FOOT PEDAL FORCE CAPABILITY VERSUS SEAT POSITION

by

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YOGESH B. PARIKH.

Table of Contents

Table of Figures

INTRODUCTION

The foot pedal is a frequently used control device in vehicles such as automobiles, airplanes and tractors.

Federal Motor Vehicles Safety Standards No. 105 and Society of Automotive Engineers Recommended Practice J937a (Service Brake System Performance Requirements) specify " force applied to a brake control of not less than 6.8 kg and not more than 68.2 kg" unless otherwise specified. However one test requires 10 "spike stops" (90.0 kg applied to the control for 0.08 seconds).

As demonstrated by Aoki (1960) and Mortimer (1970) the fifth percentile woman is weaker than the first percentile man. Chernicoff (1974) estimated that 44.24 % of the U.S. licensed drivers are females. On the basis of the above information it is worthwhile to consider female force capabilities.

There has been considerable discussion in the government and in the auto industry as to whether the 90.9 kg of force allowed is realistic when consideration is given to actual usage and the pedal force capabilities of the weaker portion of the driving population.

The maximum force which can be exerted on a brake pedal depends on several parameters such as the driver's sex, age, height, weight, strength, position of the driver, and the friction between the clothing and the seat.

This study will emphasize the effect of the body position of the driver on brake pedal force capability with the other parameters controlled.

LITERATURE SURVEY

Several experiments have been conducted to find brake pedal force capabilities and factors influencing the capability.

Elbel (1949) defined leg strength and leg endurance for his experiment while he tried to establish a relationship between leg strength, leg endurance and other body measurements.

Leg strength (kg): Maximum forceful extension of the leg hip against the resistance furnished by the dynamometer (initally the leg is resting on dynamometer).

Leg endurance (seconds): Amount of time the subjects could exert sufficient force by sustained contraction of the leg and hip muscles to hold the dynamometer indicator at a predetermined figure.

In his experiment the seating position was such that the knee angle was $115^{\circ}\pm5^{\circ}$ and the ankle angle was $60^{\circ}\pm5^{\circ}$.

Mean leg strength for all 515 male subjects was 250.9 kg for the right leg and 234.1 kg for the left leg. He concluded that the left leg has higher leg strength than the right leg. (This was not proved statistically as σ was not calculated.) He found no difference in the endurance limits of the right vs left leg.

The weight of the subject and the strength were positively correlated ($r = + 0.52$); that is, a heavier subject could exert more force (see Fig. 1).

Martin and Johnson (1952) conducted an experiment on 166 Army men. There were 28 positions of the seat. The seat was adjustable such that the vertical distance between the

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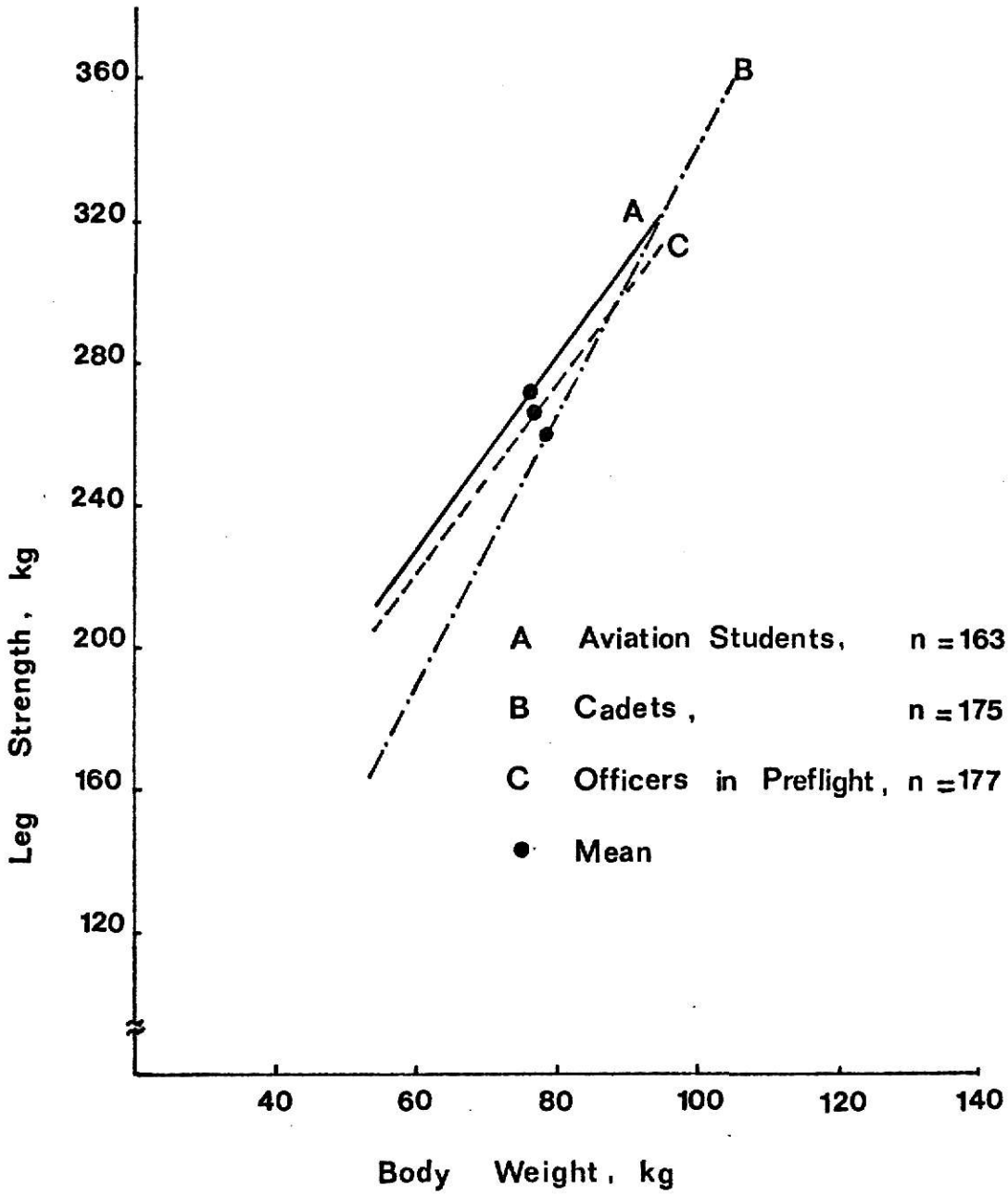


Fig. 1 Relationship Between Leg Strength and Body Weight by Elbel

pedal and the seat reference point (SRP) was from 45.7 cm below SRP to 29.2 cm above SRP: horizontally it was from 73.7 cm to 111 cm.

Changes in the horizontal distances from the SRP to the pedal affected the foot pedal pressure more than changes in vertical distances from SRP to pedal. In Fig. 2 all 28 positions are plotted giving both the rank and the ratio of the force on the position to the maximum force in all 28 positions. The contours are drawn for ratios 0.875, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, and 0.2.

For the greatest force on the brake pedal, the pedal should be 6.1 ± 0.8 cm vertically above the SRP and 82.6 ± 10.8 cm horizontally from the SRP.

If the vertical distance is above the SRP and H is the subject height in cm. the optimum range of the seat position to the pedal distances could be related to the body height as 1.21 H ± 10.8 cm for horizontal distance and 0.089 H ± 0.8 cm for vertical distance. They have not specified anything about the experimental situation and also they have not said anything about the measured response, i.e. for how long the force was applied and how it was measured.

Rees and Graham (1952) defined waist level as a position in which the subject feels the back rest fits his back most comfortably. With 20 subjects, the greatest push corresponded to a back rest position 5.1 cm above the waist level. The maximum force was exerted when the backrest was at a mean of 29 cm above the seat. Mean force was 174 kg with σ = 6.9.

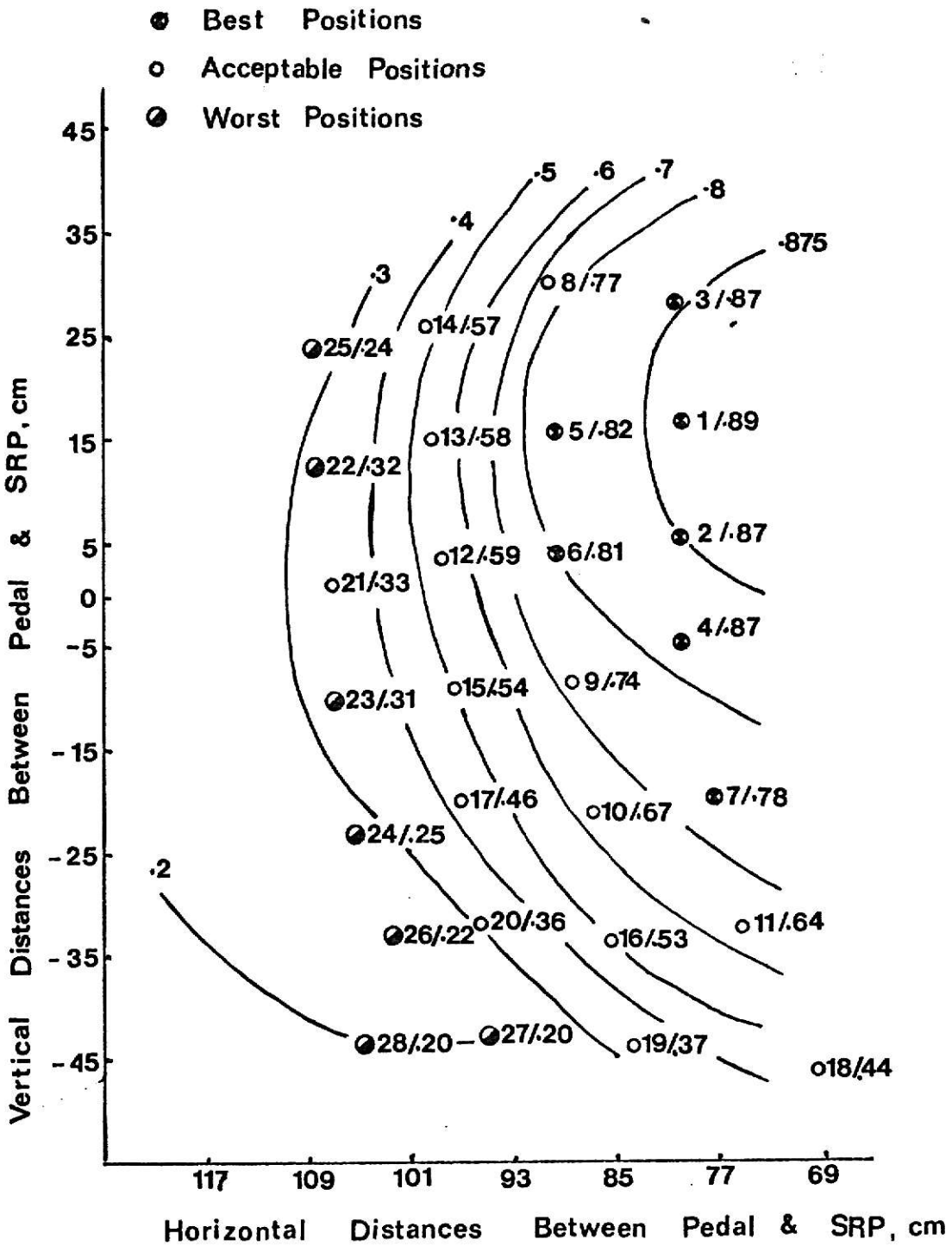


Fig. 2 Ranked Position by Johnson & Martin and Contours of Ratio EI. The First Number Is The Rank and The Second Number Is The Ratio EI. SRP = 0·0.

Maximum force was exerted with $\alpha = 15^{\circ}$, $\beta = 160^{\circ}$ and the pedal 12.7 cm above SRP (see Fig. 3). There was no significant correlation between the maximum force exerted by an individual and an individual's height, weight, lower leg length, upper leg length or total leg length.

In another experiment they found maximum force was attained when the pedal was 11.4 cm above the SRP and the back rest between 30.5 cm to 35.6 cm above SRP; mean force was 145 kg with $\sigma = 7.7$. They do not specify the duration of the applied force. Fig. 4 shows the results of the experiments.

Dupuis and Kreuzach (1957) found that for maximum force the best position of the pedal was:

$$H = L - A$$

$$V = SRP - 15.5$$

Where H = Horizontal distance from the seat reference point, cm

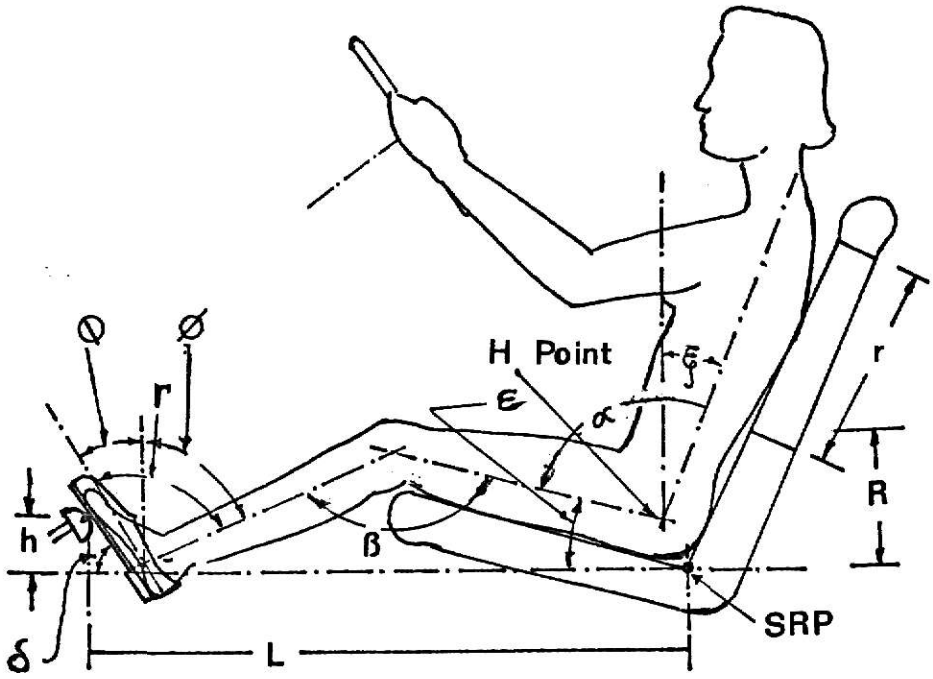
L = Leg length (extended); cm

A = 5.1 to 10.2 cm

V = Vertical distance from seat reference point, cm

SRP = Seat reference point, cm

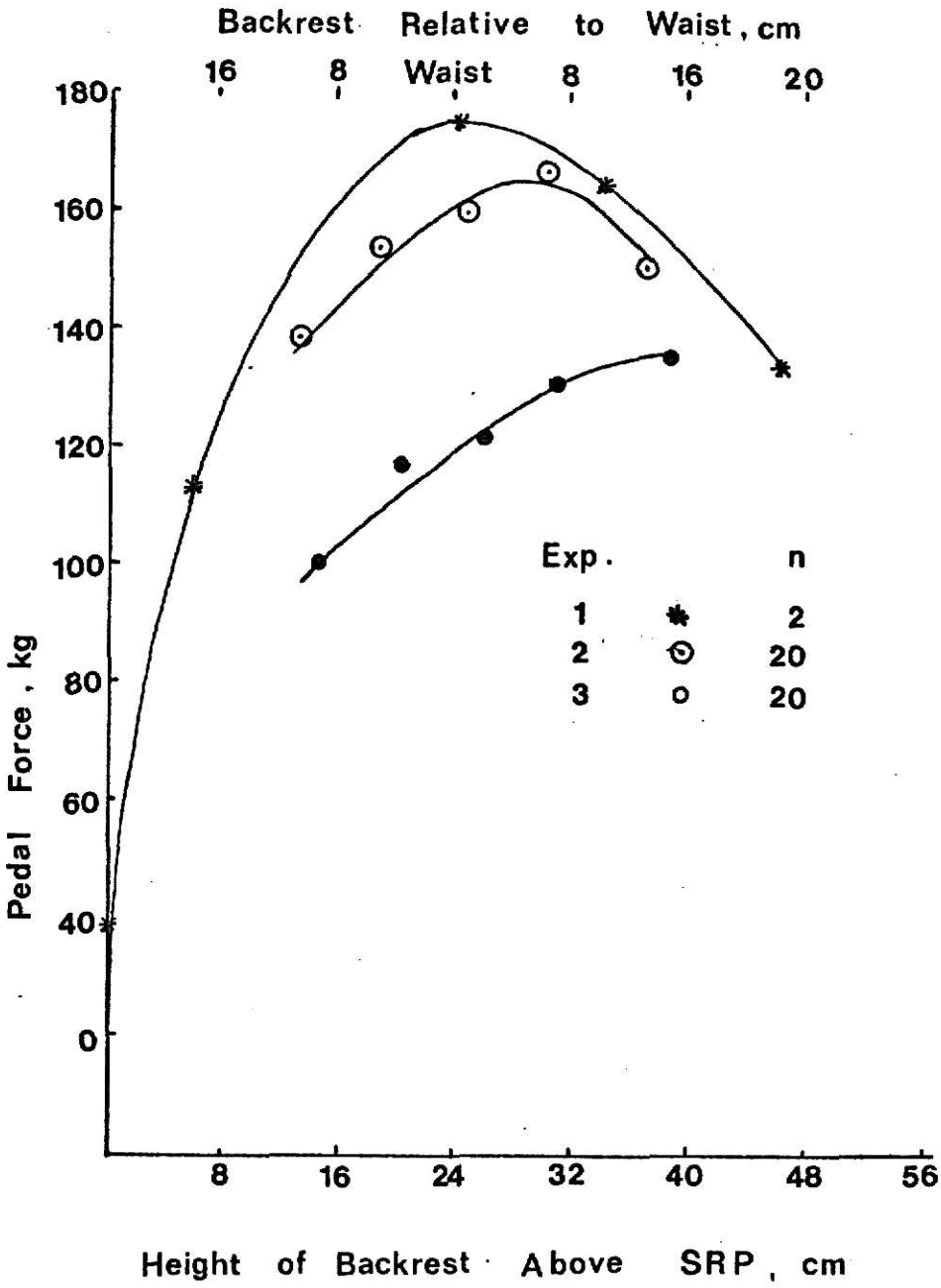
They did not define "extended leg length", but from their description, I understand that the extended leg length is same as buttock foot length given for seated operator in G-13, page 5-17 of Woodson and Conover. Dupuis and Kreuzach state that for maximal force, $\phi = 70^{\circ}$, but did not mention the sample size, situation of the experiment, response measure, or duration of the applied force.



L, Horizontal Distance

h, Vertical Distance

Fig.3 Body Posture and Related Dimensions



F'g. 4 Backrest Positions vs Force by Rees & Graham

Aoki (1960) conducted an experiment on 60 Japanese male drivers, 54 highschool girls of 16 years of age and 37 handicapped adults (polio and disabled limb victims) of both sexes.

An experimental formula relating force versus hip joint angle α and knee joint angle β is given by

$$P(kg) = 57\left[1 - \left(\frac{|\alpha - 73|}{110}\right)^{1.35} - \left(\frac{|\beta - 110|}{185}\right)^{1.35}\right]$$

Figure 5 shows the contours of the maximum attainable force for various posture angles. The definition of the maximum force is not given and the duration of the applied force also is not specified. Figure 6 shows the distribution of the pedal force. Normal paper is used to check the assumption of normality. Normality is appropriate for males and females but it is not a appropriate assumption for the handicapped.

According to Aoki, 70 kg of force can be attained by 80 % of Japanese male drivers. In his opinion, however, this value should be reduced to the neighbourhood of 40 kg to operate the brake pedal with ease. Aoki believes that a force of 30 kg may be kept as a limit of force required to operate the brake pedal of a passenger car successfully but 20 kg of force would be a more preferable limit.

Bierly (1965)conducted an experiment in a Chevrolet on three parking brakes. The height and weight of the subjects were "not significantly different from U.S. driver's population norms." With 25 women subjects he obtained a median force of

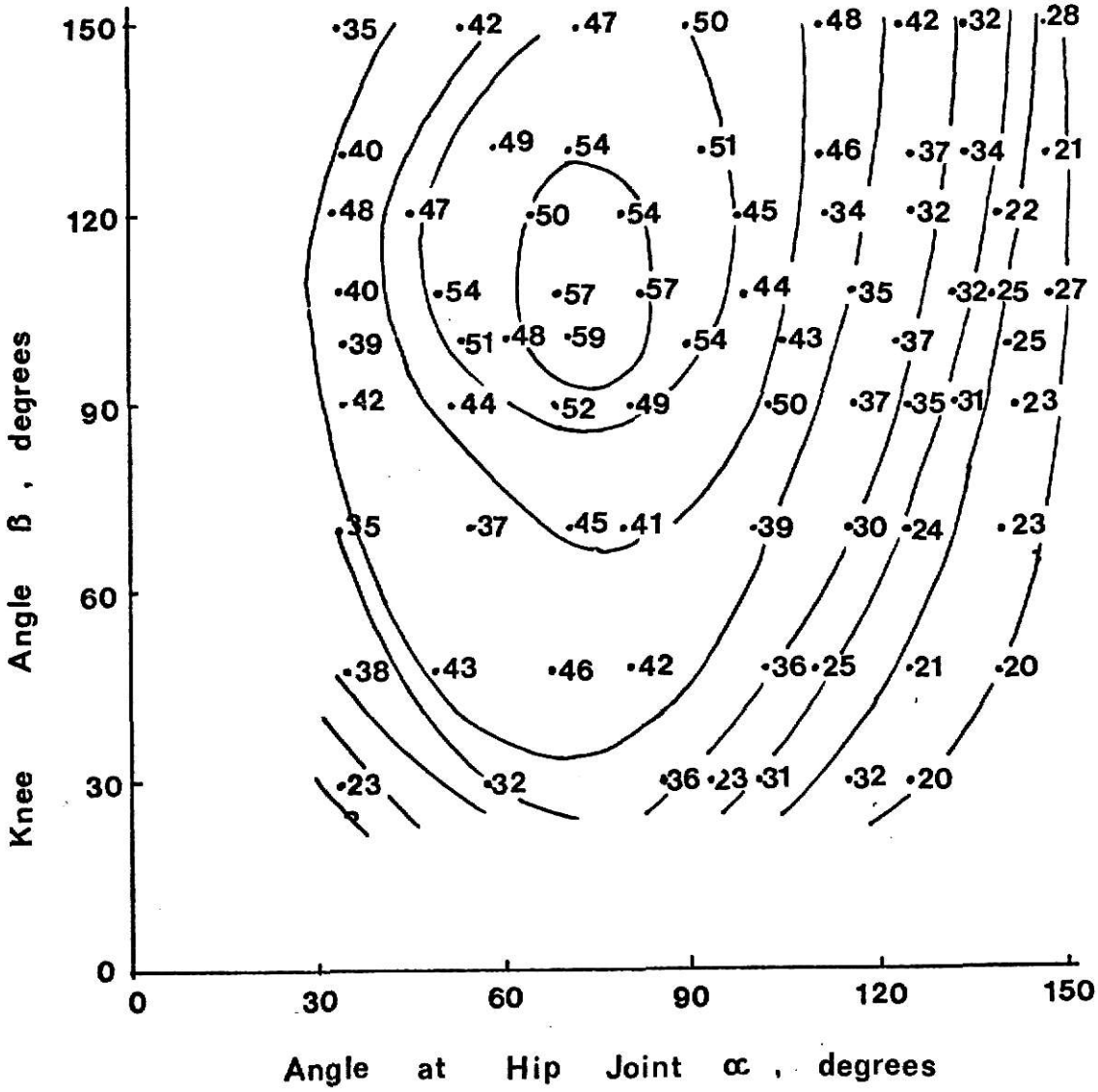


Fig. 5 Maximum Pedal Force (kg) for Various Posture Angles by Aoki

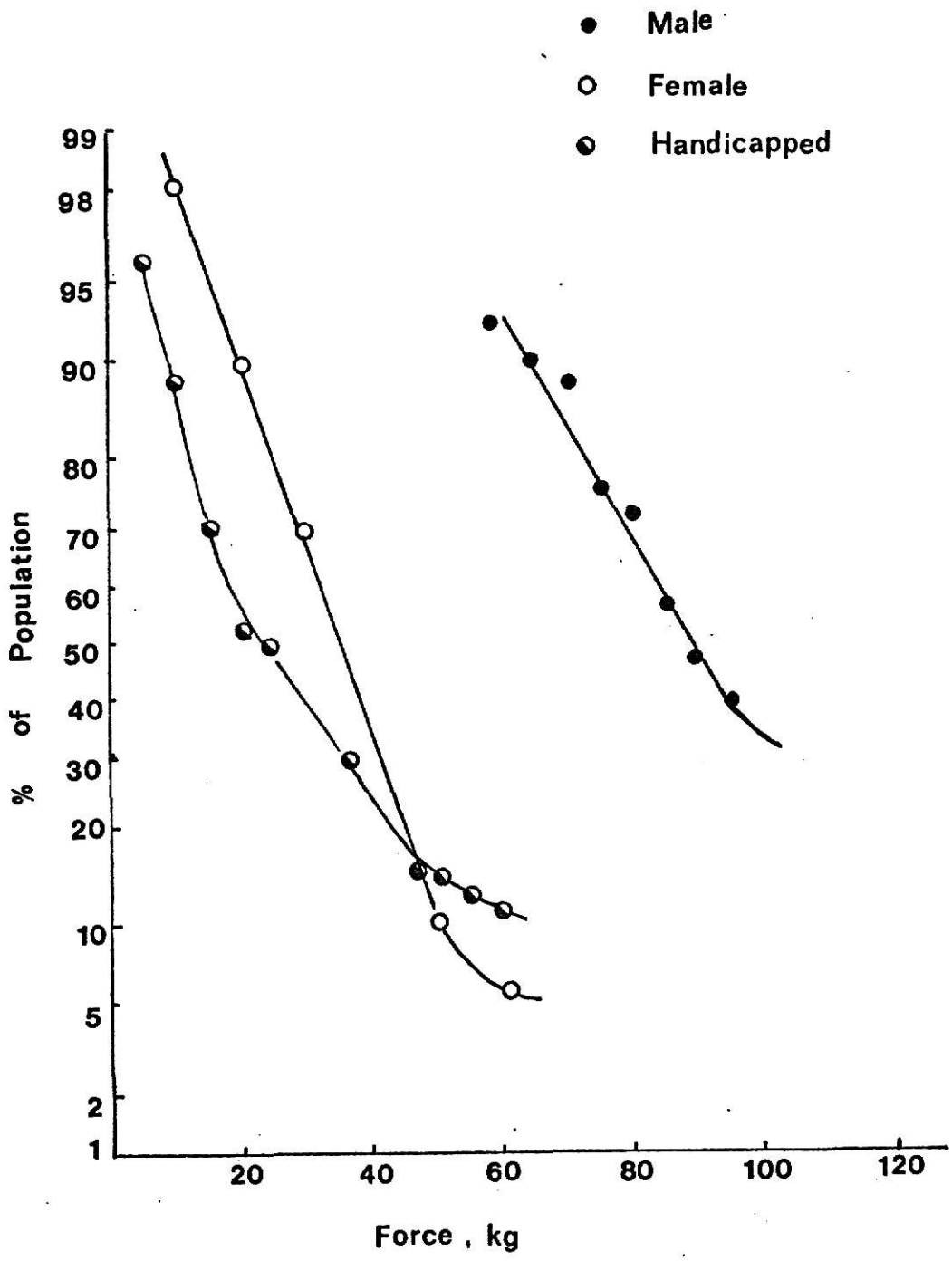


Fig. 6 Distribution of Pedal Force by Aoki

43.6 kg for the 5th percentile of the population. He did not mention the duration criterion or the equipment used to measure the applied force. He noted the important point that the angle between thigh and calf affects the appliedforce. Aoki called this angle β .

VonBuseck (1965) obtained a median force of 136.4 kg with 42 female subjects. His experiment was in the laboratory. He measured the force with a special transducer for 1, 2, 4, 6, 8 and 10 seconds. He said that there is a decrease in the force capabilities over the 10 seconds.

Eaton and Dittmeier (1970) carried out an experiment on 48 female subjects representing the stature of U.S. female population. The force was measured with a strain gauge while the subjects drove a sedan on a predetermined road path. They defined braking effort as the highest force applied at the brake pedal for a 0.5 second interval. Mean force was 72.2 kg (σ = 14) on a full size sedan and 63.2 kg (σ = 12.7) on an intermediate sedan. The difference in the mean brake pedal effort values for the two cars was the result of the large difference in the brake effectiveness of the two vehicles, with the power booster inoperative. In other words, the 63.2 kg and 72.2 kg are not a maximum force but a sufficient force.

Radlinski and Price (1970) believed that the mean force sustained for five seconds during the application is of more interest than the maximum value since the area under the force-time curve has a direct relationship to the vehicle stopping distance.

They had 105 female subjects representing the U.S. female driver population (mean of 35 years of age, 162.6 cm of height and 60.4 kg of weight). Over 50 % of their subjects could not achieve a mean of 61.4 kg. They found no relationship between the height of the subjects and the distance between the pedal and SRP for maximum force. Similarly they failed to establish a correlation between force vs height and force vs age.

Woodson and Conover (1970) drew a leg reach envelope (see Fig. 7) for pedal brakes operated by the toe and heel. They do not say what is optimized with this envelope.

They also drew a leg strength envelope, see Fig. 8, assuming "proper" back support and "optimum" leg angle although they did not give values for "proper", "optimum" or "average man". Area A and B in Fig. 8 represent a force of 181.8 kg and 272.7 kg respectively. C represents the recommended path of the pedal travel. The authors have not given any details of the curve. I believe that the distances are from the SRP to the center of the brake pedal at its initial position.

Kroemer (1971) compared the previous research. In his work he cnsidered the body position and the related dimensions as shown in Fig. 3.

Fig. 9 shows pedal height with respect to SRP vs % of maximum force. Fig. 10 shows knee angle vs % of maximum force. Fig. 11 shows a distance R (back rest distance) from SRP vs % maximum leg force. Fig. 12 shows a plot of ankle angle vs % of maximum leg force.

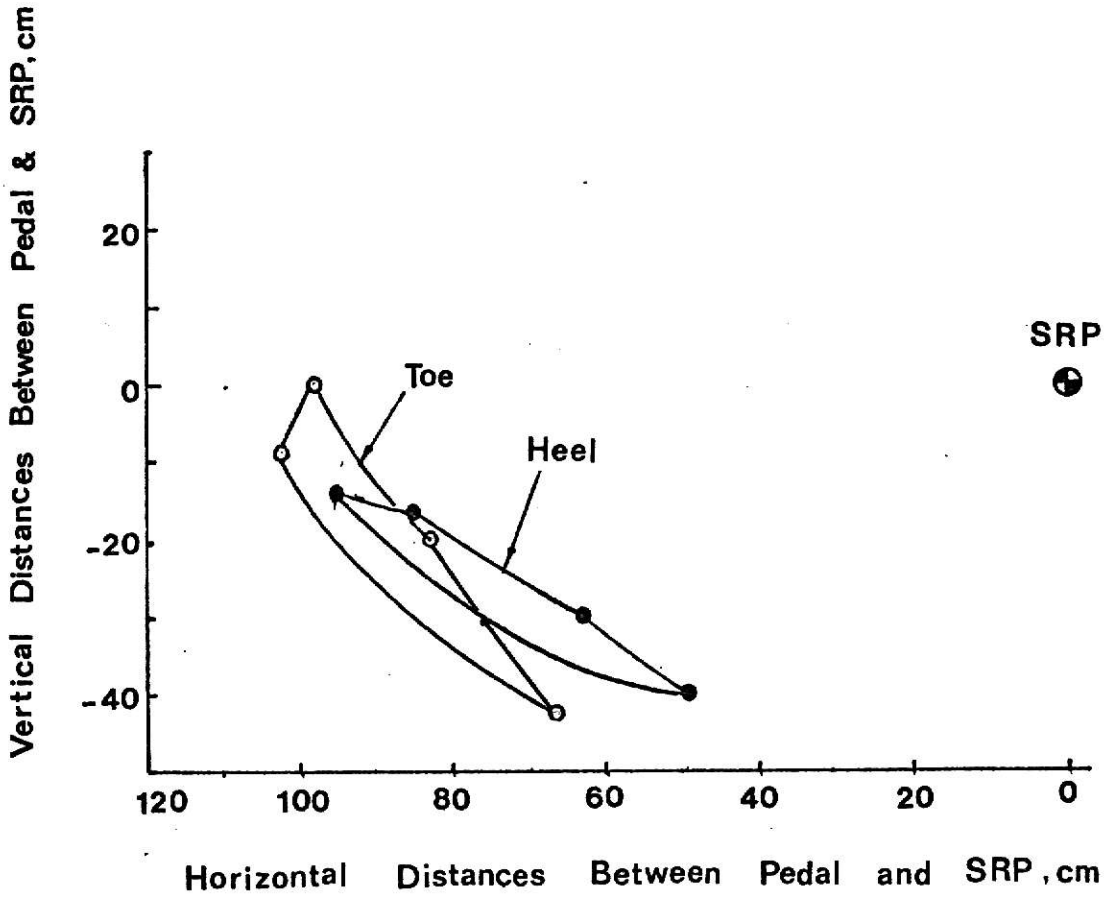


Fig. 7 Leg Reach Envelope

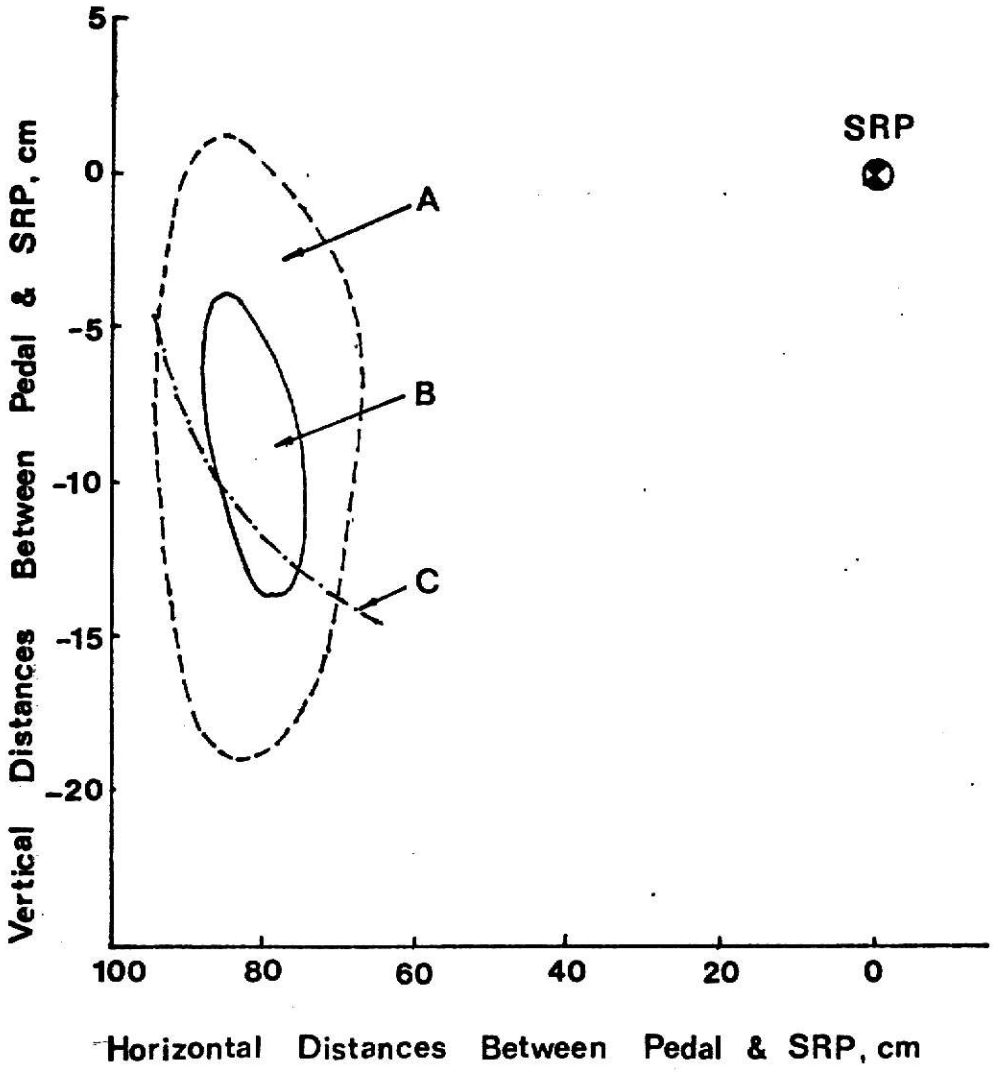


Fig. 8 Leg Strength

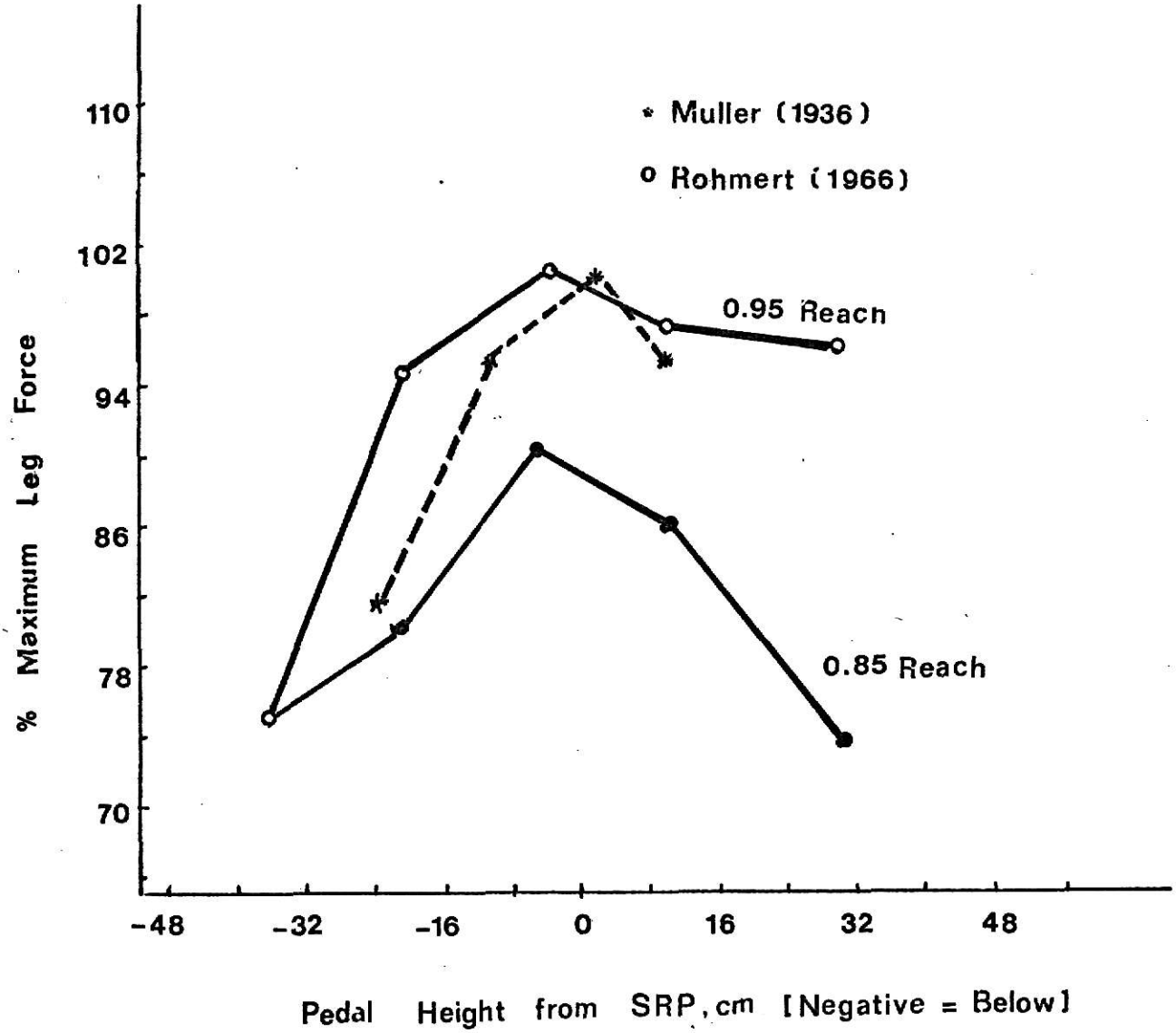


Fig. 9. Curve Plotted by Kroemer

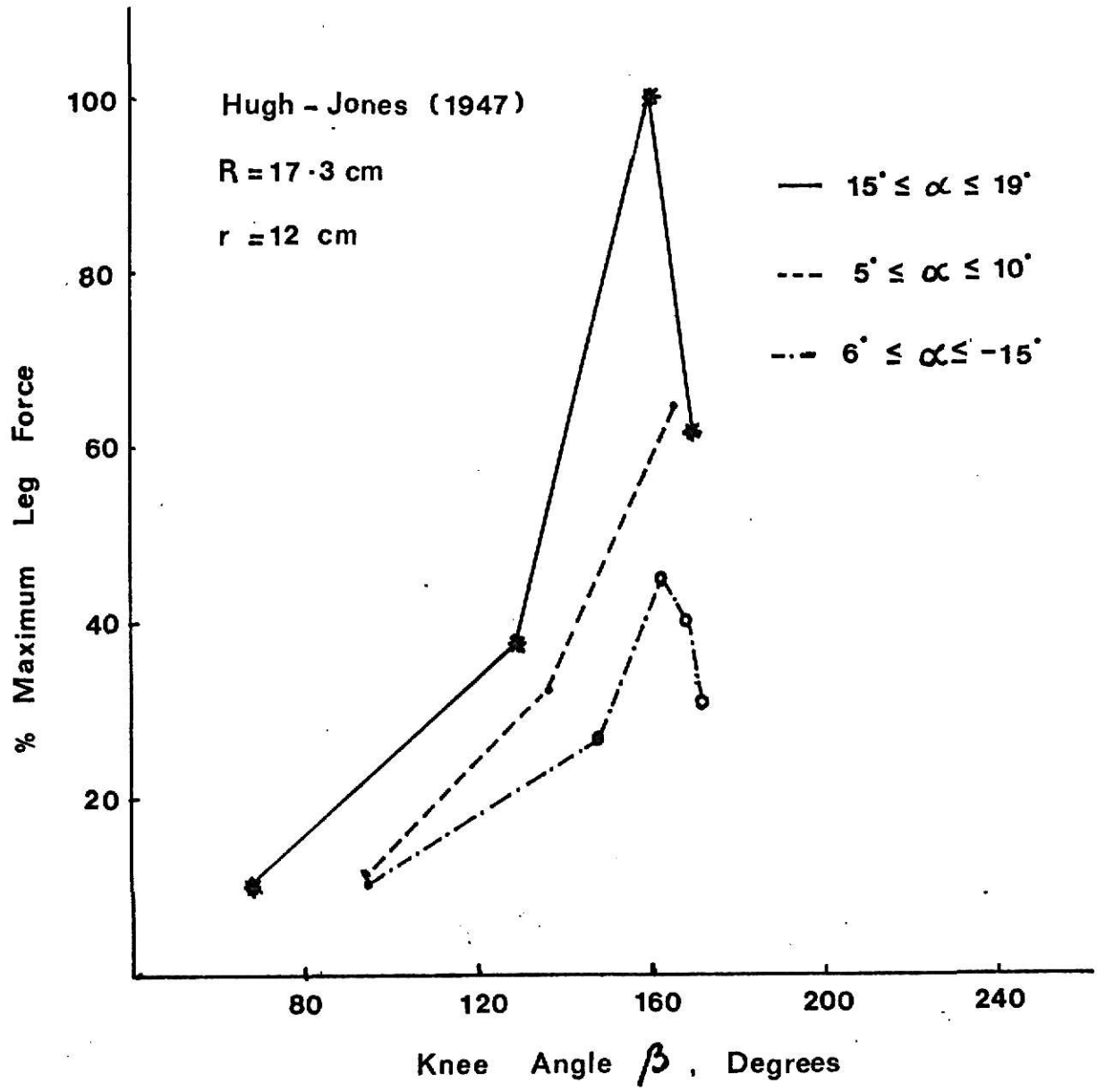


Fig. 10 , Maximum Leg Force Applied to Pedal at Different Knee Angles Plotted by Kroemer

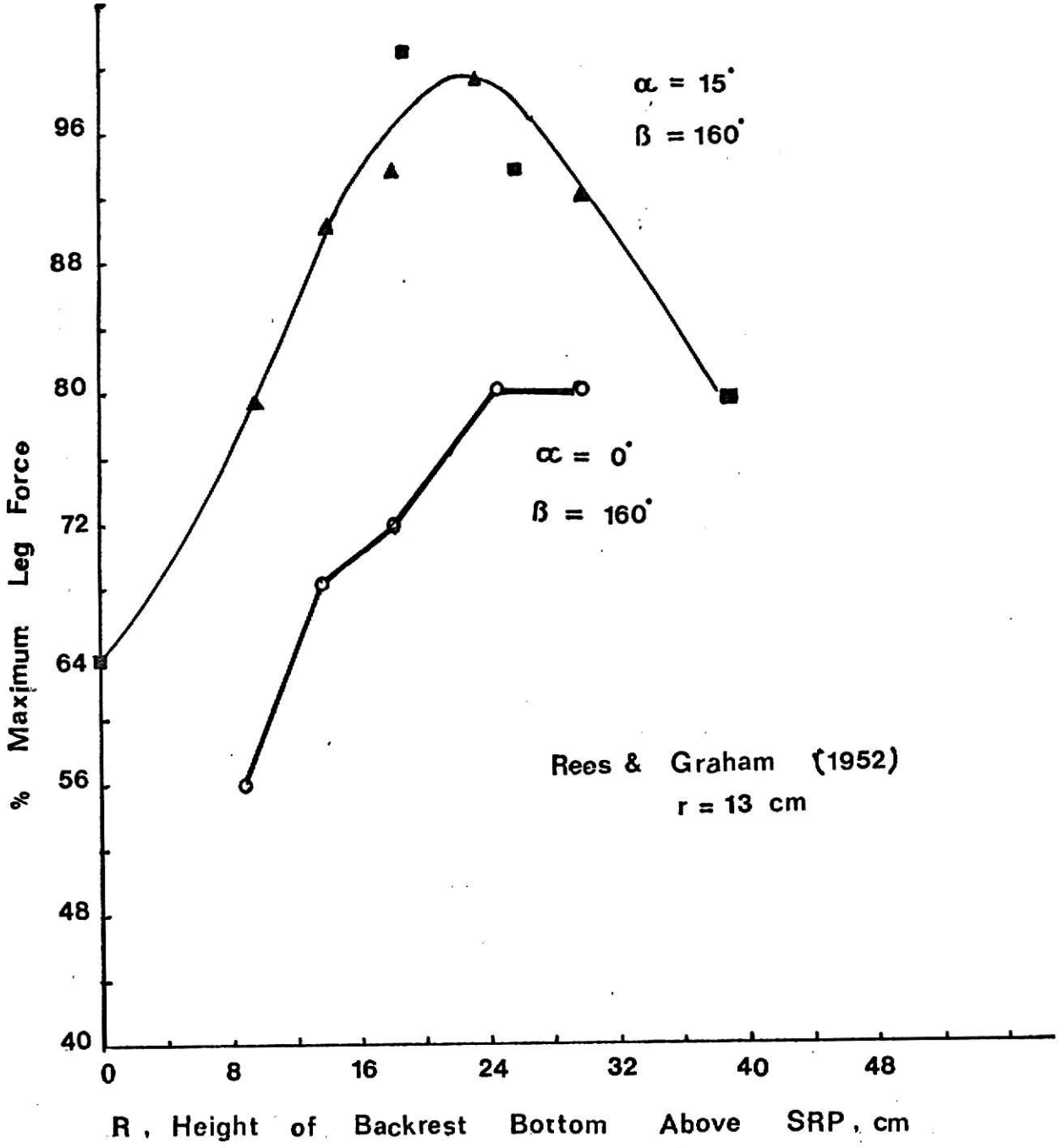


Fig. 11 Maximum Leg Force Applied to Pedal with Different Backrest Arrangements Plotted by Kroemer

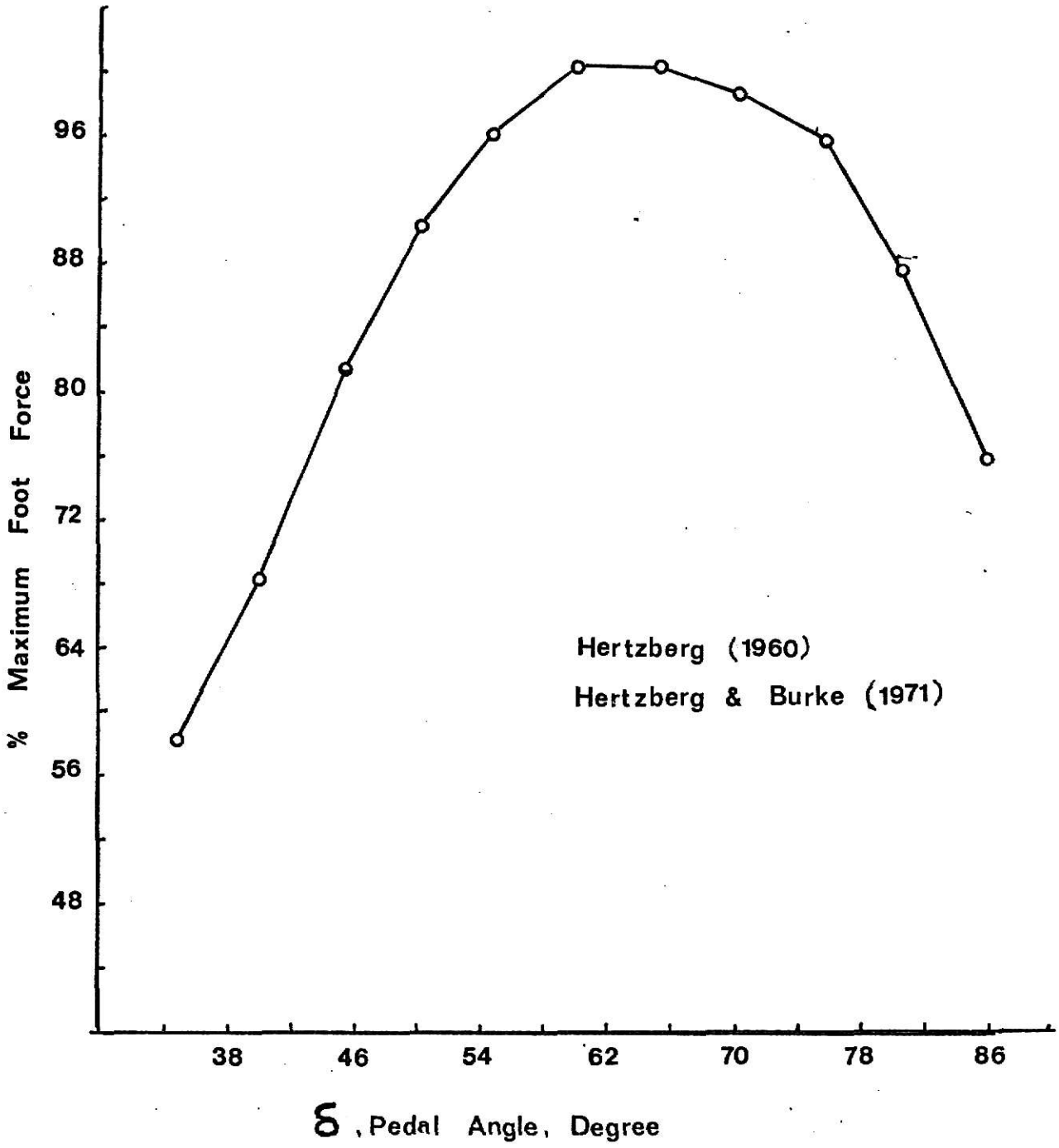


Fig. 12 Maximum Foot Force Achieved in Attempted Foot Rotation at Different Pedal Angle

Purswell, Karim and Bergey (1971) conducted an experiment on 25 female subjects in a cockpit simulator to measure strength vs endurance. They obtained a mean leg force of 80.4 kg(σ=20.9).

Pierce, Woodson and Selby (1972) measured the force on 182 U.S. licensed female drivers with a strain gauge attached at the brake pedal pivot. The maximum reading obtained in a trial was defined as maximum brake force. They did not measure the duration of the applied force.

Their conclusions are: (a) the force measured in a stationary vehicle is higher(10 %) than when the vehicle is in motion,(b) they tentatively recommended that 30 kg be the maximum force required to obtain a full braking for 5th percentile of the U.S. driver's population.

Mortimer (1974) conducted an experiment in a simulator on 276 female and 323 male drivers. Females were 16 to 79 years of age (mean of 32), 40 kg to 101 kg of weight (mean of 61.8 Kg). Male drivers were 16 to 89 years of age (mean of 32), 54.1 to 129.1 kg of weight (mean of 80.9).

He obtained a correlation coefficient of 0.24 between body weight and force. He reported 41 kg as a fifth percentile female maximum brake pedal force. He has not given the mean or duration of the applied force.

Roe (1973) collected data about preferred seat positions. Fig. 13 plots this data and confidence bands.

It is difficult to compare published data on force exertable on pedals because (1) experimental set ups are not described completely, (2) instructions to the subjects are not described, (3) the definations of the measurements of force are not described.

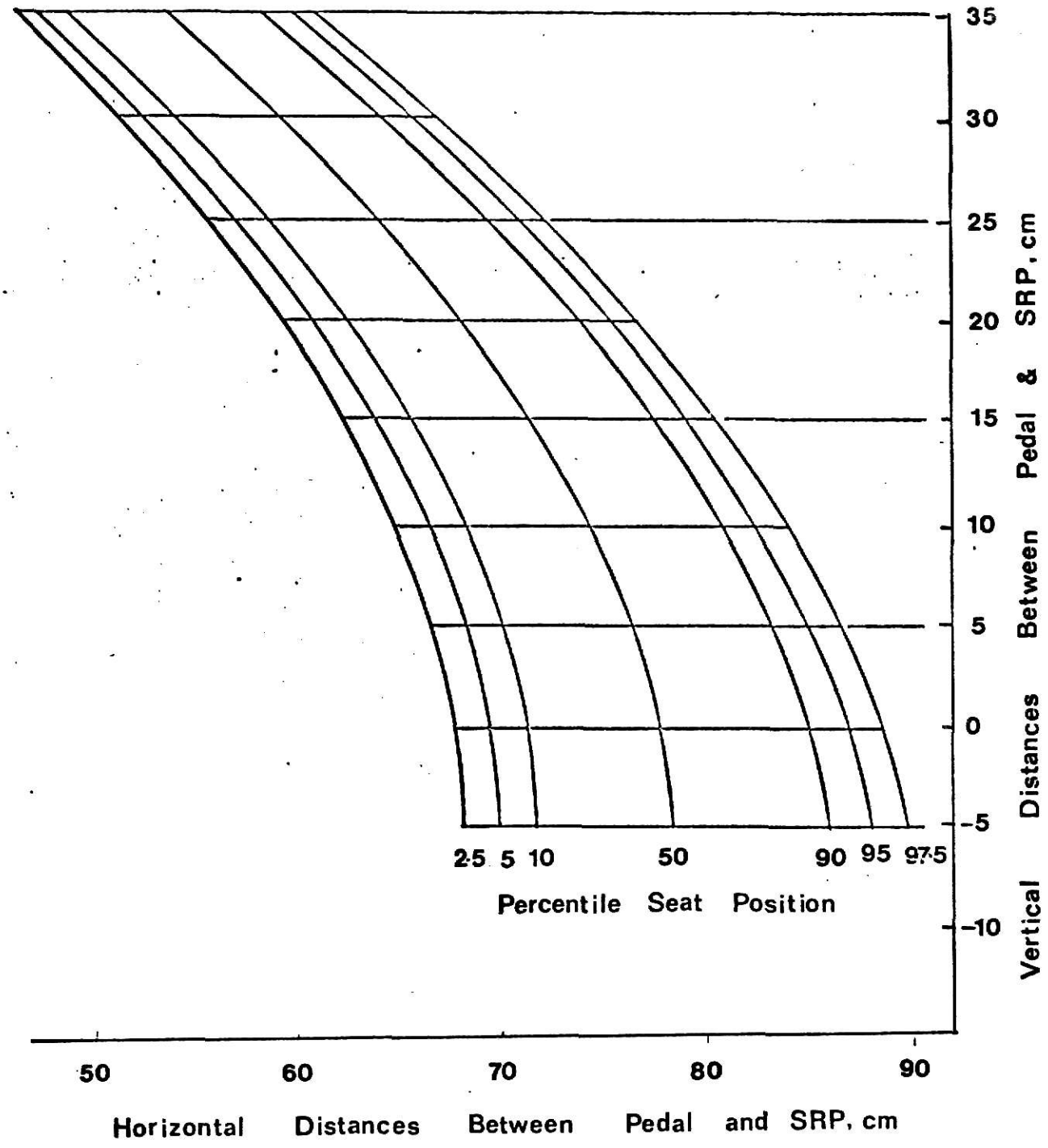


Fig. 13 Preferred Seat Positions

Konz (1974) described the various aspects to be considered in deciding the limits for a brake pedal force.

For determination of percentile of the population from the sample, he suggests normality be assumed. Calculation of the estimates of the parameters of the population should be made with the mean and standard deviation of the sample.

Regarding the effect of sex, he pointed out that females have lower force capability than males and hence the limit should be set on the basis of the weak female capability. It is important to note that too low a limit may cause trouble as a strong male can lock the wheels.

He discussed the effect of age and stated that there is a decline in strength with age. As demonstrated by Asmussen and Heeboll-Nielsen (1962), there is a decline in capability of adults once they are "over the hill"; the hill starts around age 30. Konz states that within the ranges of ages studied, age has a low correlation ($r=0.10$ to -0.20) with pedal force capability. He belives that a decline of 0.09 kg/year is a typical decline. While discussing the force over a time, he assumes that 80 % of the peak value is available for a period of 5 sec. He also says that the force over a time greatly depends upon the capability of the driver.

In describing the effect of seat resistance, he stated that the effect of the auto seat vs a rigid back seat does not seem to be major and that auto seats probably cause less than a 5 % decrement in force, if any.

For relation to seat reference point, he said that this is an important variable and force capability is very sensitive to it. Yet insufficient data are available to say what is the optimum value of distances for maximal force and what affects force the most, the horizontal or the vertical distances from SRP.

Additional pedal travel is another variable and, if additional travel is more than 12.7 cm, the decrease in the maximum force is highly significant (about 40 % reduction). It seems to be reasonable that additional pedal travel may lie within 5.1 cm to 12.7 cm for power assisted brakes which fail.

Brake force in a static vehicle will be higher than in a moving vehicle because the driver has to do other tasks while driving and he applies only the necessary force rather than maximum. With the reference to the Pierce data, Konz calculated that the moving vehicle has 29 % less force than the static vehicle. If this is true, the limit should be based on moving vehicle force capability only.

Konz also states that there is no significant difference between right and left foot forces. For a matter of simplicity it is recommended to assume both the feet equal, neither stronger nor weaker.

As a broad conclusion, he states that a relatively large amount of work is desirable to establish the limit on the force. He stresses that the study should be made to know the pedal location's effect on force with respect to SRP and effect of learning is also to be investigated.

I had an opportunity to do a pilot study (1974) on

pedal forces. I ran an experiment on 6 female subjects. They operated a brake pedal for 6 times in each of 8 different seat positions for a length of 5 seconds in each trial.

The mean maximum forces (peak value attained in 5 seconds was defined as maximum force) for each subject were 50, 64, 40, 43, 47, and 47 kg. The overall mean for all subjects was 50 kg. The horizontal distances between the pedal and SRP had a significant effect on the pedal force. It was found that

$$F = 358.60 - 4.63\ C + .0206\ C^2 \qquad SE = 3.5\ \%$$

Where F = Subject's percent force relative to group's force

C = (pedal to SRP distance) /Individual's crotch length .

There was no significant learning or fatigue effect.

METHOD

Task

The subjects were asked to sit on the simulator seat, fasten the seat belt,hold the steering wheel, watch the movie " Driving in the city ", enjoy the background music, and, upon the lighting of red light signal (situated on the right hand upper corner of the movie screen),push the brake pedal as hard as possible and hold it for 5 seconds. They were also asked to give their opinion about the comfort of the seat. The movie " Driving in the city " was an instructive movie for driver training. The movie showed what the driver has to do at various signals and signs in the city.

Subjects

There were four female subjects (age mean = 21.4 years, σ = 1.2 ; height mean = 164.8 cm, σ=6.2 ; weight mean = 54.3 kg, σ= 4.6 kg). The subjects worked for 2 hours and were paid $ 4 each.

Measurements

The following data were collected for each subject.

1. Name, address, phone number, social security number (for payments), birth date, and driving experience (see appendix 1).
2. Measured height with shoes, cm
3. Crotch length, cm
4. Weight, kg
5. All angles and dimensions as shown in Fig. 3
6. Horizontal and vertical distances of each seat position from SRP, cm
7. Force for each position (2 observation per position),kg
8. Subject's opinion about seat position, categorize as
   1 Very good
   2 Good
   3 O.K.
   4 Poor
   5 Very poor
9. H poit (refer to Fig. 3)

Item 2 was measured with a tape. The subjects stood against a wall with hips and shoulder touching the wall and a horizontal mark was made on the wall. This mark then was measured from the floor in cm. The subjects had their shoes on.

Item 3 was measured with the tape. The subject stood straight and the measurement was taken from the crotch to the floor.

Item 4 was measured with a Fairbanks-Springless F713389,an accurate weighing scale.

Item 5 angles , and were measured with the device shown in Fig. 14.

Item 6 The different positions of the seat were measured horizontally and vertically in cm from SRP.

Item 7 The brake pedal force was measured as follows.

A linear potentiometer (7.5 kilo-ohms,3.33 cm travel, model 108 BOURNS) was linked to the brake pedal spring push rod; see Fig. 15. The potentiometer was fed with 5 volt D.C. from a constant voltage power supply. The traverse of the pedal was converted into an electrical signal through the potentiometer, attached to the spring push rod. The brake pedal was also loaded with some other springs such that total force capability of the pedal was 88.7 kg; see Fig. 16. The springs have a linear deflection with respect to the force. Thus the linear movement of the potentiometer linearly measures the force. The generated signal was then recorded on a 3960 Hewlett-Peckard instrumentation tape recorder. The whole setup is illustrated in a block diagram in Fig. 17.

Calibration of the system was done with the device shown in Fig. 18. Known weight were kept and the respective output from the potentiometer was noted. The setup of the instrumentation for calibration

Scale 1cm = 2.5cm

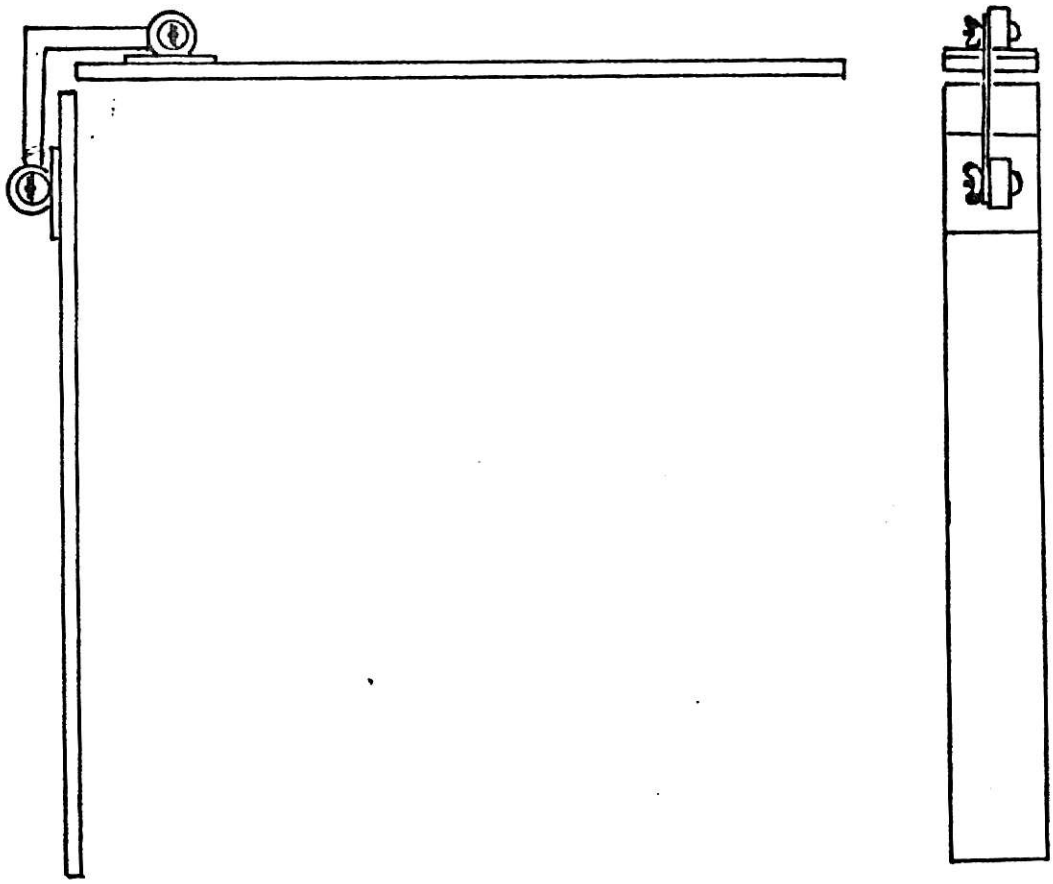
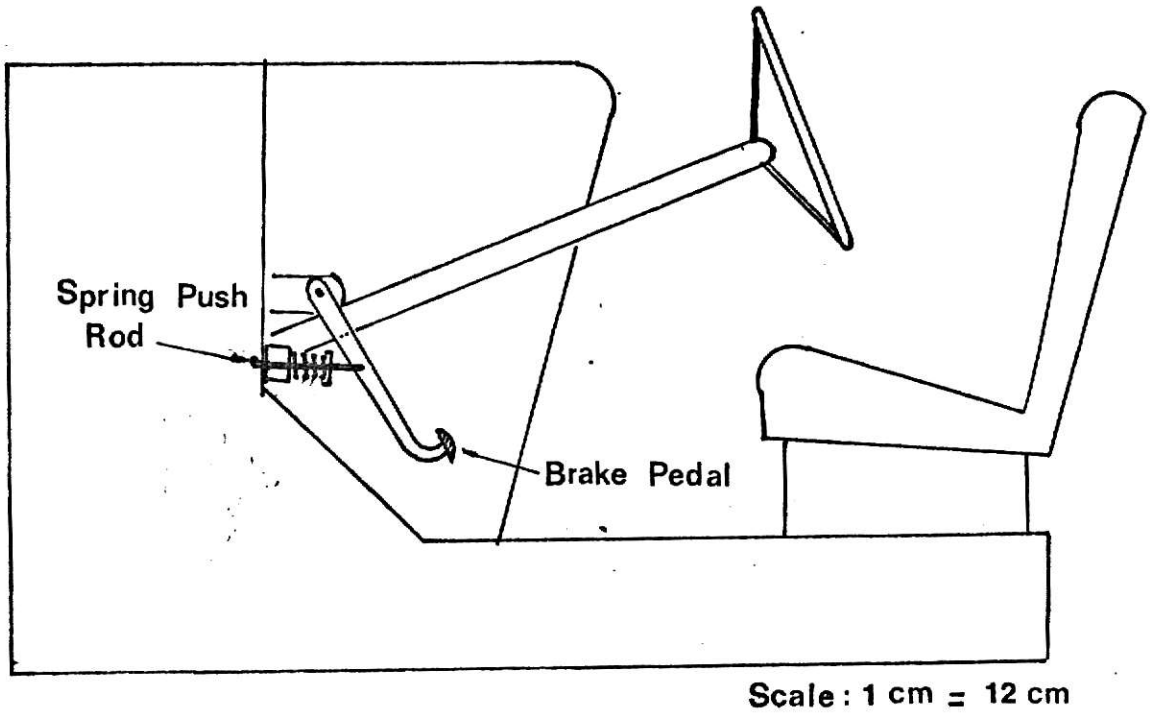


Fig.14 Angle Protractor for Measuring α, β, and γ Angles



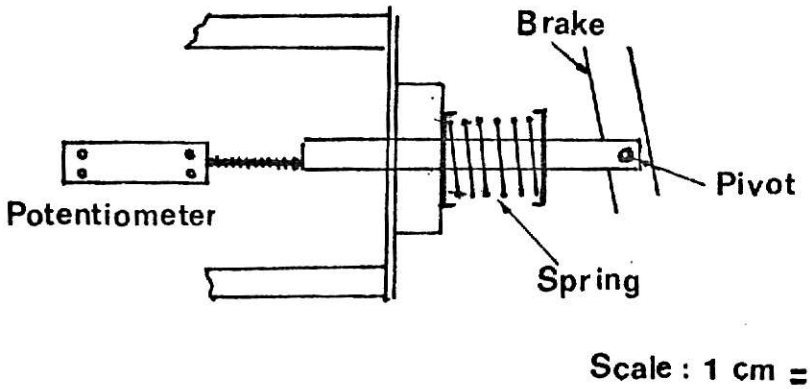


Fig. 15 Details of Spring Push Rod and Attached Potentiometer

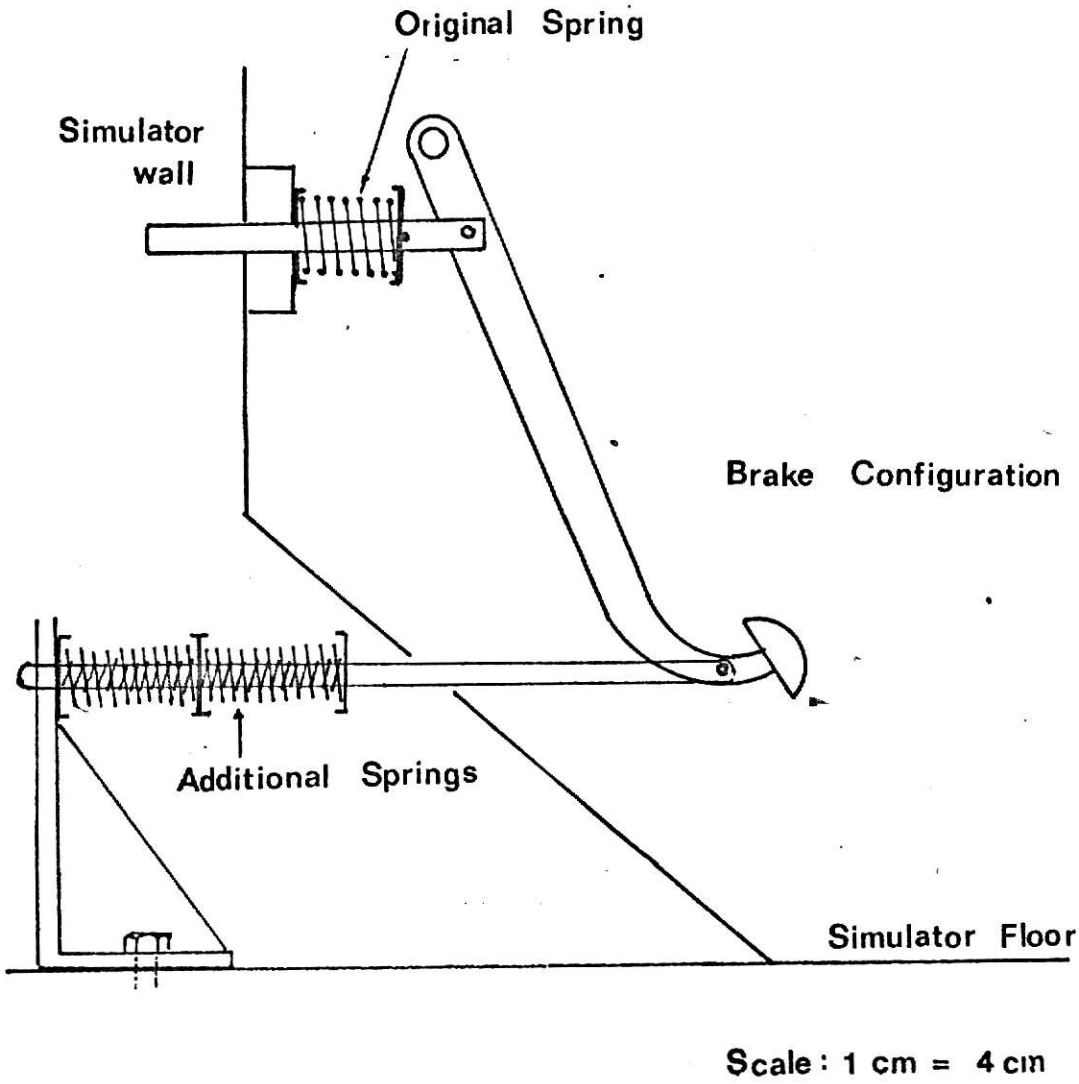


Fig. 16 Spring Arrangement

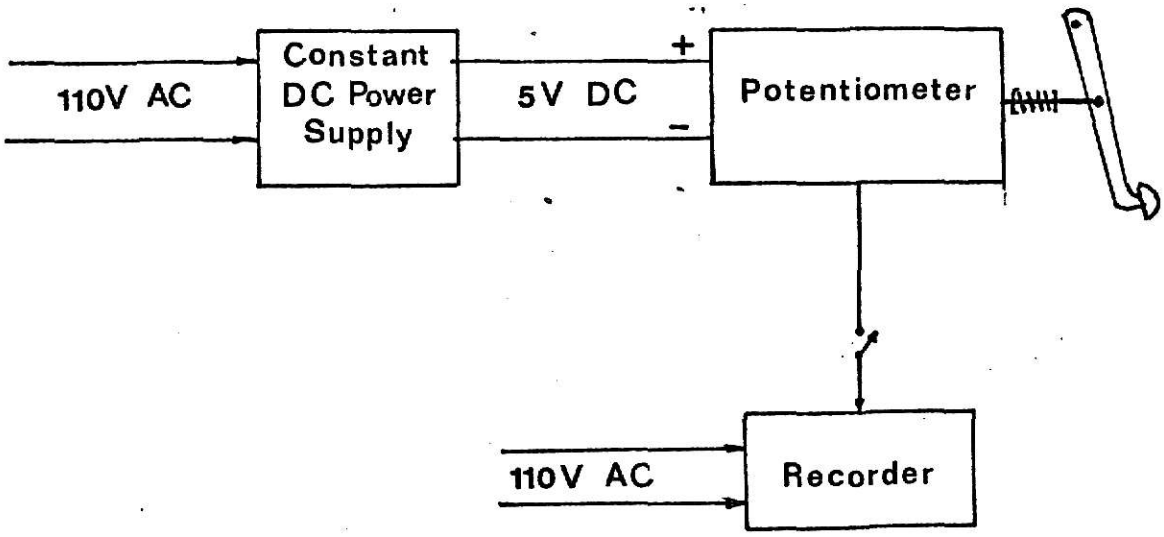


Fig. 17 Schematic Instrument Setup For Force Measurement

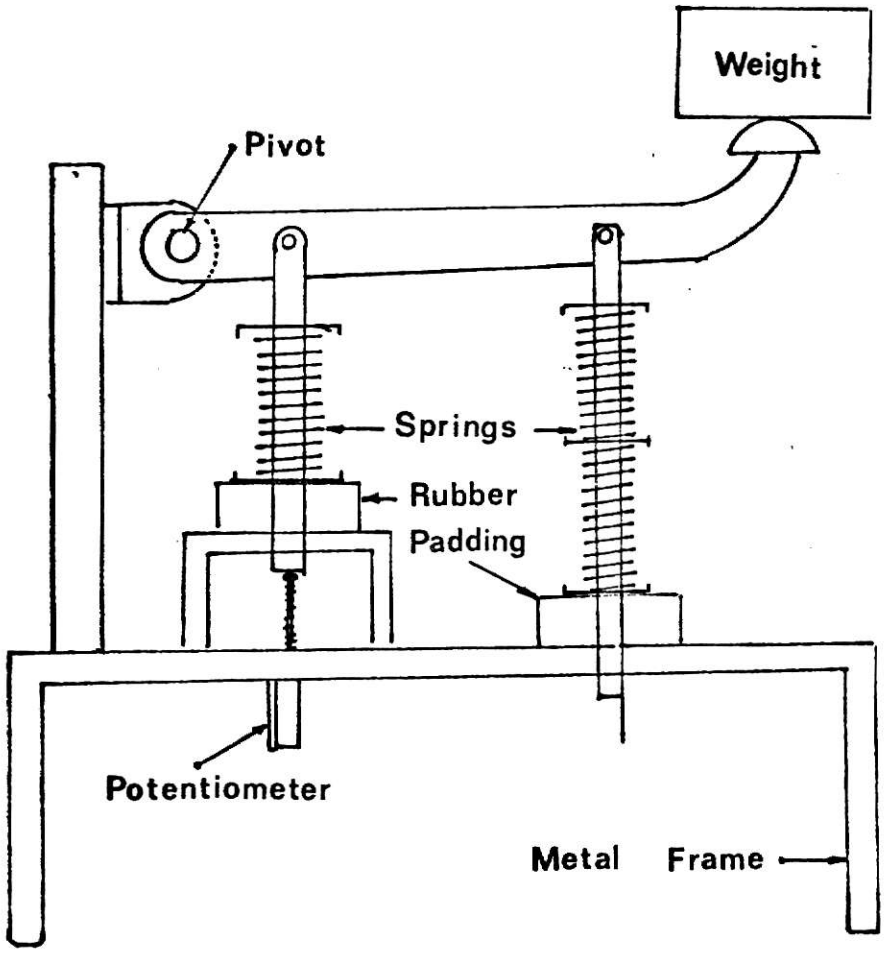


Fig. 18 Calibration Device

was as shown in Fig. 19.

Calibration observations are tabulated in Table 1 and are plotted in Fig. 20. The calibration equation is:

Force, kg = 23.7 + 30.66 V

Where V is in volts.

Item 8 was asked for each position and was noted.

Item 9 H point was measured with the device shown in Fig. 21. The instrument was placed on the thigh and torso joint and the horizontal and vertical distances of this joint from SRP were noted. The respective H dimension then was calculated.

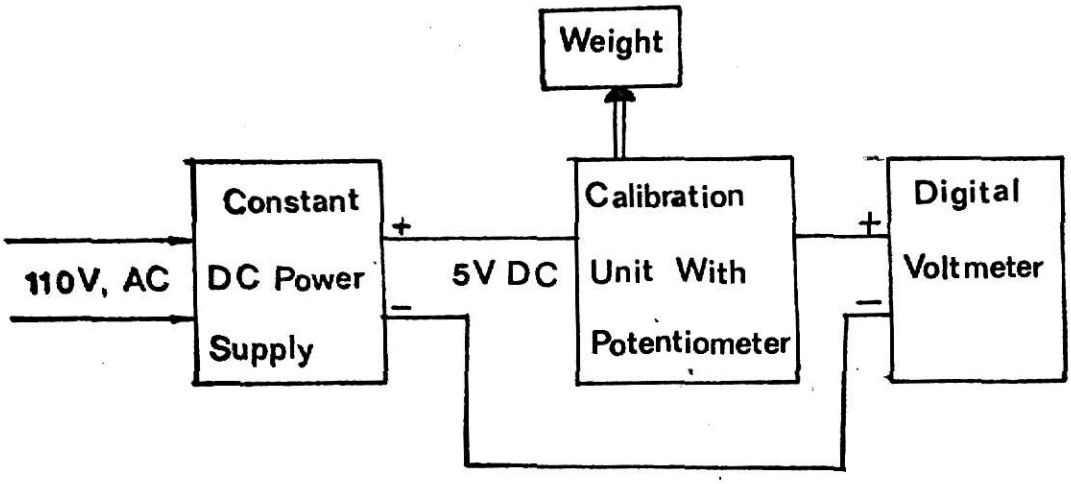


Fig. 19 Schematic Diagram for Calibration Instrumentation

Table 1

Calibration Observations

Observation Number	Weight in kg	Output signal in volts
1	20.0	0.04
2	31.6	0.07
3	41.4	0.22
4	56.4	0.57
5	70.7	0.80
6	79.8	0.88
7	85.0	0.95
8	88.7	1.10

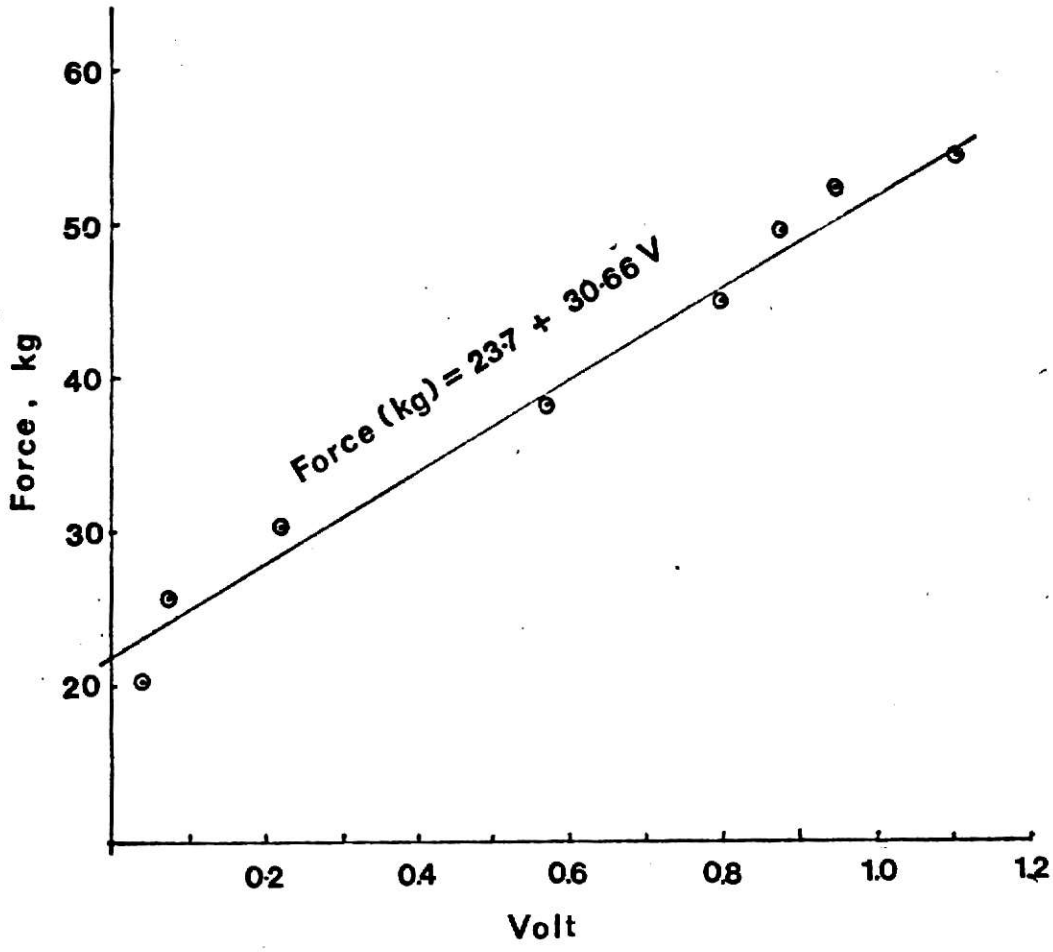
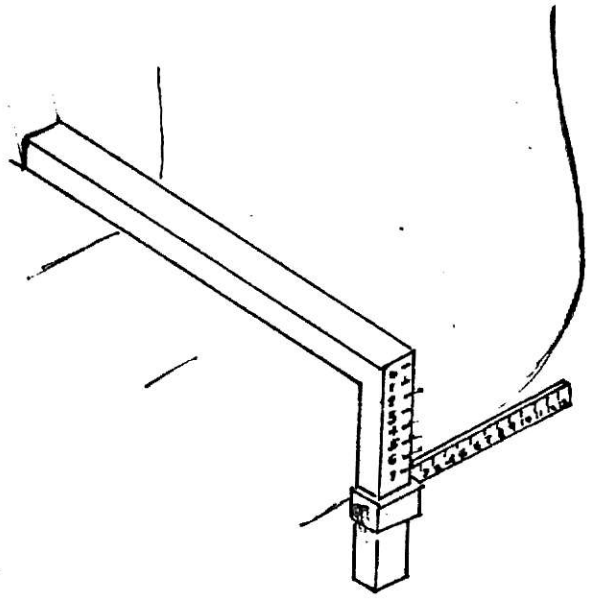


Fig. 20 Calibration Curve



Scale : 1 cm = 12cm

Fig. 21 Device for H Point Measurement

Procedure

The subject's canvas top shoes and jean clothing were kept more or less identical to keep the same resistance between brake vs shoes and cloth vs seat. Very thin shoes and very smooth clothes were not permitted.

The information blank (appendix 1) was completed and instruction sheet (appendix 2) was read to the subject. There were 25 seat positions as listed in Table 2 and as shown in Fig. 22. In each position there were two trials. The randomly selected position sequences, as tabulated in Table 3, were followed for the first trial and mirror images of these sequences were followed for the second trial.

The background music was turned on.

The seat was adjusted, subjects were asked to sit down, fasten the seat belt and put their foot on the brake pedal. The angles (at hip joint, knee joint, and heel joint) were measured. Their opinion of the position's comfort was noted. The movie was run. The magnetic tape recorder switch and potentiometer switch was put on. The red light signal was turned on and was kept on for 5 seconds. The tape recorder switch and the potentiometer switch was turned off.

Table 2

List of Seat Positions

Condition	Horizontal Distance from SRP, cm	Vertical Distance below SRP, cm
01	90.2	- 0.64
02	91.5	- 0.64
03	94.0	- 0.64
04	96.5	- 0.64
05	97.8	- 0.64
06	90.2	0.64
07	91.5	0.64
08	94.0	0.64
09	96.5	0.64
10	97.8	0.64
11	90.2	1.9
12	91.5	1.9
13	94.0	1.9
14	96.5	1.9
15	97.8	1.9
16	90.2	3.2
17	91.5	3.2
18	94.0	3.2
19	96.5	3.2
20	97.8	3.2
21	90.2	4.5
22	91.5	4.5
23	94.0	4.5
24	96.5	4.5
25	97.8	4.5

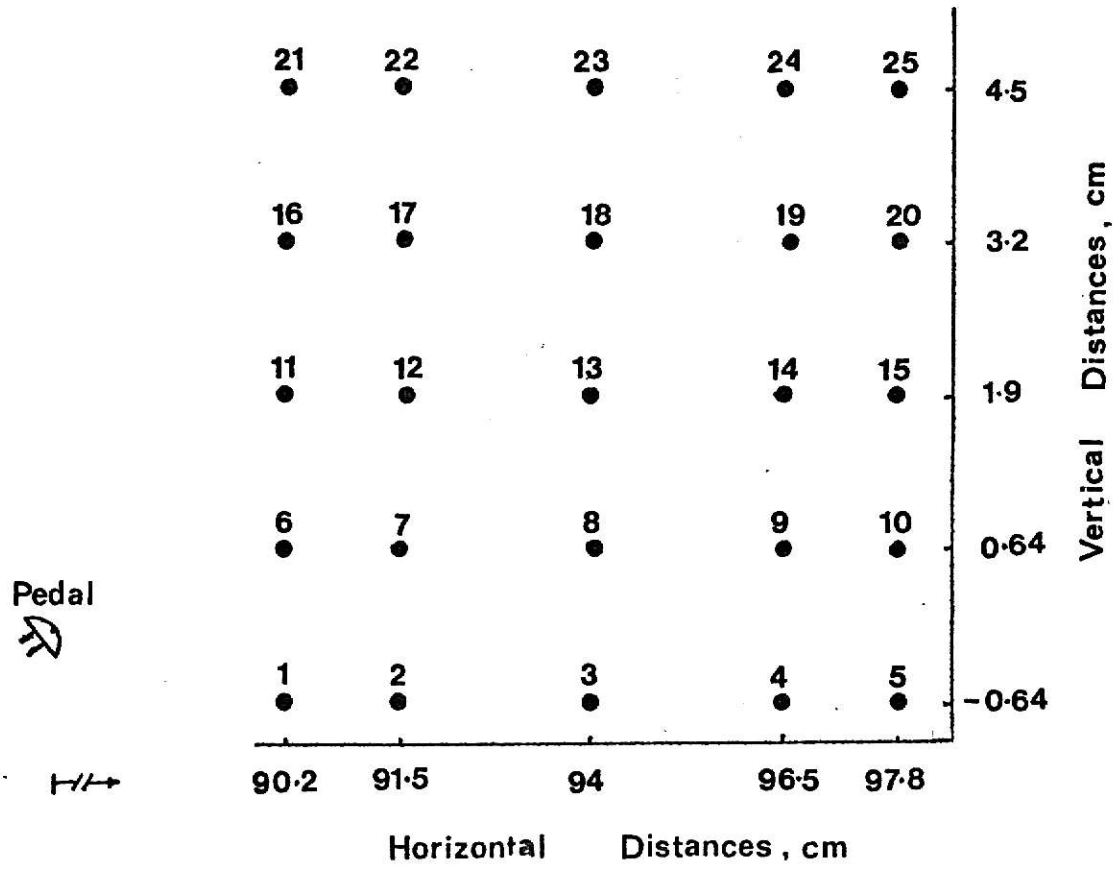


Fig. 22 SRP Positions

Table 3

Randomly Selected Position Sequences

Trial Number	Subject Number			
	1	2	3	4
1	22	09	22	12
2	08	04	25	17
3	15	17	06	20
4	18	21	19	10
5	23	13	10	05
6	02	01	05	02
7	13	20	18	24
8	16	11	15	23
9	01	25	16	19
10	11	22	08	03
11	03	23	09	14
12	05	05	11	21
13	10	03	07	08
14	20	12	13	18
15	21	24	21	09
16	07	02	20	16
17	06	18	23	07
18	17	08	24	13
19	09	15	03	11
20	12	07	04	04
21	14	10	12	15
22	24	06	01	22
23	19	19	14	06
24	04	16	02	01
25	25	14	17	25

RESULTS

Data Reduction

Six females served as subjects, but two did not push the brake pedal hard enough to record on the instrumentation for 49 times out of 50 trials and 45 times out of 50 trials respectively. Therefore they were not considered in the further data analysis. The minimum force required for recording was 23.7 kg.

The observations were recorded on the magnetic tape in analog form. This tape was played and digitalized on a Nova 1200, a mini computer. The frequency was set at 130 hz. This means that 130 digital values/second were obtained. The digital values were plotted on the screen of the cathode ray tube. The area under the force-time curve was calculated with the digital intigration method on the computer and then the area was divided with the duration of the time the force was applied. This was called the mean force. Mean force is defined as an average exertable force over the period of exertion of the force (maximum of 5 seconds).

The maximum force was defined as the highest attained force in a trial.

The raw data are as listed in appendix 3.

Representative Curve of Mean Force vs Time

The average force time curve of the 200 force-time curves was drawn as shown in Fig. 23. The curve also shows the $\pm 1\sigma$ limits of the force-time curve.

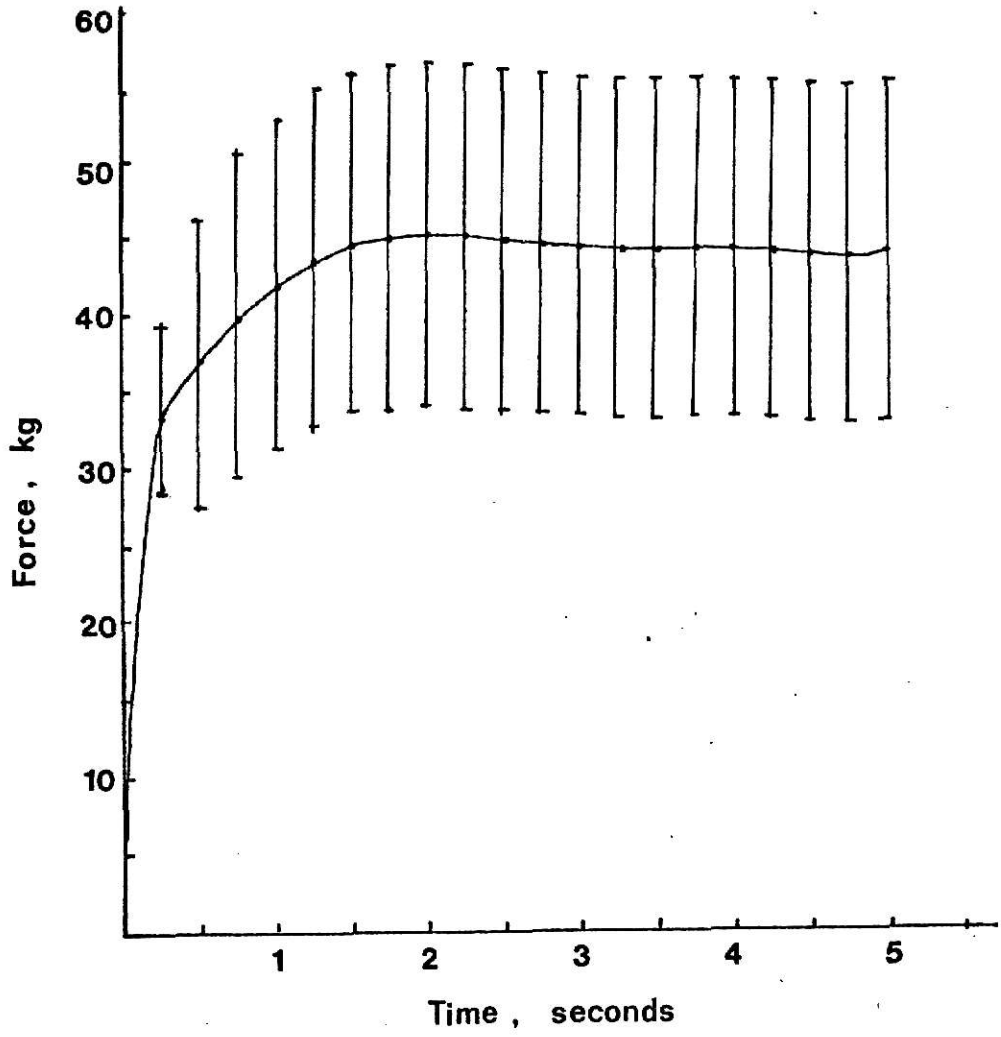


Fig. 23 Representative Curve with ± 1 σ

Average Force vs Maximum Force

The ratio of average force to the maximum force was calculated for each trial. The mean and standard deviation for each subject are tabulated in Table 4. The overall mean and standard deviation of the ratio is 0.833 and 0.061.

The force attains a maximum value in approximately the first 1.5 seconds and then it remains fairly constant.

Forces

The mean forces were used for analysis. The word force is used for mean force and maximum force for peak force. The mean forces and standard deviations for each subject's are listed in Table 5. The overall mean force was 39.1 kg and standard deviation was 9.5 kg.

An analysis of variance is tabulated in table 6. The subjects were considered to be random whereas horizontal and vertical positions were considered to be " fixed effect ". The model was:

Force = S(I) + V(J) + H(K) + SV(IJ) + VH(JK) + HS(IK)
+ SVH(IJK) + E(IJKL)

Where S is for subject (I = 1,...,4)
V is for vertical positions (J = 1,...,5)
H is for horizontal positions (K = 1,...,5)
and L is the replication index (L = 1,2)

All F ratios except for subject in the analysis of variance table were non-significant at the 5 % level.

The forces for each position were plotted as shown in Fig. 24. There was no obvious pattern present.

Table 4

Mean and Standard Deviation of Ratio of Maximum Force to Average Force for Each Subject

Subject	Mean Ratio	Standard deviation
1	0.828	0.067
2	0.813	0.065
3	0.865	0.058
4	0.827	0.041
Mean	0.833	0.061

Table 5

Mean Force and Standard Deviation for Each Subject

Subject number	Mean Force, kg	Standard Deviation, kg
1	33.8	7.7
2	45.2	7.0
3	31.4	4.1
4	45.1	7.9
Mean	39.1	9.5

Table 6

Analysis of Variance Table

Source	D.F.	Mean Square	F Ratio
Subjects	3	2905.00	65.73 *
Vertical Position	4	19.76	0.33
Horizontal Position	4	18.84	0.25
Interaction SV	12	59.79	1.35
Interaction VH	16	41.42	0.77
Interaction HS	12	74.70	1.69
Interaction SVH	48	53.69	1.21
Error	100	44.19	
Total	199		

*$\alpha < 0.05$

re-align

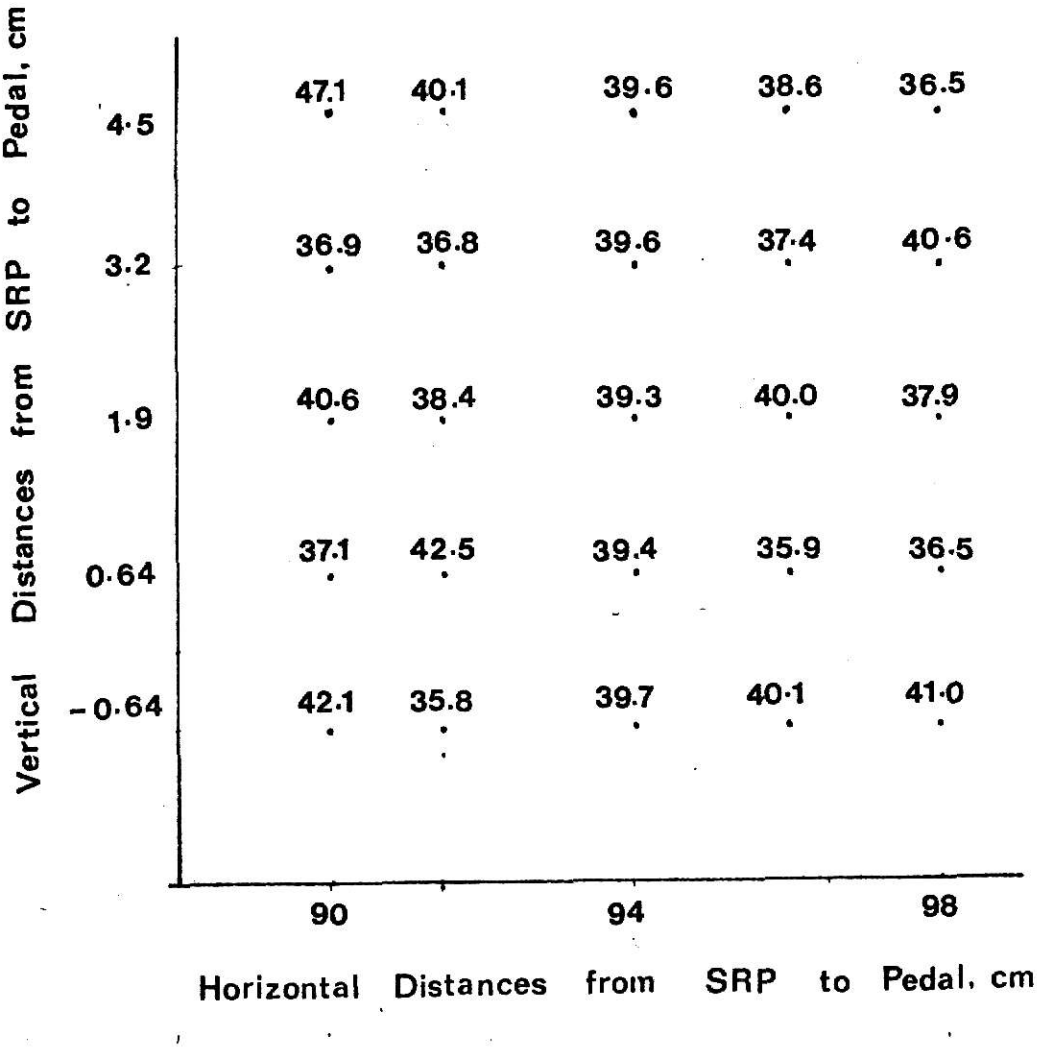


Fig. 24 Position vs Force

The horizontal distances as % of the subject's height and vertical distances were plotted and were marked with appropriate forces. No pattern was observed; see Fig. 25.

Various parameters were correlated with force. Table 7 gives the correlation coefficient, standard error of estimation, intercept and coefficient of regression for various parameters. The significant parameters are marked with an asterisk (*) in Table 7.

Knee angle and hip angle were plotted. For simplicity the data were grouped in bands of 5^{o} intervals. The force, and were averaged over a group and were plotted; i.e. and angles were plotted with the force values marked appropriately. No obvious pattern was recognised. See Fig. 26.

Opinion

The opinions for each position by each subject are as listed in Appendix 3.

The opinions of the subject for the seat position was plotted. No pattern was observed; see Fig. 27.

The horizontal distances as % of the subjects height and vertical distances were plotted and were marked with appropriate opinions. See Fig. 28. No obvious pattern was found.

Force vs Opinion

The forces and opinions were averaged in the following groups.

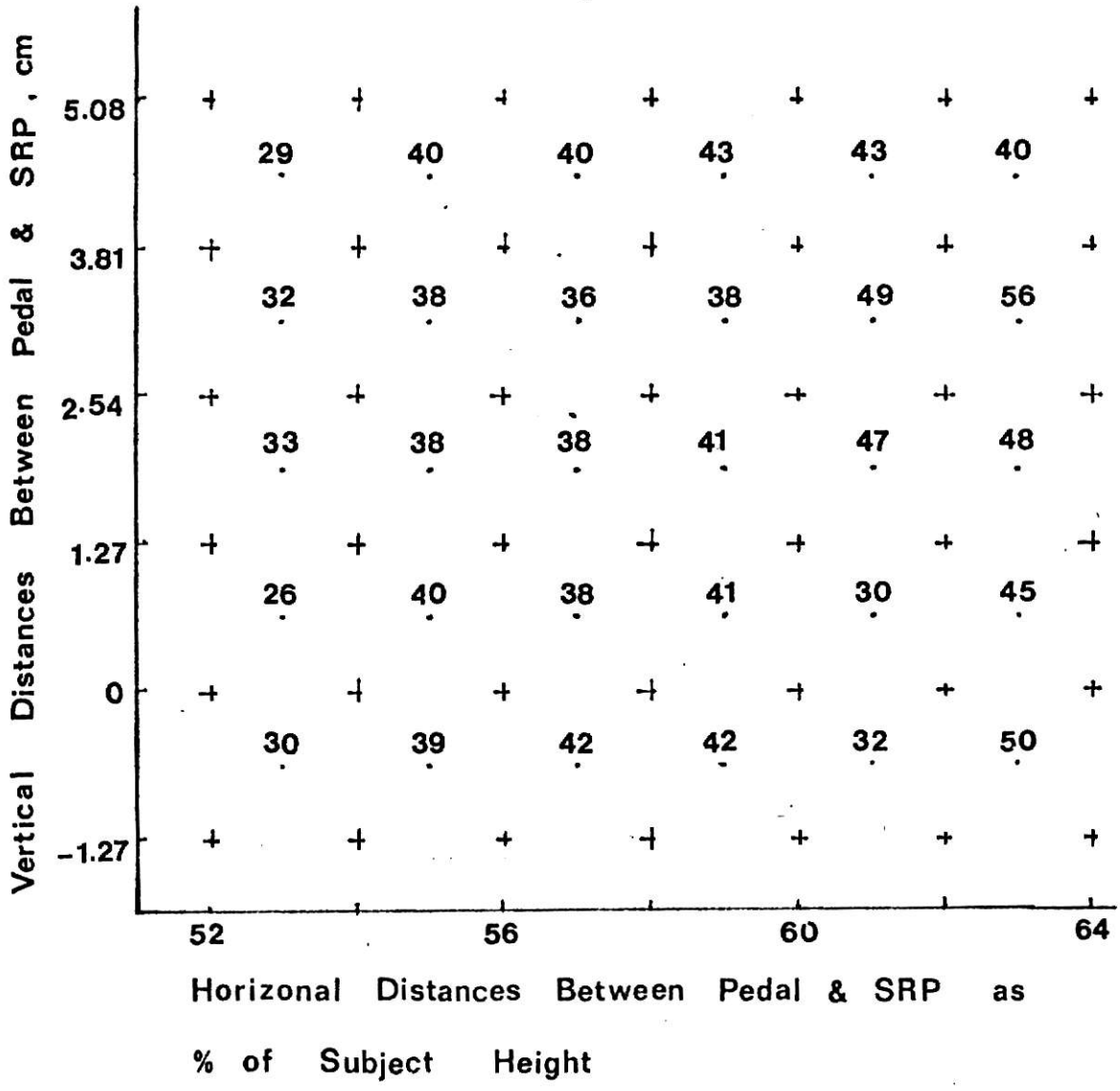


Fig. 25 Force (kg) at Various Positions

Table 7

Correlation Coefficient, Standard Error, Intercept and Slope of Regression for Various Parameters

Parameter	Correlation Coefficient	Standard Error	Intercept of Regression	Slope of Regression
Distances from SRP to pedal in cm.				
Horizontal	-0.05	24.24	135.80	-0.99
Vertical	-0.04	24.27	99.39	-0.15
Diagonal	-0.05	24.24	135.58	-0.98
Distance from H pt. to pedal, cm.				
Horizontal	-0.11	24.12	174.80	-2.27
Vertical	-0.28	23.31	134.26	-8.29 *
Diagonal	-0.14	24.05	191.48	-2.75
Body posture angles(degrees)				
at hip joint	+0.02	9.55	36.62	+0.02
at knee joint	+0.17	9.42	18.74	+0.16 *
at ankle joint	-0.00	9.55	39.39	-0.00
Subject's				
height (cm)	-0.48	21.34	449.02	-5.39 *
weight (kg)	-0.55	7.99	105.43	-0.56 *
crotch length (cm)	-0.22	23.65	167.10	-2.12 *
age (year)	-0.67	7.03	175.85	-6.39 *

* Statistically significant, = 0.05

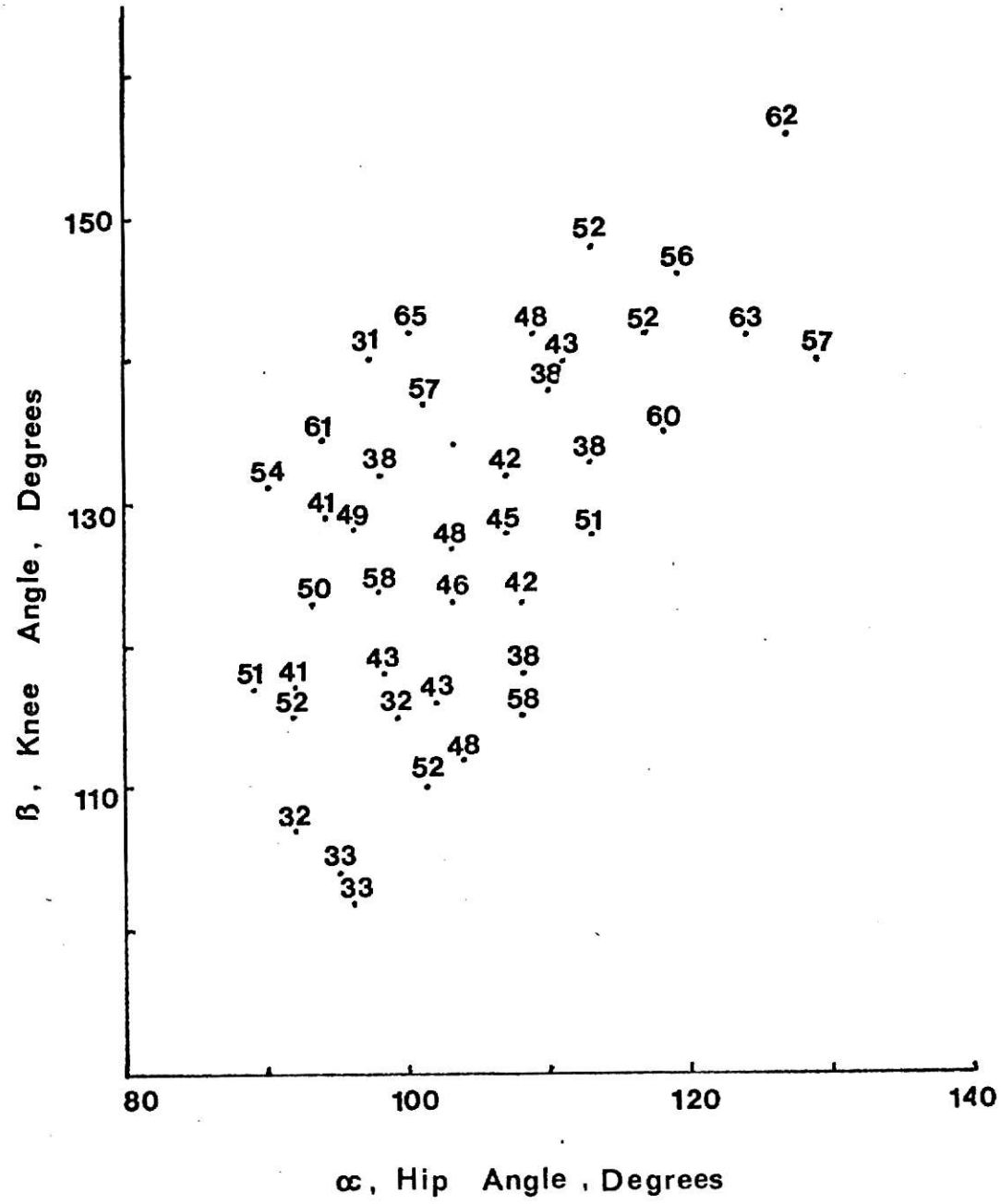


Fig. 26 Posture Angles vs Force (kg)

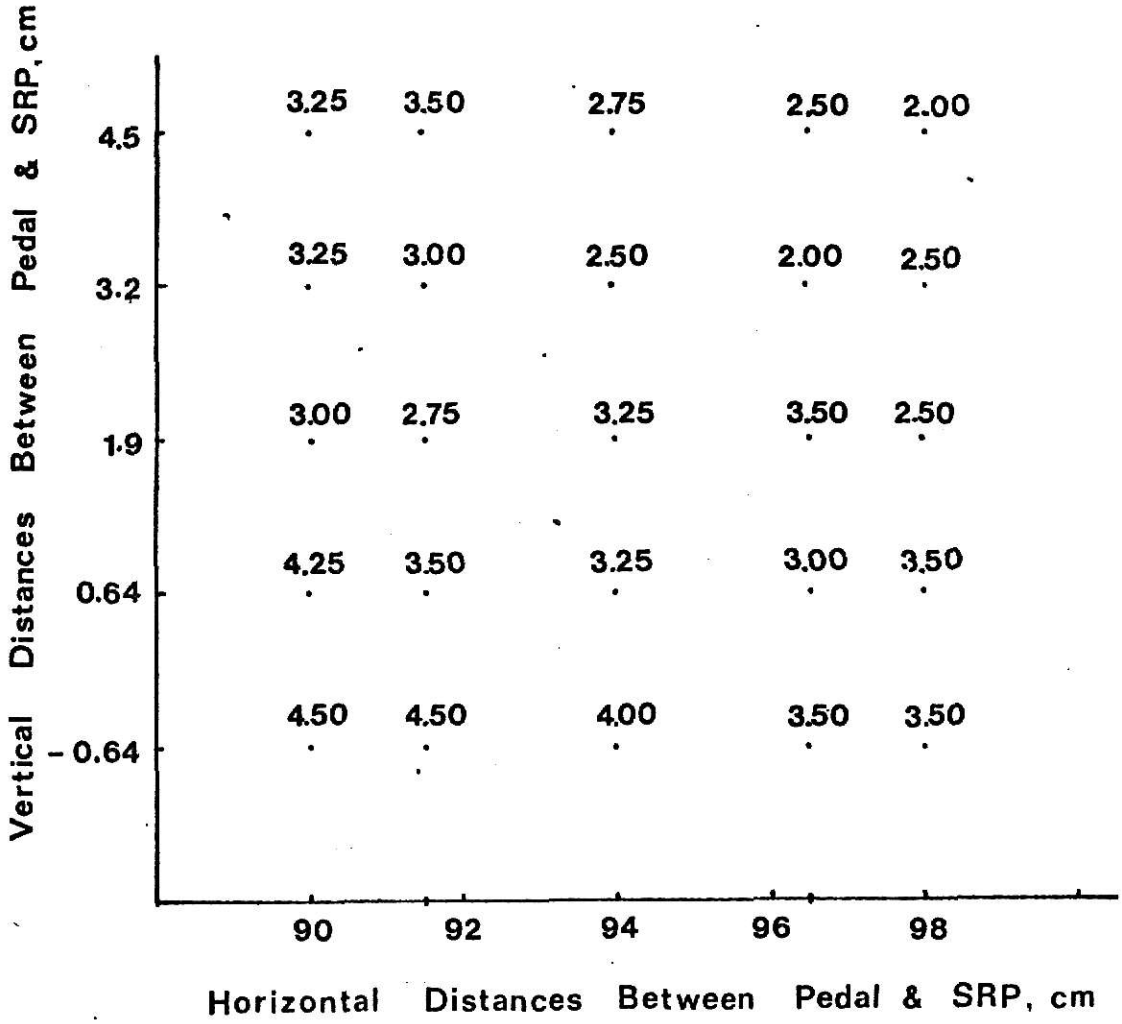


Fig. 27 Position vs Opinión

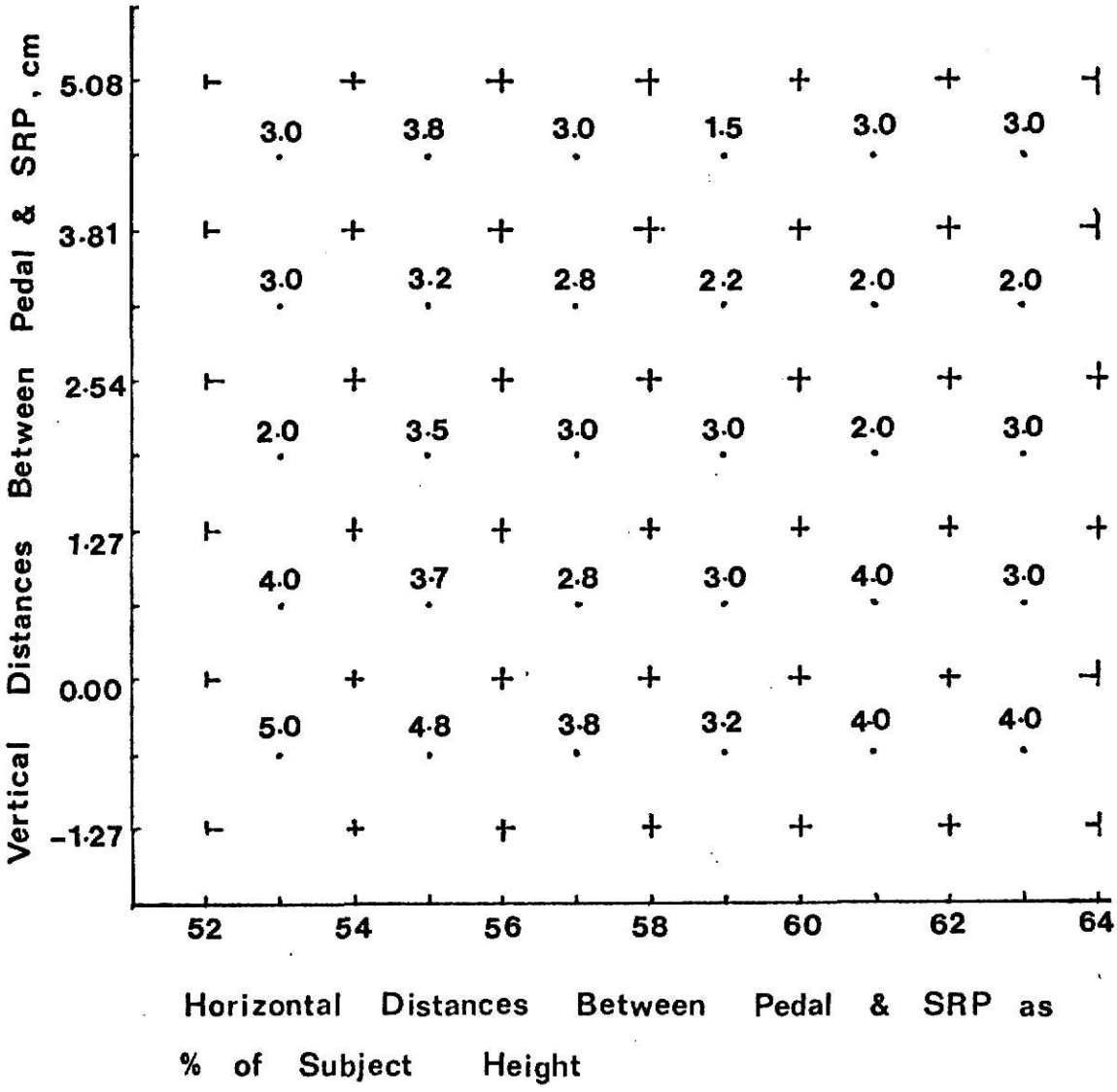


Fig. 28 % Position vs Opinion

X axis Groups (Horizontal distances as a % of subject's height)	$52\% \leq x < 54\%$
	$54\% \leq x < 56\%$
	$56\% \leq x < 58\%$
	$58\% \leq x < 60\%$
	$60\% \leq x < 62\%$
	$62\% \leq x < 64\%$
Y axis Groups (Vertical distances)	$-1.27 \leq Y < 0.0$ cm
	$0.0 \leq Y < 1.27$ cm
	$1.27 \leq Y < 2.54$ cm
	$2.54 \leq Y < 3.81$ cm
	$3.81 \leq Y < 5.08$ cm

The opinions vs forces in kg were plotted as shown in Fig. 29. The regression analysis was run for forces vs opinions. The correlation coefficient (r) was found to be 0.15 (significant) with standard error of 9.5 kg. The correlation equation is

Force, kg = 42.7 - 1.13 (opinions, vote 1 to 5)

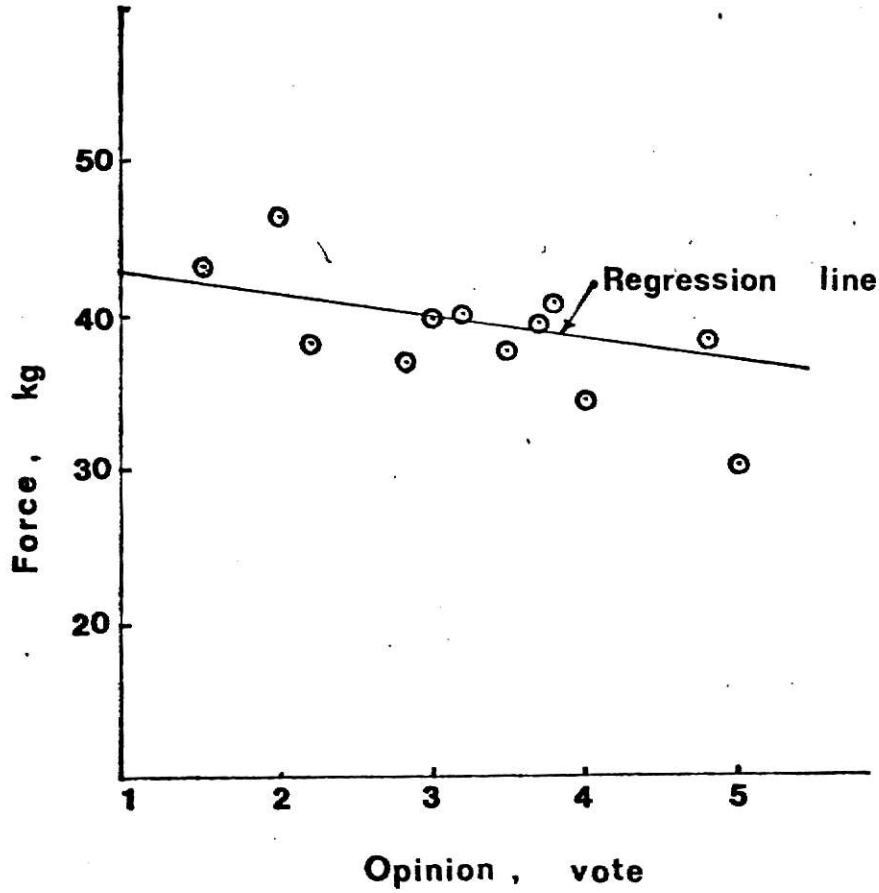


Fig. 29 Force vs Opinion

DISCUSSION

Two subjects did not do well. With reference to the past studies and my own intitutive feeling, the subjects with their physique should have done well, but they did not. It can be inferred from this that people do not follow the instructions. People may not do the task even though they may be capable of doing the task.

The force attains a maximum value in approximately the first 1.5 seconds and then it remains fairly constant. There could be a substantial drop in applied force if it is extended ober a longer period.

In measuring the force over time it is easy to measure the peak force. On the other hand, mean force over time is important information. The ratio of mean force to peak force was 0.833. It would be safe to apply a ratio of 0.8 in converting maximum force to mean force or mean force to maximum force because 0.8 is smaller than the lowest value of the ratio of the four subjects in this experiment.

The mean force was 39.1 kg with standard deviation of 9.5. The 5th percentile force then would be 23.5 kg.

From analysis of variance it can be said that the force values vary from person to person, but horizontal seat positions, vertical seat positions, and the interaction of the seat positions are not significant; that is, there is no effect of seat position.

The plot of force vs seat position also did not reveal any pattern of force. It was expected that the seat positions

will greatly affect the force capability, but it is not so in this study. The main technical reason could be the physical limits of the simulator. The seat positions were not in the preffered region. The physical dimensions of the simulator were constraints in getting the smallest horizontal distance and lowest and highest vertical distances.

Similarly, the force vs the body position angles did not gave any pattern and it was not possible to compare force with the Aoki formula.

The opinions vs force has a significant correlation of - 0.15. Lower opinion gives higher force. i.e. the better you like the seat position the higher the force you apply.

The other factors have a significant correlation with force. The minimum significant correlation is 0.14 for 5 % confidence level and 0.18 for 1 % confidence level. To count on this result is not advisable because of the small sample size. In my opinion it would be nice to have a larger sample size for a correlation between the subject's parameter such as height, weight, age. For example, age has a coefficient of -6.3 kg/year. This is not reasonable as the force capability will increase to a certain age and then decrease.

I would suggest that the same experiment should be run with seat position within the preferred area given by Roe. At the same time I suggest using an instrument with a capability to record the force from zero value to the maximum value of 90 kg.

CONCLUSION

The mean force for four female subjects with 50 trials per subject (n = 200) was found to be 39.1 kg, σ= 9.5.

There was no effect of seat position. No obvious pattern of force vs seat position was observed.

The force is correlated with height of the subject (r = 0.48), weight (r = 0.55), crotch length (r = 0.22), age (r = 0.67), angle at knee joint (r = 0.17) and vertical distance from H point to pedal (r = 0.28). The failure to confirm the Aoki formula can be attributed to the absence of any pattern of force.

The mean ratio of mean force to the maximum force is 0.833.

The force over time is fairly constant.

My personal feeling for not having very strong conclusive data is the physical limitations of the simulator. The seat positions were not in the preferred region. It was not possible to have all the positions in the desired area because of the dimensions of the simulator.

APPENDIX 1

INFORMATION BLANK

Name: _____

Ph. No: _____

Address: _____

_____

Social Security No:

Birth date: Height:

Weight: Crotch length:

R measurement: Horizontal: _____ Vertical: _____

Driving experience:

(1) How long have you been driving? _____

(2) List the cars you have driven in past years.

Car make	No. of years you used.	Does it have power brake (Yes/No)
_____	_____	_____
_____	_____	_____
_____	_____	_____

APPENDIX 2

INSTRUCTION SHEET READ TO THE SUBJECTS BEFORE RUNNING THE EXPERIMENT.

To: Dear subject

I am thankful for your participation in this experiment. The purpose of running this experiment is to find out how much force one can apply on the brake pedal at various seat positions.

Please fill out the application blank (given to you). Please be seated in the seat. Fasten your seat belt. Put your hands on the steering wheel and your right foot on the brake pedal. Watch the driving movie and enjoy the back ground music. Whenever there is a red signal light on at the right hand upper corner of the screen, push the pedal uniformly as hard as possible and keep it in the same position until the red signal light is off. Allow the experimenter to measure the dimension of the posture of the position and give your opinion for the seat position.

1 Very good.

2 Good.

3 O.K.

4 Poor.

5 Very poor.

The first trial will be ignored. It will be for your understanding-what you have to do. If you have any difficulty, doubt or question, please ask and get it clear.

That's all !.Thanks, once again.

APPENDIX 3

RAW DATA

RAW DATA

Subject # 1. Experiment date: 11-18-1975

Name: Cindy Close

Height: 163.8 cm. Weight: 59 kg. Crotch length: 76.2 cm

Date of Birth: 08-01-53 Age: 22.25 Years

H point dimension from SRP X = 7.9 cm. Y = 10.5 cm.

Distance from SRP to pedal

Horizontal cm. 90.2, 91.5, 94.0, 96.5, 97.8

Vertical above SRP (+) cm. -0.64, +0.64, 1.9, 3.2, 4.5

Distances from H point to pedal

Horizontal:82.3, 83.6, 86.1, 88.6, 89.9

Vertical above SRP(+): 9.86, 11.14, 12.4, 13.7, 15.0

Position	Angle (degree) at			Opinion	Force, Kg.		Ratio
	hip	knee	ankle		Avg.	Max.	Avg./Max Force.
1	92.5	117.5	90.0	5	37.23	49.15	0.757
					48.74	57.39	0.849
2	91.0	116.5	100.0	5	34.52	41.96	0.823
					25.00	32.52	0.769
3	101.0	115.5	81.5	4	48.52	56.04	0.866
					26.53	33.72	0.788
4	106.0	129.0	105.0	4	34.30	39.26	0.873
					46.72	57.54	0.812
5	103.0	133.5	91.0	1	30.07	35.97	0.836
					37.55	47.95	0.783

Position	Angle (degree) at hip	knee	ankle	Opinion	Force, Kg. Avg.	Max.	Ratio Avg./Max Force.
6	97.0	120.0	91.0	5	49.42	54.09	0.914
					34.27	41.66	0.822
7	95.5	121.0	89.0	5	45.47	56.19	0.809
					48.74	57.39	0.849
8	93.5	129.0	88.5	3	29.02	35.96	0.807
					37.65	46.45	0.811
9	110.0	138.0	90.0	2	31.65	35.67	0.887
					33.34	40.76	0.818
10	106.0	132.0	99.0	5	31.74	37.17	0.854
					26.59	29.83	0.892
11	97.0	117.5	91.0	5	39.58	52.74	0.750
					35.47	45.26	0.784
12	102.0	119.0	84.0	5	27.23	31.97	0.851
					25.47	29.68	0.858
13	98.0	132.0	96.5	4	25.50	28.48	0.895
					36.64	47.80	0.767
14	100.0	116.5	82.5	5	46.78	56.49	0.828
					25.28	26.53	0.953
15	104.0	135.0	102.0	2	29.89	34.47	0.867
					28.65	36.12	0.793
16	97.0	119.0	95.5	5	34.83	40.46	0.861
					35.90	44.51	0.807
17	102.0	126.5	92.0	4	28.65	26.12	0.793
					35.20	58.74	0.599

Position	Angle (degree) at			Opinion	Force, (kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg./Max. Force.
18	96.5	140.0	104.0	3	25.63	31.36	0.817
					26.69	31.18	0.856
19	114.5	135.0	88.5	2	25.73	28.78	0.894
					31.57	47.12	0.670
20	111.0	133.5	96.5	1	42.95	53.94	0.796
					26.98	33.57	0.804
21	92.5	122.5	90.0	5	53.54	63.68	0.841
					31.10	37.32	0.833
22	114.5	132.0	98.0	3	27.43	31.29	0.876
					25.50	28.48	0.895
23	94.5	125.0	101.0	4	32.98	38.80	0.850
					31.04	37.32	0.832
24	112.0	133.5	84.0	1	30.68	32.89	0.933
					25.28	26.53	0.953
25	111.0	140.0	91.0	1	26.69	31.18	0.856
					36.11	54.84	0.658

RAW DATA

Subject # 2. Experiment date 11-19-1975

Name: Sarah Call

Height: 165.1 cm Weight: 53.5 kg. Crotch length: 73.7 cm

Date of Birth: 03-25-55 Age: 20.66 Years

H point dimension from SRP X = 10.2 cm Y = 7.6 cm

Distances from SRP to pedal

Horizontal(cm): 90.2, 91.5, 94.0, 96.5, 97.8

Vertical above SRP(+) (cm): -0.64,0.64, 1.9, 3.2, 4.5

Distances from H point to pedal

Horizontal: 80, 81.3, 83.8, 86.3, 87.6

Vertical above SRP(+): 6.96, 8.24, 9.5, 10.8, 12.1

Position	Angle (degree) at			Opinion	Force, (Kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg./Max Force.
1	101.0	110.0	77.5	5	43.93	50.50	0.870
					43.42	53.94	0.805
2	103.0	116.5	79.0	4	40.47	49.30	0.821
					48.40	56.34	0.859
3	108.0	114.5	82.5	4	49.97	58.74	0.851
					38.30	56.34	0.680
4	114.5	126.5	87.5	2	39.90	46.90	0.851
					56.88	68.32	0.833
5	123.5	141.5	79.0	5	55.74	84.80	0.657
					33.50	40.61	0.825

Position	Angle (degree) at hip	knee	ankle	Opinion	Force, (Kg) Avg.	Max.	Ratio Avg/Max Force.
6	104.0	111.0	79.0	3	43.82	52.89	0.828
					41.44	58.74	0.706
7	92.0	114.5	76.5	4	46.38	69.67	0.666
					50.54	63.53	0.796
8	100.0	125.0	77.5	1	66.88	79.11	0.845
					34.99	39.26	0.891
9	114.5	133.5	81.5	3	49.09	55.29	0.888
					57.46	65.63	0.876
10	115.5	143.5	77.5	3	37.64	47.95	0.785
					47.01	53.79	0.874
11	107.0	126.5	74.0	3	60.38	74.31	0.812
					34.16	44.51	0.768
12	105.0	121.0	76.5	2	42.33	46.45	0.911
					48.92	61.13	0.800
13	108.0	126.5	73.5	3	47.10	59.93	0.786
					41.04	46.60	0.881
14	117.5	135.0	88.5	3	44.29	57.54	0.770
					45.38	61.48	0.738
15	129.0	140.0	80.5	2	49.00	66.08	0.742
					42.41	45.56	0.931
16	102.0	121.0	85.5	1	38.01	43.78	0.868
					41.69	47.80	0.872
17	101.0	116.5	86.5	3	62.65	78.96	0.793
					41.24	50.38	0.819

Position	Angle (degree) at			Opinion	Force, (Kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg/Max Force.
18	105.0	126.5	80.0	2	43.11	50.35	0.817
					53.77	59.64	0.902
19	115.5	140.0	71.0	1	42.20	50.35	0.838
					38.67	51.25	0.755
20	126.5	155.5	78.5	4	47.04	64.88	0.725
					43.15	58.74	0.735
21	108.0	125.0	78.5	4	50.88	67.27	0.756
					53.50	63.68	0.840
22	112.0	129.0	74.0	5	42.66	58.74	0.735
					51.63	60.08	0.859
23	119.0	145.5	85.5	3	50.72	63.38	0.800
					42.17	49.15	0.858
24	120.0	141.5	76.5	3	47.22	61.13	0.772
					44.42	49.15	0.904
25	129.0	140.0	71.0	1	42.92	52.74	0.814
					51.76	62.48	0.828

RAW DATA

Subject # 3 Experiment date:11-19-1975

Name: Terry Navinsky

Height: 172.7 cm Weight: 56.8 kg Crotch length: 88.9 cm

Date of Birth: 05-15-53 Age: 22.5 Years

H point dimension from SRP X= 10 cm Y = 9.0 cm

Distances from SRP to pedal

Horizontal (cm): 90.2, 91.5, 94.0, 96.5, 97.8

Vertical above SRP(+) (cm): -0.64, 0.64,1.9, 3.2, 4.5

Distances from H point to pedal

Horizontal: 80.2, 81.5, 84.0, 86.5, 87.8 cm

Vertical above SRP(+): 8.36, 9.64, 10.9, 12.2, 13.5 cm

Position	Angle (degree) at hip	knee	ankle	Opinion	Force, (Kg) Avg.	Max.	Ratio Avg/Max Force.
1	92.0	107.0	78.5	5	30.39	34.17	0.889
					31.71	34.17	0.928
2	95.5	102.0	76.0	5	31.25	34.25	0.912
					28.70	32.40	0.885
3	94.5	104.0	74.0	5	29.69	33.81	0.878
					29.02	32.97	0.880
4	112.0	127.5	73.5	4	40.87	50.33	0.812
					37.84	50.51	0.749
5	108.0	129.0	75.0	4	37.40	50.96	0.733
					36.06	45.60	0.790

Position	Angle (degree) at hip	knee	ankle	Opinion	Force, (Kg) Avg.	Max.	Ratio Avg/Max Force.
6	93.5	115.5	82.5	5	25.05	32.96	0.773
					27.21	31.18	0.873
7	101.0	115.5	80.5	3	27.63	29.83	0.926
					25.78	28.93	0.891
8	106.0	121.0	82.5	2	28.23	34.30	0.827
					31.13	33.69	0.924
9	111.0	132.0	85.5	3	27.33	31.86	0.857
					29.31	32.82	0.893
10	114.5	129.0	80.5	3	31.13	35.49	0.877
					27.90	36.43	0.765
11	96.5	119.0	82.5	2	29.59	34.13	0.867
					31.03	34.47	0.900
12	105.0	111.0	71.0	2	34.90	45.85	0.761
					36.97	45.14	0.819
13	107.0	119.0	81.5	2	36.72	41.87	0.876
					38.78	47.87	0.809
14	110.0	123.5	82.5	4	34.30	41.29	0.830
					30.63	34.47	0.889
15	106.0	132.0	84.0	3	29.39	34.47	0.853
					27.97	31.18	0.897
16	103.0	116.5	79.0	4	32.78	38.87	0.843
					29.79	36.36	0.819
17	103.0	115.5	73.5	2	31.88	40.76	0.782
					31.71	34.17	0.928

Position	Angle (degree) at hip	knee	ankle	Opinion	Force, (Kg) Avg.	Max.	Ratio Avg/Max Force.
18	102.0	114.5	79.0	3	39.69	44.69	0.888
					33.92	38.96	0.871
19	109.0	135.0	89.0	3	28.69	33.36	0.850
					34.08	38.66	0.882
20	106.0	132.0	84.0	3	26.23	28.77	0.912
					25.35	27.28	0.929
21	109.0	116.5	73.5	2	31.12	34.17	0.911
					26.30	28.18	0.934
22	99.0	114.5	76.5	4	31.07	32.83	0.946
					28.35	31.18	0.909
23	107.0	129.0	78.5	3	33.79	36.28	0.931
					31.06	34.32	0.905
24	106.0	127.5	74.0	3	36.75	41.51	0.885
					38.73	50.16	0.772
25	110.0	129.0	80.5	3	29.46	32.37	0.910
					25.36	27.28	0.929

RAW DATA

Subject # 4 Experiment date: 11-19-1975

Name: Jane Master

Height: 157.5 cm. Weight: 47.7 kg. Crotch length: 86.4 cm

Date of Birth: 09-29-55 Age: 20.16 Years

H point dimension from SRP X =9.5 cm. Y = 8.3 cm.

Distance from SRP to pedal

Horizontal (cm): 90.2, 91.5, 94.0, 96.5, 97.8

Vertical above SRP(+) (cm): -0.64, 0.64, 1.9, 3.2, 4.5

Distances from H point to pedal

Horizontal: 80.7, 82.0, 84.5, 87.0, 88.3, cm

Vertical above SRP(+): 7.66, 8.94, 10.2, 11.5, 12.8 cm.

Position	Angle (degree) at			Opinion	Force, (Kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg/Max Force.
1	94.5	121.0	77.5	3	50.42	59.34	0.850
					51.49	62.33	0.826
2	94.5	121.0	81.5	4	47.06	54.54	0.863
					31.40	42.19	0.744
3	102.0	127.5	94.5	3	41.26	52.15	0.791
					54.69	65.03	0.841
4	104.0	127.5	72.5	4	32.49	39.86	0.815
					32.40	38.37	0.845
5	100.0	141.5	83.0	4	45.11	52.15	0.865
					54.88	67.55	0.812

Position	Angle (degree) at			Opinion	Force, (Kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg/Max Force.
6	88.5	116.5	96.5	4	31.32	38.37	0.816
					44.04	50.20	0.877
7	92.5	123.5	94.5	2	43.71	49.15	0.889
					52.05	64.88	0.802
8	99.0	125.0	92.0	3	46.56	54.54	0.854
					40.70	58.59	0.695
9	104.0	123.5	85.5	4	31.74	38.81	0.817
					35.86	39.70	0.903
10	101.0	136.5	105.0	3	39.85	52.17	0.764
					50.31	60.98	0.825
11	89.0	117.5	82.5	2	43.57	51.84	0.840
					51.08	64.09	0.797
12	101.0	123.5	80.0	2	42.92	48.55	0.884
					49.03	59.53	0.824
13	90.0	130.5	80.0	4	45.73	50.65	0.903
					43.58	56.94	0.765
14	103.0	133.5	96.5	2	45.81	56.02	0.818
					48.07	58.59	0.820
15	93.5	135.0	110.0	3	45.17	54.54	0.828
					51.80	64.73	0.800
16	92.0	123.5	92.5	3	32.40	38.37	0.845
					53.03	62.48	0.849
17	101.0	129.0	87.5	3	31.75	38.66	0.821
					31.32	38.37	0.816

Position	Angle (degree) at			Opinion	Force, (Kg)		Ratio
	hip	knee	ankle		Avg.	Max.	Avg/Max Force.
18	106.0	130.5	96.5	2	42.6	50.95	0.836
					51.80	64.73	0.800
19	106.0	135.0	113.0	2	47.62	53.64	0.888
					50.35	60.23	0.836
20	99.0	141.5	89.0	2	50.63	66.84	0.758
					62.47	74.76	0.836
21	94.5	133.5	93.5	2	44.96	52.45	0.858
					57.94	71.92	0.806
22	95.5	127.5	90.0	2	56.89	70.15	0.811
					59.74	74.01	0.807
23	102.0	125.0	89.0	1	44.73	52.00	0.860
					50.81	61.13	0.831
24	113.0	148.0	94.5	3	43.70	52.15	0.838
					42.25	51.83	0.815
25	109.0	141.5	96.5	3	41.96	47.78	0.878
					37.88	48.25	0.785

REFERENCES

1. Aoki, K., Human Factors in Braking and Fade Phenomena for Heavy Application.- Problems to Improve Brake Performance. Bulletin of JSME, Vol.3,no.12,1960,587-594.

2. Asmussen,E. and Heeboll-Nielsen,K., Isometric Muscle Strength in Relation to Age in Men and Women.Ergonomics, Vol. 5,6, 1962-63, 167-169.

3. Bierly,R.L.,Maximum Parking Brake Force Applied by Male and Female Drivers. March 30,1965, Report no. EM 23, General Motors Research Laboratory.

4. Caldwell,L.S., Chaffin,D.B., Dukes-dubos, F.N., Kroemer,K.H.E.,Laubach,L.L., Snook, S.H. and Wasserman, D.E., A Proposed Standard Procedure for Static Muscle Strength Testing. American Industrial Hygiene Association Journal, Vol. 35, no.4, April 1974, 201-206.

5. Chernicoff, Phone conversation with Dr. Konz. Jan.14, 1974. Information available with Dr. Konz, IE Dept., Kansas State University, Manhattan, Kansas,66506.

6. Dupuis,H. and Kreuzanch, B., Some Physiological Consideration of the Work Done in Driving A Vehicle. VD 1 Berichte 1957,25,49-56, Oct. 1959.

7 Eaton, D.A. and Dittmeier, H.J., Braking and Steering Effort Capabilities of Drivers, June 1970, available at SAE INC.,2 Pennsylvania Plaza, New York, N.Y.,10001.

8. Elbel,E.R., Relationship Between Leg Strength, Leg Endurance and Other Body Measurements. Journal of Applied Physiology, 1949, Vol. 2, 197-207.

9. Federal Motor Vehicle Safety Standard 571-105 - 75, 433-447.

10. Hill, W.F. and Lawrence, A.P., A Review of Research on Maximum Pedal Force Capability. General Motors Proving Ground, Milford, Michigan. For SAE Effort Task Force, Feb. 15, 1973.

11. Konz, S.A., Maximum Pedal Force Exertable by Weak Females. Draft, May 30, 1974. Available with Dr. Konz, IE Dept.,Kansas State University,Manhattan,Kansas,66506.

12. Kroemer,K.H.E., Pedal Operation by The Seated Operator. Jan. 14,1972. SAE INC., 2 Pennsylvania Plaza, New York, N.Y.,10001.

13. Martin, W.B. and Johnson. E.E., An Optimum Range of Seat Positions Determined by Exertion of Pressure Upon a Foot Pedal. Army Medical Research Laboratory, Fort Knox, Kentucky, Report no 86, 15th June, 1952.

14. Mortimer, R.G., Foot Brake Pedal Force Capability of Drivers, Ergonomics, 1974,Vol.17,no.4. 509-513.

15. Mortimer, R., Segel, L., Dugoff, H, Campbell, J., Jorgeson, C., and Murphy, R. Brake Force Requirement Study: Driver-Vehicle Braking Performance as a Function of Brake System Design Variables, National Highway Safety Bureau Final Report FH-11-6952,Washington, D.C. 20591, April 1970 (also Highway Safety Research Institute Report HuF-6, Ann Arbor, Michigan 48105).

16. Parikh,Y.B., Brake Pedal Force Capabilities vs Seat Positions.,Nov., 1974., IE 850 Class Project Report, Available With Dr. Konz, IE Dept., K.S.U., Manhattan, Kansas, 66506.

17. Pierce, B.F., Woodson, W,E. and Selby, P.H., Human Force Considerations in the Failure of Power Assisted Devices. July 1973, Report no. DOT- HS-800 889, Available through National Technical Information Service, Springfield, Virginia, 22151.

18. Purswell,J.L., Karim,B., and Bergey,K., A Study of Pilot Control Forces For A Female Ponulation Piloting Light Aircraft., Oct 1971. Available through the University of Oklahoma, Norman, Oklahoma,73069.

19. Radlinski, R.W., and Price, J.I., The Brake Pedal Force Capability of Adult Females., National Bureau of Standards, Technical Notes-557, Oct.1970, Order by SD Catalog No. C 13.46:557.

20. Rees, J.E. and Graham, N.E., The Effect of Backrest Position on the Push Which Can Be Exerted On A Isometric Foot Pedal., Journal of Anatomy, 1952,86,310-319.

21. VonBuseck,C.R., Maximum Brake Pedal Forces Produced by Male and Female Drivers., Jan.2,1965, Research Report EM 18, General Motors Research Laboratories.

22. Woodson,W.E., and Conover,D.W., Human Engineering Guide for Equipment Designers, 2nd edition,University of California Press, 1970.

FOOT PEDAL FORCE CAPABILITY VERSUS SEAT POSITION

by

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AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Abstract

The study investigated the effect of seat position on the foot pedal force capability of females.

The experiment was run on a simulator; four young females were the subjects. For each of the 25 seat positions, consisting 5 vertical levels with 5 horizontal stops, there were two trials each of 5 seconds. The force attains a maximum value in the first 1.5 seconds and then it remains fairly constant for a total period of 5 seconds. The mean force was 39.1 kg with σ = 9.5 kg. The mean force was 83 % of the maximum force. An analysis of variance did not show that the seat positions were a significant variable. The subject opinion (very good = 1, very bad = 5) for seat position vs force had a significant correlation of 0.15. The correlation between force and subject height, subject weight, subject crotch length, subject age, knee angle, and vertical distance between pedal and H point were significant and were 0.48, 0.55, 0.22, 0.67, 0.17, and 0.28 respectively.