ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

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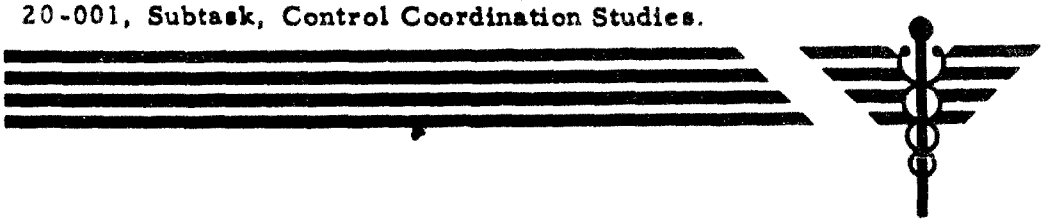
AN OPTIMUM RANGE OF SEAT POSITIONS AS DETERMINED BY EXERTION OF PRESSURE UPON A FOOT PEDAL*

*Subtask under Human Engineering Studies, AMRL Project No. 6-95-20-001, Subtask, Control Coordination Studies.



MEDICAL RESEARCH AND DEVELOPMENT BOARD
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

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AN OPTIMUM RANGE OF SEAT POSITIONS AS DETERMINED BY EXERTION OF PRESSURE UPON A FOOT PEDAL*

by

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from

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ABSTRACT

AN OPTIMUM RANGE OF SEAT POSITIONS AS DETERMINED BY EXERTION OF PRESSURE UPON A FOOT PEDAL

OBJECT

To determine an optimum range of seat positions for exertion of pressure upon a foot pedal.

RESULTS

Tests on 166 men with anthropometric measurements representative of Army male personnel in general revealed that:

1. For the positions in which the most pressure was exerted (25 per cent of total positions tested) the mean vertical adjustment of the pedal was 2.4 inches above the seat and the mean horizontal adjustment from seat to pedal was 33.2 inches.

2. The mean vertical adjustment for the position at which most foot pressure could be applied was 3.5 per cent of the average body height (SD = 2.7%) and the mean horizontal adjustment was 47.5 per cent of the average body height (SD = 2.3%).

3. In generalizing for the average height of Army male personnel (68.4 inches) the position at which the greatest pressure could be exerted upon a foot pedal would require a vertical distance from seat to pedal of 2.4 inches plus or minus 0.3 inch, and a horizontal distance of 32.5 inches plus or minus 4.25 inches.

CONCLUSIONS

1. In the optimum positions for exertion of pressure upon a foot pedal the pedal is slightly above the level of the seat.

2. Changes in horizontal seat-to-pedal distance affect the foot pressure more than like changes in vertical seat-to-pedal distance.

3. An optimum range of seat-to-pedal distances can be related to body height.

RECOMMENDATIONS

This study should be repeated with criteria of goodness of seat position other than the amount of pressure exerted. It should be repeated also to include horizontal distances less than 29 inches.

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AN OPTIMUM RANGE OF SEAT POSITIONS AS DETERMINED BY EXERTION OF PRESSURE UPON A FOOT PEDAL

1. INTRODUCTION

Since the operation of vehicles usually involves the use of a foot pedal, it would seem important that the driver's seat be placed so as to obtain the most efficient pedal operation. His leg should be in a position which enables him to exert great force or to maintain a relatively small force for a long period of time. For each operator, depending upon his leg length, there is an optimum position for efficiency in pedal operation. Hugh-Jones (1) in studying the relationship between seat-to-pedal distances and amounts of pressure that could be applied, has shown that as the seat deviates from the operator's best position his efficiency in exerting pressure decreases.

The purpose of the present study was to determine that range of seat positions in which most pressure could be exerted upon a foot pedal. The criterion of goodness of a seat position was the greatest amount of pressure that the subject could exert on the foot pedal at that position. It must be noted that there are other possible criteria of goodness of seat positions, i.e., comfort, fatigability, speed of reaction, etc.

II. EXPERIMENTAL DESIGN

A. Apparatus and Subjects

The apparatus employed in this study is illustrated in Figure 1. The seat could be moved horizontally in relation to the foot pedal and the pedal manipulated vertically in relation to the seat. The junction of the back cushion with the buttock cushion of the seat (A) served as a reference point in determining seat-to-pedal distances for all positions studied. The pedal (B) was mounted upon a hydraulic brake master cylinder (C) which was bolted to a cradle (D) mounted on a horizontal bar (E). The bar could be raised or lowered, thus permitting the entire pedal assembly to be adjusted vertically to the position desired. When pressure was applied to the pedal it swung out until its surface was perpendicular to the axis of the subject's lower leg. Thus a constant angular relationship of approximately 90 degrees was maintained between the foot and leg regardless of pedal position. Under pressure the maximum displacement of the cylinder head (the pedal) was 0.25 inch. Pressure was read on a hydraulic gauge (F) which had a scale graduated in 10-pound units.

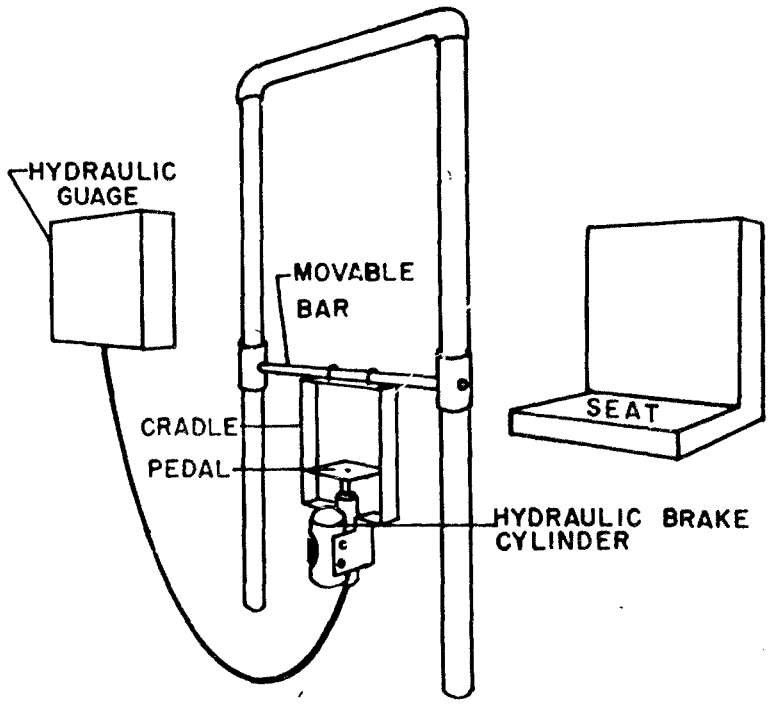

FIGURE I. A SCHEMATIC DRAWING OF THE APPARATUS.

A limitation of the apparatus was that the pedal was mounted on the master cylinder in such a way that the horizontal bar interfered with the subject's leg when small horizontal distances were used. As a consequence, horizontal distances less than 29 inches could not be tested.

The 166 subjects for the study were members of a tank battalion at Fort Knox, Kentucky. Height, weight, and leg length measurements were obtained for each man by using standard anthropometric

techniques. Throughout the study the subjects wore combat boots and Army fatigue uniforms. The mean height of the men in stocking feet was 68.8 inches. The mean height of 24,500 Army males has been found to be 68.43 inches, with a standard deviation of 2.485 inches (2). Thus it is reasonable to believe that at least in the physical dimension of height, the subjects of this study were representative of the Army male population. The frequency distributions of anthropometric measurements found in this investigation also correspond to those obtained by Damon (3) on Air Force personnel.

B. Procedure

A pilot study was carried out on 25 subjects from the Army Medical Research Laboratory at Fort Knox to determine the best procedures and range of seat positions to use.

In the main study every subject had one trial in each of 28 different positions. Each subject was rotated with 3 other subjects, the rotation providing a rest at the end of every series of 7 trials for each of the subjects being tested. All positions were presented randomly. The range of pedal positions selected was from 18 inches below the seat to 11.5 inches above it (vertical distance), while the seat was moved from 29 to 43.7 inches horizontally from the pedal (horizontal distance). Horizontal distances were measured from the pressure position of the pedal. All pressures were exerted with the ball of the foot. Subjects sat with the buttocks firmly against the back of the seat and a safety belt prevented them from rising up or sliding forward. In order to motivate the men, they were briefed on the purpose of the study and the pressure gauge was placed in full view so that they could obtain immediate knowledge of their performance.

III. RESULTS

The highest pressures exerted by the subjects varied from 350 pounds to 1250 pounds, with a median of 724 pounds. In order to equate the subjects for muscular strength a conversion technique was employed to calculate an EI ("Efficiency Index") for each man. The EI is defined as the ratio of each pressure score attained by the individual to his highest obtained pressure score. Thus for each subject there were 28 EI's, one for each seat position.

Table 1 shows the 28 seat positions ranked from highest to lowest according to the group mean EI's. Since this study was concerned with determining an optimum range of seat positions for application of pressure it was important that this optimum range

not be so large as to include "poor" positions, nor yet so small as to exclude "good" positions. It would seem that a range that covers the best 25 per cent of seat positions would meet these requirements. It was desirable to compare the best positions with the worst in order to define more clearly differences that might obtain between them. For this reason the highest 25 per cent of seat positions was compared with the lowest 25 per cent.

TABLE 1

MEAN EFFICIENCY INDICES AND STANDARD DEVIATIONS, VERTICAL AND HORIZONTAL SEAT-TO-PEDAL DISTANCES
(In Inches)

Rank	Mean EI	SD	Vertical Distance	Horizontal Distance	
1.	.891	.156	6.5	32.2	
2.	.875	.145	2.0	32.2	
3.	.874	.142	11.0	32.4	Highest or Best 25% of Positions
4.	.854	.116	-2.0	32.2	
5.	.818	.127	6.0	36.1	
6.	.809	.134	1.5	36.0	
7.	.782	.111	-8.0	31.3	
8.	.769	.123	11.5	36.3	
9.	.740	.140	-3.5	35.6	
10.	.656	.117	-8.5	35.0	
11.	.637	.156	-13.0	30.4	
12.	.586	.158	1.0	39.7	
13.	.582	.159	5.5	40.0	
14.	.559	.148	10.0	40.2	
15.	.541	.161	-4.0	39.3	
16.	.531	.144	-13.0	34.5	
17.	.461	.179	-8.0	39.1	
18.	.442	.158	-18.0	29.0	
19.	.367	.132	-17.5	33.9	
20.	.355	.145	-13.0	38.5	
21.	.334	.116	0.0	43.0	
22.	.316	.122	4.5	43.5	
23.	.310	.122	-4.5	42.9	
24.	.248	.164	-9.5	42.2	Lowest or Worst 25% of Positions
25.	.240	.147	9.0	43.7	
26.	.218	.161	-13.5	41.0	
27.	.202	.170	-17.0	38.2	
28.	.196	.188	-17.5	41.9	

It will be noted that the highest 25 per cent of positions varied considerably in respect to vertical distances, ranging from minus 8 inches to plus 11 inches (minus being pedal below the seat and plus above), but showed little difference in horizontal distances, the range being 31.3 to 36.1 inches. In the lowest 25 per cent the vertical distances also varied greatly, ranging from minus 17.5 inches to plus 9 inches, while the horizontal distances only varied from 38.2 inches to 43.7 inches. These findings would seem to indicate that the horizontal seat-to-pedal distance is a more critical

determiner of the foot pedal pressure that an individual can exert than the vertical seat-to-pedal distance.

A further comparison of the highest and lowest 25 per cent of positions revealed that in the best positions the pedal tended to be above the seat (average plus 2.4 inches), whereas in the worst positions it tended to be below the seat (average 6.9 inches). The best seat positions averaged 33.2 inches and the worst seat positions 41.9 inches in horizontal distance from the pedal. The seat-pedal relationships are presented graphically in Figure 2, where the best 25 per cent and the poorest 25 per cent of seat positions are shown.

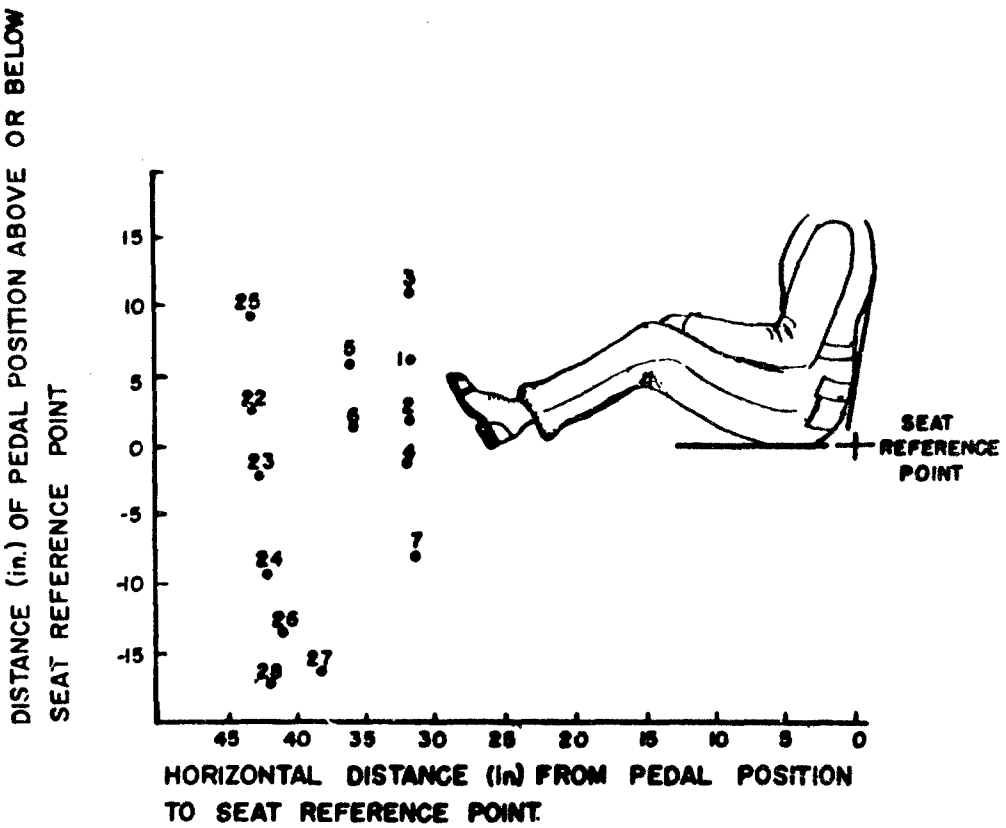

FIGURE-2 THE BEST & WORST SEAT POSITIONS

1-7 = RANK NUMBER OF BEST POSITIONS (SEE TABLE 2)
22-28 = RANK NUMBER OF WORST POSITIONS (SEE TABLE 2)

In order to obtain some indication of total subject efficiency in relation to seat position two arbitrary levels of mean EI's were calculated in relation to seat position.

Table 2 shows for each position the per cent of subjects having EI's of .75 or better and .90 or better. For example, for seat position four, 46 per cent of the subjects had EI's of .90 or better and 70 per cent of them had EI's of .75 or higher.

TABLE 2

PER CENT OF SUBJECTS HAVING EI'S OF .75 AND ABOVE AND .90 AND ABOVE FOR EACH SEAT POSITION

Position	Per Cent with EI of .75 or better	Position	Per Cent with EI of .90 or better
1.	86	1.	66
2.	86	2.	57
3.	86	3.	54
5.	75	4.	46
4.	70	5.	28
7.	63	6.	26
8.	59	7.	18
9.	47	8.	14
10.	29	9.	13
6.	28	12.	5
11.	22	10.	4
12.	16	13.	4
13.	16	14.	3
14.	13	15.	2
16.	10	11.	1
15.	9	16.	1
17.	2	17.	0
18.	2	18.	0
20.	1	19.	0
21.	1	20.	0
22.	1	21.	0
19.	0	22.	0
23.	0	23.	0
24.	0	24.	0
25.	0	25.	0
26.	0	26.	0
27.	0	27.	0
28.	0	28.	0

The vertical and horizontal distances at which each subject attained his highest pressure score was divided by his height in inches and the resulting proportion was multiplied by 100. The percentages thus obtained were analyzed in order to determine whether there was a relationship between the per cent of body height of the vertical and horizontal distances and amount of foot pressure that could be exerted at a given position. The horizontal distance at which each subject attained his best pressure was found to be approximately 47.5 per cent of his body height, with a standard deviation of 2.3 per cent. The vertical distance at which each subject

attained his maximum pressure was approximately 3.5 per cent of his body height, with a standard deviation of 2.7 per cent (see Table 3).

TABLE 3

FREQUENCY DISTRIBUTIONS OF PER CENT OF BODY HEIGHT OF HORIZONTAL AND VERTICAL DISTANCES AT POSITIONS OF GREATEST APPLICATION OF PRESSURE (N=166)

Vertical Distance		Horizontal Distance	
% of Body Height	Frequency	% of Body Height	Frequency
10	13	55	1
8	15	54	3
6	15	53	1
4	54	52	3
2	37	51	10
0*	10	50	16
-2**	19	49	14
-4	3	48	20
		47	33
Mean 3.5		46	36
		45	23
		44	3
		43	3
		Mean 47.5	

*Vertical position in which pedal was at seat level.
**Negative percentage indicates that the pedal was below the seat.

IV. DISCUSSION

As has been mentioned above, the amount of pressure that a subject can exert on a foot pedal from a given seat position is not the only possible criterion of goodness of a seat position. It would be useful to carry out further studies which would employ other criteria, e.g. comfort, fatigability, speed of reaction, etc.

In this study the best positions for exertion of pressure tended to be above the seat. However, this finding does not mean that the pedal should be placed above the seat in all instances. The criterion of goodness of a seat position was the amount of pressure that could be exerted at that position. It would seem that the pedal placed above the seat enabled the subjects to perform better than when it was placed below the seat, since muscle power could be employed more effectively in the former case.

The analysis of the per cent of subjects having EI's of .75 and above and .90 and above for each position indicated that a seat position at which subjects attained at least 75 per cent efficiency

does not necessarily hold the same relative rank when one is concerned with at least 90 per cent efficiency. The analysis revealed further that the seat positions at which no subject attained at least 75 per cent efficiency invariably involved relatively great horizontal distances between the seat and the pedal.

The fact that changes in the horizontal distance affected performance more than like changes in the vertical distance is important and must be taken into account in future studies of this nature. If this relationship continues to be found for other criteria of goodness of a seat position, the designer perhaps should be more concerned with horizontal than with vertical seat-to-pedal distances.

The mean vertical and horizontal distances for maximum exertion of foot pressure have been found to be related to body height, the best horizontal distance being 47.5 per cent of the average body height of the subjects, and the best vertical distance being 3.5 per cent of the average body height. Thus it becomes possible to predict approximately the best seat position for any given subject merely from knowledge of his height.

Height of Army personnel ranges from 60 to 78 inches. These height limitations require, for positions of greatest exertion of foot pressure, a range of the horizontal adjustment of approximately 8.55 inches (78 x .475) - (60 x .475), and a range of vertical adjustment of approximately 0.63 inch (78 x .035) - (60 x .035). The average height of Army males is approximately 68.4 inches. Generalizing further from the findings of this study, it becomes possible to state that for Army male personnel, the position at which greatest pressure can be exerted upon a foot pedal requires a horizontal distance from seat to pedal of approximately 32.5 inches (68.4 x .475), with an adjustment of plus or minus 4.25 inches, and a vertical distance from seat to pedal of approximately 2.4 inches (68.4 x .035), with an adjustment of plus or minus 0.3 inch.

V. CONCLUSIONS

From the findings of this study the following conclusions appear warranted:

1. In the optimum positions for exertion of pressure upon a foot pedal the pedal is slightly above the level of the seat.

2. Changes in horizontal seat-to-pedal distance affect the foot pressure more than like changes in vertical seat-to-pedal distance.

3. An optimum range of seat-to-pedal distances can be related to body height.

VI. RECOMMENDATIONS

This study should be repeated with criteria of goodness of seat position other than the amount of pressure exerted. It should be repeated to include horizontal distances less than 29 inches.

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