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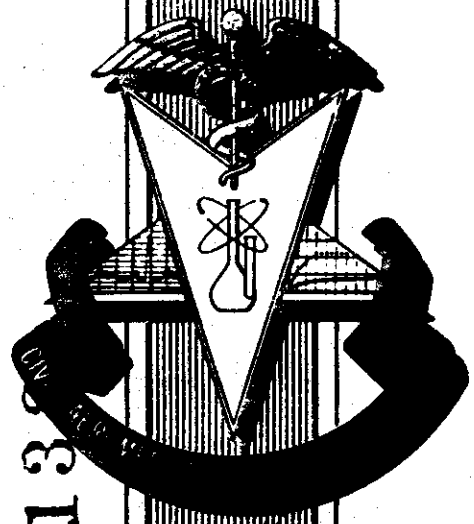

AN ANALYSIS OF SITTING AREAS AND PRESSURES OF MAN

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Civil Aeromedical Research Institute
FEDERAL AVIATION AGENCY
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OKLAHOMA CITY, OKLAHOMA

JANUARY 1962

AN ANALYSIS OF SITTING AREAS AND PRESSURES OF MAN

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AN ANALYSIS OF SITTING AREAS AND PRESSURES OF MAN

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Studies of sitting area on a plane rigid surface for a group of 104 male subjects were made. Area was found to vary with height and weight and to increase with age up to 40 years after which there is a steady decline. Means were 179.4 sq. in. for area and .92 pounds/sq. in. for average pressure.

Sitting contact area was found to increase with experimentally applied force of magnitudes up to something less than body weight.

Analysis of pressure distribution in the sitting area reveals that nearly half of the body weight is supported on 8% of the sitting area. This high pressure area is under or adjacent to the ischial tuberosities.

Over one-third of the body weight on the sitting area is removed by the addition of a footrest, chair arms, and a slightly sloping seat back.

INTRODUCTION

A study of pressures and contact areas in the seated position has been in progress at CARI for some time. The results of this study will have application in designing more comfortable seating to lessen the discomfort and fatigue of crew and passengers during long flights. The results will also have application to the important problem of preventing spinal and other injuries which can result from the vertical component of crash forces.

This report of preliminary results presents pressures and areas observed at contact surfaces of men sitting on a rigid, plane surface. The data obtained from this simple seating arrangement are necessary for understanding force and area relationships in more complex seating designs.

Four different kinds of measurements are reported:

I. Measurement of sitting area of a large group of male subjects 17-74 years of age.

II. Variations of the sitting contact area with magnitude of experimentally appliéd forces.

III. Determination of distribution of pressure over the sitting area.

IV. Evaluation of the use of chair arms, seat back, and foot rest as aids for reducing sitting pressures.

I. MEASUREMENT OF SITTING AREA

Tracings of area of contact were made on 106 male subjects sitting on the transparent platform (Fig. 1). Note that the platform extends to the bend of the knees in order to record maximum sitting area. Area tracings on the plastic platform were transferred to sensitized paper by the Ditzen "Directo" process and measured with a planimeter.

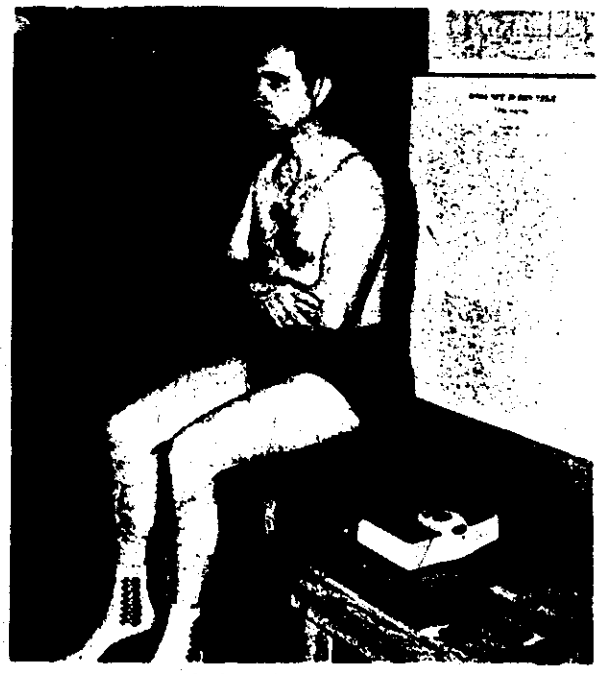

Figure 1. Platform for measuring sitting areas

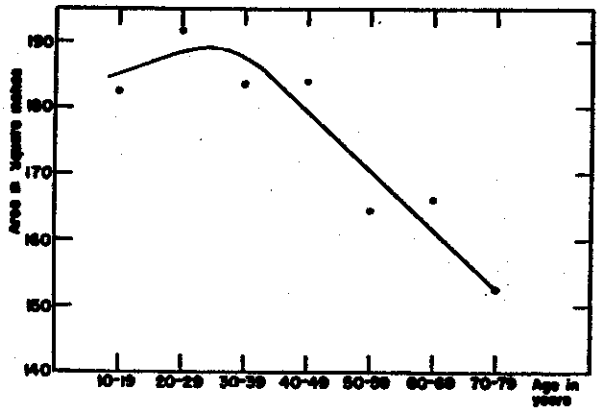

Figure 2. Sitting area (average per age groups)

Figure 2 shows an increase in sitting area with age up to 40 after which there is a steady decline.

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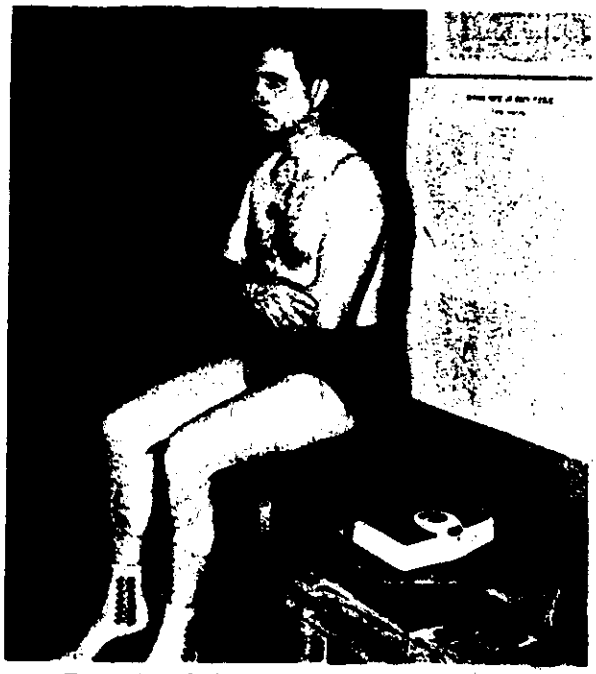

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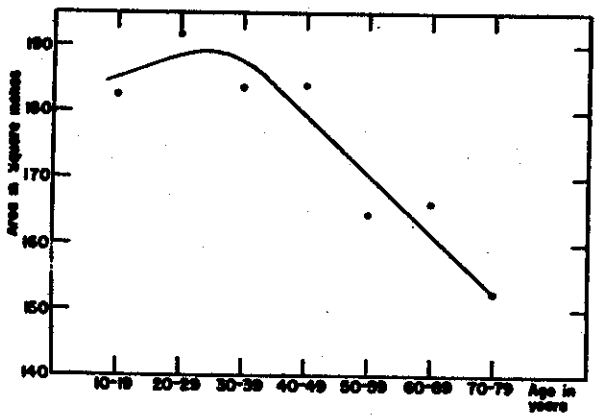

Figure 2. Sitting area (average per age groups)

Figure 2 shows an increase in sitting area with age up to 40 after which there is a steady decline.

Figure 3 is a plot of weight and area. Note that there is a positive relation between weight and area of contact. There is also a similar relationship between area and height (*Fig.* 4).

Table I. Summary Data of Sitting Area

	Range	*Mean*
Area (in^2)	101-268.4	179.4
Weight (lbs)	106-269	164.4
Av. Pressure (lb/in^2)	.69-1.23	.92
Age (yrs.)	17-74	36
Height (in.)	62-78	69.3

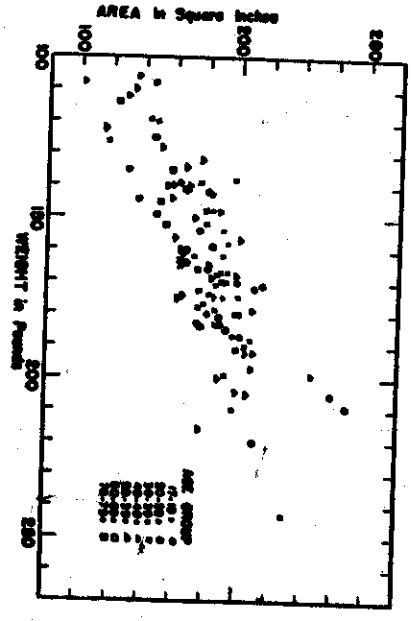

Figure 3. Plot of sitting area as related to weight and age (106 Subjects)

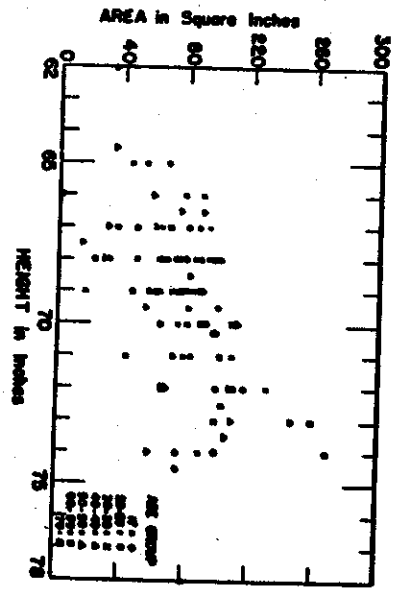

Figure 4. Plot of sitting area as related to height and age (106 Subjects)

Table II. Height, Weight, and Age of Subjects

Height (inches)	*Number*	*Weight*	*Number*	*Weight*	*Number*	*Age*	*Number*
62	1	106	1	170	4	17	2
64	1	108	2	171	2	18	5
65	3	110	1	172	1	19	2
66	6	112	1	173	1	23	1
67	11	114	1	174	2	25	2
68	20	120	1	175	4	26	3
69	21	122	1	177	3	27	1
70	11	125	1	179	2	28	4
71	6	126	1	180	2	29	2
72	9	128	1	181	1	30	3
73	5	129	1	183	3	31	4
74	6	132	1	184	2	32	2
78	1	134	1	185	1	33	2
		135	2	187	2	34	6
		138	1	188	1	35	9
		139	2	190	1	36	1
		140	3	191	1	37	3
		141	2	192	2	38	3
		142	1	197	1	39	1
		143	1	199	2	40	5
		144	2	200	1	41	3
		145	2	204	1	42	1
		147	1	205	2	43	1
		148	3	209	1	44	1
		150	1	210	1	46	2
		152	2	216	1	47	1
		154	2	220	1	48	1
		156	1	243	1	49	2
		157	2	269	1	50	1
		159	1			51	2
		160	2			52	2
		161	1			53	2
		162	2			54	1
		163	1			55	3
		164	1			56	2
		165	2			57	1
		166	2			58	2
		167	1			59	3
		168	2			60	1
		169	1			61	1
						62	1
						63	4
						64	1
						66	2
						68	1
						74	1

II. VARIATIONS OF THE SITTING CONTACT AREA WITH MAGNITUDE OF EXPERIMENTALLY APPLIED FORCES

Each of the nine subjects was supported over a transparent sitting platform by means of a special chest harness and lowered stepwise so as to make the platform scales read 5, 10, 15, 20, 40, 60, 80, etc., up to total body weight After the scales supported the subjects' total weight, loads on the sitting area were further increased by having him hold additional weights in his arms (namely, 20, 40, and 60 pounds). Contact area tracings were made for each increment of weight and are presented in Figure 5. Very large weight loadings on the buttocks and thighs, such as are produced by the vertical component of force in a crash, were not investigated. However, it may be noted in this study that man reached his maximum supporting area with his own body weight.

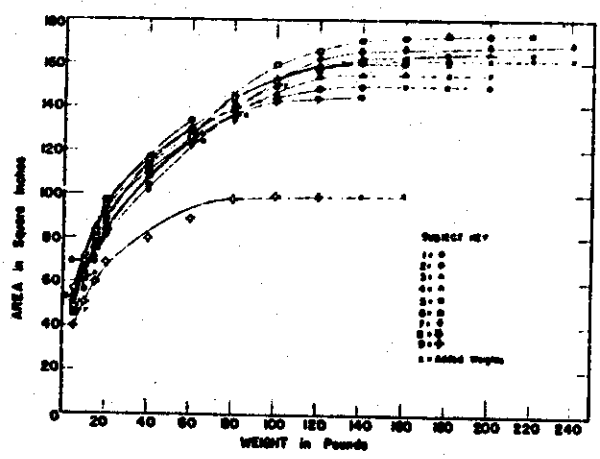

Figure 5. Area of sitting with weight increments (9 Subjects)

Table III. Subjects for Phase II

Subject	*Age*	*Height*	*Weight*
1	27	72"	172
2	35	66"	154
3	28	74"	209
4	35	68"	175
5	31	72"	243
6	28	69.5"	180
7	34	71"	269
8	41	68"	151
9	30	68"	120
Average	32.1	69.7	175.4

The nine subjects used in this study fell within the age-weight-height range of the total group of subjects tested in the seated position.

III. STUDY TO DETERMINE DISTRIBUTION OF PRESSURE OVER THE SITTING AREA

Table I of this report shows that average sitting pressure ranges from .69 to 1.23 lbs/in² but Hertzberg[7] has pointed out that sitting pressures under the ischial tuberosities may be as high as 60 lbs/in². This phase of our study was was conducted to extend the above observations by determining distribution of pressure over the entire sitting area.

Prints (Fig. 6a and 6b) were made of sitting pressure distribution using absorbent paper over inked corduroy cloth. Density of ink transfer was calibrated in lbs/in² and the sitting pressure prints evaluated using a photometer.

Repeat prints of a single individual showed the technique of inking the cloth to be reliable and reproducible.

Four areas of density were established:

Area I – Very black = 10-60 lbs/sq. in. Since the inking became solid with 10 lbs. or over it was not possible to define the upper limit of pressure. However, Hertzberg found maximum pressures in very small areas under the tuberosities to range up to 60 lb/sq. in. Hence, we assume that solid black areas represent pressures between 10 and 60 lbs./sq. in.

Area II – Dark lines almost merging = 4-9 lbs/sq. in.

Area III – Dark lines separated by distinct white lines = ½-3 lbs. sq. in.

Area IV – Dark lines incomplete = 1/8-1/2 lbs/sq. in.

Results on 5 subjects are presented in Tables IV and V.

Figure 6a. Sitting pressure print of a subject with prominent Tuberosities

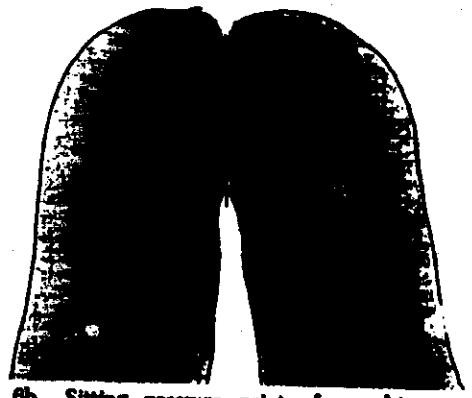

Figure 6b. Sitting pressure print of a subject without High Pressure area

Averages for the group show nearly half of the body weight is concentrated on 8% of the sitting area. This high pressure area is located under or adjacent to the ischial tuberosities. In some individuals, because of differences in body structure, this percent of weight concentration ran as high as 70% while in others the highest pressure readings found in the entire sitting area did not exceed the limit of Area III, i.e., 3 lbs/in² (See Fig. 6b).

Table IV. Summary Data of Sitting Pressures

Pressure	*Area I 10-60 lbs/in²*	*Area II 4-9 lbs/in²*	*Area III ½-3 lbs/in²*	*Area IV ¼-½ lbs/in²*
Per cent of total sitting area	3.5	4.5	34.0	58.0
Location	Under ischial tuberosities	Near tuberosities	Adjacent to periphery	Peripheral

Table V. Subjects 1, 2, 5, 6, 8 of the Preceding Test were Used in This Experiment.

Subject	*Area I 10-60 lbs.*		*Area II 4-9 lbs.*		*Area III ½-3 lbs.*		*Area IV ¼-½ lbs.*	
	Area	Wt.	Area	Wt.	Area	Wt.	Area	Wt.
1	8.96	86.22	9.71	36.48	33.57	30.55	78.91	18.75
2	0	0	0	0	89.42	134.13	31.14	20.60
5	0.96	10.12	3.67	25.68	53.42	168.90	76.61	38.30
6	6.89	95.12	3.46	29.30	29.70	30.70	71.51	24.88
8	5.62	66.04	12.71	44.48	9.75	19.50	107.94	26.98
Average	4.48	51.50	5.91	27.18	43.17	76.75	73.33	25.9
Average Pressure	11.50 lb/in²		4.60 lb/in²		1.78 lb/in²		0.354 lb/in²	

IV. EVALUATION OF THE USE OF CHAIR ARMS, SEAT BACK, AND FOOT REST AS AIDS FOR REDUCING SITTING PRESSURES.

Contact areas were made of individuals seated relaxed on a transparent platform and weight readings made from the supporting scales. A foot rest (18" below platform), chair arms (9" above platform), and a chair back (15° back of vertical) were added individually and in various combinations to determine their effects on reducing body weight on the platform scales. Results are presented in Table VI.

Table VI. Reduction of Body Weight on Sitting Area by Adding Chair Arms, Back Support, and Foot Rest to Sitting Platform.

Experimental Weight Loss					
Singularly		In Combination		Arithmetic Addition of Individual Accessories	
Sitting Platform with —	*Loss of Body Weight on Sitting Area*	*Sitting Platform with —*	*Loss of Body Weight on Sitting Area*	*Sitting Platform with —*	*Loss of Body Weight on Sitting Area*
Foot Rest only (1)	18.4%	Foot Rest (1) and Chair Arms (2)	30.8%	Foot Rest (1) and Chair Arms (2)	18.4% 12.4% 30.8%
Chair Arms only (2)	12.4%	Chair Arms (2) and Chair Back (3)	16.4%	Chair Arms (2) and Chair Back (3)	12.4% 4.4% 16.8%
Chair Back only (3)	4.4%	Foot Rests (1) and Chair Back (3)	31.3%	Foot Rest (1) and Chair Back (3)	18.4% 4.4% 22.8%
		Foot Rests (1), Chair Arms (2) and Chair Back (3)	39.4%	Foot Rest (1), Chair Arms (2) and Chair Back (3)	18.4% 12.4% 4.4% 35.2%

While addition of these chair accessories may reduce body weight on a sitting platform by more than 1/3, it does no follow that the average sitting pressure is reduced by a corresponding amount. Figure 7 presents a comparison of weight, area, and average pressure for each of the sitting conditions.

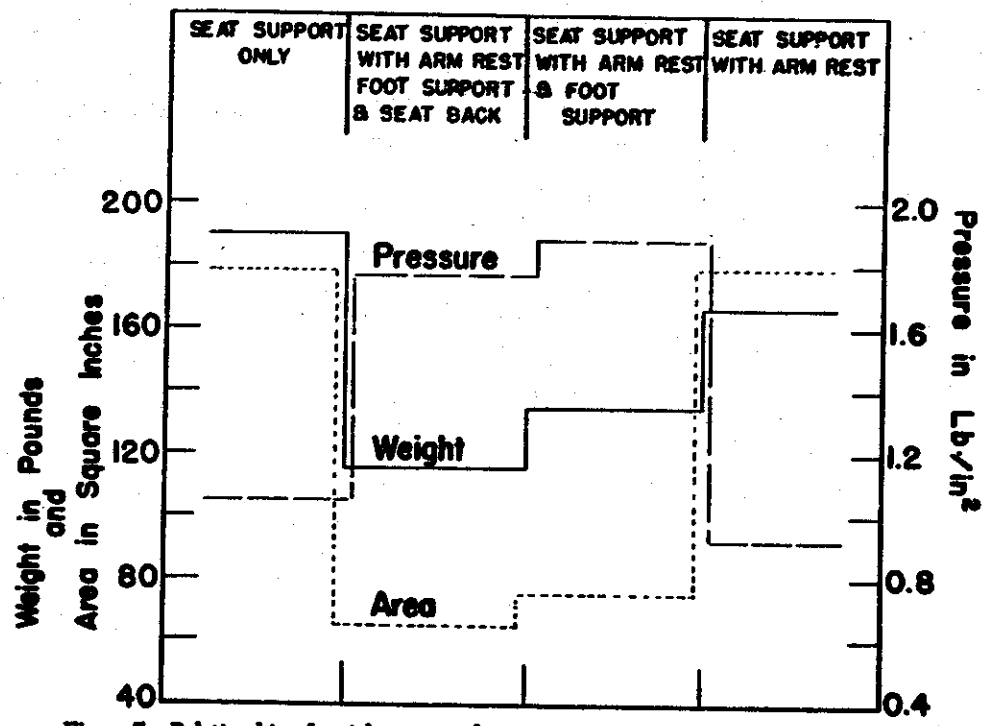

Figure 7. Relationship of weight, area and pressure in various seating arrangements

Table VII.

Subject	*Area on Sitting Platform only*			*Sitting Platform with chair back, foot rest and chair arms*			*Sitting Platform with chair back and foot rest*			*Sitting Platform with chair arms*		
	Weight	*Area*	*Average Pressure*	*Weight*	*Area*	*Average Pressure*	*Weight*	*Area*	*Average Pressure*	*Weight*	*Area*	*Average Pressure*
2	155	160.3	0.967	98	62.1	1.576	113	82.1	1.376	138.5	161.1	0.860
3	214.5	212.2	1.011	130	69.2	1.877	148	78.4	1.888	192.5	206.4	0.933
4	175	170.7	1.023	100	56.3	1.775	122	55.8	2.190	152	177.1	0.858
5	247	194.6	1.269	148	85.0	1.741	173	84.1	2.056	226	204.4	1.105
6	180	174.2	1.032	106.5	52.0	2.050	123	56.0	2.195	151.5	169.9	0.892
7	269	187.3	1.436	179.5	100.7	1.782	192	99.2	1.936	250	188.9	1.323
8	157	178.6	0.879	84.5	58.6	1.441	111	71.5	1.553	127.5	176.6	0.722
9	117	153.7	0.761	77	36.6	2.103	98			102	152.5	0.669
Average	189.3	178.9	1.047	115.4	65.1	1.793	135	75.3	1.884	167.5	179.6	0.920

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