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Measurement of Seat Pressure Distributions

DELIA TREASTER,[1] *Battelle Memorial Institute, Columbus, Ohio, and* W. S. MARRAS, *The Ohio State University, Columbus, Ohio*

Knowledge of seating pressures is important for proper chair design. This study demonstrates the usefulness of a new methodology for measuring pressure distributions. It refines and advances an optical-reflection technique introduced several years ago. In this way precise quantitative measures of the pressure distribution can be obtained. Video image digitization, which converts analog video signals to digital ones, provided data in a form that could be easily submitted for computer analysis. Additionally, a novel method of analysis is presented that allows for the measurement and evaluation of the distribution of seated pressures, rather than peak pressures alone. A preliminary experiment with eight subjects was conducted to demonstrate the validity of the experimental apparatus and the data treatment.

INTRODUCTION

Chairs and related types of seating devices are among the most common and important fixtures in society. They are found in virtually every work environment. It has been estimated that three-fourths of all work in industrial countries is sedentary. Proper chair design is thus essential: chairs should provide adequate support for the user, allow efficient performance of the desired task, permit changes in posture, and be comfortable to the user (Andersson and Ortengren, 1974; Andersson, Ortengren, Nachemson, and Elfstrom, 1974). Poor chair design may hinder productivity, lead to user discomfort and dissatisfaction, and aggravate existing medical conditions such as back pains.

Assessment of chair designs is often based on anatomical and physiological measures such as electromyographic (EMG) activity, pressure distribution, and anthropometric data. These evaluate the physiological compatibility of various seating configurations to the human body.

Some common seating guidelines, applicable to all types of chairs, are the following:

(1) Avoid compression of thighs, which may restrict blood flow to the lower extremities and pinch nerves, causing pain and numbness (Tichauer, 1978).
(2) Avoid flattening the lumbar spine by providing a backrest for lower back support.
(3) Distribute weight equally on the weight-bearing bony prominences (ischial tuberosities) in the buttock.
(4) Allow adjustments to be made in the dimensions of the chair—such as height and angle of inclination—in order to accommodate a variety of user sizes.

The issue of support is an important one in seat research. Support for the seated individual is provided primarily in the buttocks and thighs. The ischial tuberosities or "sitting bones," which are bony protuberances in the buttock regions, are the major weight-bearing structures. The soft tissues covering the ischial tuberosities are subjected to ex-

[1] Requests for reprints should be sent to Delia Treaster, Battelle Memorial Institute, 505 King Avenue, Columbus, OH 43201.

tremely high pressures. These high-pressure regions are associated with discomfort and pain. In extreme cases, as with some handicapped individuals, high pressure can lead to pressure sores, cardiovascular problems, and other medical complications. Ideally areas of high pressure should be minimized, with pressure distributed as uniformly as possible over the entire sitting region. Thus it can be seen that measurement of sitting pressures is an important facet of proper chair design.

Early Pressure Measuring Systems

Numerous attempts have been made to quantify sitting pressures. Swearingen, Wheelwright, and Garner (1962) measured sitting pressure by seating subjects on absorbent paper placed over inked corduroy cloth; the density of the ink transfer provided a measure of pressure intensity. The experimental method was not able to distinguish pressure levels above 70 kPa. Crude as it was, this method represented one of the first measurements of the distribution of pressures under the thighs and buttocks during sitting.

Other attempts to measure sitting pressure used a variety of pressure-sensitive devices. Bush (1969) utilized one pressure transducer taped over the ischial tuberosities and another under the thighs just behind the seat edge. He found the maximal empirical ischial pressures to be approximately 207 kPa. Hertzberg (1972) described a "pressure-measuring blanket" that consisted of an array of closely spaced thin flexible capacitors, each 1 cm^2 in area; increased pressure was measured by the change in capacitance. Peak ischial pressure exceeded 413 kPa. Holley, Long, Stewart, and Jones (1979) employed a small matrix of pressure transducer cells taped over the ischial area, and found the mean pressure for 10 areas to be 15.5 kPa. Transducers were also used by Fisher and Patterson (1983) for long-term ischial pressure recordings in spinal-cord-injured patients. Average ischial pressure on foam cushions was approximately 14 kPa.

Drummond, Narechania, Rosenthal, Breed, Lange, and Drummond (1982) developed a microcomputer-based pressure scanner composed of 64 strain-gauge-resistive transducers to create a contour map of the seated pressure distributions. The raw data obtained from the scanner were interpolated for three intermediate pressures between each transducer. The results showed that 18% of body weight was supported by each ischial tuberosity, 21% by each thigh, 5% over the sacrum, and that the remaining body weight was evenly distributed throughout the sitting region.

In another study Garber, Krouskop, and Carter (1978) devised a pressure evaluation pad (PEP). This pad consisted of a 12 × 12 matrix of pneumatically controlled contact switches and was used to compare the relative efficacy of various wheelchair pressure-relieving cushions. The PEP has also been used to evaluate the effect of wheelchair cushions (Seymour and Lacefield, 1985), the effect of wheelchair cushion modifications (Garber and Krouskop, 1984), and the relationship between body build and pressure distribution (Garber and Krouskop, 1982).

All of these studies have yielded valuable information. However, there are some problems inherent in the methods used. For example, many potential sources of error are associated with the use of pressure transducers. The process of attaching the transducer to the sitting region is one possible source of error. If the transducer is affixed with adhesive tape, a pressure artifact may be created by the tension of the tape across the transducer. In addition, a pressure artifact may be created by the thickness of the transducer itself, causing artificially high pressure loading on the tissues. Matrices of pressure devices record discrete, not continuous, data. A single value, which is the average pressure over the surface of the transducer, is obtained from each transducer; thus resolution of the data is limited by the size of the transducer. The larger the transducer, the coarser the level of resolution. Interpolation is necessary to estimate pressure intensities between transducers. The result is that the interpolated data are analytically rather than empirically derived and lack an acceptable level of accuracy.

In recent years several types of pressure-measuring equipment have been developed. These devices, based on the optical principle of total internal reflection, circumvent many of the problems and limitations of pressure transducers and provide continuous pressure measurements.

Hertzberg (1955, 1972) described a device in which zones of high buttock pressures were represented by areas of bright light intensities. Using this device the location and size of the tuberosities were easily determined. The angle between the tuberosities and changes in tuberosity shape due to changes in body positions were observed. However, the pressure intensities were not quantified, so precise ischial pressures were not obtainable.

A similar device, called the "wheelchair barograph," was used by Mayo-Smith and Cochran (1981). It provided a portable, adjustable device to locate high-pressure regions clinically by means of easily discernible light patterns. These high-pressure regions were qualitatively identified by a visual scan but were not calibrated to standard units of pressure. Thus use of the wheelchair barograph was limited to the clinical applications of locating the ischial tuberosities for subsequent modifications of wheelchair cushions.

A "pedobarograph," based on the same optical principles as the devices just described, was utilized by Minns and Sutton (1982). A video camera recorded the pattern of light intensities, and the use of a gray-scale-to-color converter enabled the researchers to quantify the light intensities to known pressure levels. The results showed a maximal ischial pressure of 1.6 kPa for healthy subjects and up to 40 kPa (near pressures sores) for paraplegic patients. This represented a significant improvement in measuring and quantifying sitting pressures. However, the data were not stored in a format that permitted statistical analysis.

Numerous researchers have measured sitting pressures using a variety of techniques. Many utilized pressure transducers and experienced some of the problems described earlier. Others employed measuring devices that did not have the desired sensitivity or were not amenable to analysis. Additionally, the effects of seat pan and backrest inclinations on the pressure distributions were not evaluated. Since an inclined backrest is recommended for most chairs, it would be desirable to know the effect of different backrest angles. The following study attempts to consider all of these relevant issues.

Objective

The objective of this study was to design an experimental chair for measuring seating pressures that would circumvent many of the aforementioned problems and incorporate the effects of different backrest angles on the pressure distribution. A preliminary experiment was conducted to demonstrate the effectiveness of such a device.

Experimental Equipment Description

An experimental chair was developed that eliminated many of the problems of previous pressure-measuring devices. This chair was based on the same optical principles utilized by earlier researchers. It provided continuous rather than discrete measurements of pressure, thus eliminating the need for interpolation. Furthermore, the degree of resolution was greatly increased over that of transducer-based systems. The experimental chair was also more economical and easier to construct than the traditional transducer system, since preamplifiers and other electronic accessories were eliminated.

The pressure distributions of the buttock and back areas were recorded on the experimental chair, which was composed of a seat unit and a backrest unit linked within a frame (see Figure 1). The seat pan unit allowed anterior or posterior inclinations of up to 30 deg; the depth of the seat pan could be adjusted to accommodate various sizes of subjects. The seat unit also had adjustable footrests to provide support for the feet and lower legs. The backrest unit likewise could assume a range of inclinations, from a vertically upright position at 90 deg to a fully reclined position at 180 deg. The seat and backrest units could move independently of each other (see Figure 2).

This pressure-measuring apparatus utilized the principle of total internal reflection. The interface pressure distributions were measured from the seat and backrest surfaces, which were composed of transparent acrylic sheets with optically polished edges. A fluorescent light was attached along one edge. The light that entered the acrylic sheet from the fluorescent light was totally reflected internally between the top and bottom surfaces of the acrylic. Because none of the light was refracted out of the acrylic, it appeared dark when viewed from the underside.

The acrylic was overlaid with a pedobarograph foil (Baromat, available from Biomechanics, Le Mesa, CA), which is composed of silicon rubber with deformable conical projections on one surface. The points at which the foil contacted the acrylic (at the apex of the conical projections) caused the light to be reflected out of the bottom of the acrylic and to appear as light areas on the underside. As

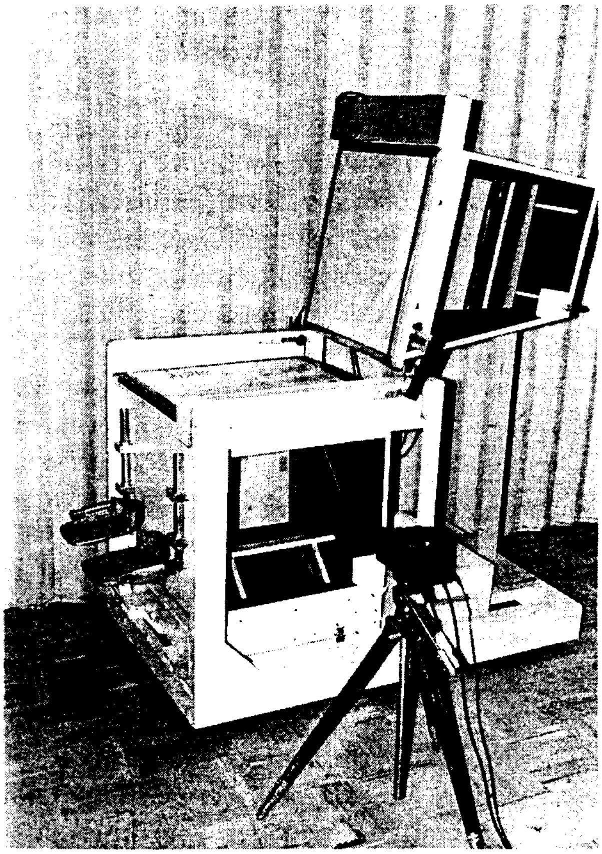

Figure 1. *Experimental chair.*

the body weight of the subjects exerted pressure on the foil, the deformable projections were forced into more intimate contact with the acrylic, increasing the total contact area, with the result that more light was refracted out of the bottom of the acrylic. When viewed from the underside, these areas appeared as brightly lit spots, with intensity of light correlated to intensity of pressure. Mirrors positioned on the underside of the seat and backrest surfaces facilitated viewing and recording of the light intensity patterns. This technique of using total internal reflection to measure pressure intensities has previously been used in gait analysis (Betts, Duckworth, and Austin, 1980; Betts, Franks, and Duckworth, 1980a, 1980b; Betts, Franks, Duckworth, and Burke, 1980; Franks, Betts, and Duckworth, 1983; Spiegal, Cass, Bleimeyer,

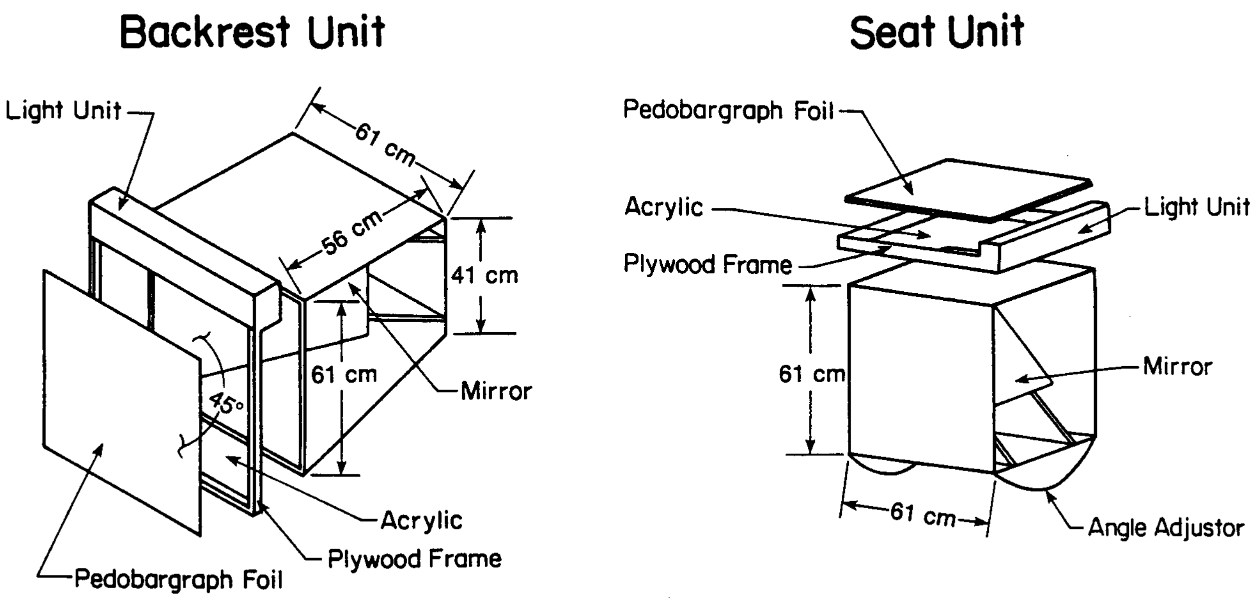

Figure 2. *Schematic drawings of seat pan and backrest units.*

Cahill, and Chao, 1985; P. Cahill, personal communication, May 10, 1985).

Digitization process. A low-light-sensitive video camera was used to record the image of light intensities. A commercially available computer-based video digitizer (Video Van Gogh, by Tecmar, Inc.) was used for digitization. Digitization consisted of breaking the video image into discrete picture elements (pixels). A video signal was sent to an analog-to-digital converter for each pixel. The signals represented intensity measurements, which were stored as binary values. After the image was digitized, the data buffer contained a brightness value between 0 and 255 for each digitized pixel (0 represented the darkest pixel and 255 the brightest). The luminance levels were positively correlated with pressure; the larger the luminance value, the higher the pressure level. A digitized video frame consisting of 250 horizontal pixels × 240 vertical pixels yielded 60 000 data points per frame. The digitized data were subsequently transferred to a computer for analysis.

Visual inspection of the digitized data revealed nonzero values for areas where no pressure was applied, such as around the edges of the chair that extended beyond the subject's thighs. Since a digitized pixel with a value of 0 represented a black pixel (i.e., no pressure), it was clear that these nonzero values represented noise in the optical reflection system. Hence values below a predetermined level were eliminated from the analysis. The response criterion, β, was established qualitatively by visual examination of the digitized data. A conservative response criterion was chosen in order to minimize the risk of false-positives, given that high pressure values were of greater interest in this study.

To facilitate interpretation of the results, the light intensities were converted into standard units of pressure (pascals) according to an empirically determined calibration curve. A small block of aluminum placed on the surface of the seat unit served as the base upon which known weights were placed. For each weight level the deformation of the pedobarograph foil was recorded and digitized. The digitized values were averaged to obtain the luminance level for each weight interval. The resultant calibration curve is shown in Figure 3. From this graph it can be seen that the digitized luminance levels have a fairly linear relationship to the pressure intensity.

Data Treatment

Most of the research described earlier focused on peak sitting pressures. It is well known that peak pressures usually occur under the ischial tuberosities, or "sitting bones." Knowledge of maximum pressures is useful in the analysis of chair design, given that high-pressure regions in the buttocks are known to cause pain and discomfort. But it would be erroneous to measure ischial pressures alone even though doing so would eliminate the areas of high pressure concentration and minimize user discomfort. It is better to distribute pressure evenly over the entire sitting surface in order to maximize user comfort.

Several other factors should be considered in the measurement of sitting pressures. Changes in the backrest angle affect the location of the center of gravity and, consequently, the site and magnitude of peak pressure. Likewise, shifts in posture (e.g., from an upright posture to a slouched one) or changes in leg position (crossing legs or elevating feet) also change the location and magnitude of peak pressure. All of these factors interact to affect the pressure distribution on the buttocks and thighs. Measuring the pressure distributions would provide useful data for designing various seat parameters. The edge of the seat could be properly contoured to avoid compression of the soft tissues under the thighs, and the depth of contouring for both the seat pan and backrest could be empirically determined based on analysis of the pressure distributions.

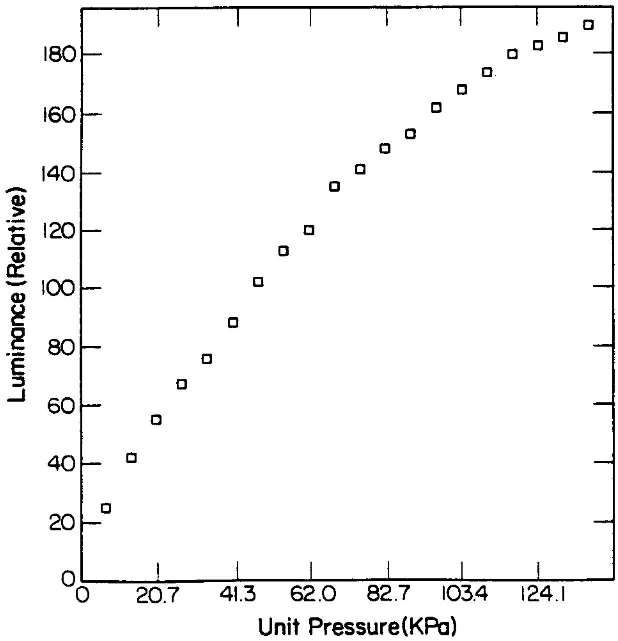

Figure 3. *Calibration curve.*

Thus knowledge of the distribution and magnitude of pressure provides far more information than peak pressure alone. This knowledge goes beyond minimizing user discomfort; it allows for optimal chair design in order to *maximize user comfort.*

Three-dimensional and isopressure contour plots, such as those in Figures 4 and 5, were created by smoothing the raw data (luminance intensity) by using running means and then plotting them along the x and y axes. They graphically demonstrate the variations in intensities of pressure on the thighs and buttocks: pressure is highest under the ischial tuberosities, as expected, and decreases along a gradient to the edges of the thighs.

Weibull distribution. Probabilistic statistical analysis assumes that a set of data arises from a distribution in a class of probability distributions. If a set of data can be described as a sample from a certain theoretical distribution, then there is a valuable compactness of description for the data. For example, in the case of a Gaussian distribution, the data can be succinctly described by the mean and standard deviation and by stating that the distribution of the data is approximated by

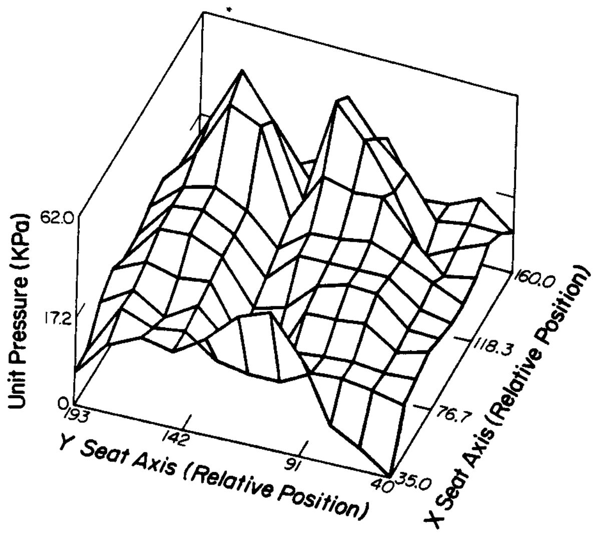

Figure 4. *Three-dimensional plot of smoothed pressure intensities on seat pan.*

the Gaussian distribution. Distributional assumptions can lead to useful statistical procedures. To test distributional assumptions about data, the data should be "fitted" to the assumed distribution.

In order to assess the effects of seat and backrest angles on the buttock and thigh areas, the pressure data were fitted to the Weibull family of distributions. The Weibull distribution is a general distribution readily characterized by shape and spread parameters, θ and λ. Since the distribution of pressure can assume many forms, the Weibull distribution serves as an ideal measure with which to evaluate the experimental conditions. The shape and spread parameters, θ and λ, provide succinct measures that encapsulate the behavior of the data under a given experimental condition. Analysis of these quantitative parameters allows evaluation of the direction in which the distribution changes.

With θ constant, increasing λ increased the dispersion or variability of the distribution; that is, the distribution became flatter, as can be seen in Figure 6a. In terms of the seating pressure, this indicates that the pressure was more uniformly distributed. For constant values of λ, as θ increased, the distribution shifted to the right to higher pressure levels. In Figure 6b, for λ = 1 and θ = 1–3, the shape of the distribution changes from an exponential shape to a more Gaussian one. This indicates that the concentration of pressure shifts to higher levels. When applied to the backrest data, increased values of θ indicated that more body weight was transferred from the seat pan to the backrest. Thus higher θ values for backrest data are considered desirable. For seat data the opposite is true: distributions with lower θ values and short right-handed tails, which indicate concentration at lower pressure levels, are more desirable.

Frequency histograms were constructed on the digitized data for each subject. All digital values below the response criterion, β, were eliminated from the analysis. A total of 20 evenly spaced pressure levels were used as intervals in the histograms. Frequencies, cu-

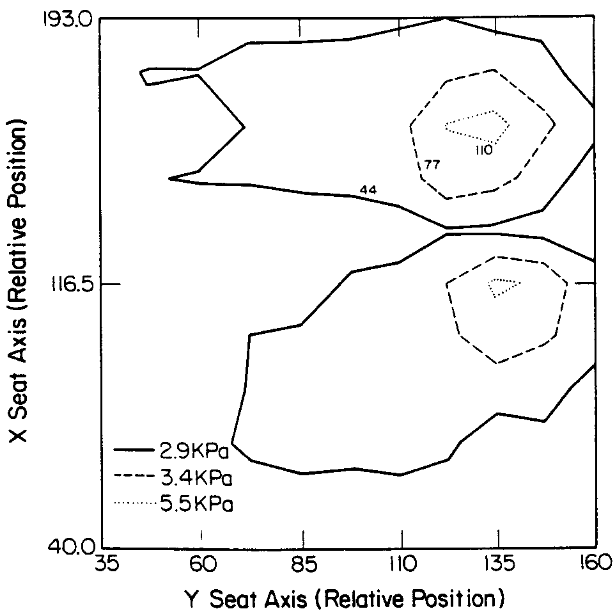

Figure 5. *Contour plot of smoothed pressure intensities on seat pan.*

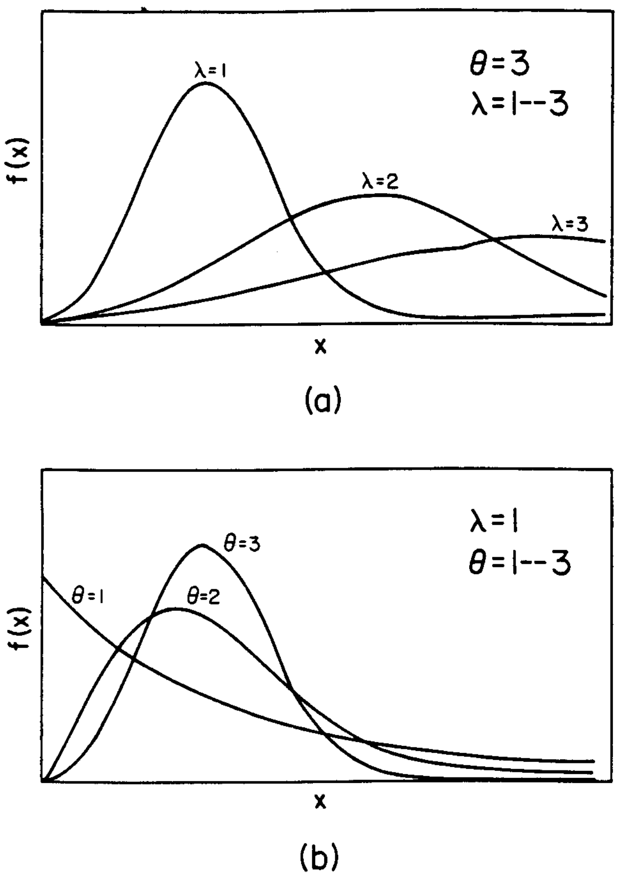

Figure 6. *Weibull Distribution: (a) with differing values of* λ; *(b) with differing values of* θ.

mulative frequencies, percentages, and cumulative percentages were calculated along with the histograms, and the data were fitted to the Weibull distribution. For each digitized frame the cumulative percentage was plotted against the log of the pressure, obtaining slope and intercept parameters. These parameters were used as the dependent variables for comparison of different seat configurations.

METHOD

Subjects

Eight males participated as subjects in this experiment. Their ages ranged from 22 to 29 years, with a mean of 27 years. The mean and standard deviation for height were 183 cm and 8.64 cm, respectively; mean and standard deviation for weight were 190 kg and 25.9 kg, respectively. Thus the sample size was not representative of the general population, as it consisted only of young adult males and had a disproportionate percentage of tall subjects.

Experimental Design

The experiment utilized two seat angle conditions, 0 deg (horizontal) and 10 deg (inclined posteriorly), and four backrest angle conditions: 90 deg (vertical), 100 deg, 110 deg, and 120 deg. The backrest conditions were randomized within the seat conditions. The order of testing was randomly determined, first for the seat condition and then for the backrest condition. The order of testing for the backrest condition was the same within each seat condition. Each subject was tested once in each of the eight test conditions.

Procedure

Each subject received standard verbal instructions regarding the experiment and signed a consent form. Three skinfold measurements were taken on the right side of the body: behind the upper arm, at the abdomen along the waistline, and on the chest. Six other anthropometric dimensions were also taken (unilateral dimensions measured on the right side of the body): standing height, sitting height, shoulder breadth, seat breadth, popliteal length, and buttock-popliteal length. These measurements were used to determine body build characteristics and to make equipment adjustments.

The length of the seat pan was adjusted to fit the subject and the footrests were adjusted to support the feet and lower legs with the knees at 90 deg. The subject then changed into a hospital gown, with the opening of the gown in back, and was seated in the experimental chair such that no portion of the hospital gown was interposed between the subject's body and the chair surface. This was necessary to avoid interference of the light pattern by seams and wrinkles in the clothing that appeared as lines of high luminance intensity.

The subject was instructed to sit with the upper body leaning backward against the backrest, arms folded across the chest, head resting against the backrest, and legs supported by the footrests. He was to maintain this posture during the data-recording interval. Deformation of the pedobarograph foil by the subject's body weight was recorded by a video camera positioned in front of the mirrors of the seat and backrest units. After the data had been collected for a given position, the subject was instructed to get off the chair. This was done in order to change the chair to the next test position, provide an opportunity for the subject to move around, and minimize the possibility of hysteresis of the pedobarograph foil. When the chair had been changed to the next test position, the subject sat down again and the data collection process was repeated.

RESULTS

In order to assess the effects of the seat and backrest angles upon the pressure distributions, the pressure data were fitted to the Weibull distribution and the parameters were compared under the experimental conditions. Table 1 shows an analysis of variance (ANOVA) summary for the λ and θ parameters for the seat and backrest. A highly significant subjects effect is seen in this table and will be discussed in further detail in the discussion section.

The seat data parameter θ was affected primarily by changes in the backrest angle. Both backrest and seat angles affected the backrest data parameters θ and λ Although these results are not unexpected, the analysis indicates that the Weibull parameters, λ and θ, have the desired sensitivity to changes in the seat and backrest angles.

Figure 7 shows how these parameters change as a function of the experimental conditions for seat data. Post hoc tests showed that the 0 deg seat angle had higher λ and θ values than the 10 deg seat angle. Thus in-

TABLE 1

ANOVA for θ and λ, Seat and Backrest Data

	Seat Data		*Backrest Data*	
	θ	λ	θ	λ
Subject				
F-statistic	7.60	23.91	3.25	12.95
P-value	0.0001*	0.0001*	0.0066*	0.0001*
Seat				
F-statistic	3.01	1.76	11.92	1.48
P-value	0.0890	0.1904	0.0012*	0.2300
Back				
F-statistic	4.30	2.44	4.65	6.07
P-value	0.0018*	0.5113	0.0062*	0.0014*
Seat × Back				
F-statistic	4.30	2.44	1.70	0.90
P-value	0.0090*	0.0751	0.1804	0.4468

* Significant at .01 level

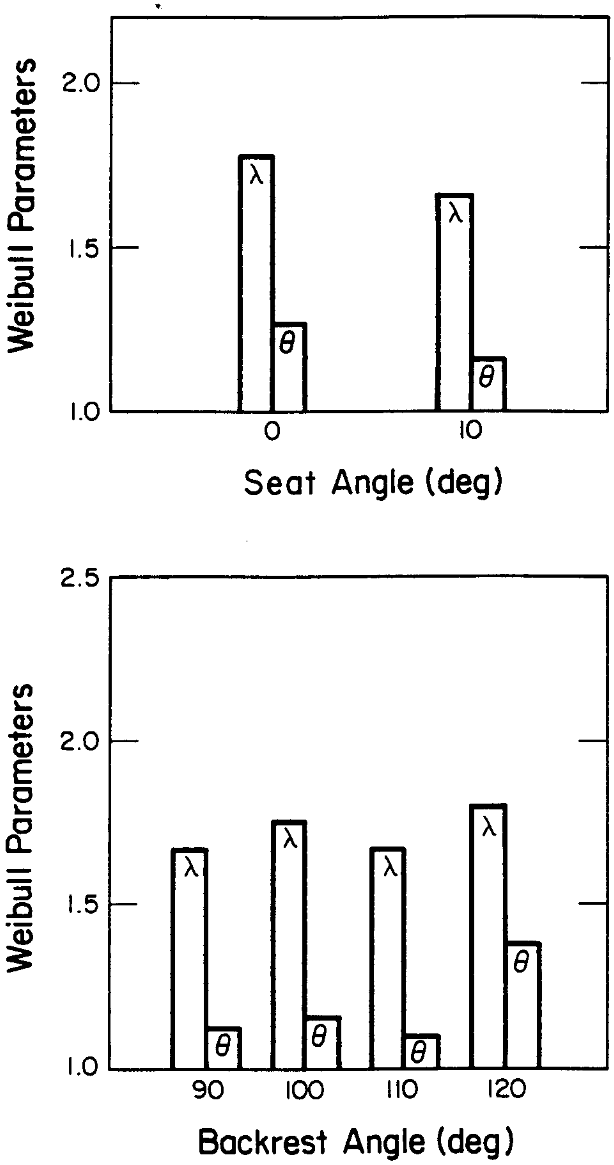

Figure 7. *Seat-pan data.*

creasing the seat pan angle from 0 to 10 deg reduced the variability in the data and shifted the distribution to the left, indicating a higher percentage of the data at lower pressure levels. The response of the seat pressure to backrest changes was more obscure. Post hoc tests did not reveal any noticeable trends. Significant effects occurred in θ when the backrest was at 120 deg. The increased value for θ indicated a Gaussian distribution for the backrest at 120 deg, whereas the other backrest angles showed a more exponential distribution. Qualitatively this means that higher pressure intensities were experienced on the backrest with the greatest degree of inclination, which was due to increased body weight on the backrest. Again, although the results were not unexpected, they provided further validation for the analytical technique.

Figure 8 shows the corresponding changes in the backrest data. Increasing the backrest

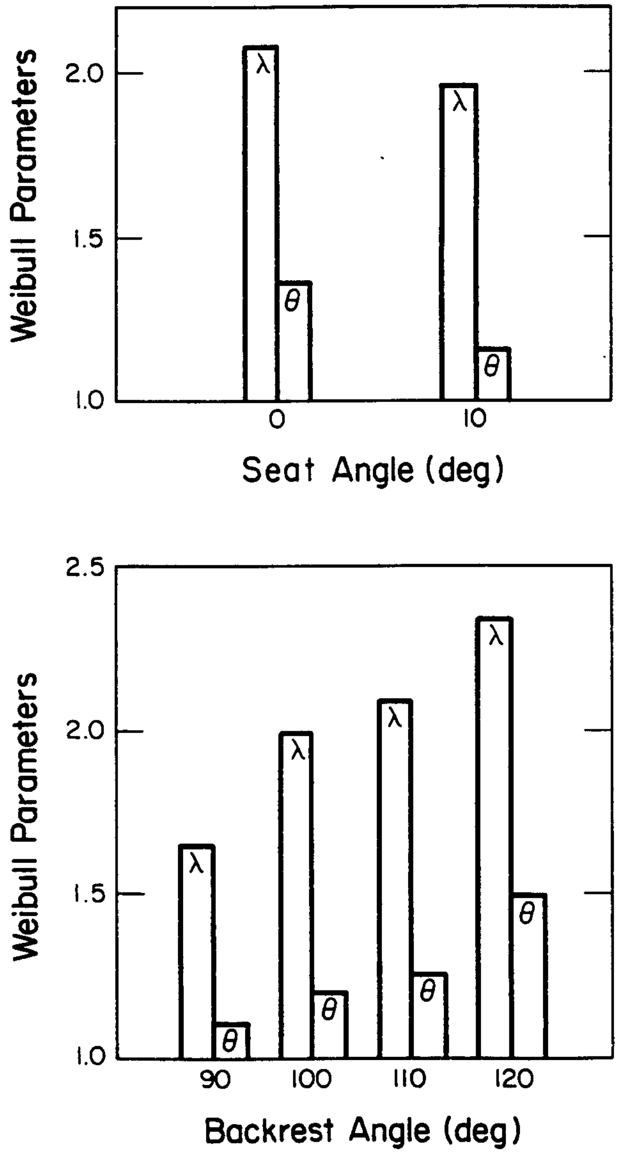

Figure 8. *Backrest data.*

angle increased the variability and shifted the distribution to the right for the backrest data, reflecting the increased body weight on the backrest as it was inclined. The shape parameter, θ, significantly decreased when the seat angle increased from 0 to 10 deg. Both parameters increased significantly as the backrest angle increased. Increases in λ indicated greater variability whereas increases in θ indicated a trend to a Gaussian, rather than an exponential, distribution. A more detailed discussion of the statistical analysis may be found in Treaster (1986).

DISCUSSION

This research has demonstrated the utility of a new device that can measure seat and back surface pressures. The principle of total internal reflection has been used to construct an adjustable chair that provided continuous pressure data. It was found that the seat and backrest angles affected the distribution of pressure on both the seat pan and the backrest. Previous research did not examine the effects of backrest angles on pressure distributions. The present research showed that when the backrest was at 120 deg the distribution of pressures on the seat pan had a more Gaussian distribution than at lower angles. For the lower backrest angles the distribution was shifted to the left, indicating a greater percentage of data at lower pressure values. However, these results must be interpreted with respect to the pressure magnitude values. Although the seat pressure distributions were shifted to the left for the lower backrest angles (90–110 deg), the upper tails of these distributions contained greater pressure intensities compared to the 120 deg backrest values. Thus insofar as one objective of seating design is to minimize high pressures, the 120 deg backrest is preferable.

Pressure on the backrest was more exponentially distributed for seat pan at 10 deg than at 0 deg. An increased backrest angle increased the spread, λ, of the backrest distribution as well as changing the shape of the distribution to a more Gaussian shape.

The torso center of gravity is shifted posteriorly when more body weight is supported by the backrest, which results in a smaller area of high pressure. The amount of weight over the ischial tuberosities is the major determinant in the location of peak pressures. When the trunk is at 90 deg to the thighs, most of the torso weight is located directly above the ischial tuberosities. Since the surface area of this structure is relatively small, there are high pressure intensities on the seat pan. As the angle between the torso and thighs increases (with increased inclination of the backrest), more body weight is transferred to the backrest and less pressure is placed on the ischial tuberosities, hence the changes in the spread and shape parameters, λ and θ, as noted earlier.

These results agree with previous recommendations for seating based upon other physiological measures. Andersson et al. (1974) investigated backrest angle effect on disc pressure and found that as backrest angles increased, the disc pressure decreased. Andersson and Ortengren (1974) also investigated the effects of electromyography on back muscle activity as a function of backrest angle. Collectively these studies indicate that seat pressure and electromyographic activity decreased as backrest angles increased, thus providing corroborative support for the recommendations for reclining backrests.

As mentioned in the results section, a significant subjects effect was noted. This may be due to the varying amounts of body fat and degree of musculature of the subjects. The higher the percentage of body fat an individual has, the larger the cushioning effect over the bony prominences and the more diffuse the resultant pressure. The same is true for well-muscled subjects. Thinner subjects lack the cushioning effect and would experience localized areas of high pressure intensities over the weight-bearing regions of the body. Post hoc tests verified this for thinner subjects.

The design of the experimental chair is such that it can be used to test other seating conditions. The effects of postural shifts (crossing legs, slouching) as well as the relative efficacy of different densities of foam seats may be measured on this chair. The results would have implications for workplaces that constrain sitting posture or limit the range of movements of the worker, such as truck cabs and fighter plane cockpits. Such results may indicate the need to redesign the chair for the task: for example, providing additional cushioning, contouring the seat pan, or altering the relative angles of the backrest and seat pan to eliminate high pressures. This technique would also provide an invaluable tool to evaluate the pressure experienced by handicapped persons, for whom excessive pressure may result in medical complications or even life-threatening conditions.

CONCLUSIONS

This research has demonstrated the utility of a new apparatus for measuring seat and back surface pressures for seated individuals. An optical reflection technique was used to construct an adjustable chair that provided continuous pressure data. A video camera recorded the resulting visual images, which were digitized using a video-image digitizer. The digitized data were then submitted for computer analysis. The system measured sitting pressures and permitted the comparison of different seat configurations. A preliminary experiment using a small sample was conducted to demonstrate the effectiveness of the new equipment.

The method of analysis measured the pressure distribution over all of the weight-bearing regions of the body, not merely the peak ischial pressures. The data were continuous rather than discrete and were derived empirically rather than analytically, through averaging and interpolation. The transformed data were fitted to the Weibull family of distributions, and the shape and spread parameters, θ and λ, were used as the dependent variables in the subsequent analysis. Analysis of these parameters showed that they were sufficiently sensitive to changes in the experimental conditions. The results, though not unexpected, validated the usefulness of the methodology and provide additional support for previous seating guidelines that recommend reclining backrests.

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