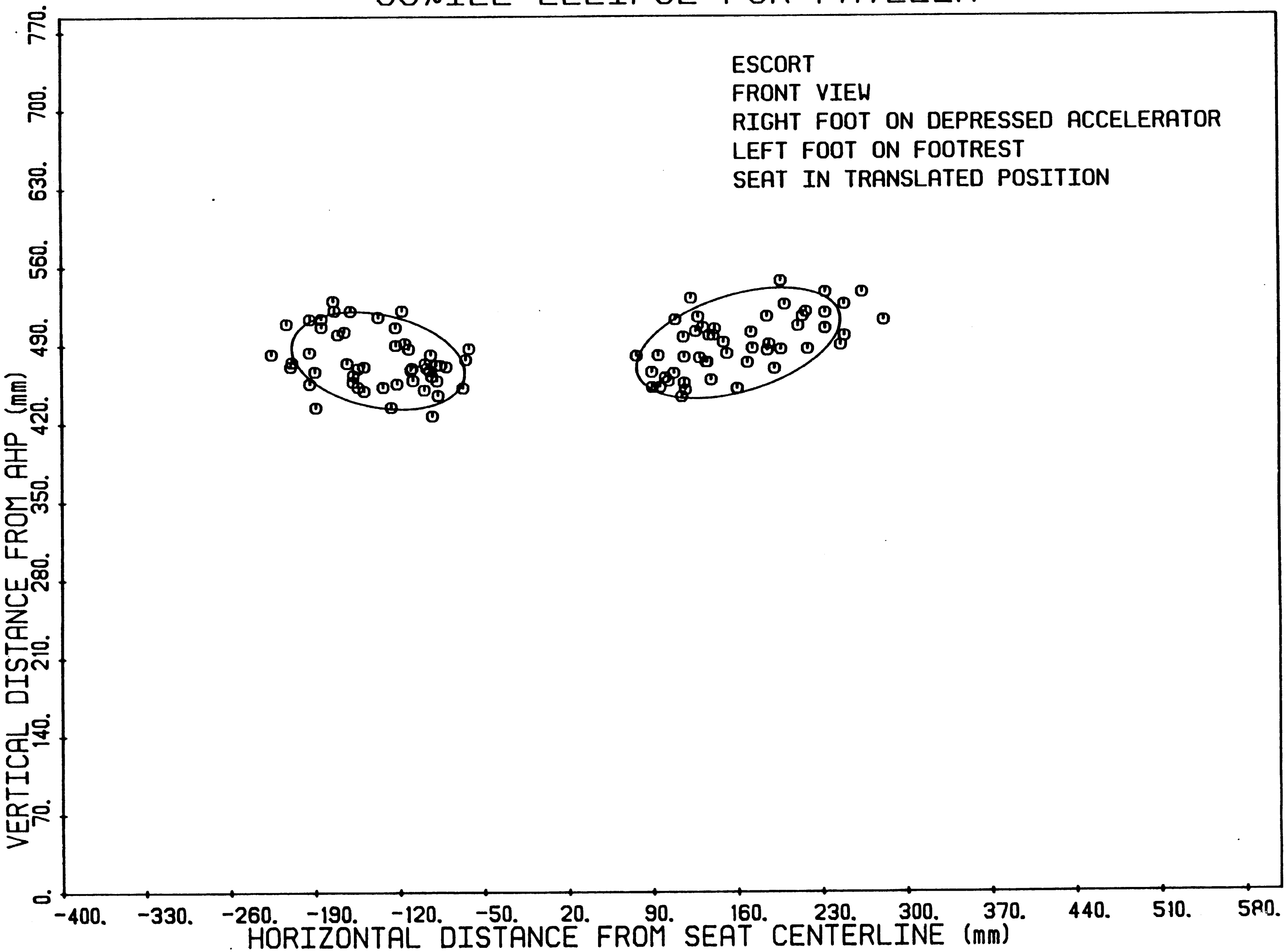

95%ILE ELLIPSE RIGHT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)

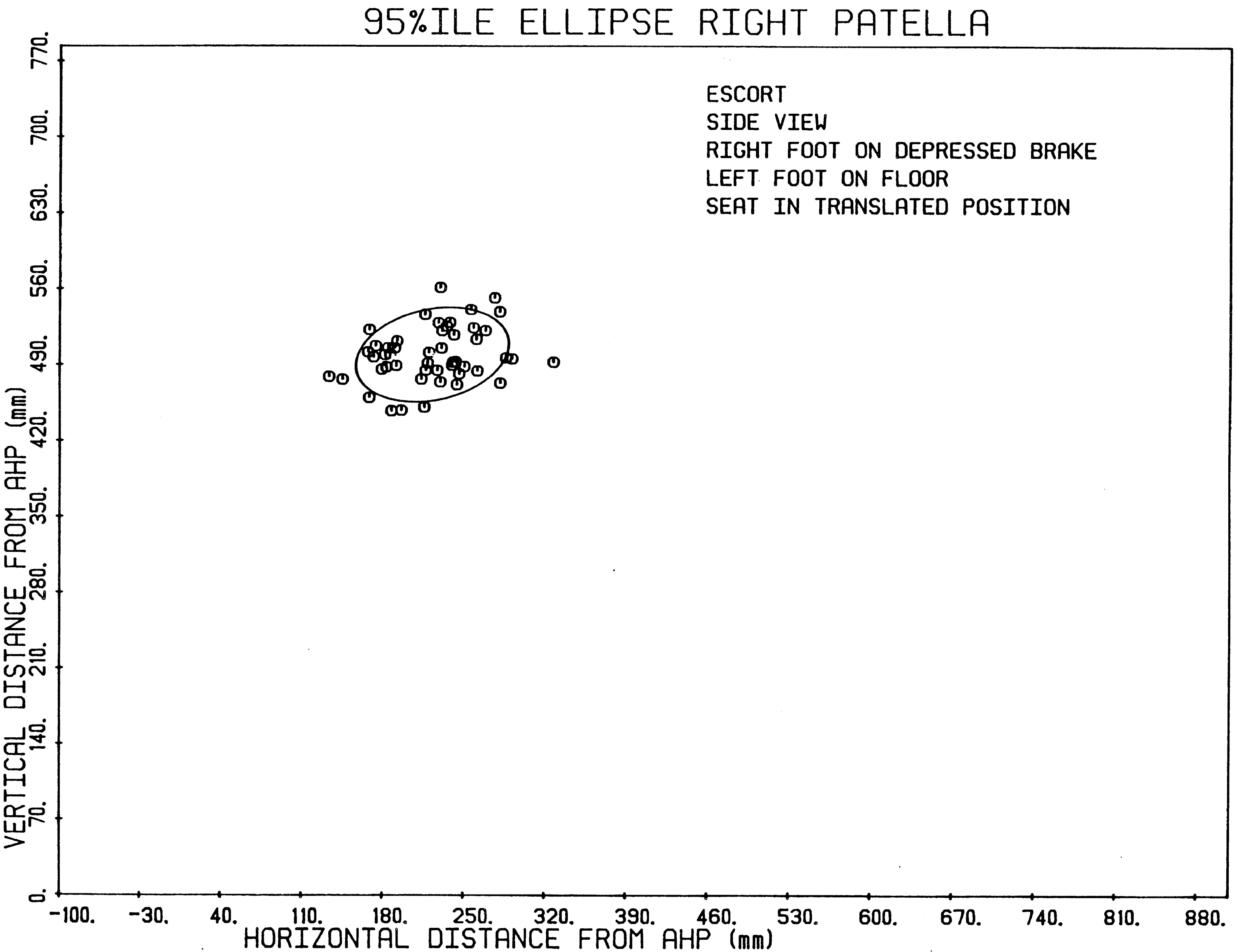
95%ILE ELLIPSE LEFT PATELLA

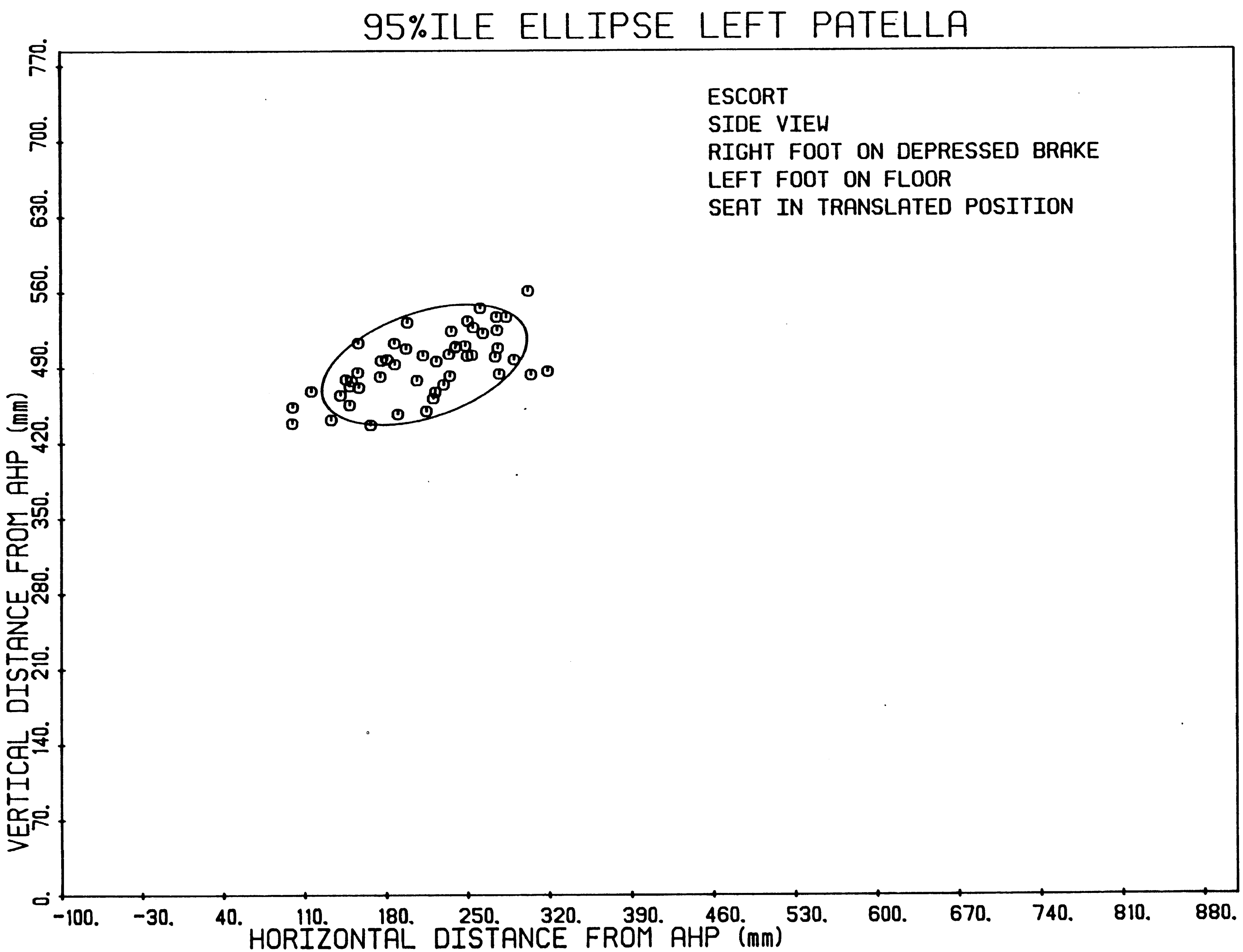


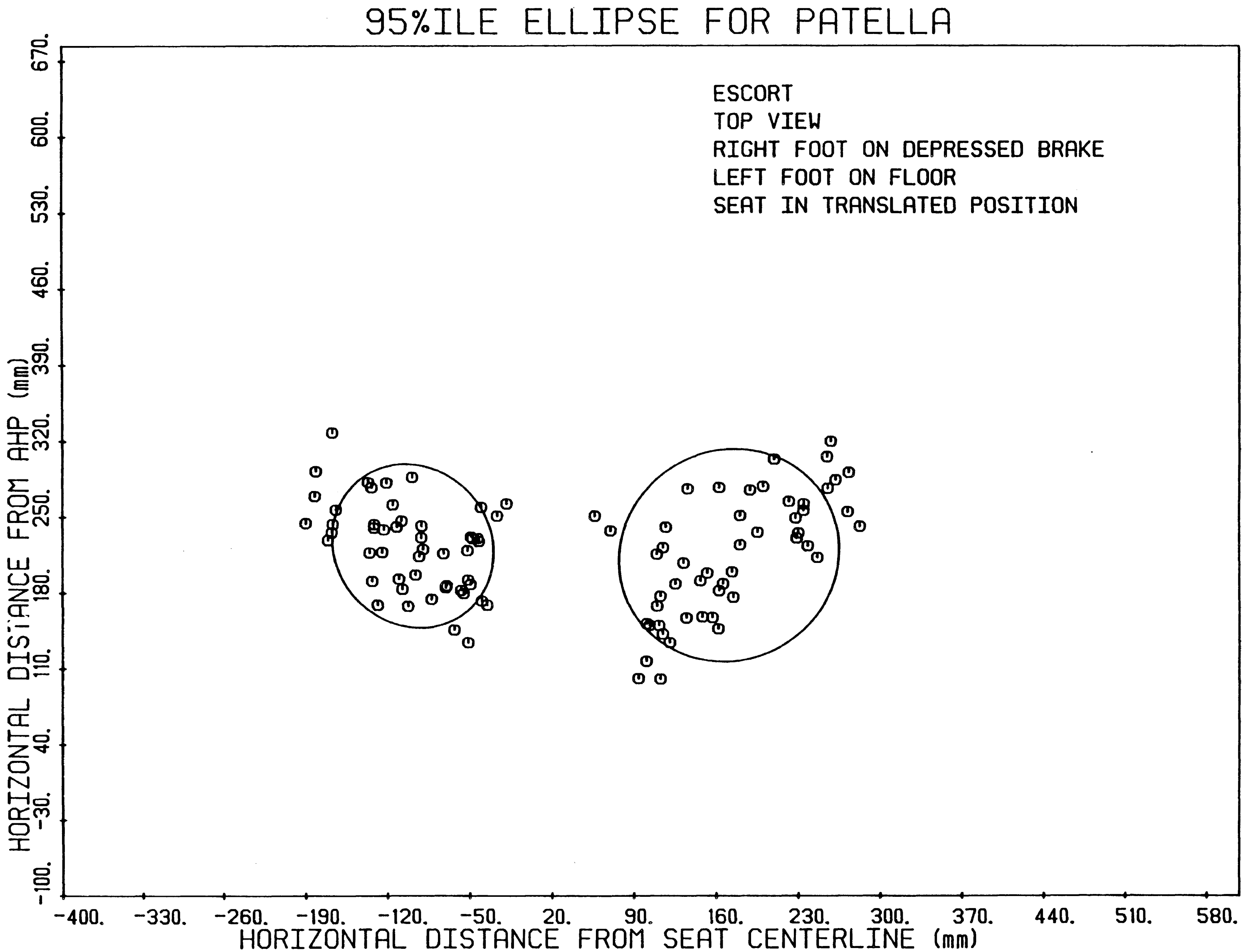

95%ILE ELLIPSE FOR PATELLA
ESCORT
TOP VIEW
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN TRANSLATED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.

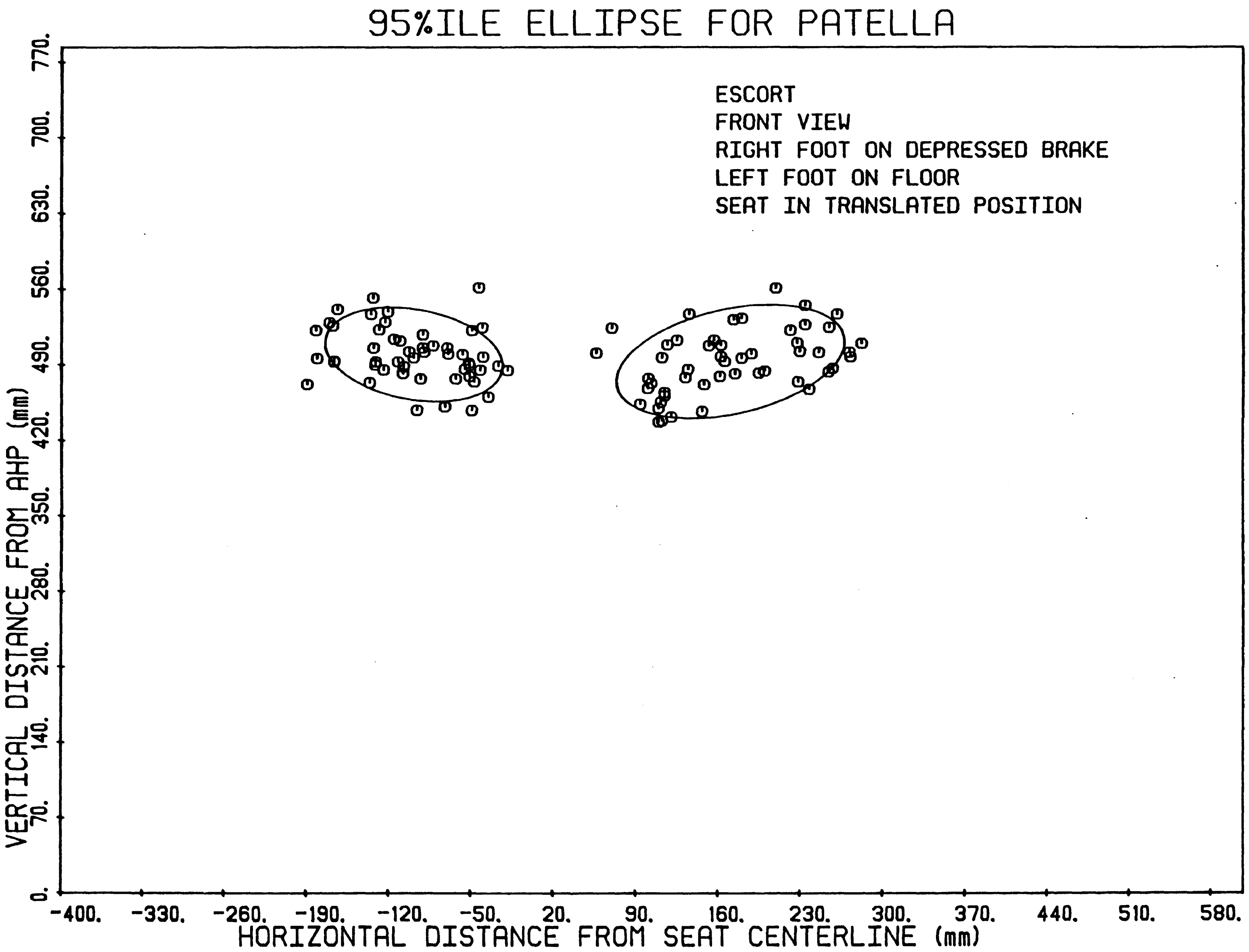
95%ILE ELLIPSE FOR PATELLA



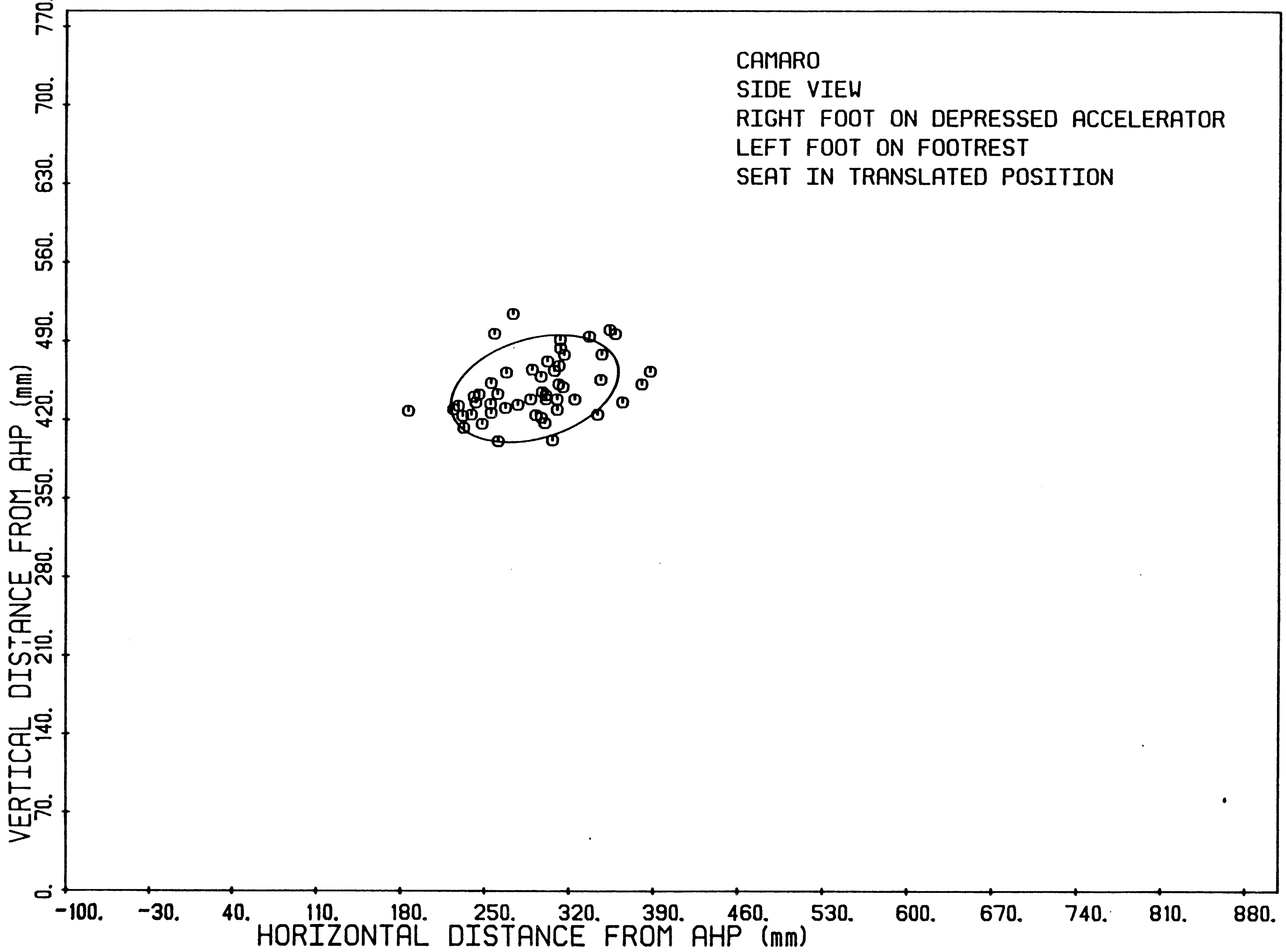

95%ILE ELLIPSE RIGHT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.
HORIZONTAL DISTANCE FROM AHP (mm)


95%ILE ELLIPSE LEFT PATELLA
ESCORT
SIDE VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0. 70. 140. 210. 280. 350. 420. 490. 560. 630. 700. 770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670. 740. 810. 880.

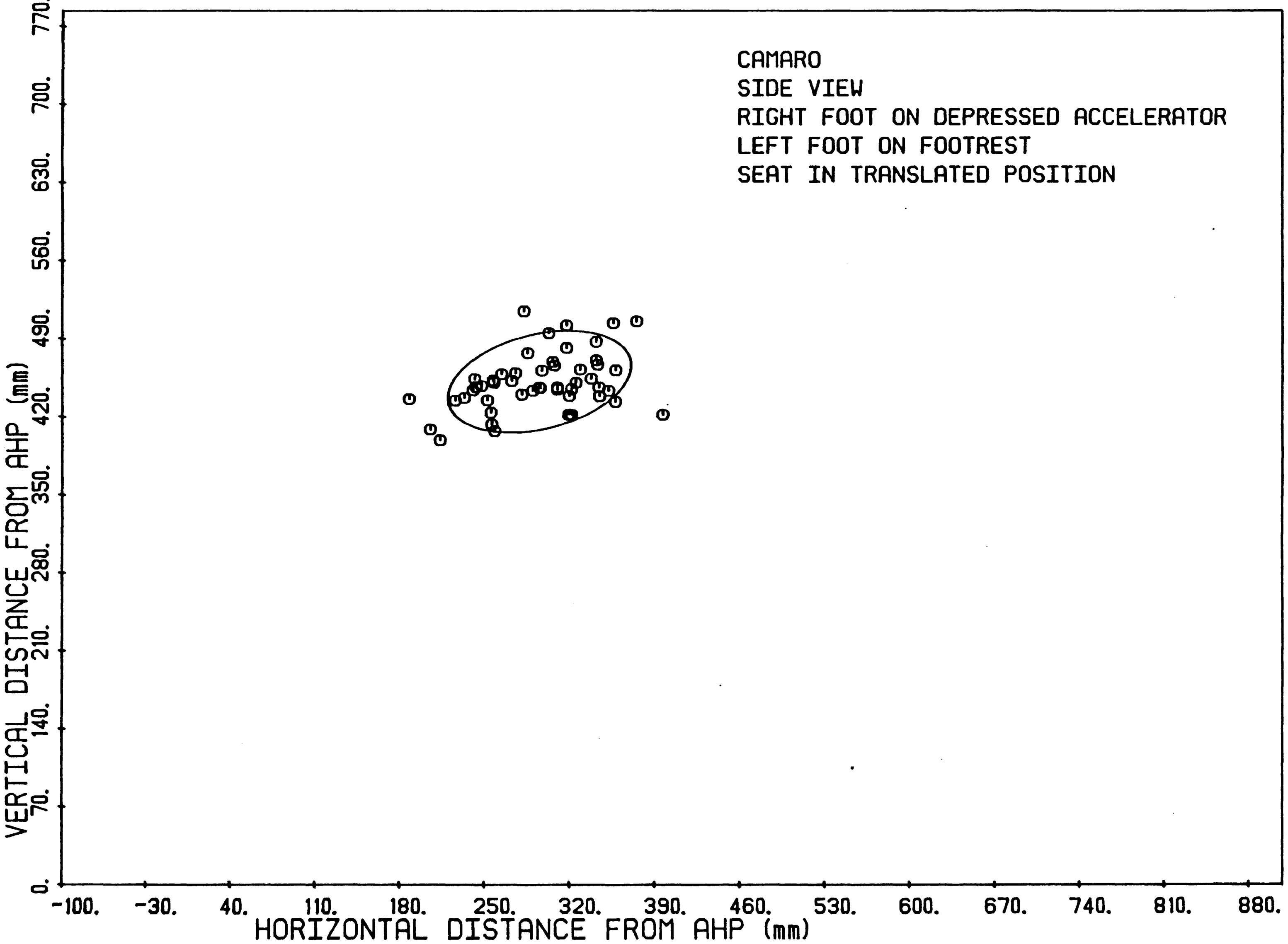

95%ILE ELLIPSE FOR PATELLA
ESCORT
TOP VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.

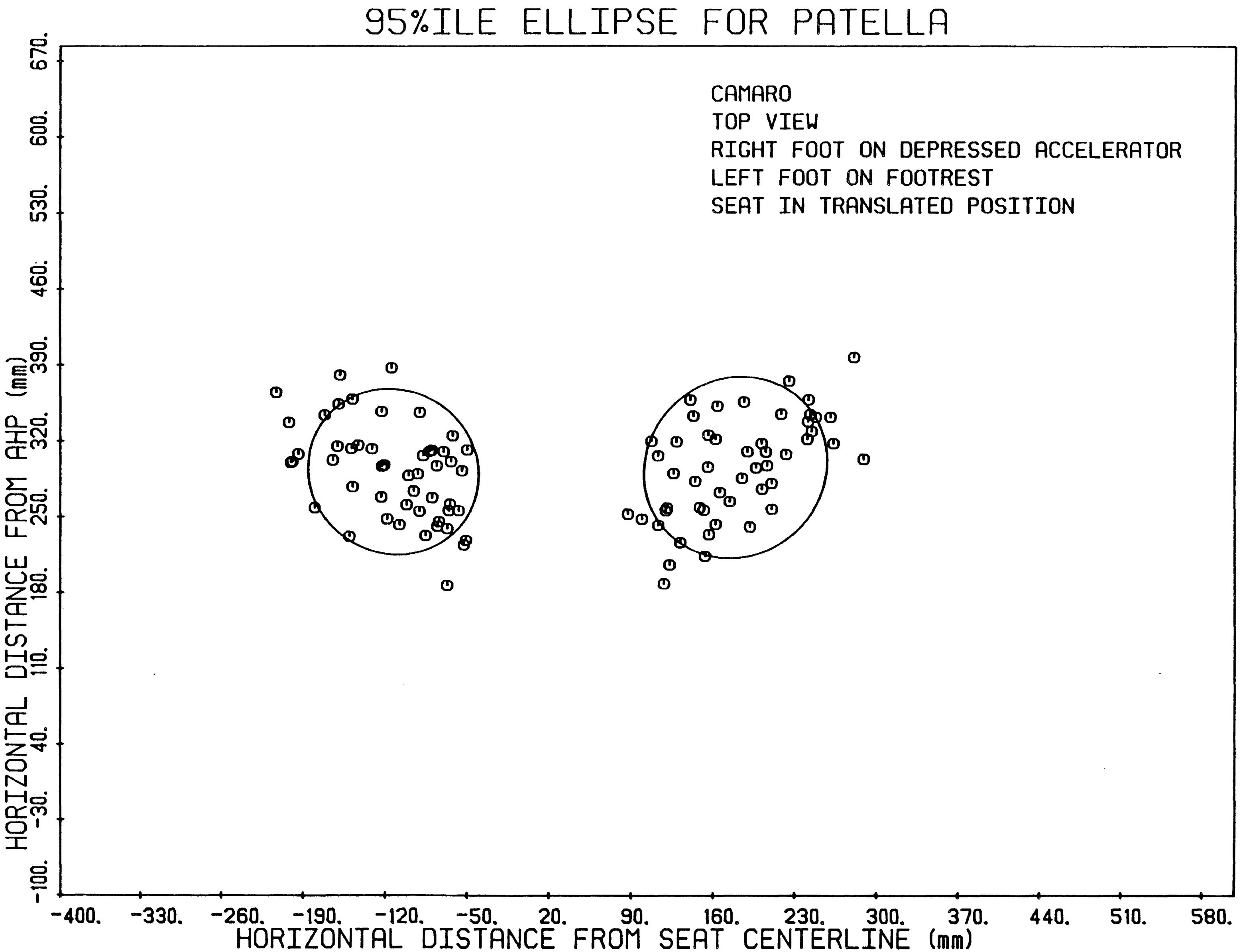

95%ILE ELLIPSE FOR PATELLA
ESCORT
FRONT VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.

95%ILE ELLIPSE RIGHT PATELLA

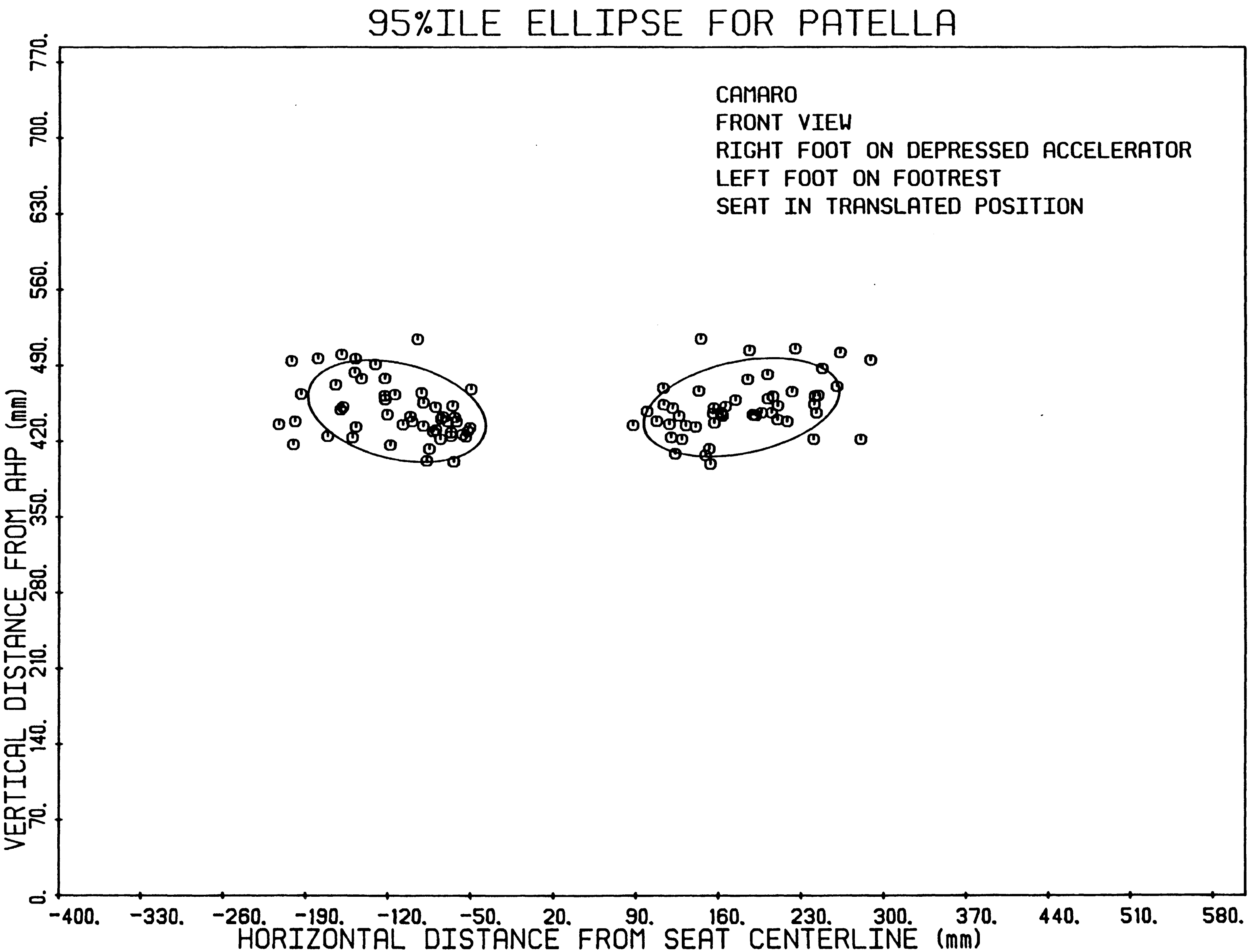


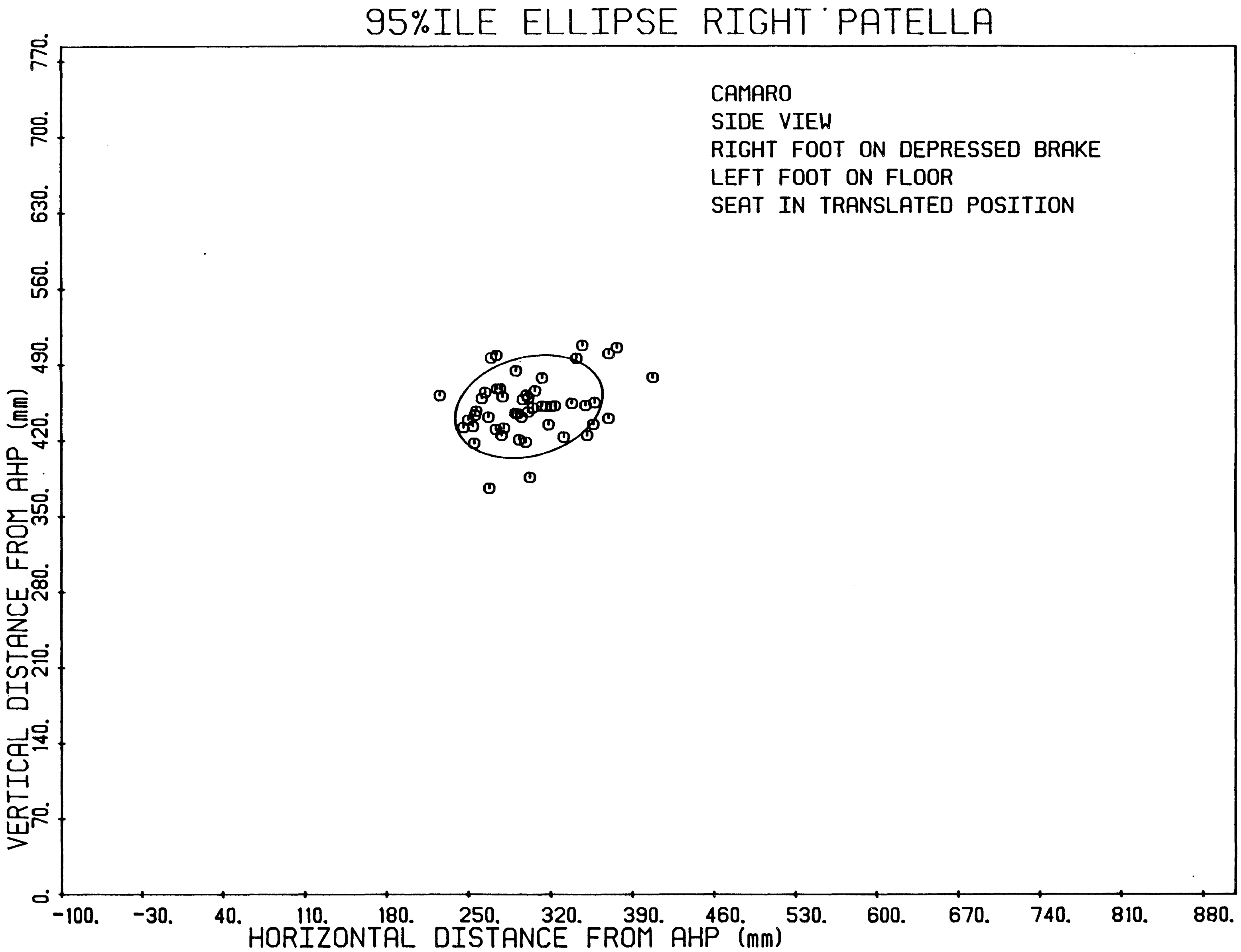
95%ILE ELLIPSE LEFT PATELLA



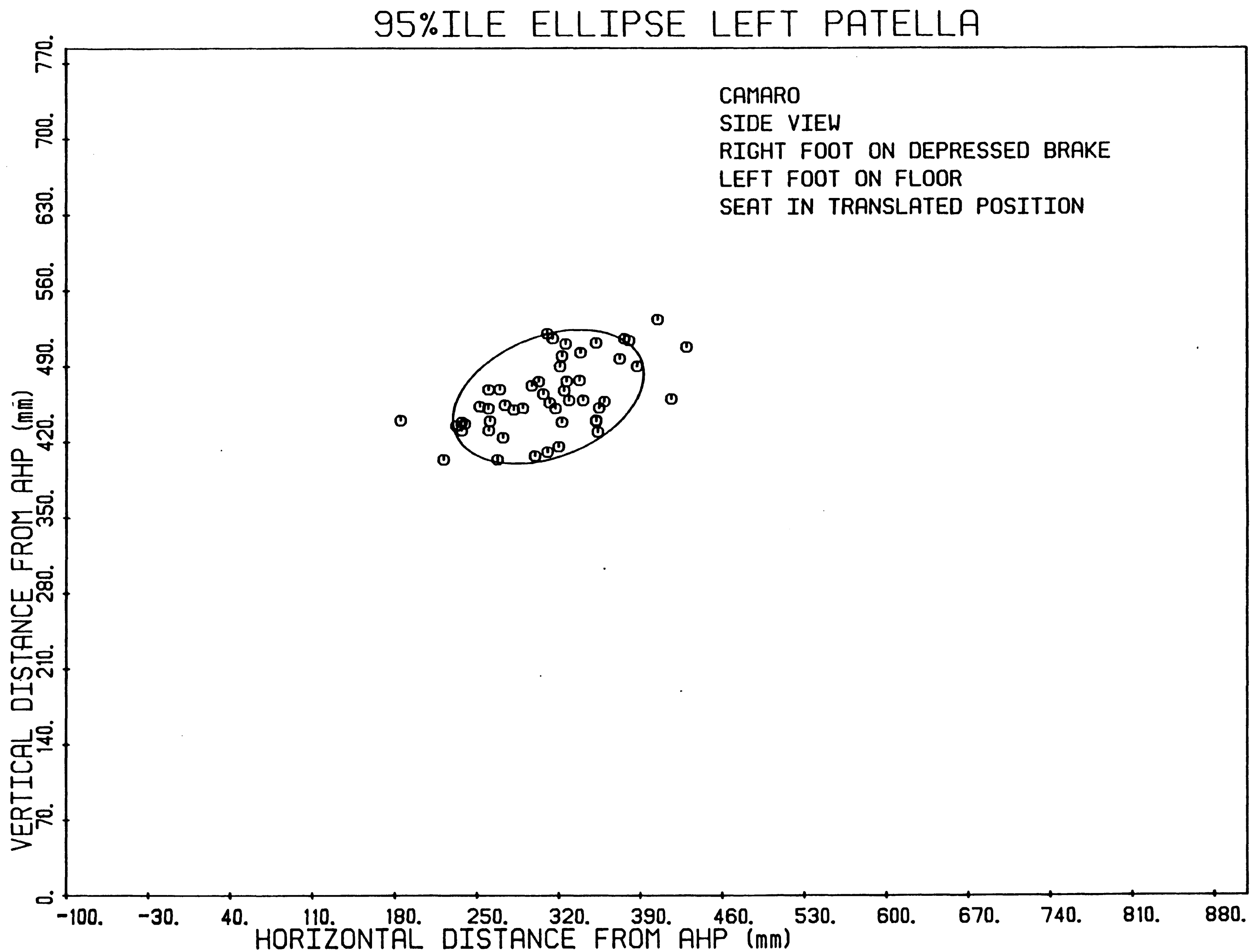


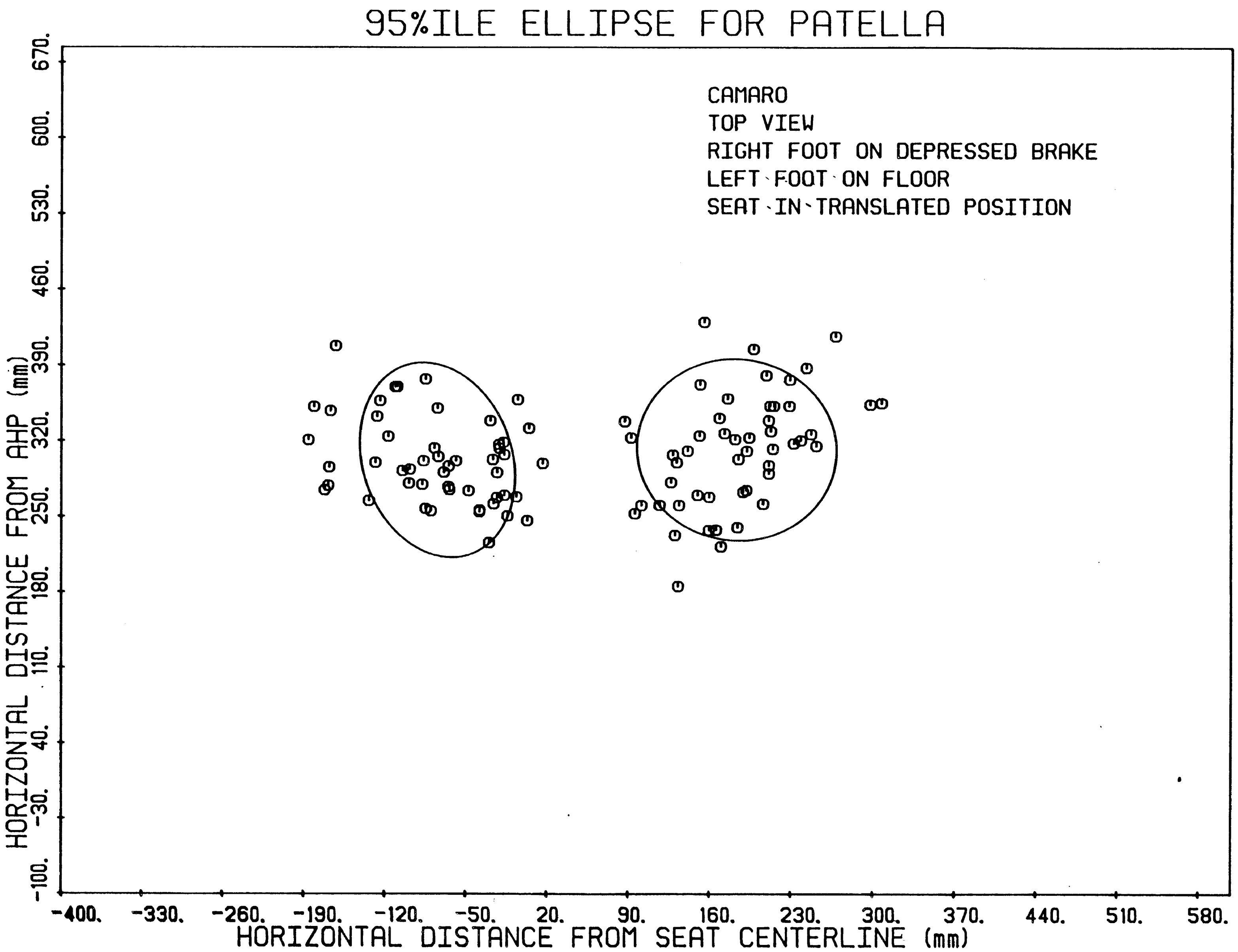
95%ILE ELLIPSE FOR PATELLA
CAMARO
TOP VIEW
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN TRANSLATED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-100. -30. 40. 110. 180. 250. 320. 390. 460. 530. 600. 670.
-400. -330. -260. -190. -120. -50. 20. 90. 160. 230. 300. 370. 440. 510. 580.

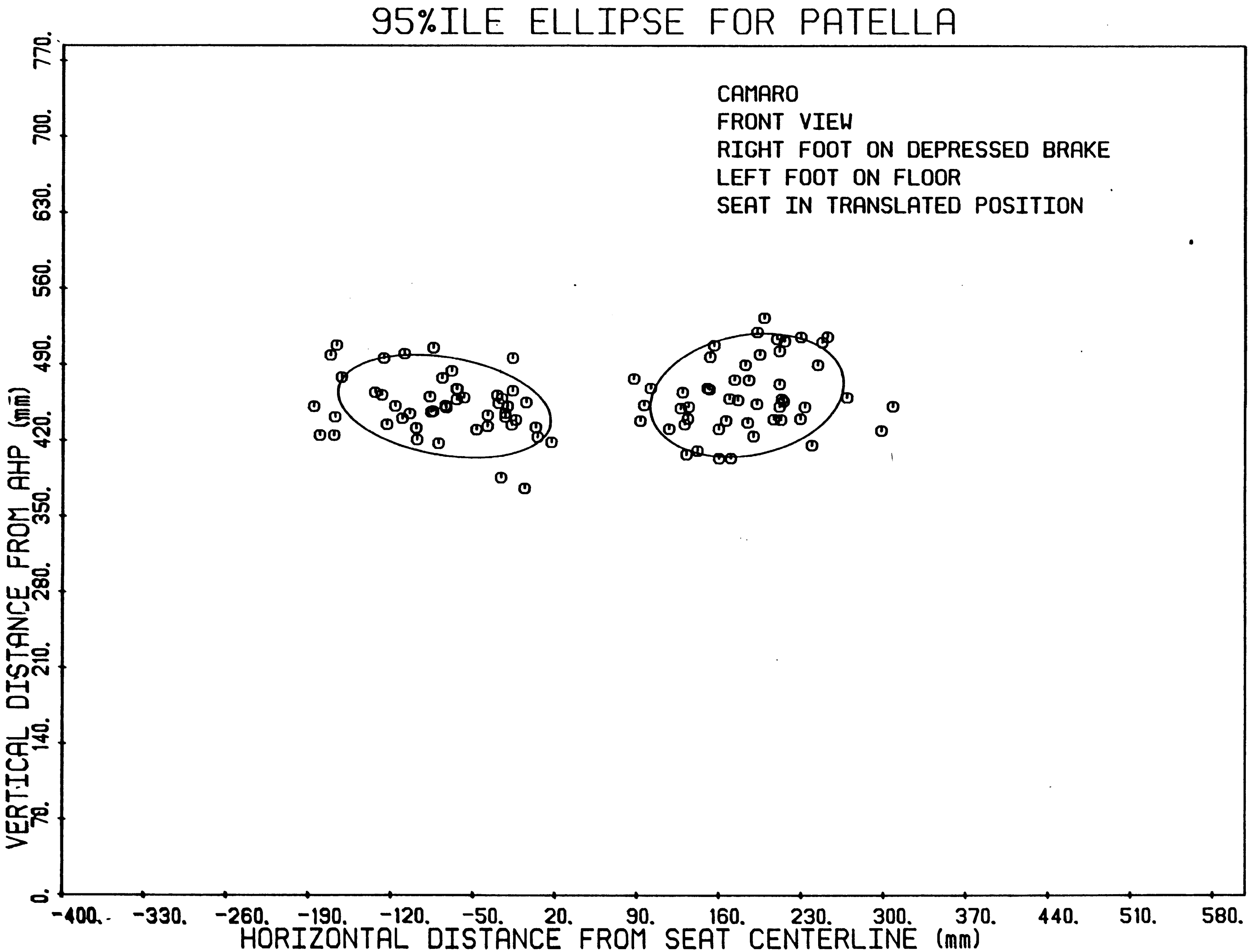

95%ILE ELLIPSE FOR PATELLA
CAMARO
FRONT VIEW
RIGHT FOOT ON DEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)



95%ILE ELLIPSE RIGHT PATELLA
CAMARO
SIDE VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.


95%ILE ELLIPSE LEFT PATELLA
CAMARO
SIDE VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM AHP (mm)
-100.
-30.
40.
110.
180.
250.
320.
390.
460.
530.
600.
670.
740.
810.
880.

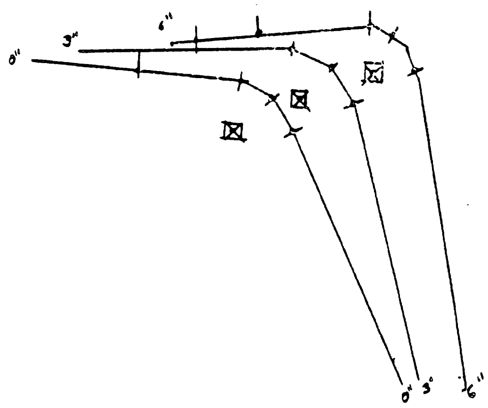

95%ILE ELLIPSE FOR PATELLA
CAMARO
TOP VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
670.
600.
530.
460.
390.
320.
250.
180.
110.
40.
-30.
-100.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.


95%ILE ELLIPSE FOR PATELLA
CAMARO
FRONT VIEW
RIGHT FOOT ON DEPRESSED BRAKE
LEFT FOOT ON FLOOR
SEAT IN TRANSLATED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
700.
770.
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
-400.
-330.
-260.
-190.
-120.
-50.
20.
90.
160.
230.
300.
370.
440.
510.
580.

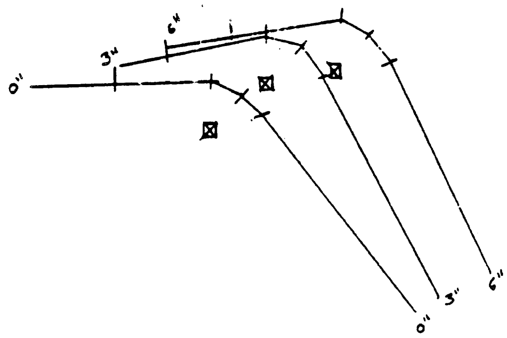
APPENDIX H

LATERAL VIEW CONTOURS OF RIGHT KNEE FOR TEN SUBJECTS IN PREFERRED, TRANSLATED-3"-FORWARD, AND TRANSLATED-6"-FORWARD POSITIONS

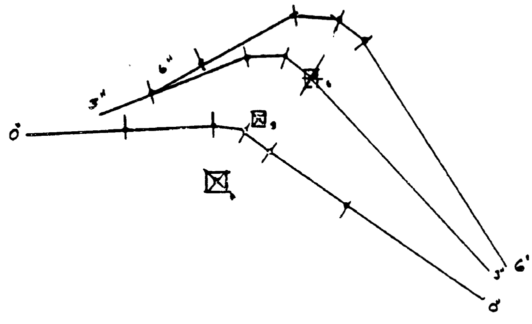
GROUP 1 SUBJECT



MINI-VAN

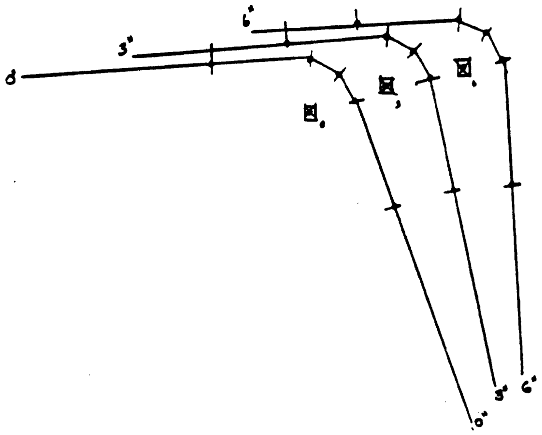


ESCORT

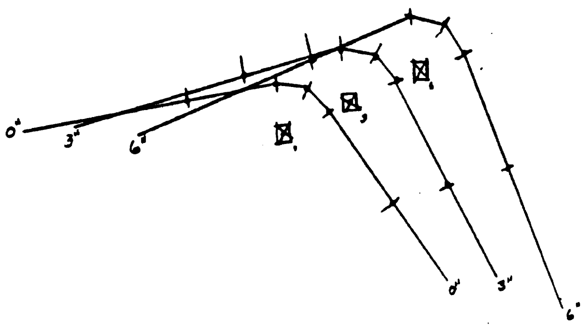


CAMARO

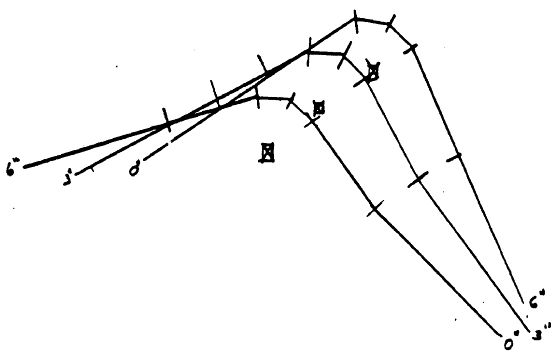
GROUP 2 SUBJECT



MINI-VAN

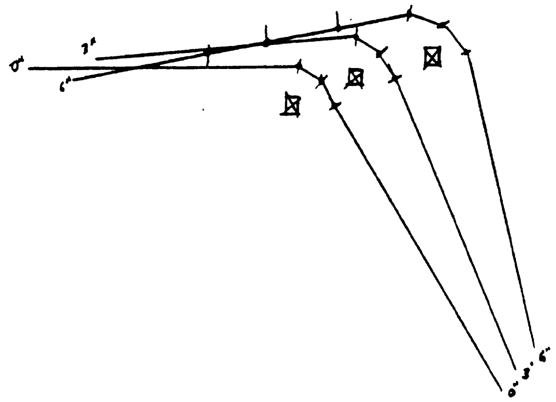


ESCORT

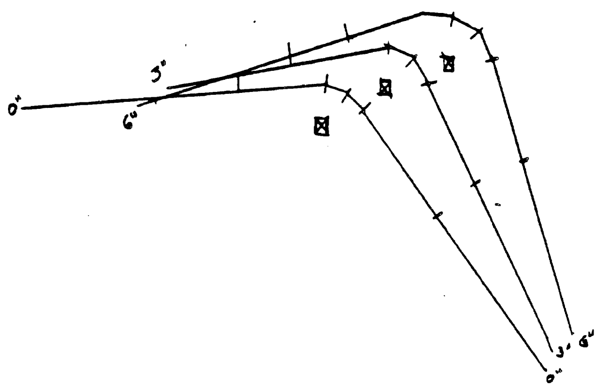


CAMARO

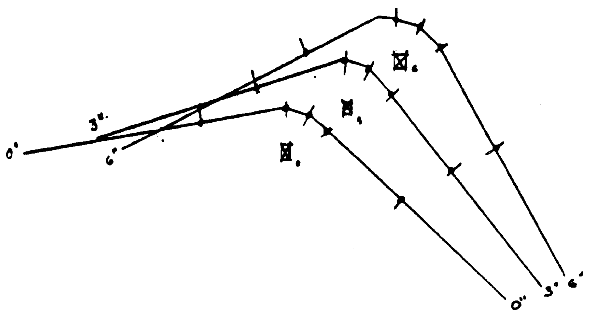
GROUP 3 SUBJECT



MINI-VAN

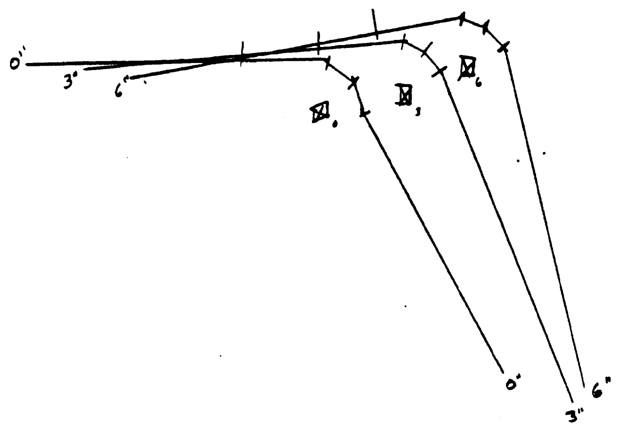


ESCORT

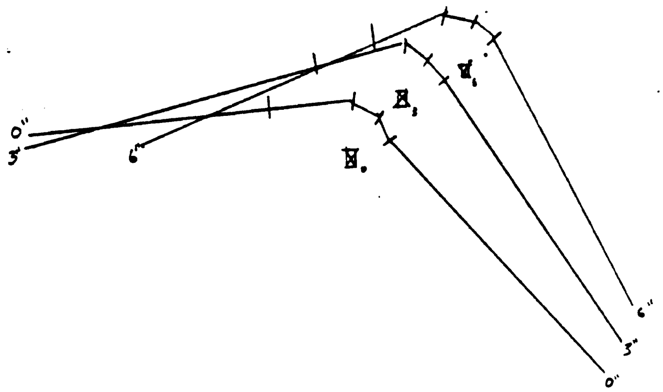


CAMARO

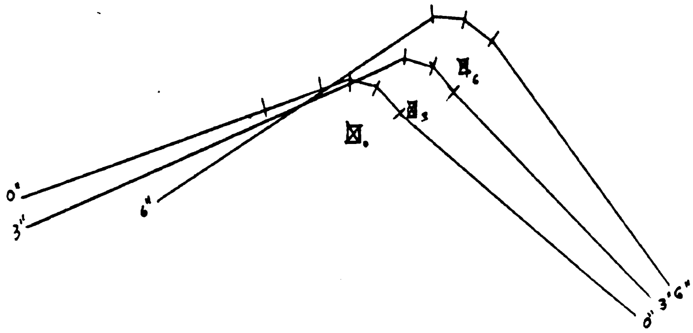
GROUP 4 SUBJECT



MINI-VAN

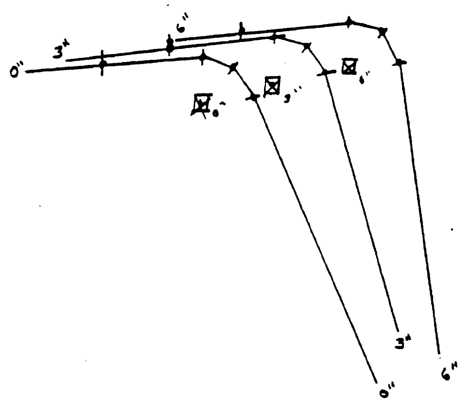


ESCORT

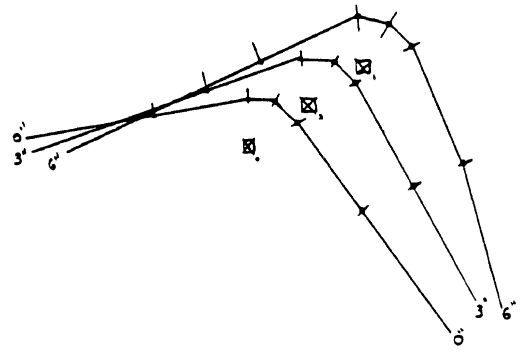


CAMARO

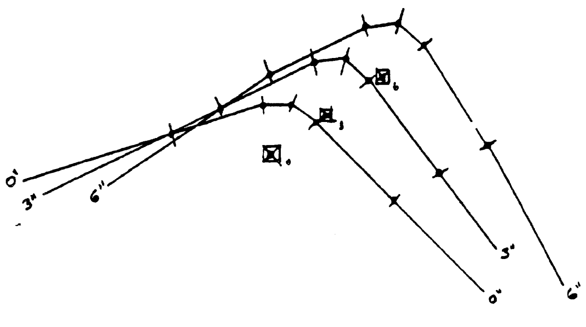
GROUP 5 SUBJECT



MINI-VAN

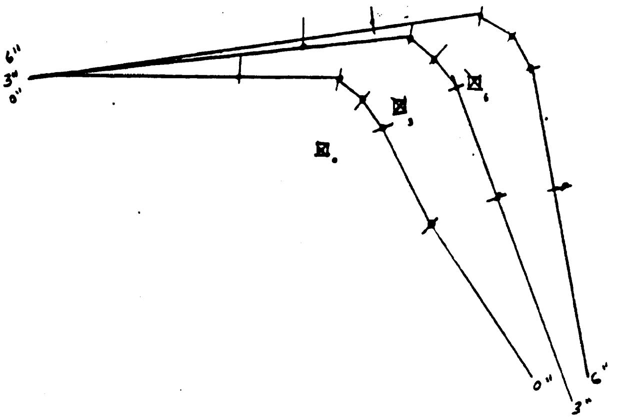


ESCORT

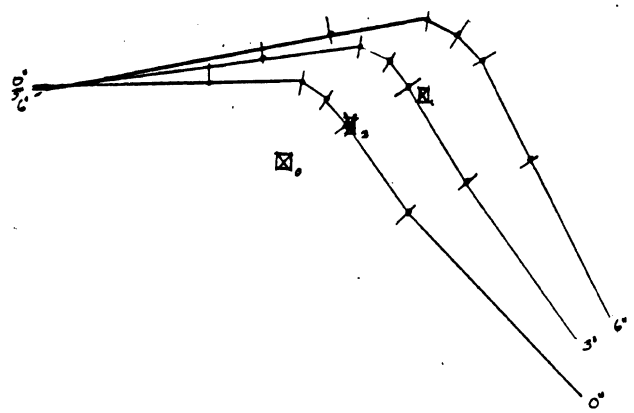


CAMARO

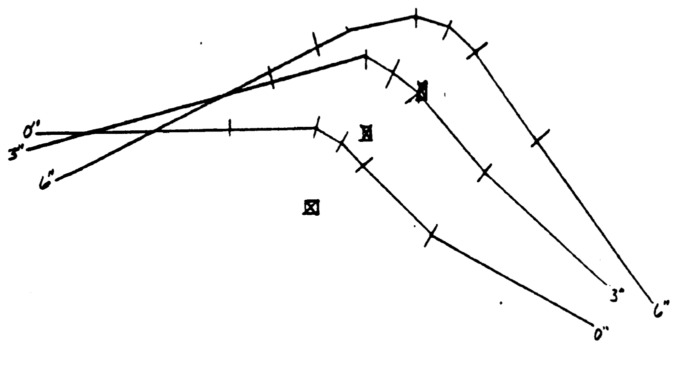
GROUP 6 SUBJECT



MINI-VAN

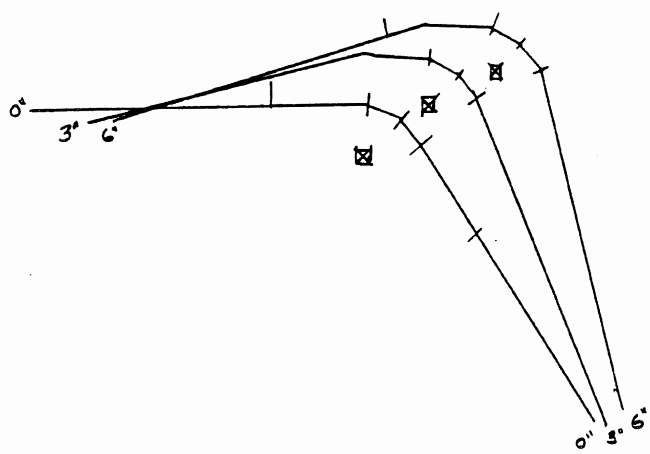


ESCORT

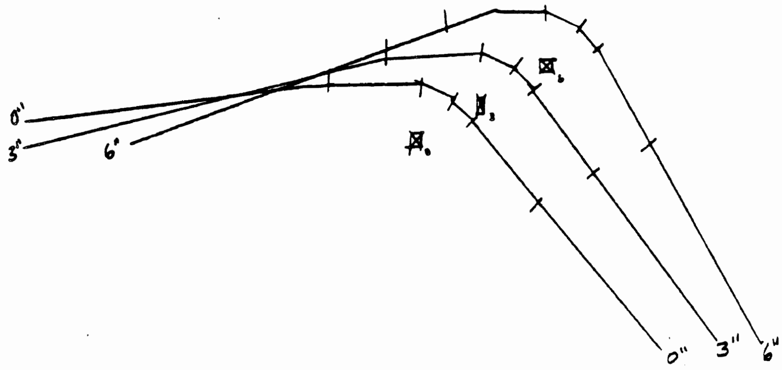


CAMARO

GROUP 7 SUBJECT



MINI-VAN



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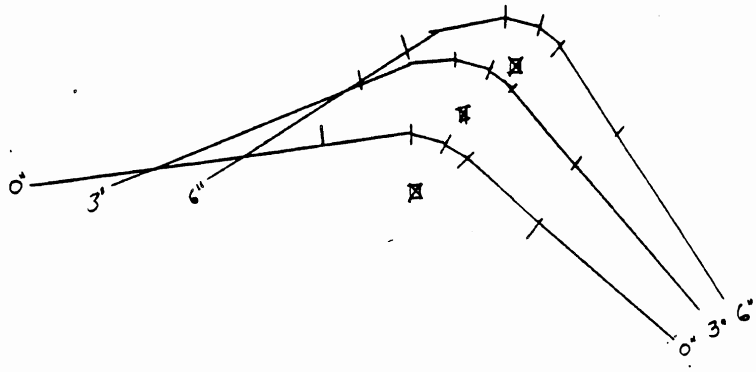
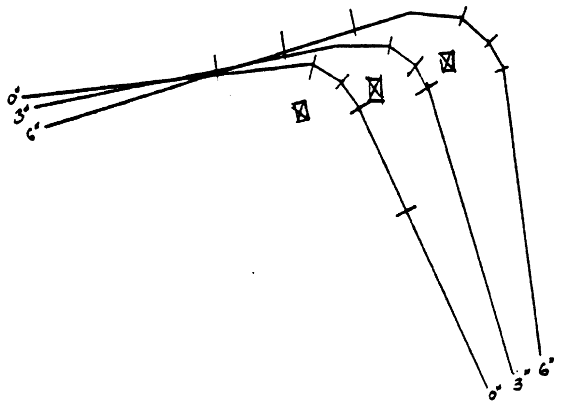


CAMARO

<u>GROUP 8 SUBJECT</u>



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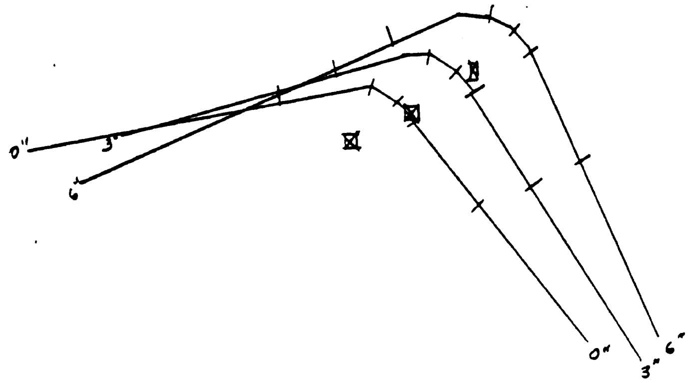

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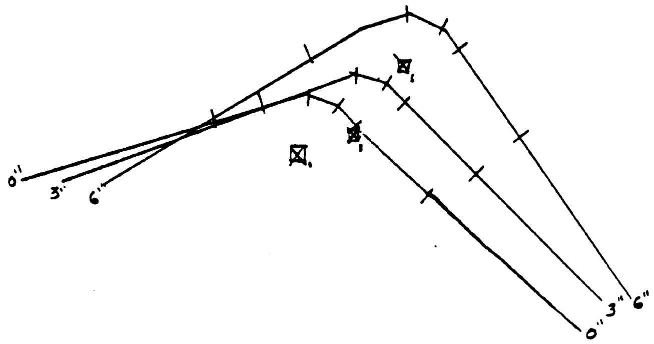

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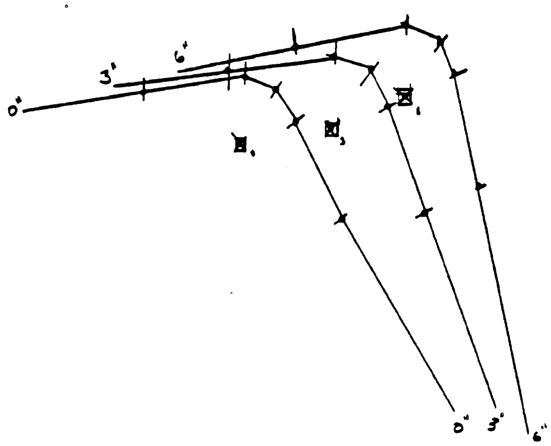
GROUP 9 SUBJECT



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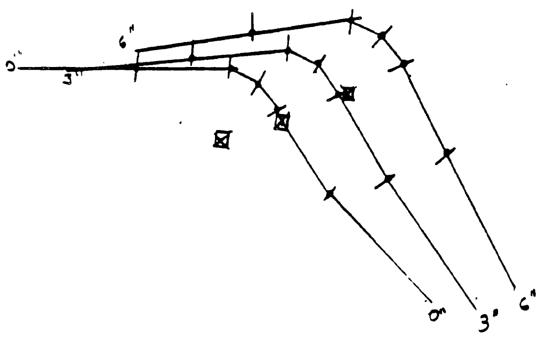

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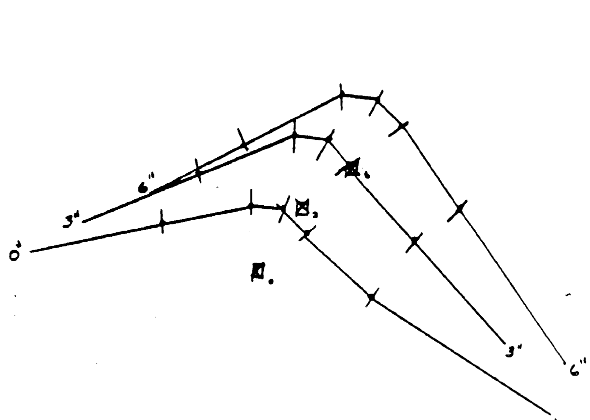

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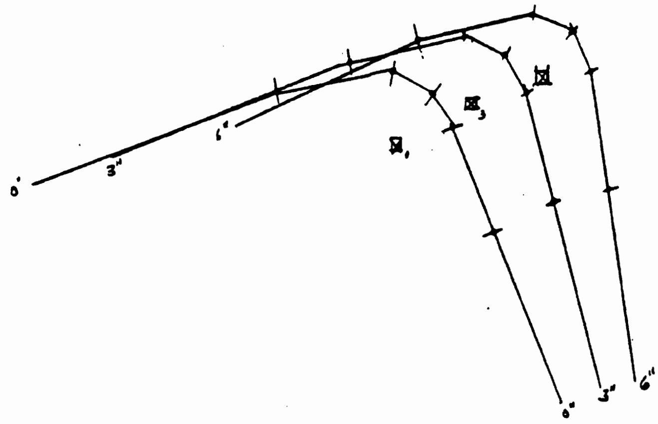
GROUP 10 SUBJECT



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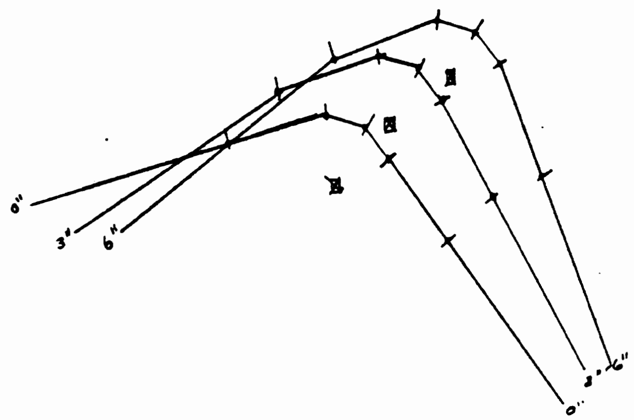

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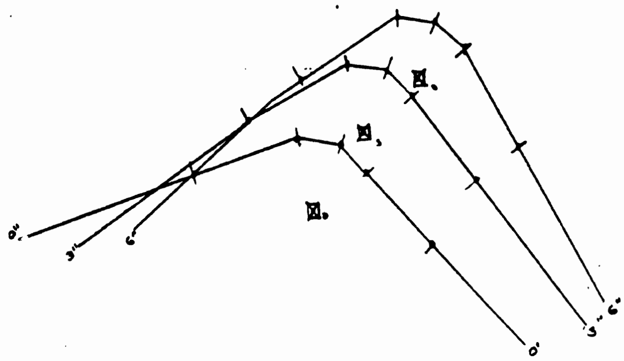
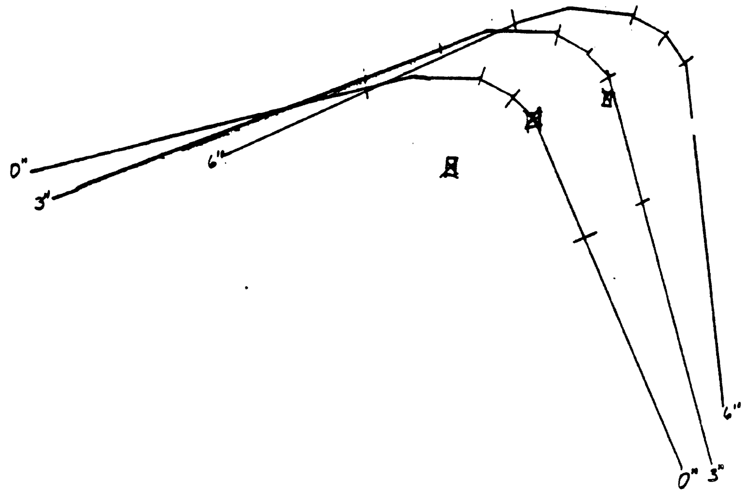
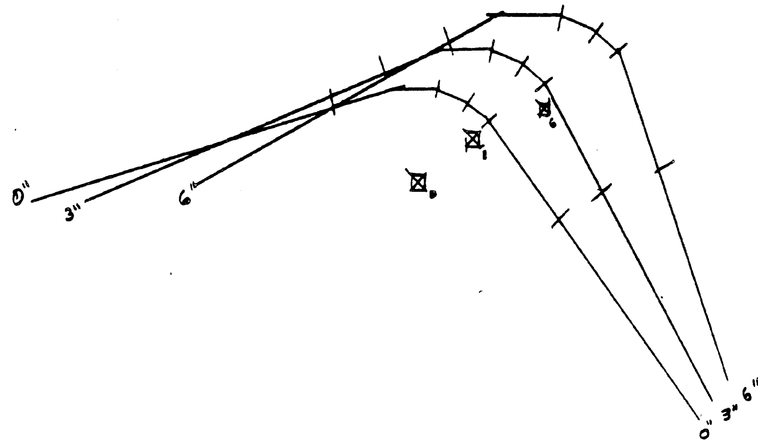


CAMARO

GROUP 11 SUBJECT



MINI-VAN



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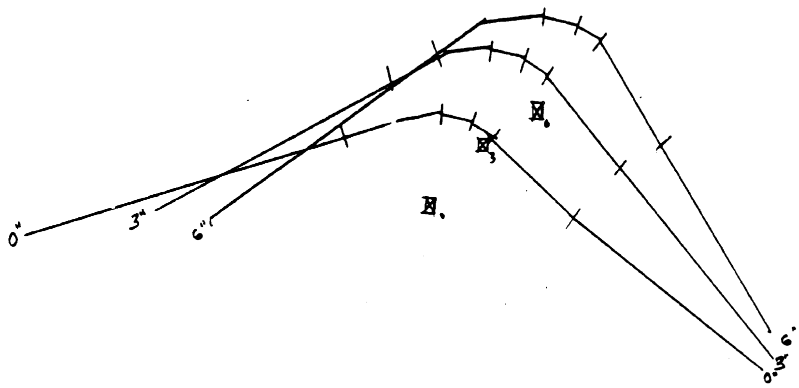


CAMARO

APPENDIX I

TABLES AND PLOTS OF 95th PERCENTILE RIGHT TIBIA TARGET ELLIPSES FOR UNTRANSLATED SEAT CONDITIONS

TABLE I-1

95%ILE AND 99%ILE DRIVER RIGHT TIBA ELLIPSES
(RIGHT FOOT ON UNDEPRESSED ACCELERATOR)

	Minivan Right Tibia	Escort Right Tibia	Camaro Right Tibia
Mean X	167.27	269.80	320.73
Mean Y	-175.27	-142.27	-121.52
Mean Z	378.36	336.42	297.69
X Std. Dev.	36.92	40.38	39.03
Y Std. Dev.	34.96	35.98	37.67
Z Std. Dev.	26.08	21.04	28.19
95% X*	121.84	133.25	128.80
95% Y	115.37	118.73	124.31
95% Z	86.06	69.43	93.03
99% X*	172.05	188.17	181.88
99% Y	162.91	167.67	175.54
99% Z	121.53	98.05	131.37
X/Z Slope	0.45	0.27	0.45
X/Y Slope	-2.20	-2.32	-1.90
Y/Z Slope	-0.54	-0.39	-0.50
X/Z Correlation	0.40	0.41	0.37
X/Y Correlation	-0.40	-0.54	-0.51
X/Z Correlation	-0.46	-0.52	-0.39

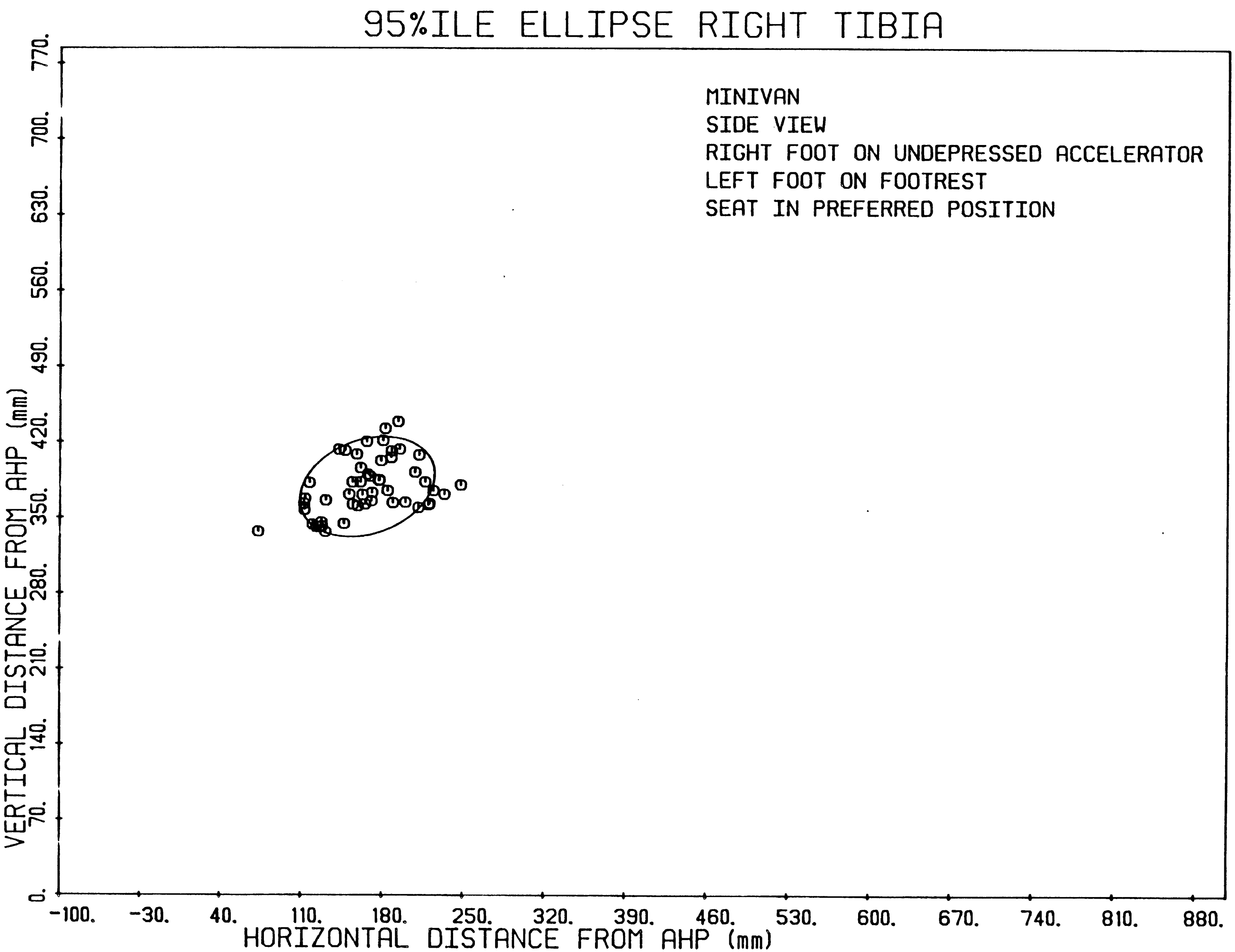
Coordinate values are in mm.
* 95%ile and 99% accommodation centrally distributed about the mean.

TABLE I-2

95%ILE AND 99%ILE DRIVER RIGHT TIBIA ELLIPSES
(RIGHT FOOT ON UNDEPRESSED BRAKE)

	Minivan Right Tibia	Escort Right Tibia	Camaro Right Tibia
Mean X	183.74	291.07	346.47
Mean Y	-114.30	-85.97	-58.60
Mean Z	422.72	382.07	336.83
X Std. Dev.	35.70	36.54	36.42
Y Std. Dev.	44.30	39.10	43.34
Z Std. Dev.	27.95	25.38	29.15
95% X*	117.81	120.58	120.19
95% Y	146.19	129.03	143.02
95% Z	92.24	83.75	96.20
99% X*	166.36	170.28	169.72
99% Y	206.44	182.21	201.96
99% Z	130.25	118.27	135.84
X/Z Slope	-0.02	0.20	0.51
X/Y Slope	-2.70	-2.18	-2.82
Y/Z Slope	-0.19	-0.14	-0.17
X/Z Correlation	-0.01	0.15	0.31
X/Y Correlation	-0.35	-0.47	-0.29
Y/Z Correlation	-0.19	-0.13	-0.14

Coordinate values are in mm.
* 95%ile and 99% accommodation centrally distributed about the mean.


95%ILE ELLIPSE RIGHT TIBIA
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
0.
70.
140.
210.
280.
350.
420.
490.
560.
630.
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740.
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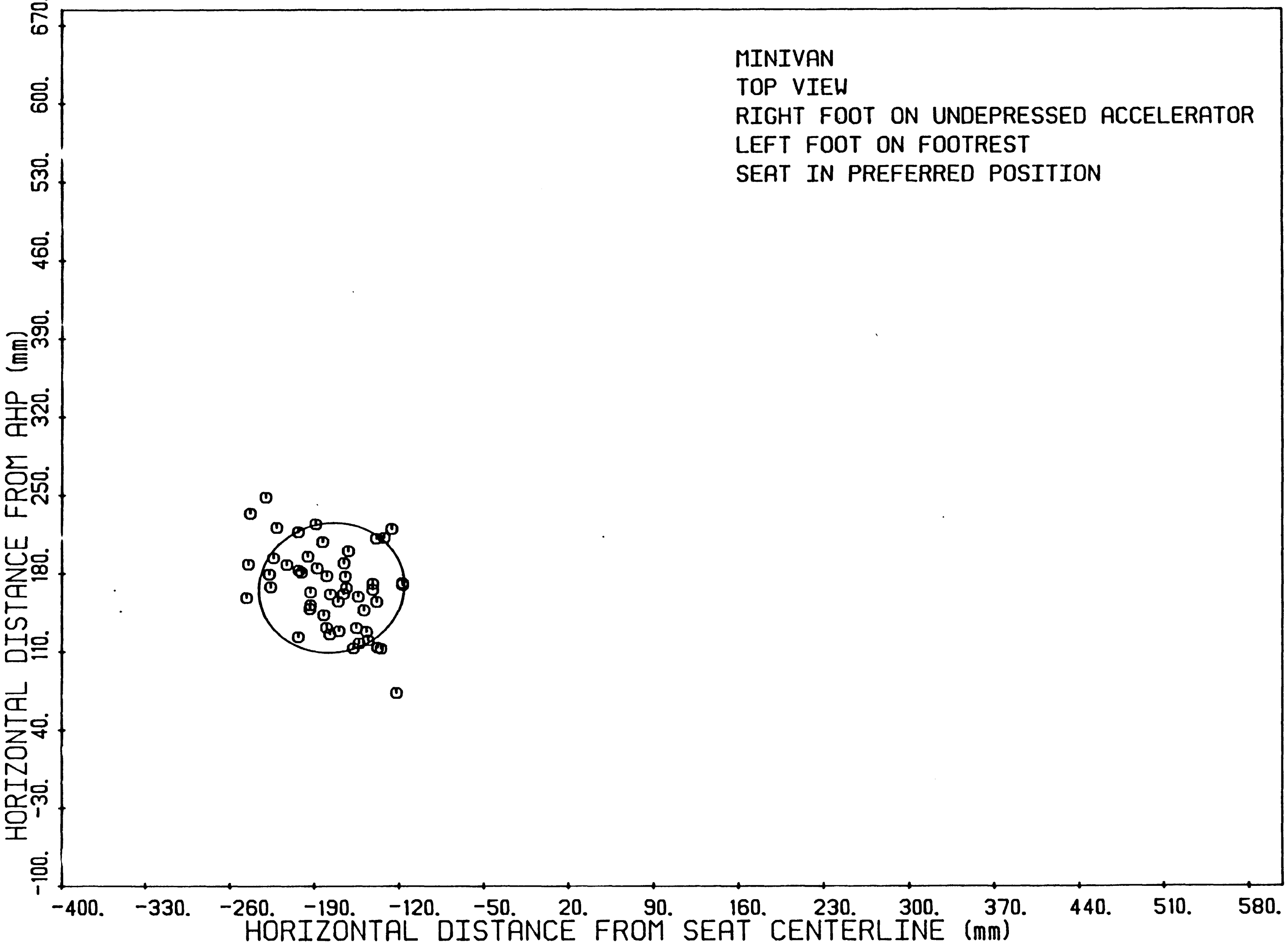
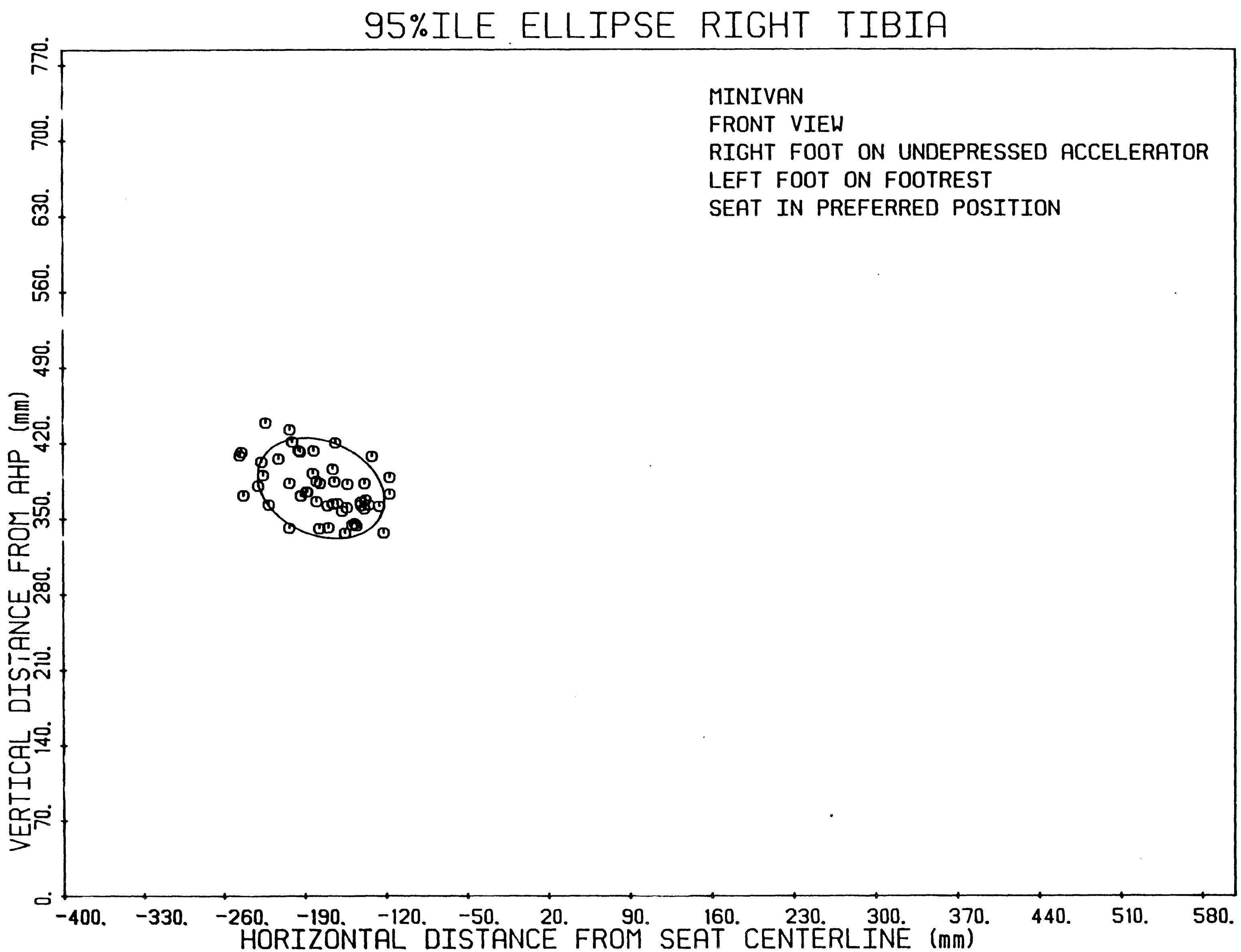
880.
HORIZONTAL DISTANCE FROM AHP (mm)

95%ILE ELLIPSE RIGHT TIBIA




95%ILE ELLIPSE RIGHT TIBIA
MINIVAN
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
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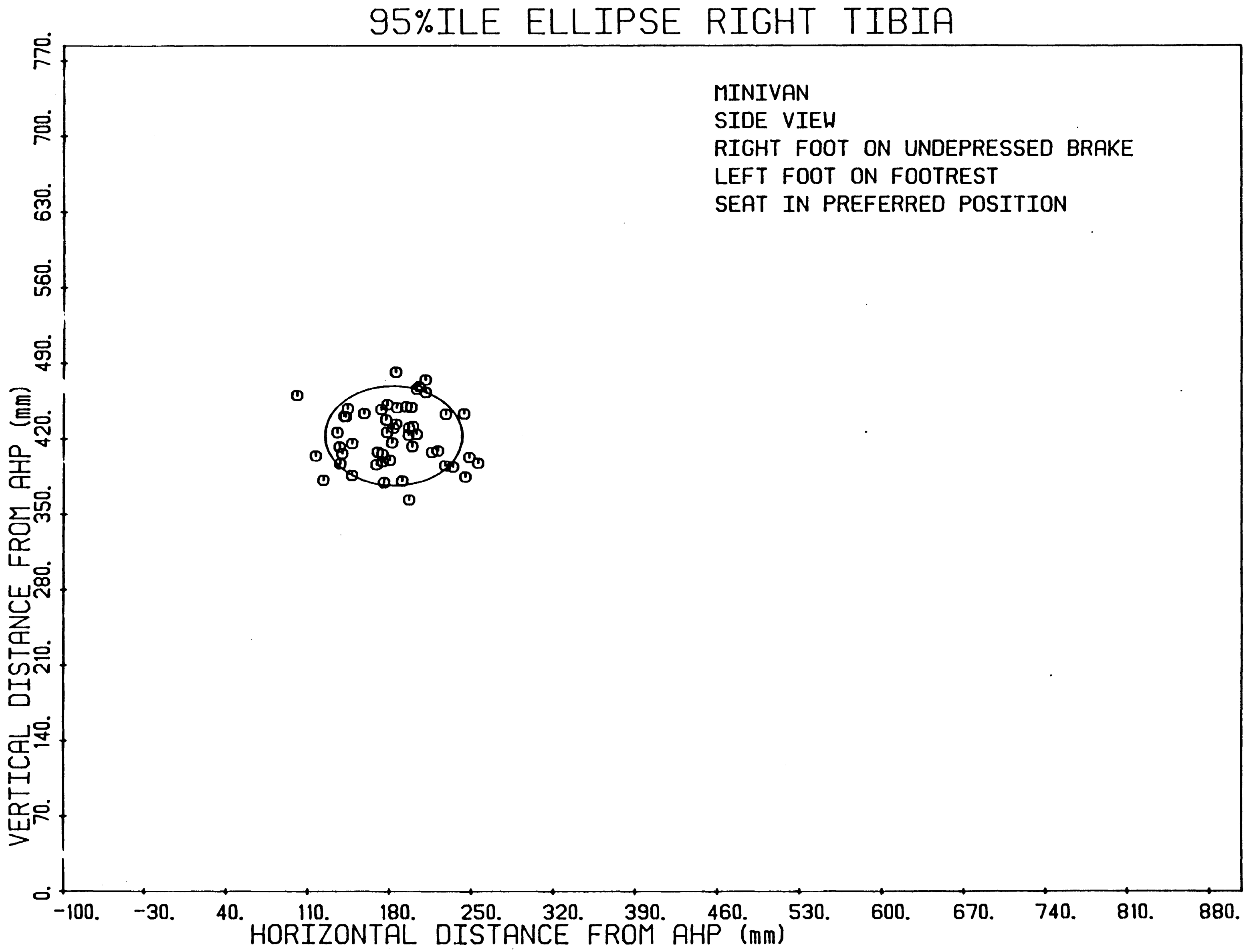
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)


95%ILE ELLIPSE RIGHT TIBIA
MINIVAN
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
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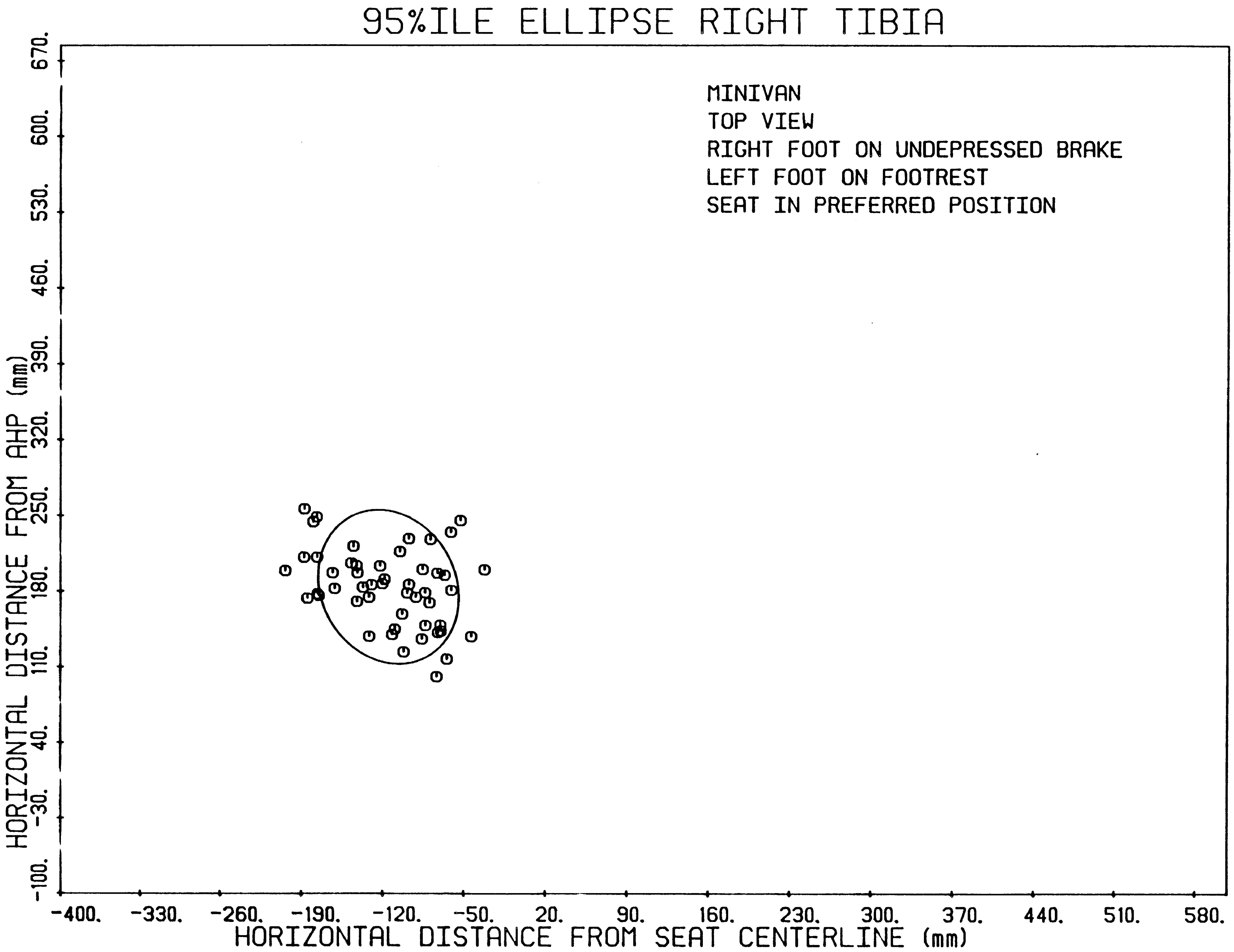
HORIZONTAL DISTANCE FROM AHP (mm)


95%ILE ELLIPSE RIGHT TIBIA
MINIVAN
TOP VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
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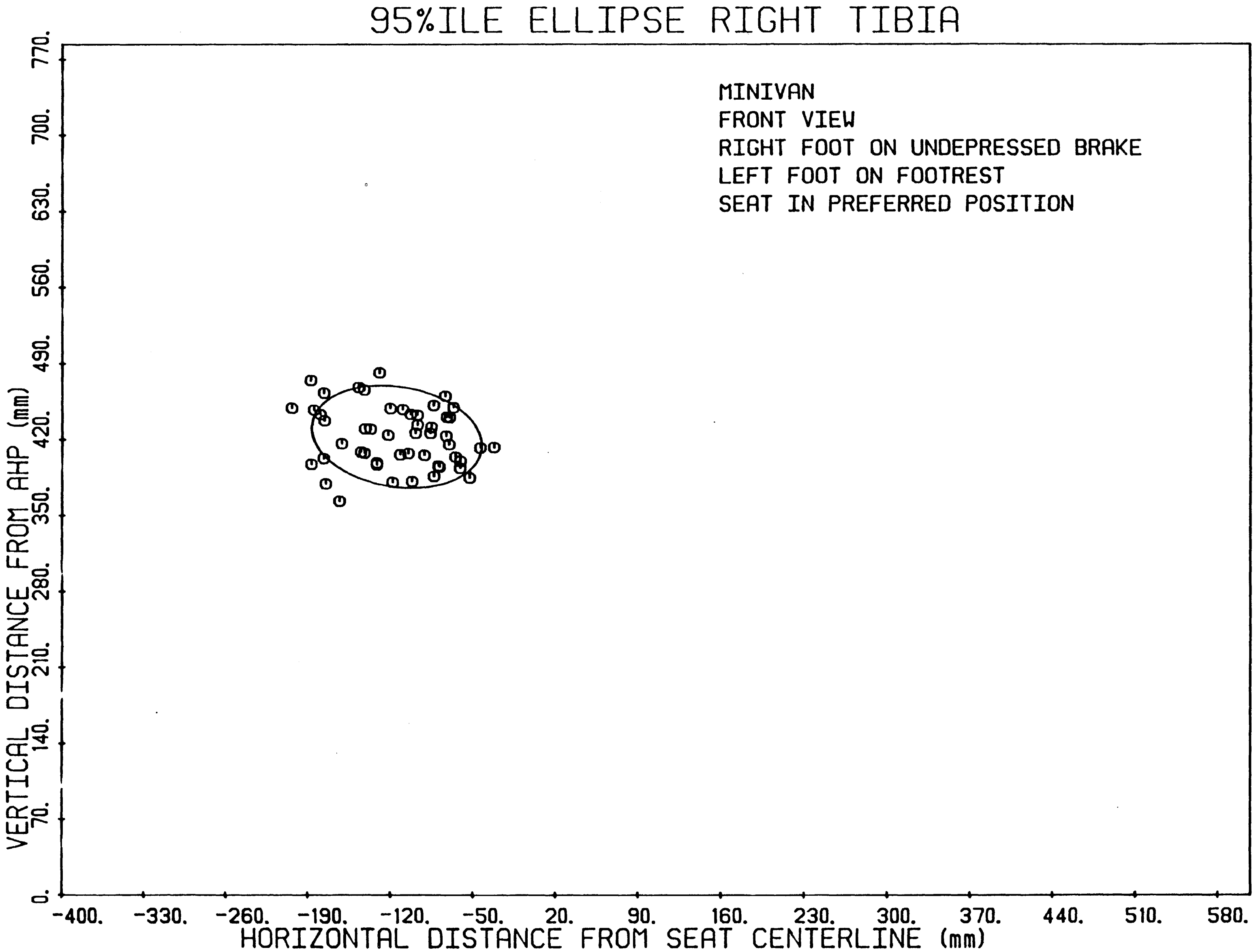
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)



95%ILE ELLIPSE RIGHT TIBIA
MINIVAN
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)
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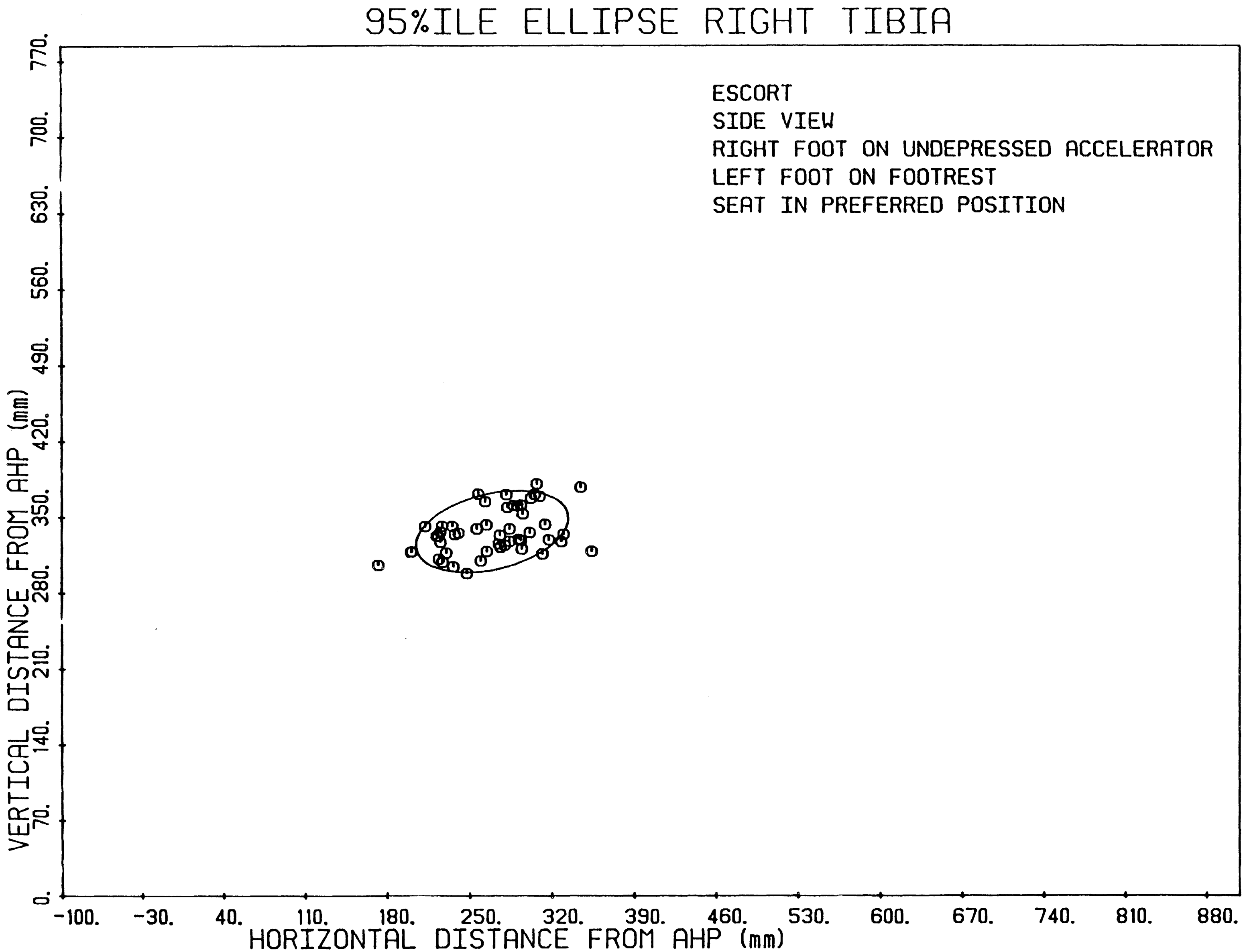
95%ILE ELLIPSE RIGHT TIBIA
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SIDE VIEW
RIGHT FOOT ON UNDEPRESSED ACCELERATOR
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
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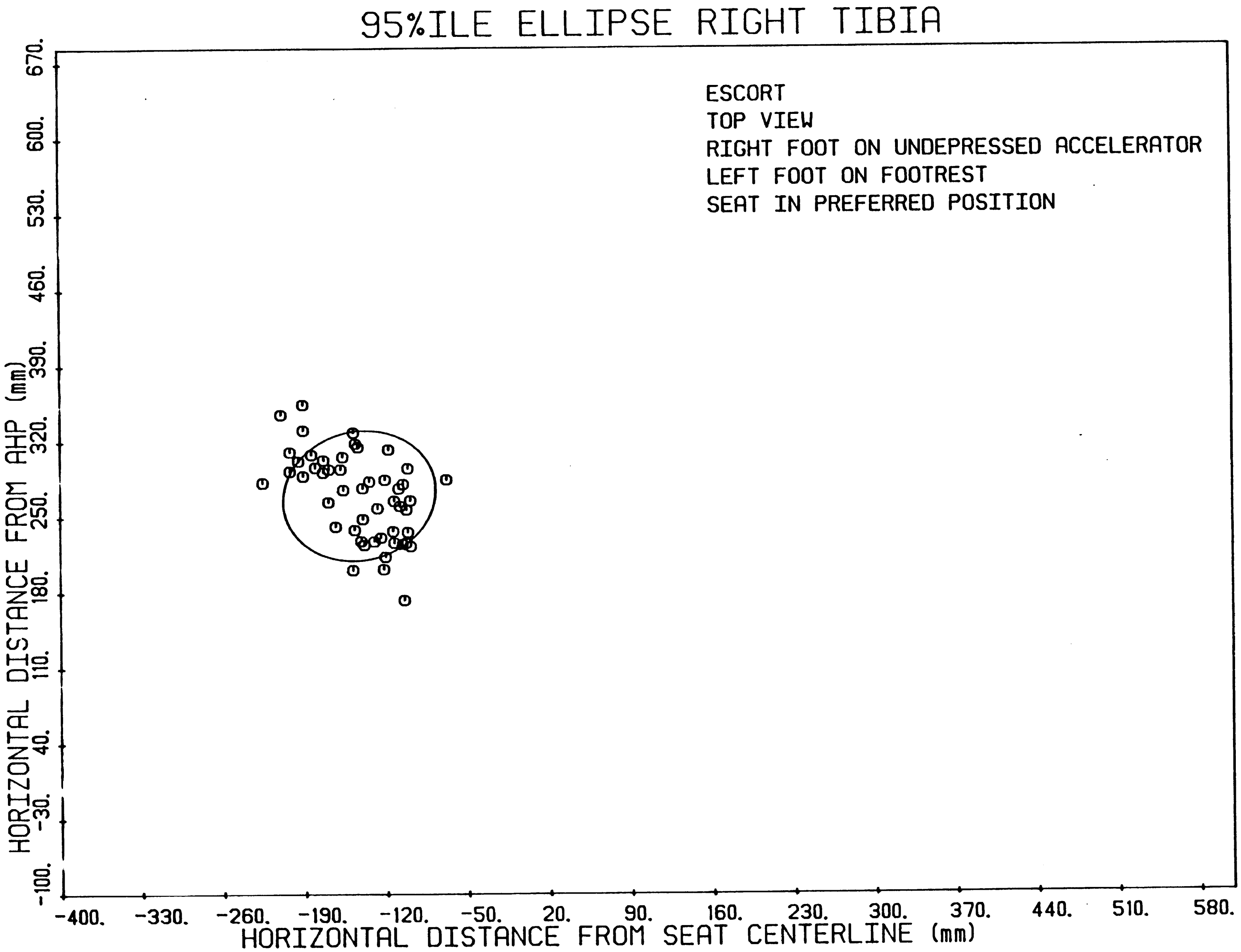
95%ILE ELLIPSE RIGHT TIBIA
ESCORT
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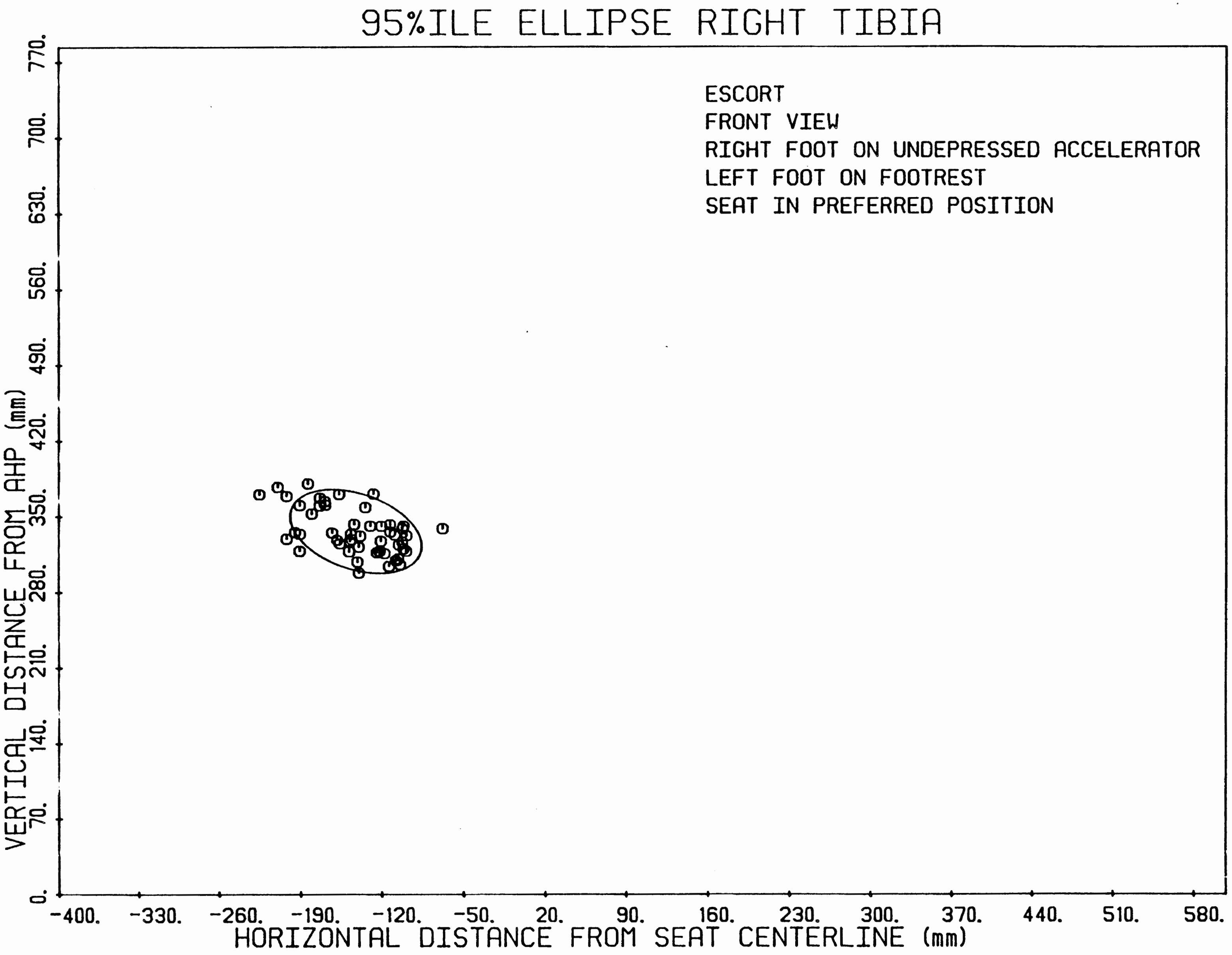
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)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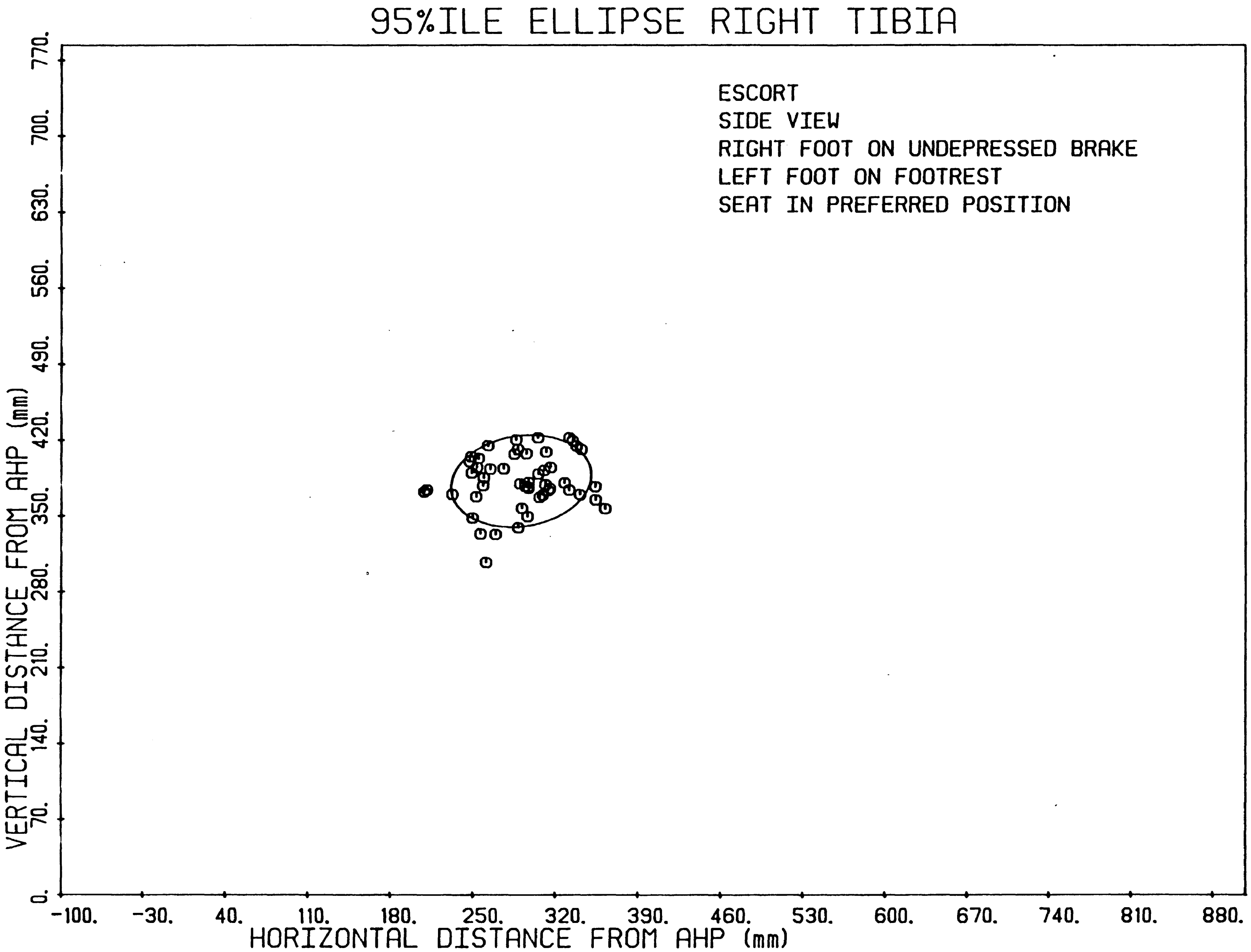

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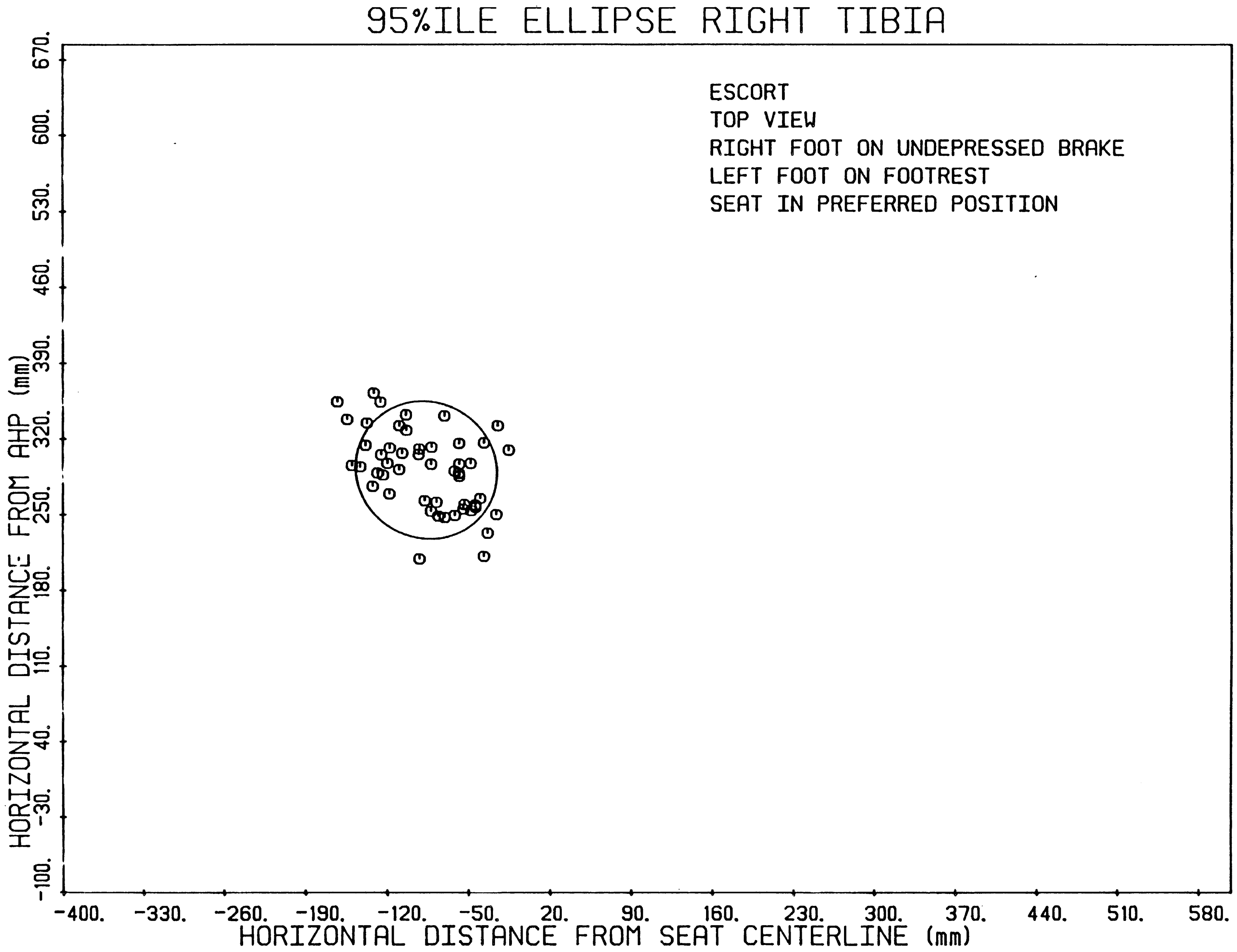
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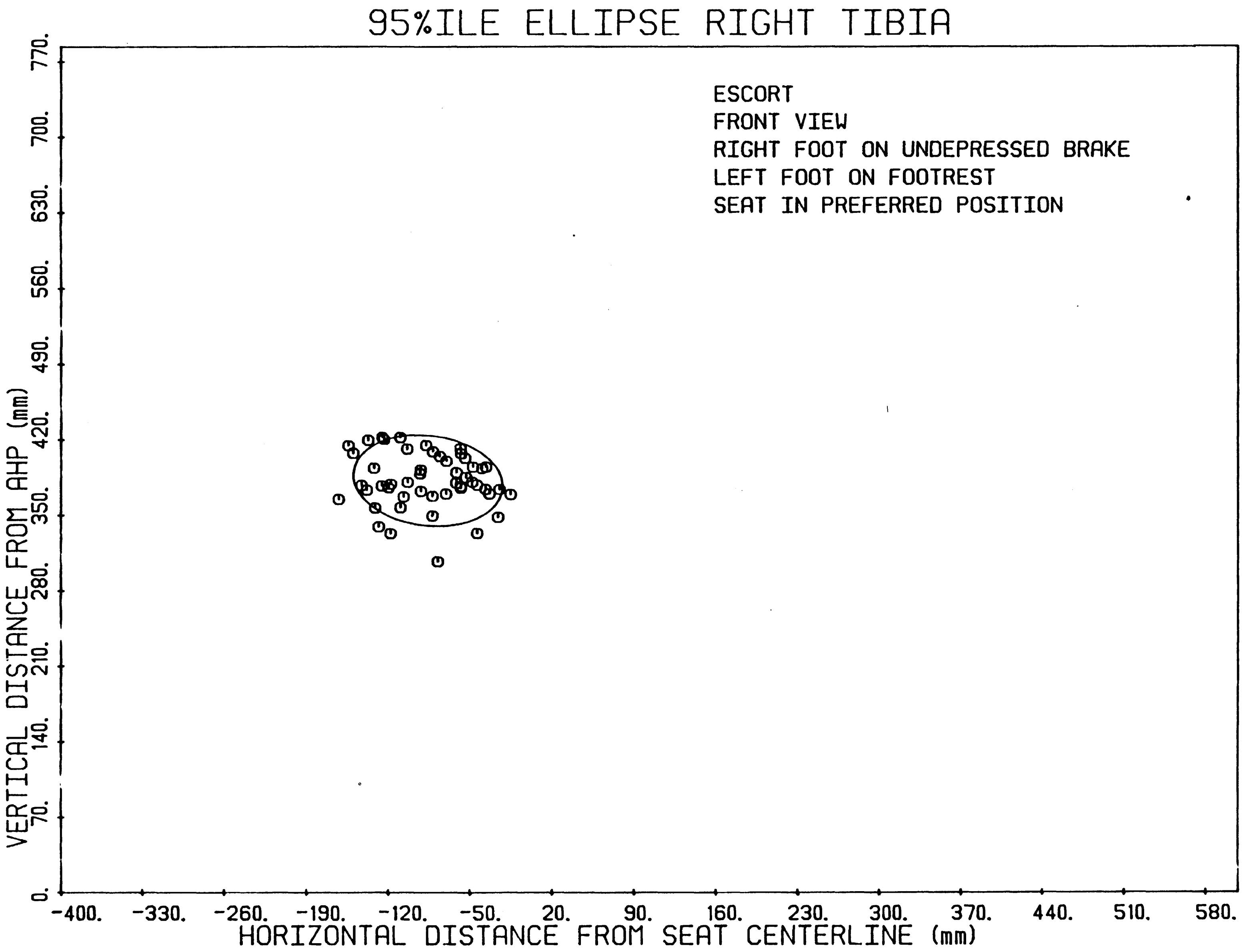
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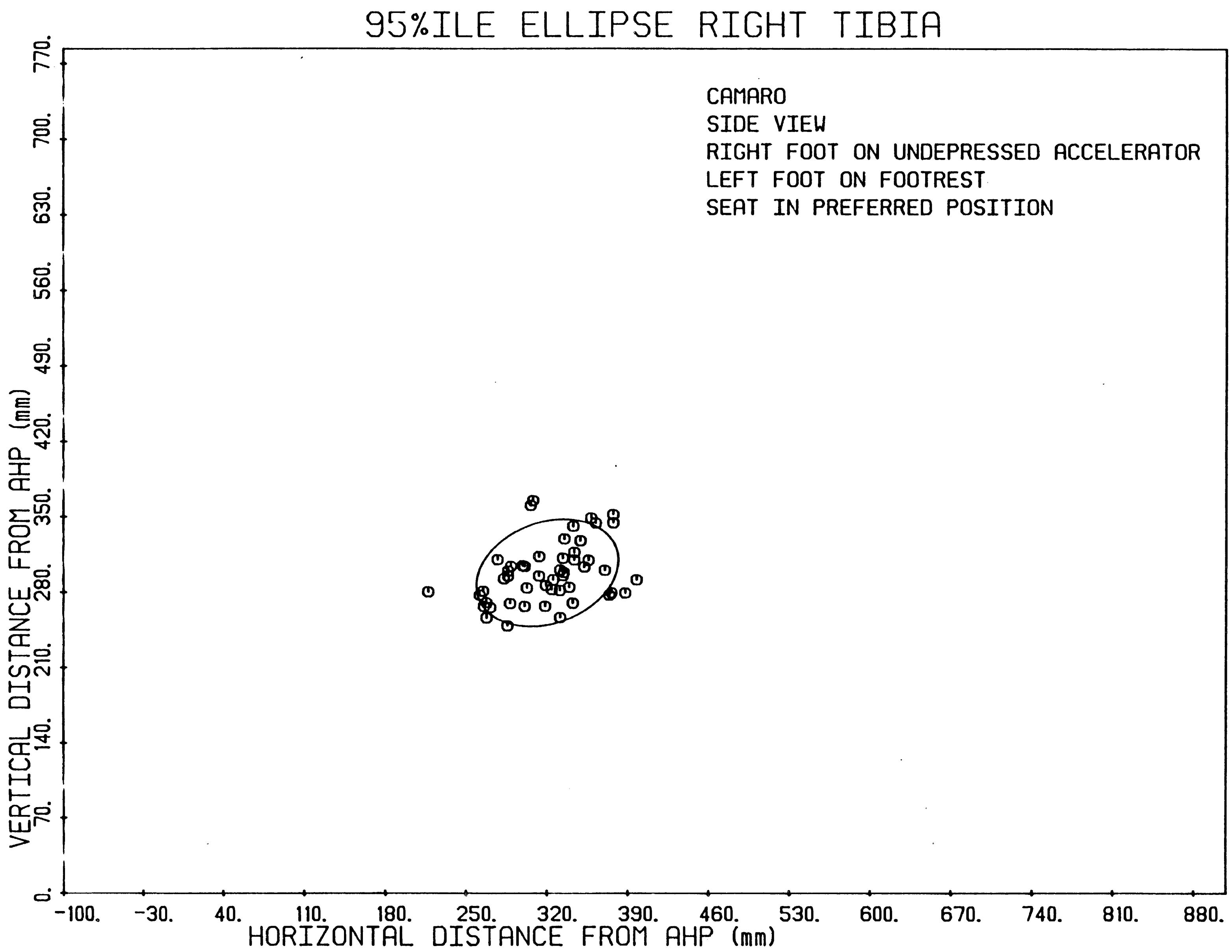
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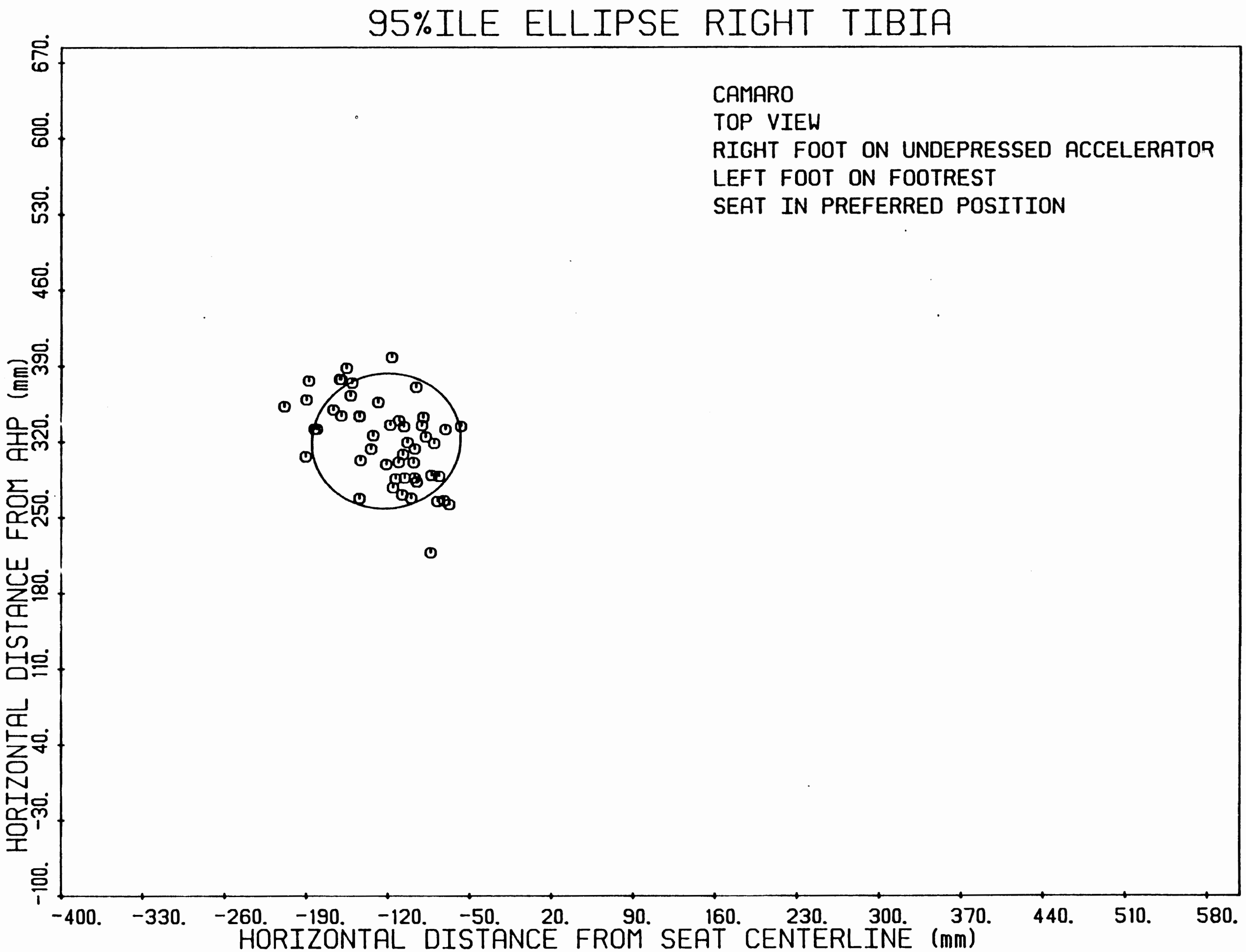
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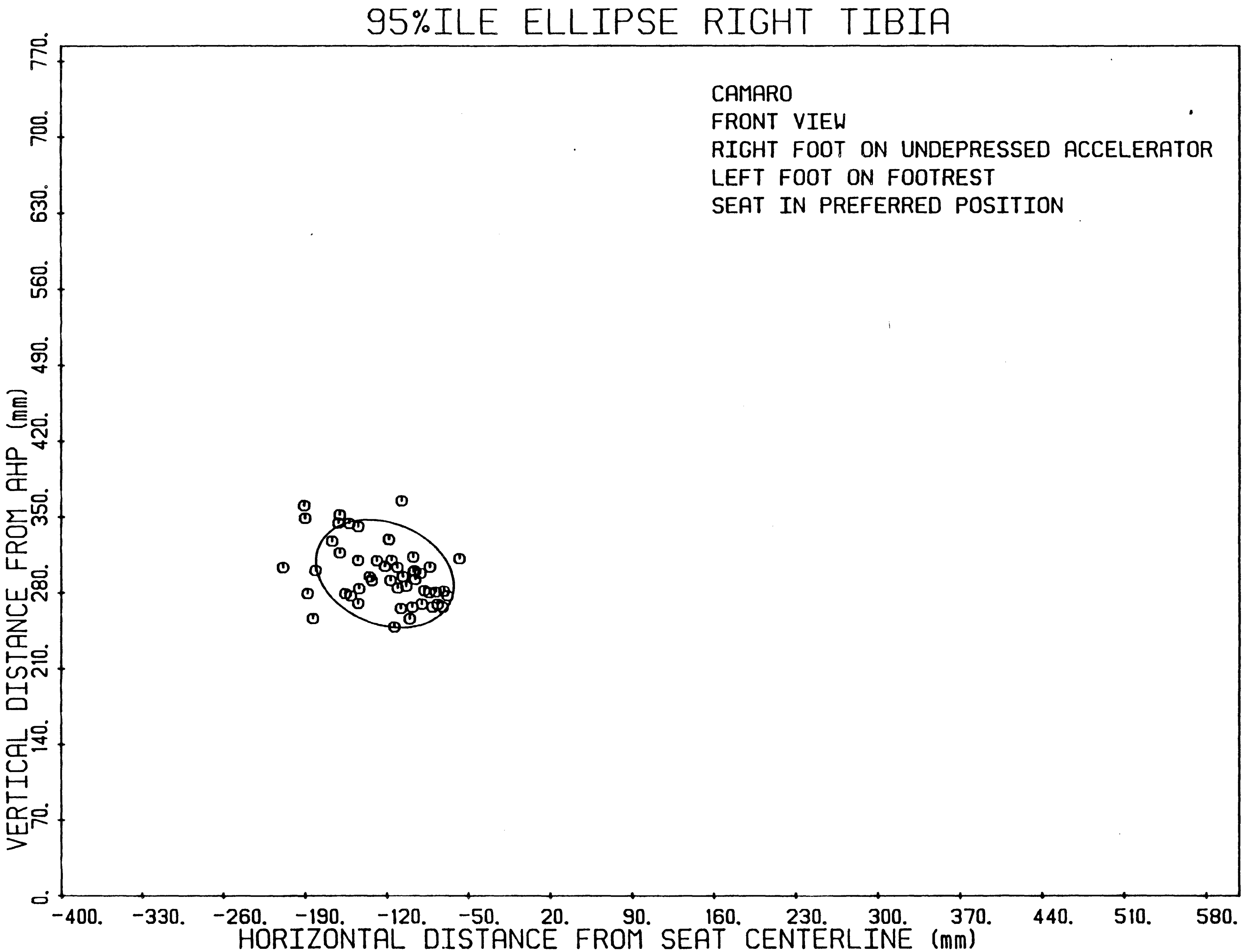
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)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LEFT FOOT ON FOOTREST
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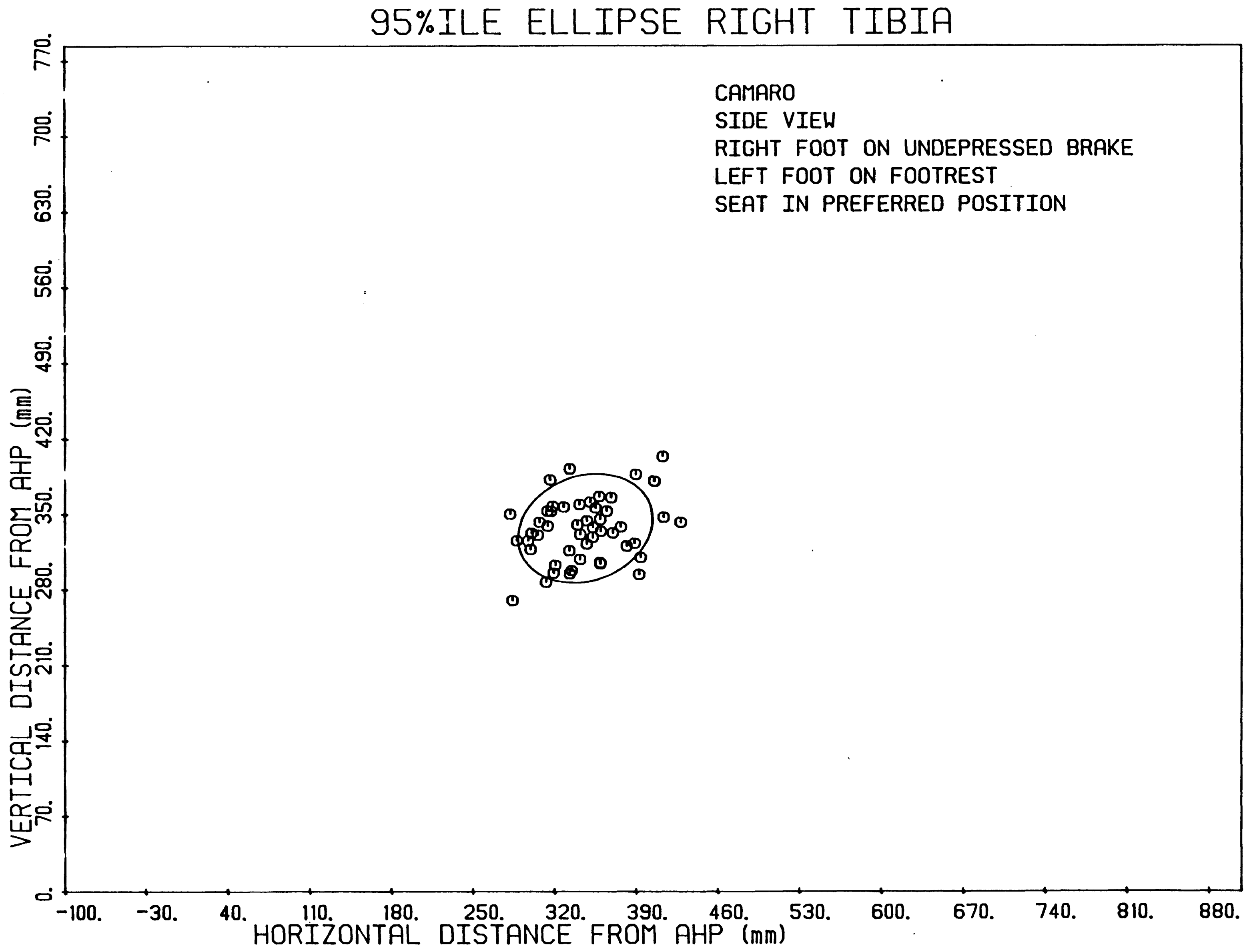
95%ILE ELLIPSE RIGHT TIBIA
CAMARO
SIDE VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
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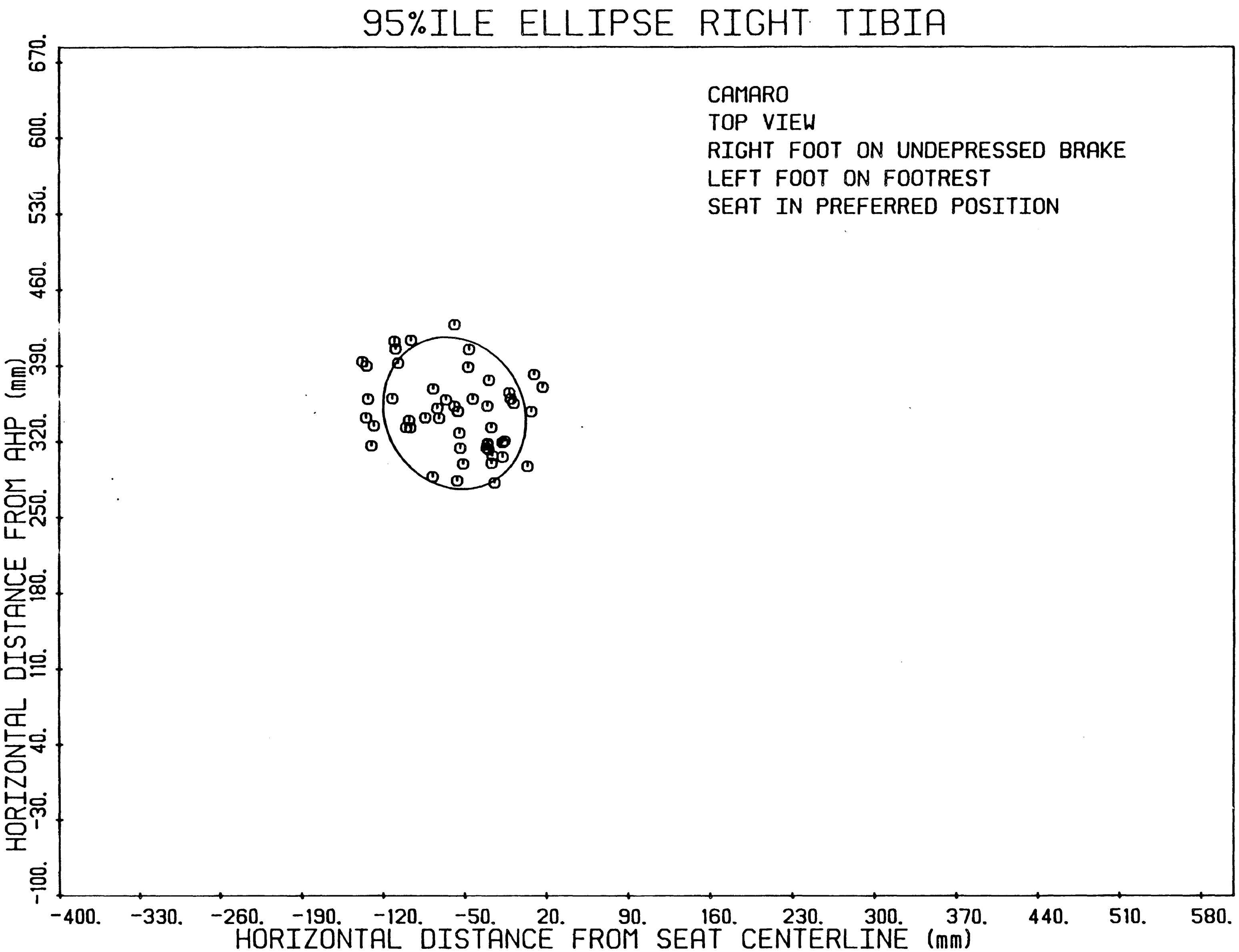
HORIZONTAL DISTANCE FROM AHP (mm)


95%ILE ELLIPSE RIGHT TIBIA
CAMARO
TOP VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
HORIZONTAL DISTANCE FROM AHP (mm)
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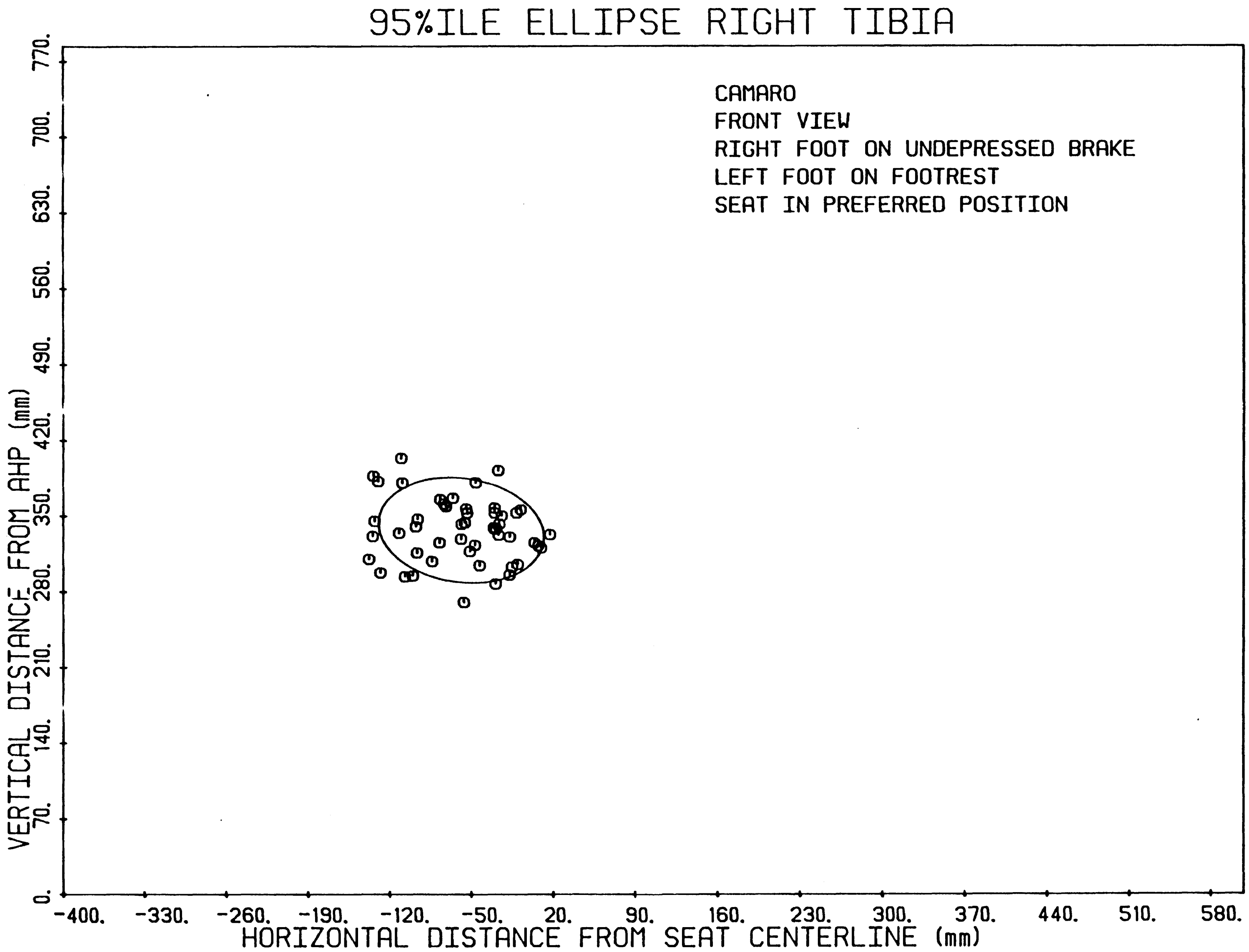
HORIZONTAL DISTANCE FROM SEAT CENTERLINE (mm)


95%ILE ELLIPSE RIGHT TIBIA
CAMARO
FRONT VIEW
RIGHT FOOT ON UNDEPRESSED BRAKE
LEFT FOOT ON FOOTREST
SEAT IN PREFERRED POSITION
VERTICAL DISTANCE FROM AHP (mm)
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