THE OBESE OFFICE WORKER SEATING PROBLEM

A Dissertation

by

MARK E. BENDEN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2006

Major Subject: Interdisciplinary Engineering

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Approved by:

Co-Chairs of Committee,	William Hyman
	Jerome Congleton
Committee Members,	Gordon Vos
	Rainer Fink
Head of Department,	N.K. Anand

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ABSTRACT

The Obese Office Worker Seating Problem.

(December 2006)

Mark E. Benden, B.S.; M.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. William Hyman
Dr. Jerome Congleton

A field study was performed using 51 participants that were randomly selected from several Brazos Valley, Texas businesses to participate in an 8-hour assessment of office seating habits that influence seating design and testing. A control group was established as those with BMI's < 35 and an obese group was established as those with BMI's >35. Data was collected through written survey and through data logging of seat and back contact pressure (average and peak), surface area, center of gravity and duration of contact by recording 8 metrics, once per second using the X-sensor pressure mapping device and software. Additionally, 50 days of caster roll distance was recorded for the participants using a caster mounted digital encoder. It was determined that at alpha = 0.05, using the Student's T-test, a significant difference did exist between the groups in mean seat time per shift (p<.001) back contacts per shift (p<.002), seat contacts per shift (p<.01) and caster distance rolled per shift (p<.001). During a subsequent lab study, data were collected during 3 cycles of ingress, egress on the armrest use, along with anthropometry and critical chair testing parameters. Center of Gravity was measured from a fixed backrest (front to rear) for 16 participants. 4 male and 4 female obese with BMI greater than 35 and 4 male and 4 female with BMI less than 30 were compared. The purpose of this study was to determine whether a significant difference existed between anthropometric factors for normal and obese participants that would affect how a chair should be loaded during testing. The null hypothesis that normal means and obese means for each measure were equal was rejected by using independent samples T-test at alpha = 0.05 with p<.001 significance reported for all measures. These data suggest a need for a fresh look at several parameters used in the normal test standards as well as a need for a tougher test method for seating designed for the obese worker.

DEDICATION

To the friends and family of Neutral Posture, Inc. who made it possible to conduct this research during a full-time job.

ACKNOWLEDGMENTS

The completion of this research culminates a lifelong pursuit of knowledge and higher education that was graced to me by God and nurtured by my parents, family and extended family and friends.

To Dr. William Hyman, many thanks for the advice and counsel over the years starting with my freshman year at Texas A&M in 1985 thru the present and for being the scissors that cut the red tape of grad school on more than one occasion.

To Dr. Jerome Congleton, as the primary encourager for me to pursue this process, I have truly been blessed to have you as a friend, confidant, and mentor in the field of ergonomics.

To Dr. Rainer Fink and Dr. Gordon Vos, your council, friendship and service were invaluable during this process. Thanks for taking the time out of your hectic schedules to work with me.

Further, it is with the greatest of appreciation that I acknowledge my wife and sons for their unselfish support and understanding at an active time in their lives when I was already distracted with a busy career and yet they provided continuous love, support and encouragement.

To my boys, “All things are possible with God” so having established a worth while endeavor, pray like it depends on him and work like it depends on you.

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CHAPTER I
INTRODUCTION: GOALS OF THIS RESEARCH

Having realized a need for the office furniture industry to develop new standards for the ever increasing incidence and magnitude of obese workers in the 21st century and having realized a need to challenge the old data used in testing office seating; the author has set about establishing lab and field tests designed to gather the necessary information to support such new standards.

A. Field Study

It was expected that field study would answer the following questions (relative to per shift, per worker):

1. Amount of time spent seated by normal and obese office workers
2. Amount of contacts with the backrest by normal and obese office workers.
3. Frequency of enter/exit cycles by normal and obese office workers.
4. The range and mean of each of these measures per person and per group based on a sampling rate of 1 cycle per second.
5. Average distance rolled per shift for obese and normal workers.
6. Statistical comparison of the means of each of the above measures will be compared to determine whether there is a significant difference between normal and obese workers, males and females and normal and obese measures by gender, race and job type.

This dissertation follows the style of Applied Ergonomics.

B. Lab Study

The goals of the lab study were to determine whether several anthropometric criteria, critical to chair design were different for obese and normal participants. It was expected that these differences could be evaluated for normal and obese and male and female:

1. Seated Hip Breadth
2. Seated Elbow Height
3. Seated elbow breadth
4. Horizontal Acromium distance from back of chair test device
5. Seat depth - popliteal to buttocks
6. Forearm width maximum
7. Body weight and height
8. Center of Gravity relative to back of chair test device
9. Additionally, arm sensors were used to track normal entry exit parameters of the aforementioned X sensor™ parameters of each participant by studying them in 3 entry exit cycles per subject at a sampling rate of 1 cycle per second on each armrest and then extrapolating that data relative to entry exit data ascertained during the days of real-time seat cycle testing collected in the field study.

Armrest data included:

1. Armrest pressure average (mmHg)
2. Armrest pressure peak (mmHg)
3. Armrest contact area (square inches)

CHAPTER II
CURRENT STATE OF THE SCIENCE

A. Present Status of the Question

This research addresses the interests of the furniture industry to study the effect of the changing office worker and work habits on seating design, associated with the shift in technology and body proportions that were not present in the 1970's when current standards and designs were initiated. The research compared the office seating habits of normal and obese office workers to determine whether a difference in use patterns exists beyond the obvious force differences associated with heavier body weights. The purpose of the collection of this data was to create a basis for new standards used to validate design requirements of office seating in the areas of quality, durability and performance.

B. Related Research

During the course of the literature search for this research, the following areas of Obesity background information were explored to narrow the field of search criteria to those actually detailed in this research. They were as follows:

Obesity/Body Mass Index (BMI) and Anthropometrics
Obesity/BMI and Socioeconomic Impacts
Obesity/BMI and Geriatrics
Obesity/BMI and Children
Obesity/BMI of the Disabled (Wheel chair studies)
Obesity/BMI as a Disability
Obesity/BMI as a Medical Liability
Obesity/BMI of the Office Worker
Obesity/BMI and Furniture Design.

Topics specifically covered in this research were limited to:

Obesity/BMI - US and Global Statistical Trends
Obesity/BMI and Chair Design
Functional and Life Cycle Testing of Seating for the Obese and Disabled
Functional and Life Cycle Testing of Office Seating
Testing of Office Seating Usage Patterns.

The combined percentage of overweight or obese in the US adult population has soared to over 60% in the last few years. (NCHS 1999) The modern way of measuring obesity is by the BMI. The BMI is determined by dividing weight in kilograms by height in meters squared. Clinical guidelines from the National Institutes of Health define overweight as a body mass index (BMI) of 25-29.9 kg/m^2, while obesity is defined as a BMI of 30kg/m^2 or more. (NIH 1998) More specifically, about 35 percent of US adults are overweight and 26 percent are obese. BMI ranges are listed below in Table 1 with the corresponding relationship to weight.

Table 1 – Weight versus BMI

Weight	**BMI (kg/m^2)**
Acceptable Weight	18.5-24.9
Overweight	25-29.9
Obese	30-34.9
Severely Obese	35-39.9
Morbidly Obese	40-49.9
Super Morbidly Obese	50 or more

The extreme forms of obesity are rising much faster than the overall epidemic. (James 2003) In the USA, the percent of African American women with BMI greater than or equal to 40 has doubled in less than a decade to 15%. Overall, 6.3% of US women (1 in 16) are morbidly obese. (James 2003) This classification is approximately 100lbs over target weight as a general rule. The World Health Organization recently announced in 2002 a commentary on the National Center for Health Statistics (NCHS) data that overweight/obesity is now a pandemic affecting nearly 1.7 Billion people worldwide. Although some cultures may have greater health risks at lower BMI's, it is undisputed that the US is leading the world in percent obese/overweight and in the rate at which those numbers are increasing as seen in Table 2. (NCHS 1999) (WTO 2002)

Table 2 – Obesity rates by Country

United States	27% obese
United Kingdom	20% obese
Spain	13% obese
Italy	9% obese
Norway	6% obese
Japan	3% obese

Source: OECD Health Statistics (2000)

It appears that obesity is now poised to take over tobacco as the number one threat to life and the cost of healthcare. (James 2003) The number of obesity related deaths each year in the US has now exceeded 400,000 which is second to the 450,000 from tobacco. (WHO 2002) The number of morbidly obese adults in the US now exceeds 4 million and is growing more rapidly than the other categories. As this occurs, it brings us to some perplexing research topics such as "how do we stop this global pandemic," "how will we afford to care for the resulting disease and burden on our medical systems," how will we be forced to modify the products that we all use to travel, work, sleep, treat and generally accommodate those that no longer fit our old designs?"

Obesity and Office Seating

Seating as we know it is a modern convenience. Much of the world today, and in fact, throughout much of recorded time had very little to do with seating for work purposes, indoors, as we have come to know it in our life times. Some have even suggested that chairs may be at the root of our ergonomic and obesity trends since we typically approach the problems of seated work assuming that the worker should be seated in a chair in the first place. (Gerr etal. 1998) Today, seating is designed for institutional purposes, for the home, for general consumer use and even as a form of artistic expression. Architects consider chairs small buildings; industrial designers see them as a platform for mass-manufacturing, modern materials, environmental barometers, and use of new technology.

In the office, the chair has become a determinant in social space, a symbol of status, and an indicator of the type of work that one performs. Chairs for work are further set apart from those for such purposes as relaxing, eating or entertaining where comfort is considered primary over function. Moreover, the computer has now defined our modern office and the need for the type of seating expected more than any other single unifying theme of what we consider "office work." Recent studies have shown that computers are used by more than 25% of the workforce for more than half of their day. (Hjelm etal. 2000) After many years of chair research with contributions from individuals with strong science and engineering backgrounds to understand the physiological, anatomical and psychosocial factors that are needed to provide good chair design, it appears that our target audience has changed dramatically without a supporting body of knowledge to transfer back to the design community. The need to fill the gap of knowledge in this area is the primary motivator for this research. Many of the anthropometric studies used in the design of modern office chairs were derived as far back as the 1950's and were often made up of primarily young males in the military. The 1980's brought some improvements with the 1988 US Army Anthropometric Survey (ANSUR) of United States armed forces personnel which found that a 95th percentile male was 6 feet, 1 inch and 216 pounds. Then in the early 1990's the NHANES III study on civilian data found that a 95th percentile male was 6 feet 2 inches and 246 lbs. (USCDC 2000) By the late 1990's a 3-D survey of human anthropometry was conducted now known as CAESAR, which stands for Civilian American and European Surface Anthropometry Resource found that a 95th percentile male was actually 6 feet, 2 inches and 253 lbs. (CAESER 2003)

This alarming trend can be seen in Figure 1. What was once an uncommon accommodation for the extremes in our population has now become a routine fixture in the modern office that appears to be proceeding unchecked as time passes.

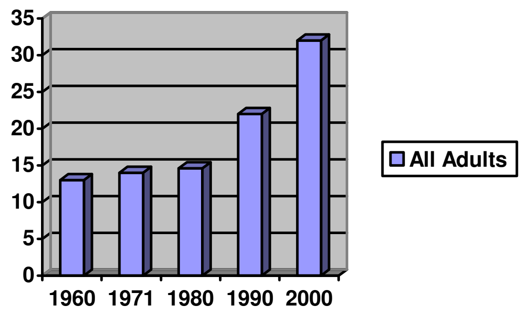


Figure 1 – Percentage of Obesity in US Adults vs. Time

Functional and Life Cycle Testing of Seating for the Obese and Disabled

The modern office chair is designed and tested to pass the ANSI/BIFMA 5.1 –2002 Guidelines for Testing of Chairs. This guideline is setup to perform functional, and proof tests of seating in both static and dynamic modes. The dynamic modes are based on some force derived from office worker averages and the cycle counts or duration are based on an 8 hour shift, for 40 hours per week and 10 total years of use. All of the key points in the test parameters are determined from 30-year-old best practices that pre-date the modern use of computers and obese worker trends. There are currently no standards or test parameters specifically for seating designed for obese workers.

There is a Federal Government Guideline for the design of "intensive use" or 24/7 seating that covers longer duration cycle counts based on the original BIFMA numbers carried to a longer duration. The FNEW 83-7 is a progressive test that pushes the test chair to failure and records the results of the level of force and cycle count to determine pass/fail standards.

In automotive and wheelchair seat design, tests are conducted with actual human like test dummies. Since both areas of manufacturing are realizing the same needs for accommodation as the office furniture industry, they have begun to call for augmentation of the 100kg ISO test dummy with higher mass. Specifically, Cooper et al suggested that testing actually needs to occur up to 250kg with the greatest need being an immediate switch to testing with a 150kg dummy. (Cooper et al 1999) His study also revealed that since mass be distributed between the lower torso and legs at a ratio of six to one. Cooper also found that the center of mass COM for the obese could be derived from the COM work done on normal subjects for both the X and the Y direction relative to a fixed back seat. It is very likely that the office furniture market may need to take the lead from these two industries and switch from a system of weights and pulleys to one that uses a more biomimetic form to apply the varying loads used during testing based on actual current data and mathematical models of the obese form.

Functional and Life Cycle Testing of Office Seating

Most notable in this search was the lack of data regarding the seating habits of the office worker as they pertain to the critical cycle data of the ANSI/BIFMA test guidelines. Research related to the short term testing of seating was found in pressure mapping studies including Vos et al who examined multiple male and female users in multiple seat styles and found that seat design was the most critical parameter in determining seat interface pressure.(Vos et al 2005)

Pressure mapping systems were validated by Stinson et al in a study that used 65 occupational therapy students (15 with experience) to evaluate two different pressure maps of the same individual to test for inter-rater reliability of data collection and interpretation between students. Pressure mapping was shown to be a reliable method of data collection. (Stinson et al 2003)

Stinson et al conducted another pressure mapping survey where 63 student volunteers (44 women and 19 men) were tested at various recline angles (10 degrees, 20 degrees, 30 degrees), foot support and foot elevation. Average pressure was found to have a significant positive correlation with BMI (r=.381, alpha=.01 level). (Stinson et al 2003)

Another study by Kernozek et al was conducted to determine whether BMI influenced seat interface pressure in the elderly. The 75 elderly were split into 4 groups by BMI. In this study as in several done on college students, peak seat-interface pressure was highest in the thin elderly group with the lowest BMI levels. Differences in peak seat-interface pressures were progressively less as BMI increased. (Kernozek et al 2002) In this case, high BMI seems to protect from the development of decubitus ulcers just as it reduced automotive fatalities in several studies designed to test the efficacy of seat belts and air bags in collisions.

High BMI was not found to be a positive correlate in Koskelo's study to investigate whether temperature and humidity of the scrotal skin during sitting on commonly used chairs. (Koskelo et al 2004) In this study, 8 men were tested in 6 different chairs with infrared photography and traditional skin surface temperature sensors. The saddle chair used in the study had a statistically significant difference in scrotal skin temperature after 20 minutes of 3degC. Also, BMI correlated with the conventional office chair but not when sitting on the saddle chair. This study was trying to determine if chairs that increase scrotal skin temperature may have contributed to the decrease of semen quality and quantity reported during the last decade in sedentary societies. Clearly, the implications for obese seating include the need for some sort of pommel in the seat to assist the user in knee abduction while seated. This should aid whole body posture, general cooling and specifically scrotal cooling for males.

Another consideration for obese seating is the extra difficulty seen in heavy individuals during egress. Alexander found that lowered seat height, increased posterior seat tilt, and seat compressibility were all found to significantly affect rise difficulty in the 29 old vs. 21 young volunteers studied for ease of egress. (Alexander et al 1996) These factors were however found to correlate positively with comfort, once seated, for both groups. Another study on chair egress by Finlay et al found that 77% of those that were normally chair fast could rise unaided if the arm and seat height were both placed at recommended levels. (Finlay et al 2002) A biomechanical analysis of foot placement during standing conducted by Kawagoe et al found that chairs should be of adequate height as well as have sufficient space under the seat to permit the backward movement of the lower legs. (Kawagoe et al 2000) This explains our field observations on the morbidly obese as they egress from the chair only after moving their center of gravity forward and to one side on the seat pan prior to attempting to stand. This is supported by Sibella's study that evaluated ten normal weight subjects and forty obese subjects during chair egress. Using optoelectronic body coordinate recording and a force platform, he was able to show that the normal group used a trunk flexion method while 100% of the obese group limited their trunk flexion. (Sibella et al 2003) All of these findings have practical design implications in the area of seating for the morbidly obese.

Some work has been done on the quantitative prediction of body diameter in severely obese individuals that might provide the basis for simple, non-gender, non-race specific models. This work may be most helpful to furniture designers and or specifiers attempting to fit or design a specific individual or group of individuals. Fontaine et al in 2002 performed a study involving 164 severely obese (greater than 300lbs) individuals in New York and 103 severely obese individuals from the NHANES III study to determine a model for body diameter. (Fontaine et al 2002) Linear regression showed that for every 10kg(22.04lb) of weight over 136kg(300lb), body diameter measurements increase by 0.9-1.1cm. More work on this model is needed to better calibrate it for stature and gender.

In 1998, a study was conducted by Coleman to determine the preferred lumbar support settings on adjustable office chairs. (Coleman et al 1998) In this study, 43 male and 80 female office workers were investigated. All subjects were equipped with identical modern office chairs with backrests adjustable in height and depth. A regression model examining the effects of standing height, BMI, and gender on mean preferred lumbar support height during a 5-week period, showed a significant relationship between preferred height and BMI. In general, higher lumbar heights were chosen by subjects with greater BMI. Gender differences in lumbar height were not noted in this study although the call for a more detailed study of the obese to morbidly obese is clearly indicated since the average BMI in this study was 25 which is well below the standard office average noted in the Bossen study which reviewed 913 call center workers for basic BMI stats and found that there was a 6% shift towards obesity vs. the overall CDC numbers for US adults. (Bossen 2005) The most significant finding of this study was the report from the author that nearly 1 out of 9 of these workers or approximately 11% of this population fell outside of the current BIFMA criteria of a standard office chair which is listed in the ANSI/BIFMA 5.1-2002 Guideline as 225lbs.

CHAPTER III
THE FIELD STUDY

A. Introduction

A total of 51 participants were randomly selected from several Brazos Valley, Texas businesses to participate in an 8-hour assessment of office seating habits that influence seating design and testing. A control group was established as those with BMI's less than 35 and an obese group was established as those with BMI's greater than 35. Data was collected thru written survey and thru data logging of seat and back contact pressure (average and peak), surface area, center of gravity and duration of contact by recording 8 metrics, once per second using the X-sensor pressure mapping device and software. This device was also constantly recording real-time video (2 and 3 dimensionally represented) for the pressure and surface area events. Additionally, 50 days of caster roll distance was recorded for 35 of the participants using a caster mounted digital encoder designed, calibrated and built by the researcher. These data points were analyzed to determine whether a significant difference existed in the mean measures of the normal group vs. the obese group. It was determined that at 0.05 significance level using the Student's T test, ($p<.001$) a significant difference did exist between the groups in seat time per shift, back contacts per shift, seat contacts per shift and caster distance rolled per shift. This data suggests a need for a fresh look at several parameters used in the normal test standards as well as a need for a tougher test method for seating designed for the obese worker.

B. Methods

Data Collection

The data for this research was collected real-time, in the actual office of each subject during normal office hours on randomly selected days of the week. Workers were randomly selected by workstation location. However, as data was collected, it became more difficult to randomly locate enough extremely obese subjects and some pre-selection based on supervisor recommendations was done to ensure adequate numbers for each group. In the end, 24 normal (BMI<35) and 27 obese (BMI >35) were included. Each subject sat for at least 1 full shift in the custom test chair designed for this research. (Figure 2) The chair utilized the X-sensor brand of capacitive pressure mapping for both seat and back on a real-time basis. This device was calibrated per the manufacturers recommendations prior to each new participant. This device collected 8 metrics, all in real-time, once per second for the full 8-hour shift. They are as follows:

1. Seat pressure average (mmHg)
2. Seat pressure peak (mmHg)
3. Seat contact area (square inches)
4. Back pressure average (mmHg)
5. Back pressure peak (mmHg)
6. Back contact area (square inches)
7. Relative time count
8. Center of Gravity (2D on seat pan and 3D combined with backrest)

Video representation of all of these measures was also recorded.

Figure 2 - Test Chair Shown During Data Collection

The data collected on each individual was typically 31,000 seconds or frames of full 2 and 3 dimensional video representations of the pressure applied to the seat and back of the chair. Given the 8 measurements, this is 248,000 data points for each person, each day. Typical participants required 80 megabytes of memory for each 8-hour session. Each of these files had to be converted from X-sensor files, to ASCII files and then converted to MS Excel files where a program to tally the relative counts of "person in chair" and "person applying pressure to back" was utilized. The printouts for 1 subjects data in Excel would exceed 1,300 pages! This summary data was then totaled over the shift with the means per hour being used in SPSS as a basis of statistical comparison. Pressure thresholds were set for the back and the seat using peak pressures at 50mmHg or higher. Counts were generated in Excel for each change that exceeded this threshold level. The level was derived from the pilot study as a consistent number that would rule out simple side-to-side shifting while in normal contact with the seat or back. The general idea for the data mining was to find the magic test numbers of seat drops and back pulls needed to simulate chair use in the test lab. For current test methods, sand bags are dropped on the seat and a mechanical pull of the back is performed with the seat anchored. Staying with that convention, it was easy to determine a threshold that would catch nearly all of these events during the shift. It is possible to drop in and out faster than 1 second, but highly improbable unless someone was purposely trying to "beat" the test recorder. Figures 3 and 4 show representative examples of the types of 2-dimensional video images created by the software.

While this approach of massive data collection was clearly a positive due to the enormous amount of information gathered on each person, it did limit itself to one day for practical purposes and therefore assumes equal use for all days of the week. During the initial data collection, 3 subjects were tested over multiple shifts to ascertain whether a day-to-day variability would indicate the need for a larger # of days. Variability was not found to be significant from day-to-day within subjects and therefore one randomly selected day was utilized for the complete study.

The test chair was physically rolled from desk to desk or driven from site to site by the researcher. It did limit the posture but not the seat height of those tested. It also was tethered to an anchored power cord that had some impact on mobility. For this reason, the caster test was performed at later dates, using the subject's own chair by simply replacing the subject's casters with the data recording casters.

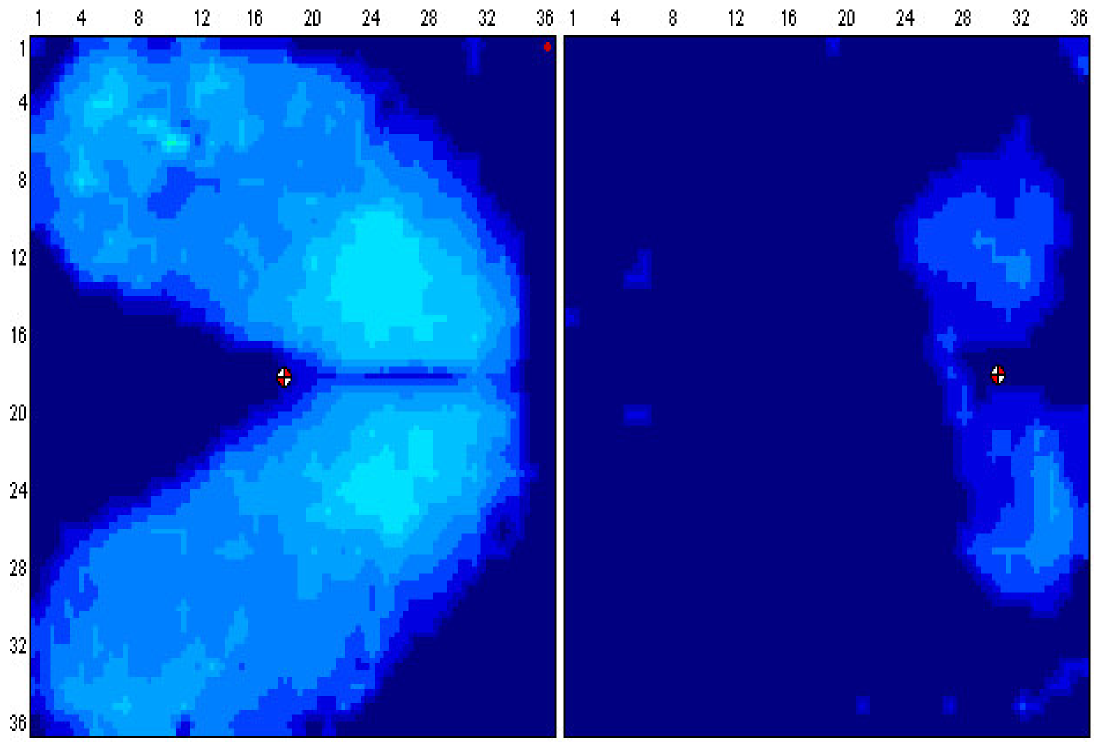


Figure 3 - Xsensor, 2-Dimensional Representation of Typical "Normal"

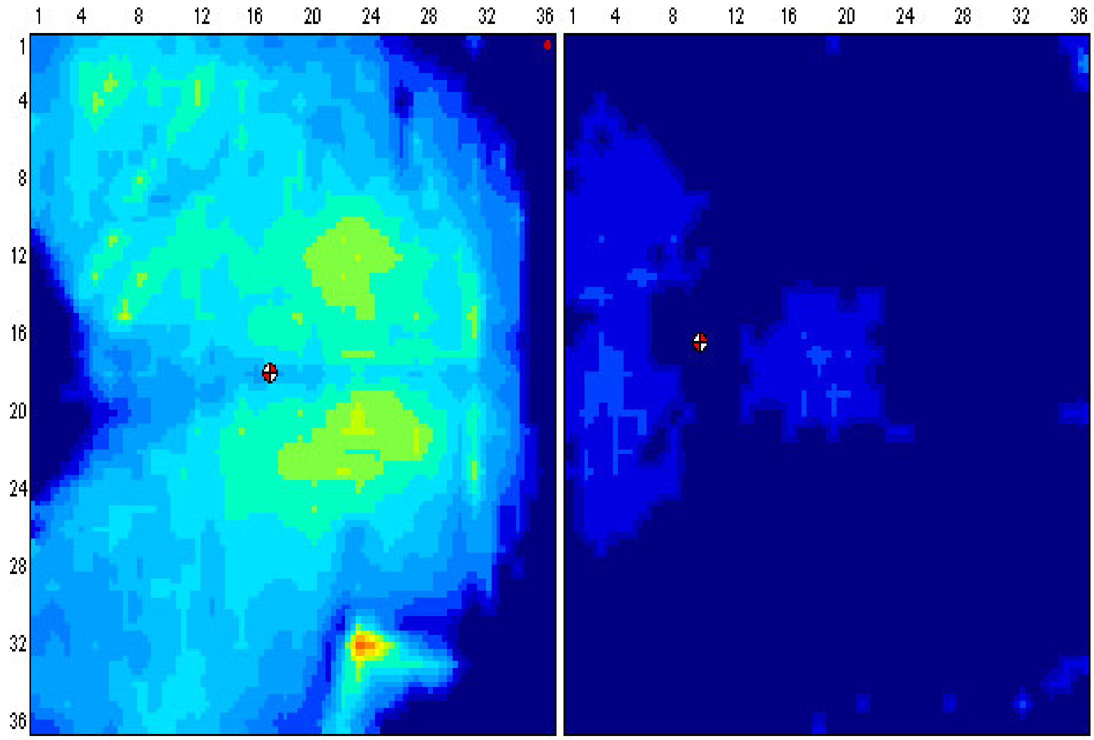


Figure 4 - Xsensor, 2-Dimensional Representation of Typical "Obese"

Information was collected from a digital roll distance evaluator designed by the researcher that tracks caster movement in roll frequency and distance per day. (Figure 5 and 6) This digital counter logs each 6" travel by the center of the chair base. 6" was selected to eliminate minor movement noise and was based on the experience of the researcher following 15 years of chair evaluation and research.

Figure 5 - Caster Roll Distance Test Device

Figure 6 – Live Caster Test

The results from this study were counter-intuitive to commonly held theories on caster use for obese workers vs. normal. The theory was that heavy workers would enter/exit less (found to be true) and roll around more (found not to be true). It appears that given the difference in caster distances, seat time as a % of the shift, and entry/exit numbers on the seat that the testing parameters for obese seating casters should be more stringent in load time and load force but to be safe, equal in distance to the normal counts rather than lowered as indicated by this research.

C. Participants

Survey Data collected from ALL Participants is summarized in Tables 3-6 and Figures 7-10.

1. Gender
2. Age
3. Race/Ethnicity
4. Geographic location within US
5. Height (cm)
6. Weight (kg)
7. Resultant BMI (hidden from participants)
8. Normal shift parameters
9. Date of Survey
10. Office classification:
    a. Clerical/support
    b. Technical
    c. Management
11. Perceived chair exposure at primary work site (duration in hours)
12. Seated exposure during work day (duration in hours)
13. Survey registration number (to maintain data with anonymity)

Summary Data

Table 3 – Male/Female Participant Mix

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Make	19	37.3	37.3	37.3
	Female	32	62.7	62.7	100.0
	Total	51	100.0	100.0	

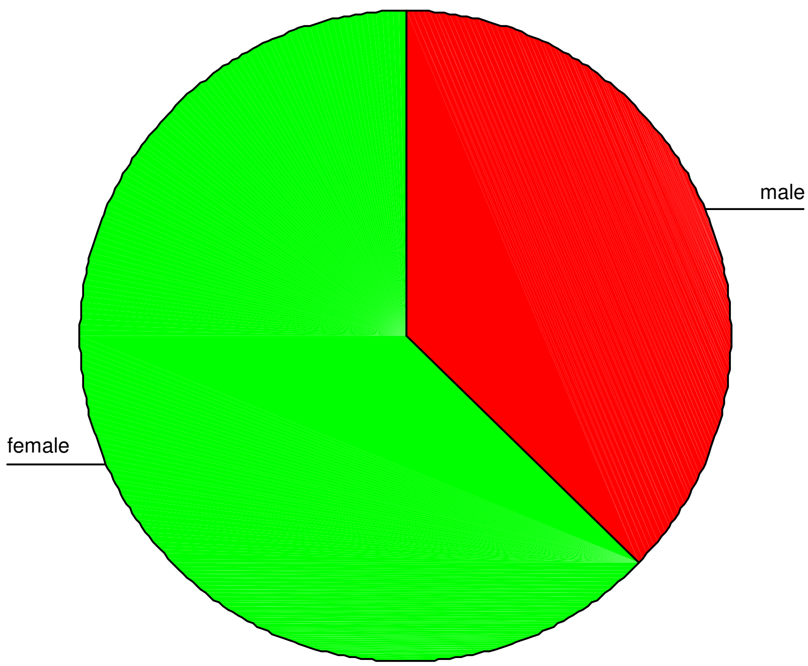


Figure 7 - Male and Female Participant Mix

Table 4 - Participant Race Mix

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Caucasian	37	72.5	72.5	72.5
	African American	7	13.7	13.7	86.3
	Hispanic	6	11.8	11.8	98.0
	Other	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

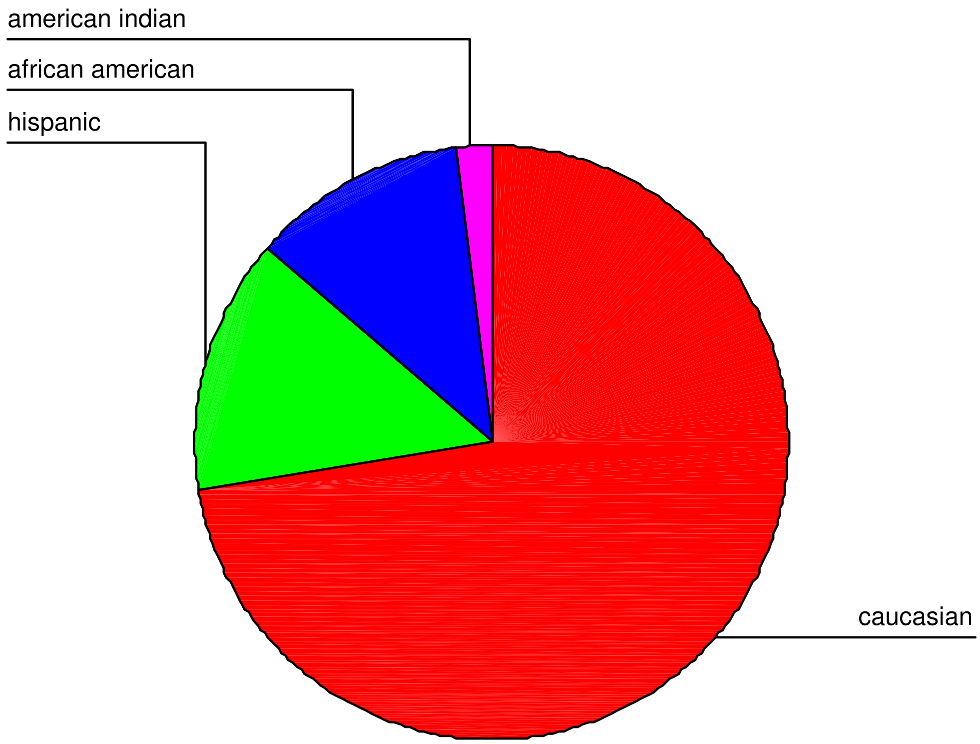


Figure 8 – Participant Mix by Race

Table 5 - Participant Mix by Job Type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Administrative	29	56.9	56.9	56.9
	Technical	10	19.6	19.6	76.5
	Management	12	23.5	23.5	100.0
	Total	51	100.0	100.0	

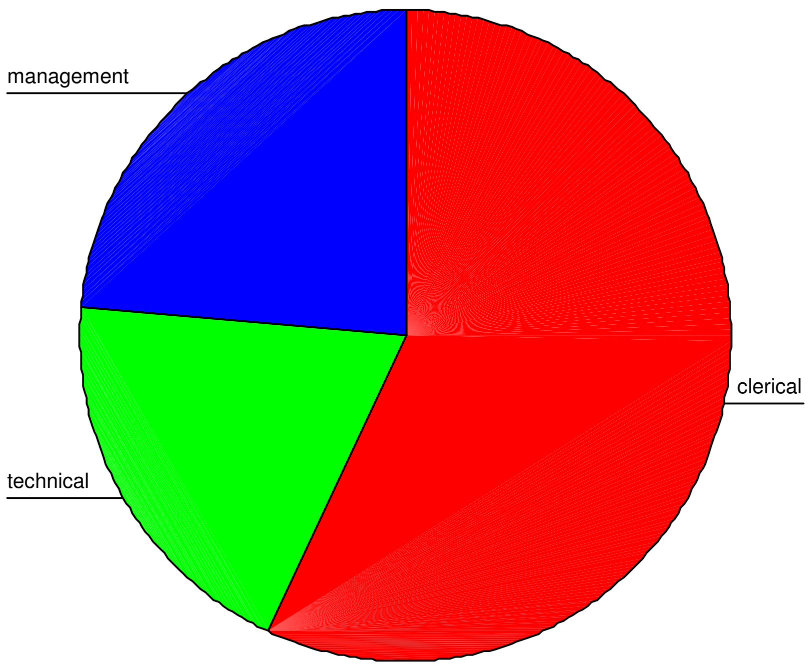


Figure 9 – Participant Mix by Job Type

Table 6 - Participant Mix by BMI Category

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	BMI < 35	24	47.1	47.1	47.1
	BMI > 35	27	52.9	52.9	100.0
	Total	51	100.0	100.0	

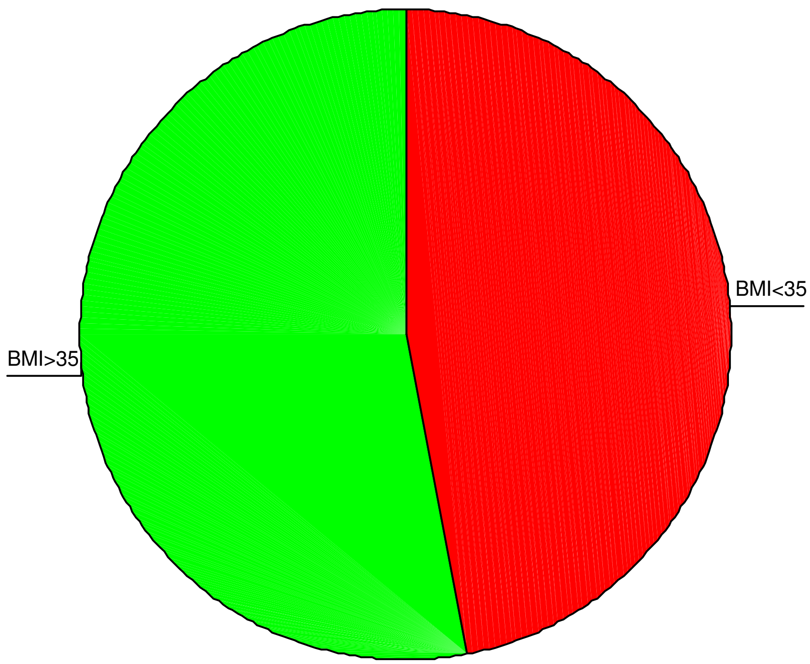
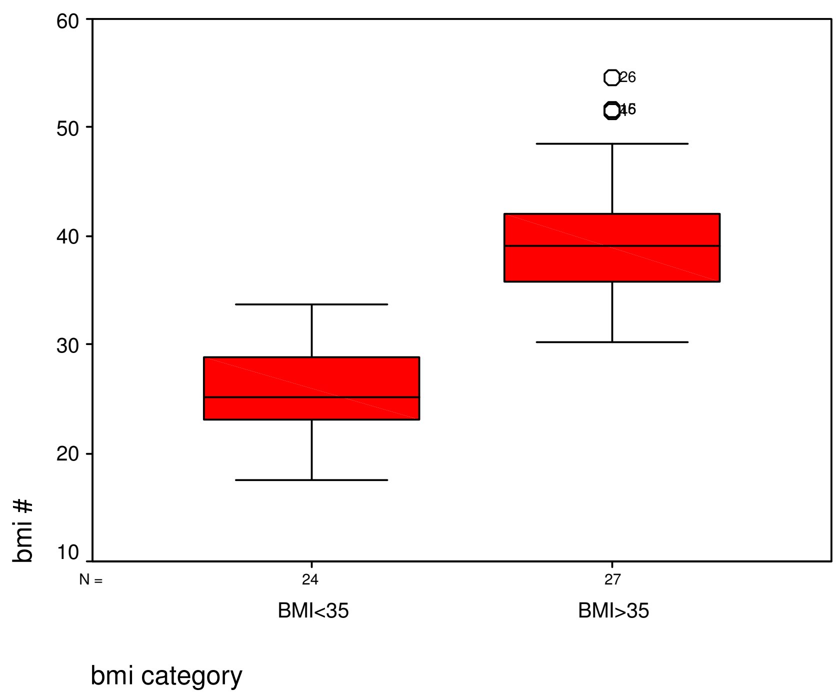


Figure 10 – Participant Mix by BMI Category

D. Results

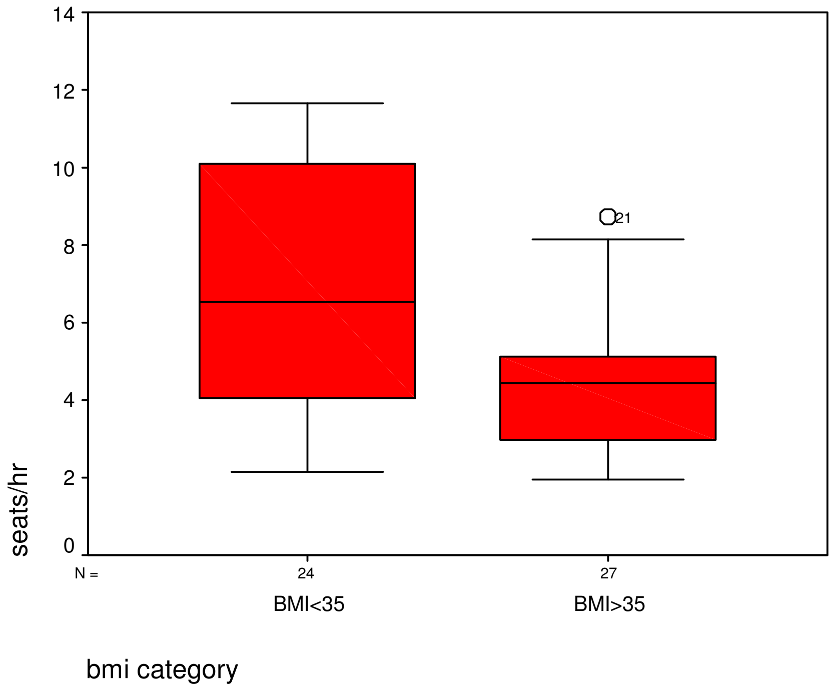
Statistical Analysis for the Field Study

Information on the results of the Field Study was processed using SPSS and standard spreadsheet software. Comparisons of the means at the 0.05 significance level were conducted using the Student's T-test. Each of these tests had a null hypothesis that the means for each normal and obese group are equal. Since normality was shown, t –tests were conducted at 95% confidence levels to determine if the populations were unique or equal. The data is summarized in the tables below. Given the BMI categorizations of Greater than 35 and Less than 35 as the definition of the two groups, there is little doubt that usage parameters were significantly different for several of the areas studied. A BMI of 35 was chosen since it most nearly equates to the body weight of individuals that would currently exceed standard ANSI/BIFMA office chair test parameters for size and force (225lbs). Summary statistics of each group are provided in Figures 11-17 and Tables 7-11..



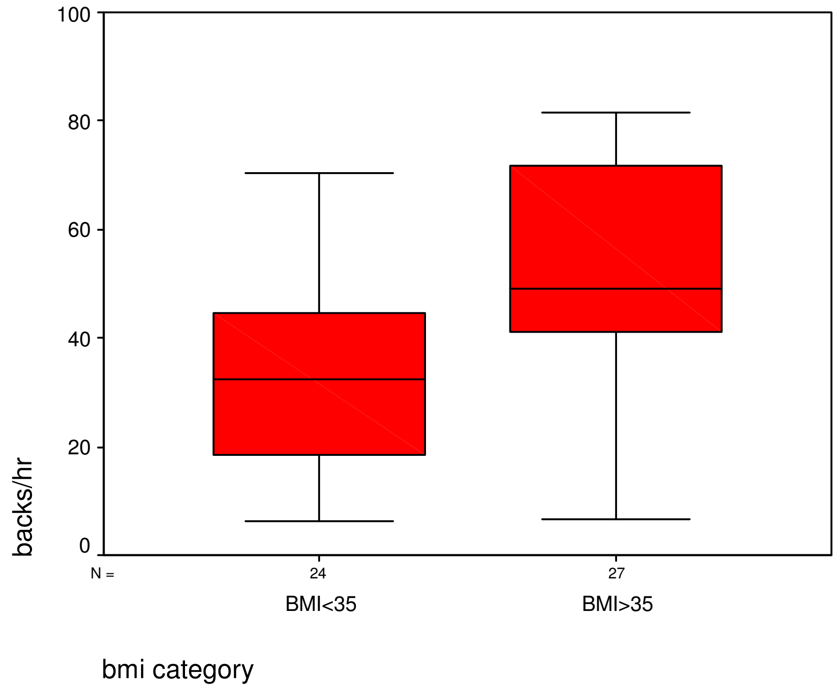
p value < 0.001

Figure 11 – Participant Distributions by BMI Number



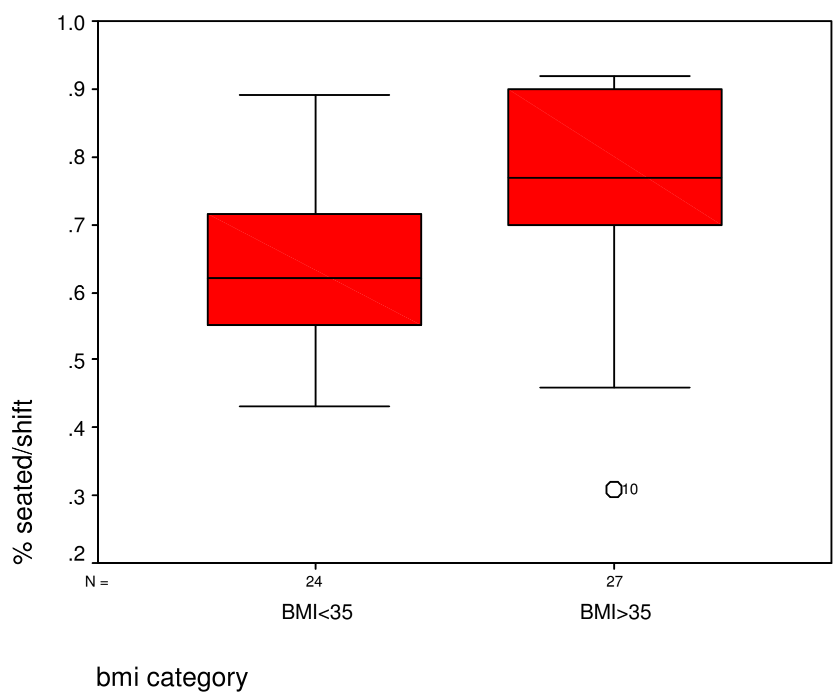
p value < 0.001

Figure 12 – Distributions for Seats/Hour by BMI Category



p value < 0.002

Figure 13 – Distributions for Backs/Hour by BMI Category



p value < 0.001

Figure 14 – Distributions for % Seated/Shift by BMI Category

Table 7 – Group Statistics by Age

	m or f	N	Mean	Std. Deviation	Std. Error Mean
age	Male	19	38.8421	9.65668	2.21539
	Female	32	36.0000	10.05469	1.77743

Table 8 – Independent Samples T test of Means by Age

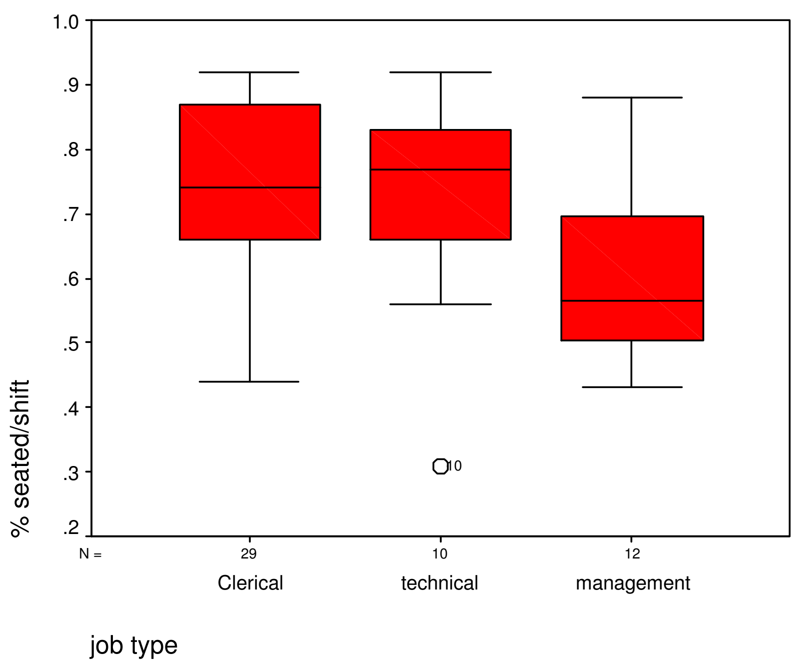
		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
age	Equal variances assumed	.000	.990	.990	49	**.327**	2.8421	2.870	-2.925	8.610

The mean age for males was 38.8 years and the mean age for females was 36 years as seen in Table 7. The lack of a statistical difference in age between genders is shown in Table 8. This was a significant indication that a potential age bias was controlled.

Table 9 – Descriptive Statistics for Male and Female

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
bmi #	Male	19	32.9	7.96	1.830	29.14	36.87	20.80	51.68
	Female	32	33.8	9.86	1.743	30.22	37.60	17.47	54.68
	Total	51	33.5	9.15	1.278	30.99	36.03	17.47	54.68
seats/hr	Male	19	5.9	2.94	.682	4.56	7.38	2.13	11.38
	Female	32	5.3	2.65	.459	4.33	6.23	1.97	11.65
	Total	51	5.5	2.73	.382	4.71	6.31	1.97	11.65
backs/hr	Male	19	42.6	23.28	5.340	31.18	53.65	8.87	81.41
	Female	32	42.4	21.3	3.77	34.71	50.11	6.40	79.78
	Total	51	42.4	21.8	3.06	36.28	48.58	6.40	81.41
% seated/ shift	Male	19	.676	.150	.034	.6038	.7489	.31	.92
	Female	32	.724	.154	.023	.6689	.7804	.43	.92
	Total	51	.706	.153	.028	.6635	.7498	.31	.92

None of the T-tests showed significant p-values for these measures when compared to male/female for the results shown in Table 9.



p value < 0.001

Figure 15 - Distributions of Percent of Time Seated per Shift by Job Type

The only significantly different means seen in Figure 15, ($p < 0.024$) by job type were Clerical (mean of 74.4%) vs. Managerial (mean of 60.4%) in the % seated/shift. Otherwise, no significant difference existed. Since this was not specifically controlled for in the experiment and since the low number of people used (51 total) represents a very poor, regional sample size with different sample sizes for each race, this data is of little practical significance.

Table 10 - Test for Equality of Means for Normal versus Obese

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
bmi #	Equal variances assumed	-9.918	49	**.000**	-14.79	1.49216	-17.79	-11.80
seats/hr	Equal variances assumed	3.799	49	**.000**	2.58	.68092	1.21	3.95
backs/hr	Equal variances assumed	-3.275	49	**.002**	-18.33	5.61218	-29.66	-7.10
% seated per shift	Equal variances assumed	-3.476	49	**.001**	-.135	.03894	-.213	-.057

As seen above in Table 10 and from confidence intervals in Table 11 , All means are significantly different at the 0.05 test level for BMI versus Seats/hr, Backs/hr and % seated/shift.

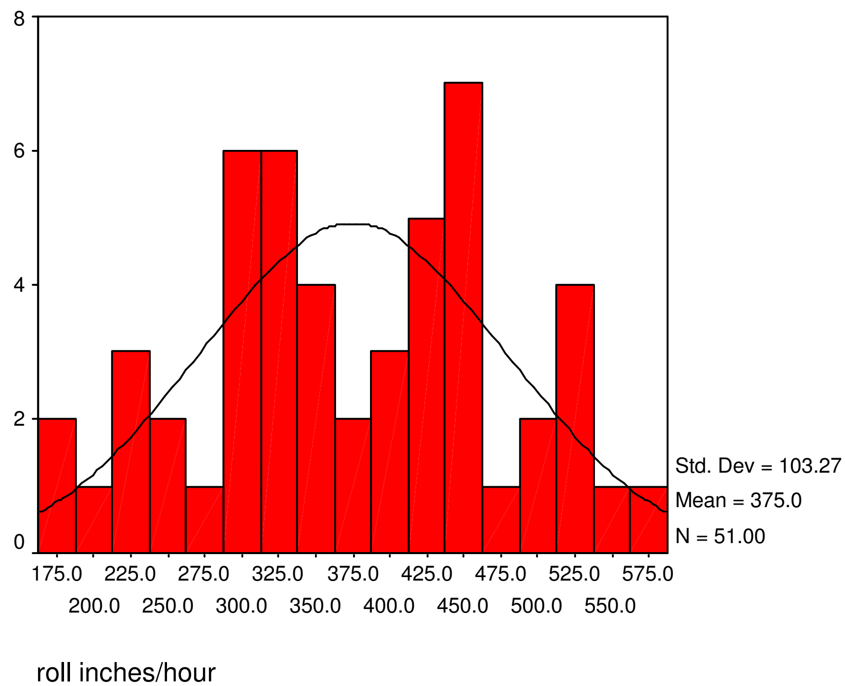
Table 11 – Descriptive Statistics by BMI Category

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
bmi #	BMI<35	24	25.6713	4.25061	.86765	23.8764	27.4661	17.47	33.65
	BMI>35	27	40.4704	6.11011	1.17589	38.0533	42.8874	30.13	54.68
	Total	51	33.5061	9.13125	1.27863	30.9379	36.0743	17.47	54.68
seats/hr	BMI<35	24	6.9175	3.05199	.62298	5.6288	8.2062	2.13	11.65
	BMI>35	27	4.3307	1.69195	.32562	3.6614	5.0001	1.97	8.71
	Total	51	5.5480	2.73381	.38281	4.7791	6.3169	1.97	11.65
backs/hr	BMI<35	24	32.6825	17.78402	3.63015	25.1730	40.1920	6.40	70.36
	BMI>35	27	51.0648	21.78136	4.19183	42.4484	59.6812	6.60	81.41
	Total	51	42.4143	21.86449	3.06164	36.2648	48.5638	6.40	81.41
% seated/shift	BMI<35	24	.6350	.12701	.02592	.5814	.6886	.43	.89
	BMI>35	27	.7704	.14847	.02857	.7116	.8291	.31	.92
	Total	51	.7067	.15342	.02148	.6635	.7498	.31	.92

E. Roll Distance Test

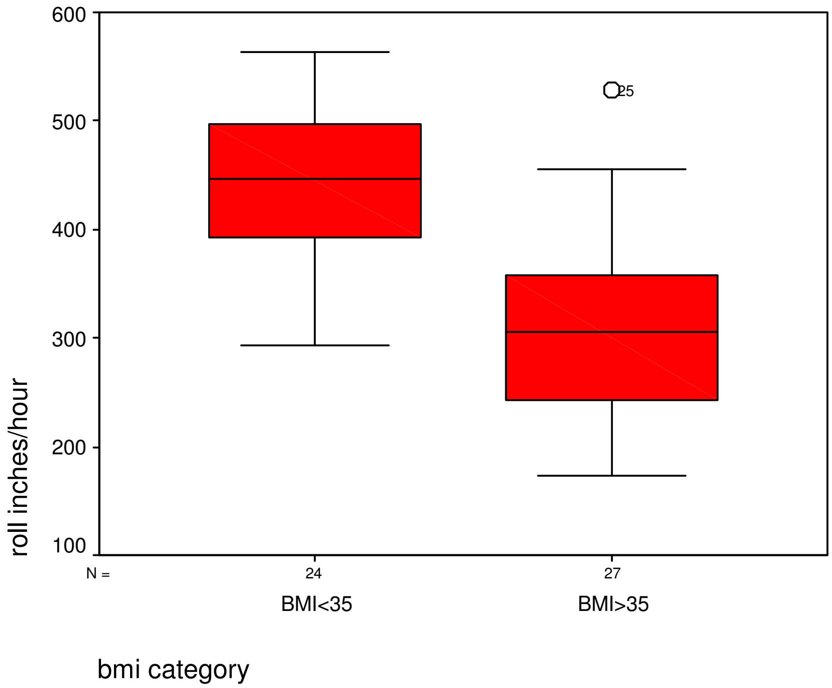
On separate days from the pressure distribution data collection, data was collected for ROLL Distance of the chair casters to determine whether BMI and or body weights in excess of the ANSI/BIFMA recommended 225lb maximum would impact total distance rolled. It should be noted that the 50 participants used in the roll study were not all the same as those tested in the pressure study. There were 35 repeat and 15 new participants. Complete survey data was once again collected but the BMI category was the only practical constraint study since none of the other constraints could be used in practical field conditions.

The roll test could not be conducted during the pressure test since the test device for pressure limited and modified rolling habits based on extra weight (25lbs) and the restriction of movement of the chair back and seat angles. For the roller test, only the participant's casters were changed to the recording caster set. This greatly reduced measurement bias that might have otherwise been introduced. While it is unfortunate that not all of the original participants could be used for the caster study, given the tight distributions and significant differences in means, it does not appear that it would have any effect on the outcomes recorded. Figure 16 clearly shows the normal distribution of the roll distance data.



p value < 0.001

Figure 16 – Roller Data Histogram



p value < 0.001

Figure 17 – Roll Distance Distribution by BMI Category

Figure 17 shows that the mean roll distance for normal (442" per hour) and obese test groups (mean of 315" per hour) are significantly different at the 0.05 test level with a significance value less than 0.001.

F. Conclusions from Field Tests

During this study, it was determined that there were 54% more seat contacts/hr for normal than for obese. Specifically, a mean of 4.5 seat contacts/hr for obese in and out of the chair and 6.92 seat contacts/hr for normal in and out of the chair was recorded. There were 62% more back contacts/hr for obese workers than normal workers. Specifically, a mean of 53 backs/hr for obese backrest contacts and 32 backs/hr for normal backrest contacts were recorded. There was 20% more seated time per shift for the Obese workers who had 77% of the shift seated for compared to 64% of shift seated for normal workers.

The ANSI/BIFMA test # of 120,000 cycles of 125lb, test drops into the seat to simulate 10 years of normal use has been in place since the 1970's. During seat use testing in this field study, it was extrapolated from daily numbers that Obese seat contacts/decade would be 89,946 while Normal seat contacts/decade would be138,348. The Average seat contacts for all subjects, extrapolated to the ANSI/BIFMA 10 year cycle was 110,330. Given that the relative difference between normals and current ANSI/BIFMA numbers was moderate, it is recommended that the testing cycles be increased to 140,000.

The ANSI/BIFMA test # of 120,000 cycles of 75lbF back pulls to simulate 10 years of use has been in place since the 1970's. During back use testing in this field study, it was extrapolated from daily numbers that Obese back contacts/decade would be 1,060,591 (8.8 x BIFMA #'s) while Normal back contacts/decade would be 653,644 (5.4 x BIFMA #'s). The Average back contacts for all subjects, extrapolated to BIFMA 10 year cycle was 838,391. Since this represents over 6 times the current test cycles, it is highly recommended that further study be done to consider raising the number of cycles used to test back rests. Further, it should be noted that a large part of the additional back contacts noted in the obese group could have simply been attributed to the larger percentage of time spent seated during the shift rather than a real difference between contacts per hour. Nonetheless, manufacturers will be interested in worst case scenarios for back use and therefore back contacts by obese workers may need to be used as the standard for all.

It is worth noting that 6 of the 51 participants had a "Sit-Stand" capable workstation. 2 were obese and 4 were normal. 2 of those Sit-Stand capable employees had sitting times in the low 40% range and were 2 of the 3 lowest "time seated" measurements recorded.

We failed to reject the null hypothesis of equality of means for Males and Females at alpha = 0.05 using the Student's T test for comparison of independent means. This was true for all the field study key measures. In simple terms, gender was NOT a significant bias in this study despite not being specifically controlled, as was BMI.

We failed to reject the null hypothesis of equality of means of Age for the obese and normal groups at alpha = 0.05 using the Student's T test for comparison of independent means ($p<0.327$). Therefore Age for Normal and Obese groups was not significantly different in the study group.

When analyzed by Job Type, the only parameter found to be significantly different was percent seated per shift with a $p<0.024$. More specifically, Management positions tested differently than Clerical and Technical. This difference may not be significant to design but it is significant in noting that the people most often called upon to select and purchase seating for workers are also those that use seating the least. This may present an obstacle to manufacturers attempting to explain the importance of proper, high-quality seating since their audience is less likely to relate to the need than the actual clerical or technical staff spending long hours in the seating.

Seat and Back Use Field Test Final Comments

The field study showed that there have been major changes in office worker seating patterns since the 1970's when the last "seating habit" numbers were derived by committee members from office furniture manufacturers.

Many of the old industry standard assumptions of seating use in the office are invalid. Key performance measures for tests of office seating should be revised to better reflect these new usage patterns along with the impact of a larger, more sedentary population. A test standard for seating designed for severely obese (BMI > 35) office workers should be developed.

Caster Roll Test Final Comments

The ANSI/BIFMA Test Standard calls for 100,000 cycles of 60" per cycle or 30" down and 30" back per cycle with a 225lb weight centered over the 5-leg base.
This is 6,000,000 inches/10 year test mode. (94.7 miles)

The results from the caster field test found that even the average for both groups was over 10,000,000 inches/decade and using the peak or highest distance test subjects for worst case, the distance was closer to 15,000,000 inches/10 years (236.7 miles)
This is based on a one hour average derived from at least 8 hours of test data per subject multiplied by 2000 hrs per year x 10 years.

Using the Student's t-test for comparison of independent means at the alpha = 0.05 significance level, we rejected a null hypothesis of equal means for roll distance between normal and obese participant groups. $p<0.001$

ANSI/BIFMA caster roll test should be revised by increasing the weight load and the roll distance. Weight should go up to at least the latest 95th percentile male #'s from the more recent, large-scale studies like CEASAR and NHANES. Distance should be at least 3 Standard Deviations from the group mean determined in this study. If an XXL test is developed, it should have less roll distance than the normal standard, but a heavier weight. What is not provided for in the current test procedure is that the same base and casters that are roll tested, be drop tested. Due to the uneven loading in real-time sitting, where one leg is often loaded with most of the drop force from a person entering a seat, and then rolling, the roll and drop test should be combined to more accurately approximate field conditions by dropping after each roll cycle.

CHAPTER IV
LAB STUDY

A. Introduction

For the lab study, data was collected during 3 cycles of ingress, egress on the armrest use, along with anthropometry and critical chair testing parameters in the categories listed below. Also, Center of Gravity was measured from a fixed backrest (front to rear) for all 16 participants. The same survey and consent form was used for lab and field study participants. (Appendix 1) An attempt to control for age related strength factors by limiting lab test participants to a range of 20-60 years was made to improve statistical power when comparing obese and normal. 4 male and 4 female obese with BMI greater than 35 and 4 male and 4 female with BMI less than 30 were compared. The primary purpose of this study was to determine whether a significant difference existed between anthropometric loading factors for normal and obese that would affect how a chair is loaded during testing. The null hypothesis that normal means and obese means for each measure were equal was established and tested using normal independent samples T-test at the 0.05 significance level. Several significant differences existed in this group and as a result, a much larger study that evaluates a broader range of BMI's and seating impacts should be conducted.

B. Methods

Data collected on Lab study participants:

1. Seated Hip Breadth (anthropometer)
2. Seated Elbow Height (tape measure)
3. Seated elbow breadth (anthropometer)
4. Horizontal Acromium distance from back of chair test device (vertical back)
5. Seat depth - popliteal to buttocks (tape measure and T-ruler)

6. Forearm width (max) (anthropometer)
7. Body weight and height (wall height gauge and Siltec 500lb capacity digital scale)
8. Center of Gravity relative to back of chair test device (built in X sensor™ scale, in 0.5" increments)*

   * seat height was set at popliteal height with feet on scale to ensure no more than 15% of body weight on feet during measurements.

Additionally, arm sensors were used to track normal entry exit parameters of the aforementioned X sensor™ parameters of each participant by studying them in 3 entry exit cycles per subject at a sampling rate of 1 cycle per second on each armrest and then extrapolating that data relative to entry exit data ascertained during the days of real-time seat cycle testing collected in the field study.

Armrest data included:

1 Armrest pressure average (mmHg)

2.Armrest pressure peak (mmHg)

3.Armrest contact area (square inches)

All anthropometric measurements were taken using standard anchor point palpation versus reference using the rulers, anthropometers and scales mentioned below.

Seated Hip Breadth was relevant for chair design in the area of arm clearance and seat-pan size. Seated Elbow Height and breadth were relevant to arm height and span. Basically, for larger BMI's seated elbow span expanded. It literally becomes impossible to move the elbows close to the body with increasing obesity. This means that a 5th percentile female in stature might have a 95% male elbow rest height. Only body fat can explain those types of vast differences seen in our study participants. For low or normal BMI participants, our request to place arms relaxed and naturally at their side with elbows at 90 degrees left their upper arm near vertical. For the high BMI participants, 20-45 degrees was more common. Exact measurements were not taken of this particular difference but it was noted as a potential measurement of interest for future study since arm angle influences where support structures might contact the body and could therefore have design input on the shape and composition of materials used in the arm pads. More importantly for this research, the force vector applied to the arm during ingress/egress was notably different for our two groups. A note for future research would be a survey of ulnar nerve entrapment from mechanical compression on the armrest for the obese given, exposure angle and greater load. At the same time, their could be a protective effect from the additional tissue between arm pad and ulnar nerve in the obese.

Horizontal distance to the acromium was taken to attempt to understand the difference in backrest contact points for the obese versus normal groups. In short, there was a significant difference between the obese and the normal groups in how far there upper back, neck and shoulders were from the back of the vertical back on the test chair. The extra girth in the mid-section was literally limiting access to the backrest. As a result, high BMI participants tended to make backrest contact only in the sacral and lumbar region. The low BMI participants generally made contact all the way up to and sometimes including the seventh cervical vertebra.

Seat depth was taken to compare obese and normal for what impact the extra body fat might have on the size needs of seat-pans as measured from the front edge to the backrest. Generally, seat pans are designed in depth to mirror stature and leg length. As found in this study, seat depth is very dependent on BMI and not just stature or leg length. In short, some of the shortest participants, needed the deepest seat pans to fully accommodate their needs.

Forearm widths were taken to determine arm pad needs for both participant groups. This was one of the more disappointing measures since the obvious desire for wider pads amongst both groups to accommodate varied work habits was an unmeasured factor that would certainly influence real world use and acceptance. Nonetheless, there were significant differences in the average forearm widths for both groups. This knowledge was important to the design of test arms in terms of surface area and material selection.

Body weight and stature were collected with a wall height gauge and the Siltec, 500lb capacity digital scale. There was resistance for the weight portion of this test by some participants even after consenting to give it and listing it on the field survey form. All were persuaded with patient encouragement. Discussions of the emotional, psychological and health impacts of obesity are beyond the scope of this study but it was noteworthy how prevalent poor self-image related to obesity manifested itself in those participants.

As part of the lab study, participants were carefully placed in a vertical backrest to 90 deg seat pan chair and adjusted to a seat height where their popliteal height with feet on scale allowed no more than 15% of their body weight on the feet during measurements of the Center of Gravity as suggested by CG studies done by Congleton in research on the neutral body position. (Congleton, 1983) This data was presented in the X sensor readouts in both 2D and 3D. For purposes of the chair test criteria, only 2D measurements were recorded. Figures 18-20 show the test equipment used for the lab study.

Additionally, arm sensors were used to track normal entry/exit parameters of the aforementioned X sensor measurements for each participant by studying them in 3 entry exit cycles per subject at a sampling rate of 1 cycle per second on each armrest and then extrapolating that data relative to entry exit data ascertained during the days of real-time seat cycle testing.

Armrest data will include:

1. Armrest pressure average (mmHg)
2. Armrest pressure peak (mmHg)
3. Armrest contact area (square inches)

Figure 18 – Anthropometer Shown at Shoulder Breadth Measurement Point

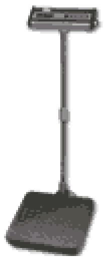


Figure 19 – Siltec PS5AP 500lbs x 0.5 lb with Digital Readout Pole

Figure 20 – Arm Test Sensors for Entry/Exit Study

C. Participants

As seen in Figure 21, a sample of 8 females and males was chosen and then split again in to BMI groups of greater than 35 and less than 30.

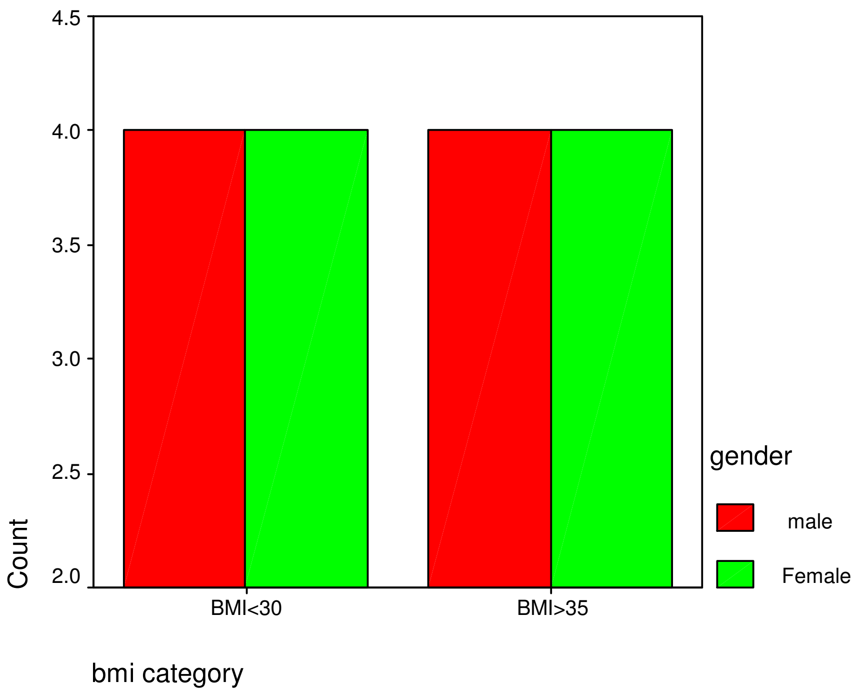
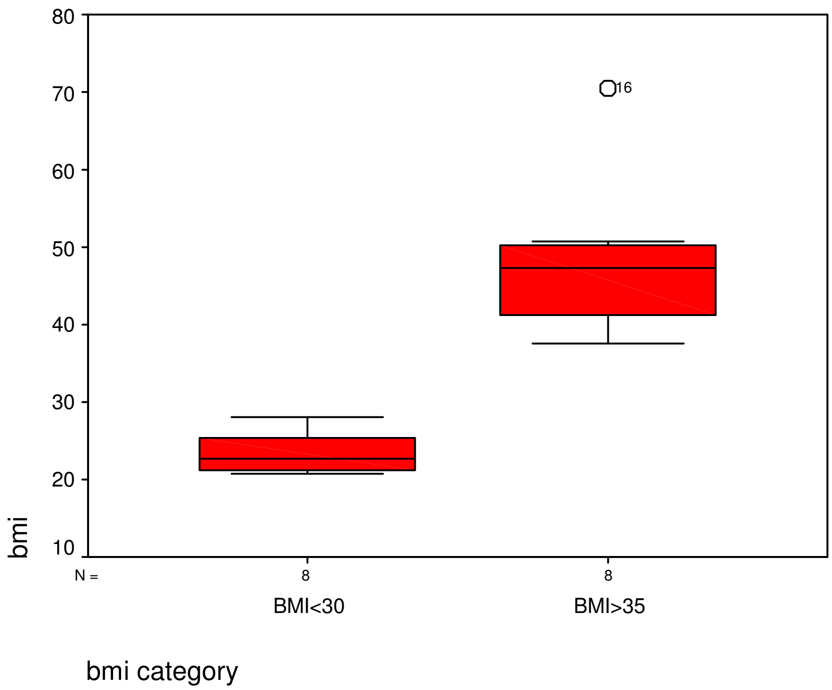


Figure 21 - Lab Participant Distribution

D. Results

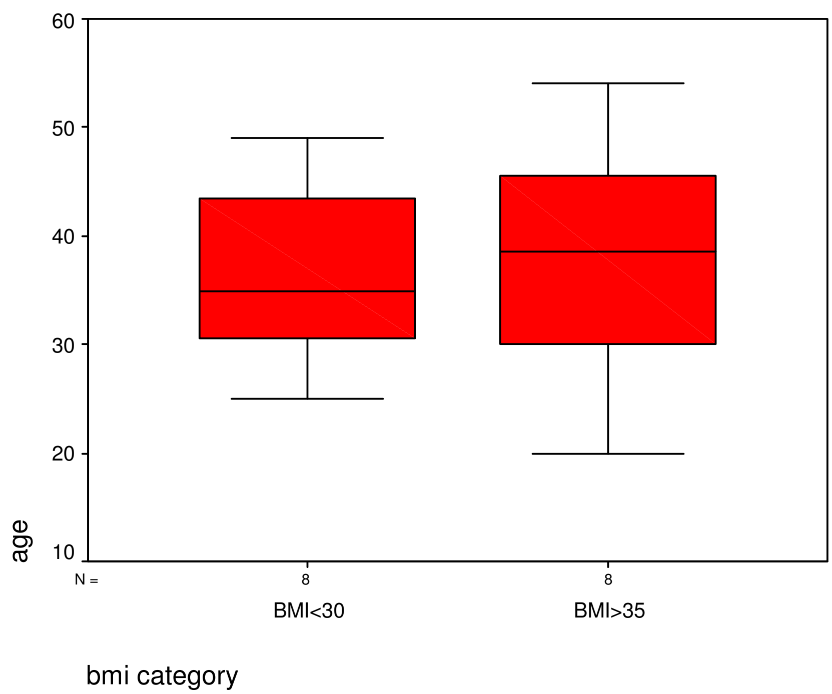
Figure 21 shows the difference in distributions between normal and obese relative to BMI #'s. Of note for the obese group was an outlier labeled O16 in the graph. This resulted in a significantly larger range of possible BMI's in the obese group compared to the normal group. However, even if this individual was removed, the results of the comparisons did not change. Figure 22 shows that Age for this study was not a bias within one group compared to the other. This was important to the quality of the results since it is assumed that age can influence anthropometric data. Figures 23 –29 show the dramatic differences in distributions for the normal and obese groups relative to the seven anthropometric measures taken in this study. Finally Figure 30 shows the distribution for

Male vs. Female with by Center of Gravity and how gender was not a significant bias in this sample. Tables 12-14 list the descriptive statistics and the results of the paired t-tests.



p<.001

Figure 22 – Distribution of BMI Number by BMI Category for all Participants



p<.932

Figure 23 – Distribution of Age by BMI Category for all Participants

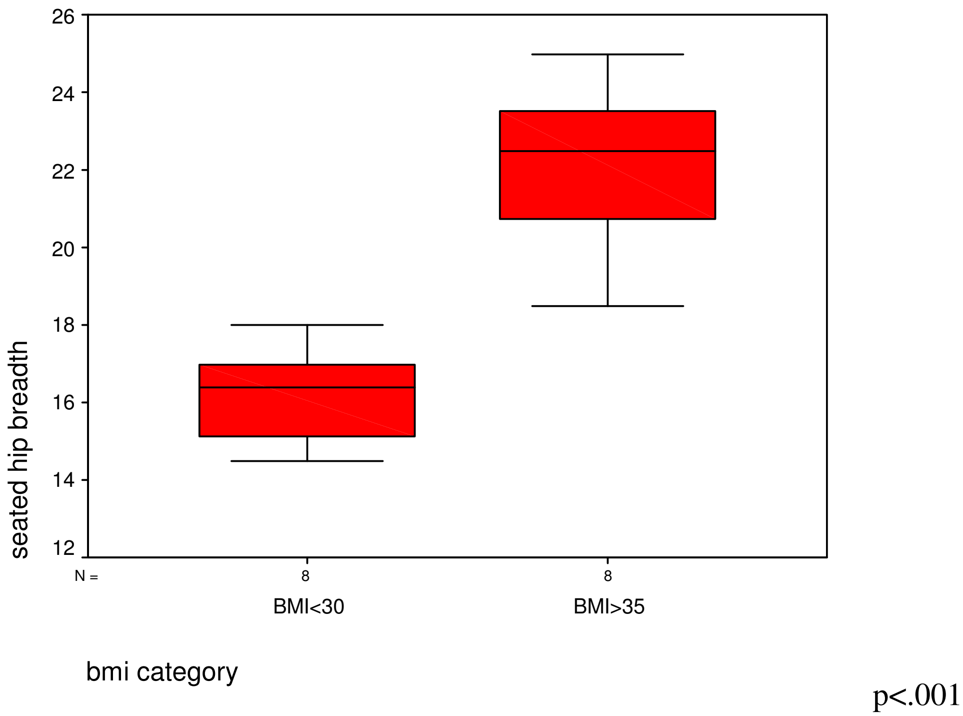


Figure 24 – Distribution of Seated Hip Breadth by BMI Category

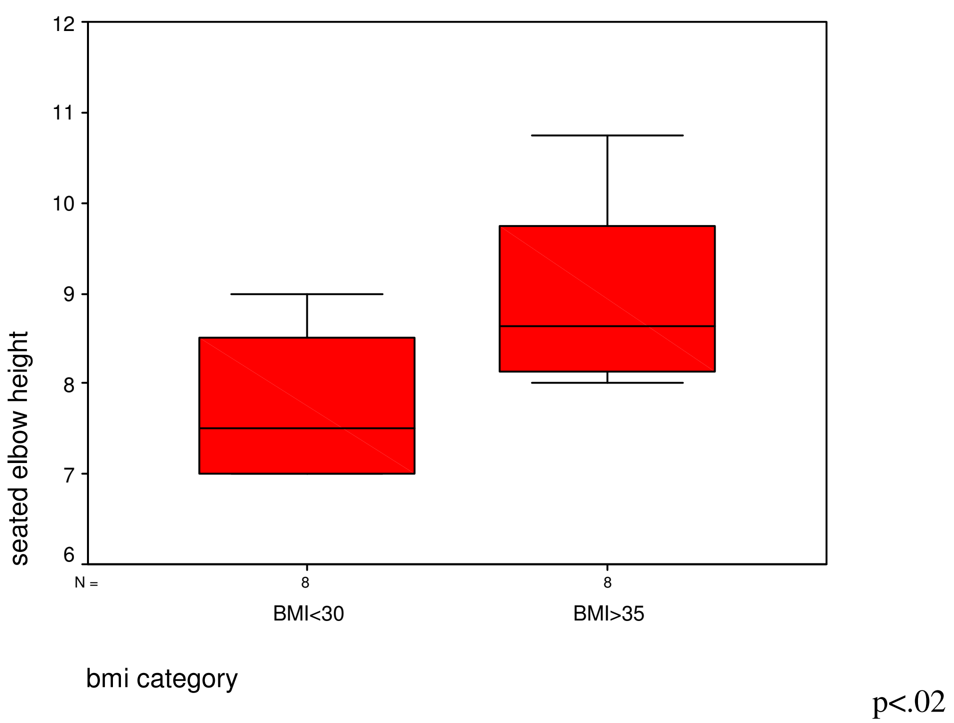
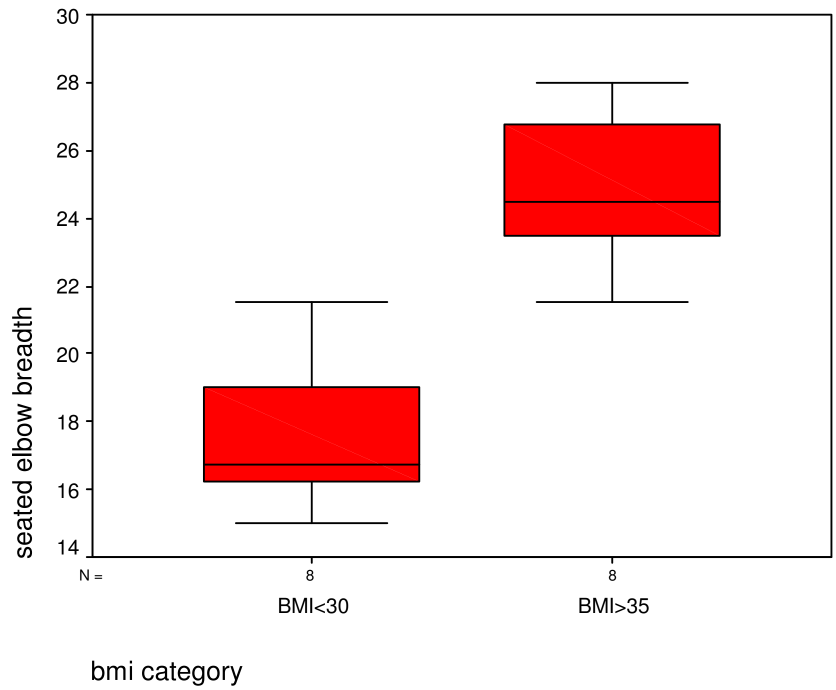
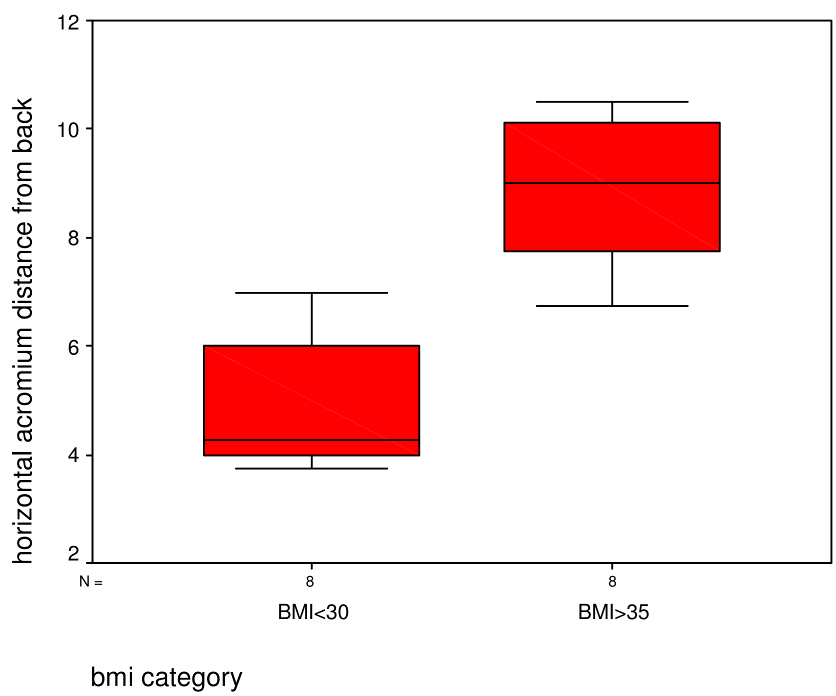


Figure 25 – Distribution of Seated Elbow Height by BMI Category



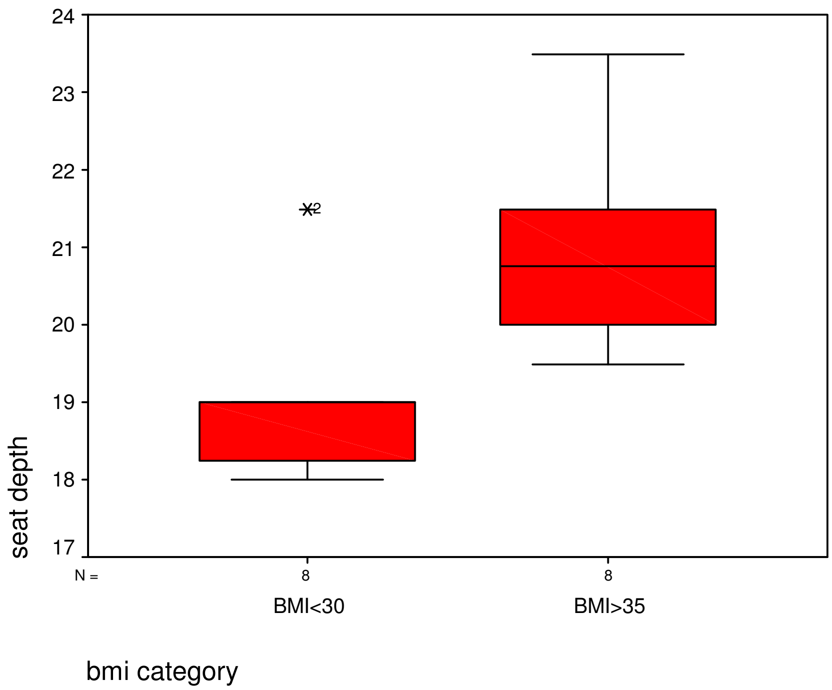
p<.001

Figure 26 – Distribution of Seated Elbow Breadth by BMI Category



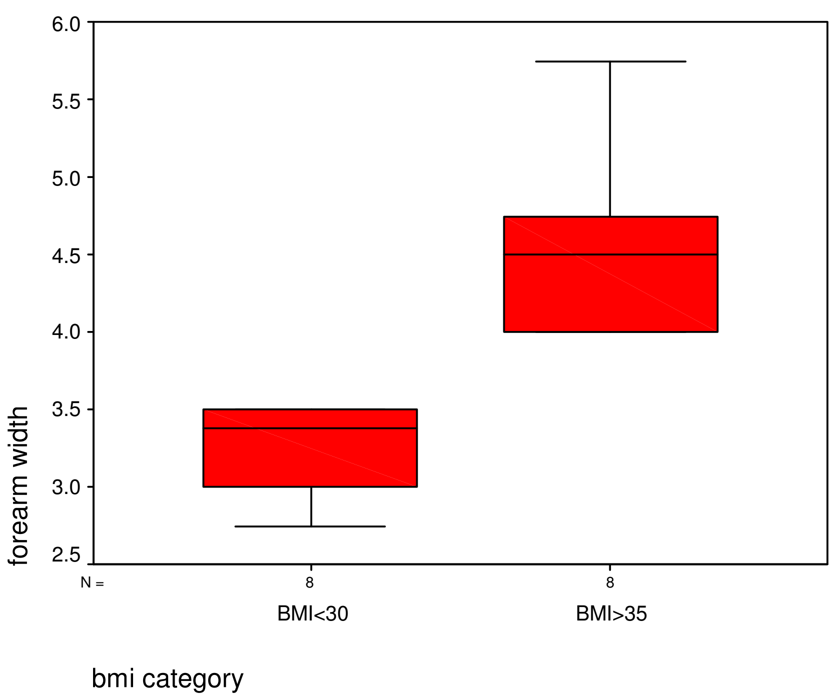
p<.001

Figure 27 – Distribution of Horizontal Distance by BMI Category



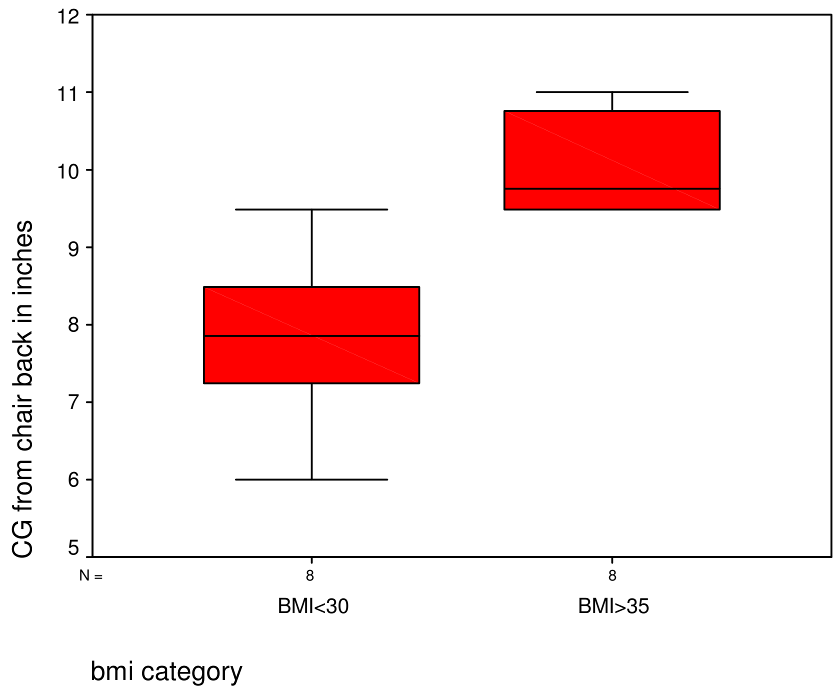
p<.006

Figure 28– Distribution of Seat Depth by BMI Category



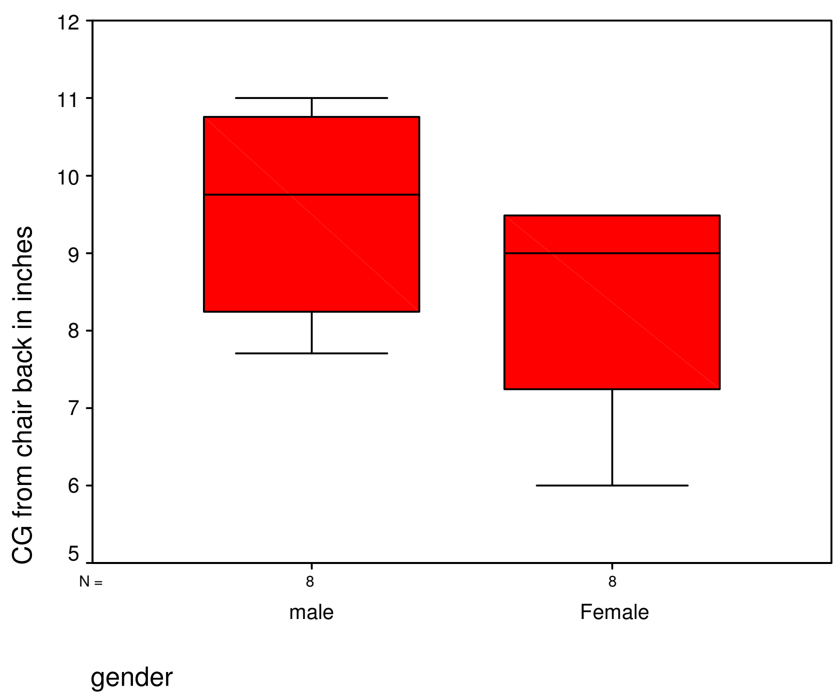
p<.001

Figure 29 Distribution of Forearm Width by BMI Category



p<.001

Figure 30 -Distribution of Center of Gravity by BMI Category



p<.095

Figure 31– Distribution of Center of Gravity by Male/Female

Figures 30 and 31 show center of gravity (CG) distributions were not affected by gender but we significantly affected by BMI. Combined with the lack of stature affects on CG, this is a dramatically important finding in the overall scheme of anthropometric study.

Table 12 - Group Statistics from the Anthropometric and Center of Gravity Analysis by BMI Group

	bmi category	N	Mean	Std. Deviation	Std. Error Mean
seated elbow height	.00	8	7.7500	.84515	.29881
	1.00	8	8.9688	1.01275	.35806
seated hip breadth	.00	8	16.1875	1.20082	.42455
	1.00	8	22.1250	2.08310	.73649
seated elbow breadth	.00	8	17.5625	2.17843	.77019
	1.00	8	24.8750	2.18354	.77200
horizontal acromium distance from backrest contact point	.00	8	4.9063	1.34919	.47701
	1.00	8	8.8750	1.38873	.49099
seat depth	.00	8	19.0000	1.10195	.38960
	1.00	8	20.9375	1.29387	.45745
forearm width	.00	8	3.2500	.29881	.10564
	1.00	8	4.5313	.60412	.21359
center of gravity	.00	8	15.7500	2.12132	.75000
	1.00	8	20.1250	1.35620	.47949
0 = Normal	1 = Obese				

Table 13 - Group Statistics from the Anthropometric and Center of Gravity Analysis by BMI Group

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
seated elbow height	Equal variances assumed	-2.613	14	**.020**	-1.218	.46636	-2.219	-.218
seated hip breadth	Equal variances assumed	-6.985	14	**.000**	-5.937	.85009	-7.760	-4.11
seated elbow breadth	Equal variances assumed	-6.706	14	**.000**	-7.312	1.090	-9.651	-4.973
horizontal acromium distance from backrest contact point	Equal variances assumed	-5.798	14	**.000**	-3.968	.68455	-5.436	-2.50
seat depth	Equal variances assumed	-3.224	14	**.006**	-1.937	.60087	-3.226	-.6487
Forearm width	Equal variances assumed	-5.377	14	**.000**	-1.281	.23829	-1.792	-.7701
Center of gravity	Equal variances assumed	-4.915	14	**.000**	-4.375	.89017	-6.284	-2.465

Table 14 - Group Statistics for Anthropometric and Center of Gravity Analysis by Gender

	gender	N	Mean	Std. Deviation	Std. Error Mean
seated elbow height	Male	8	8.9063	1.06013	.37481
	Female	8	7.8125	.88388	.31250
seated hip breadth	Male	8	18.6250	2.34521	.82916
	Female	8	19.6875	4.44761	1.57247
seated elbow breadth	Male	8	22.4375	4.22947	1.49534
	Female	8	20.0000	4.33425	1.53239
horizontal acromium distance from backrest contact point	Male	8	6.8438	2.17509	.76901
	Female	8	6.9375	2.83079	1.00084
seat depth	Male	8	20.1875	1.64615	.58200
	Female	8	19.7500	1.48805	.52610
forearm width	male	8	3.9688	.63298	.22379
	Female	8	3.8125	.98878	.34959
center of gravity	Male	8	19.1250	2.53194	.89518
	female	8	16.7500	2.76457	.97742

Unlike BMI, Gender had only moderate effects on CG and most of that can be explained by the difference in stature of the two groups. The overwhelmingly best predictor for CG is BMI as evidenced by the significant findings of mean differences between the two groups ($p<.000$). Table 15 shows a lack of anthropometric and CG differences between genders.

Table 15 – Means Tests for Anthropometric and Center of Gravity Analysis by Gender

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
seated elbow height	Equal variances assumed	2.241	14	**.042**	1.0938	.48800	.0471	2.140
seated hip breadth	Equal variances assumed	-.598	14	.560	-1.062	1.7776	-4.87	2.750
seated elbow breadth	Equal variances assumed	1.138	14	.274	2.4375	2.141	-2.15	7.029
horizontal acromium distance from backrest contact point	Equal variances assumed	-.074	14	.942	-.0938	1.2621	-2.80	2.613
seat depth	Equal variances assumed	.558	14	.586	.4375	.78455	-1.24	2.120
forearm width	Equal variances assumed	.376	14	.712	.1563	.41508	-.734	1.046
center of gravity	Equal variances assumed	1.792	14	.095	2.3750	1.3254	-.467	5.217

Figures 32-38 show the distributions for the various arm pressure and contact area measurements taken in this study. Not shown are the dramatic usage differences between the video feeds from each person. In general, obese participants entered more unilaterally and normal participants entered bilaterally. This difference was not captured well in the data and should be considered for further study.

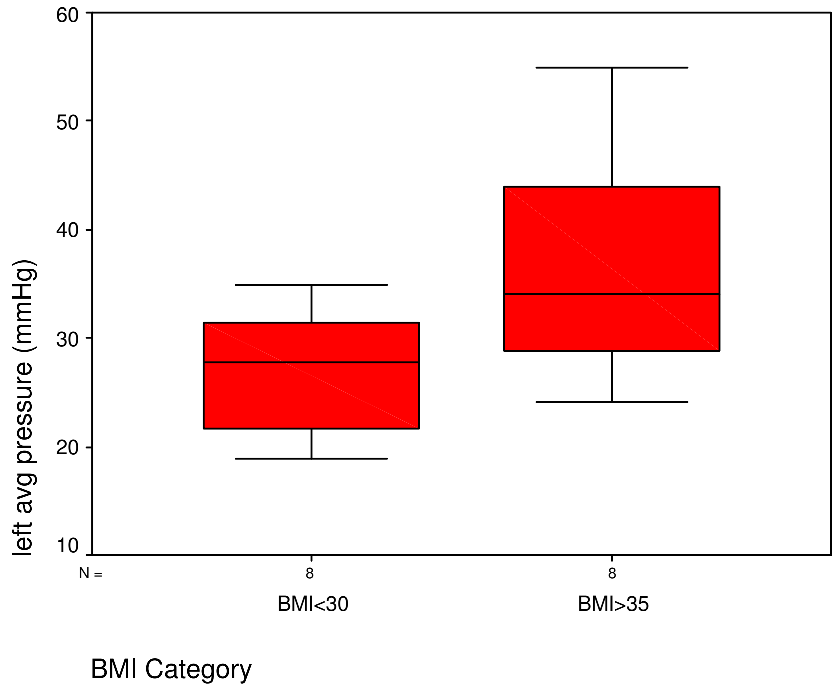


Figure 32- Distribution for Normal and Obese by Left Arm Average Pressure

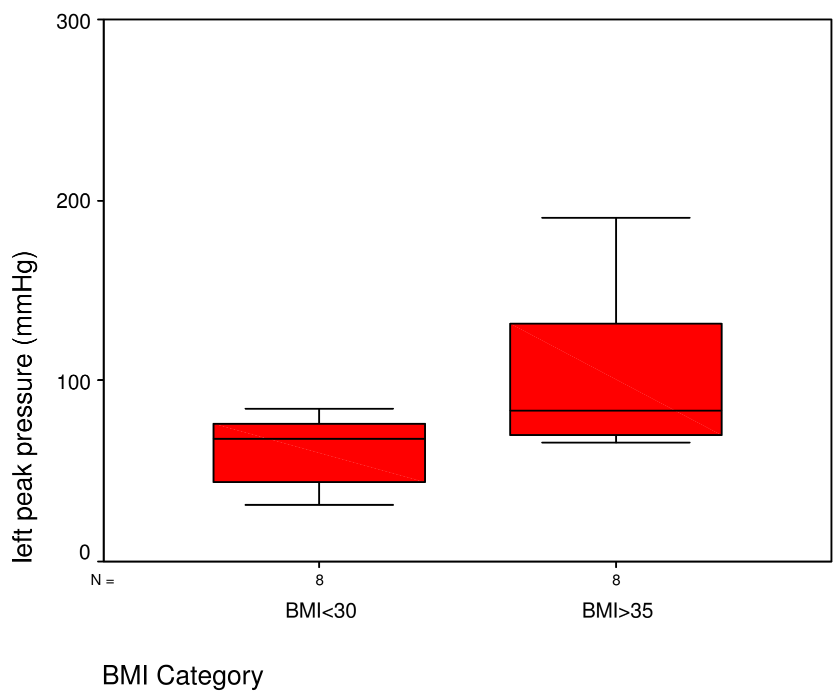


Figure 33- Distribution for Normal and Obese by Left Arm Peak Pressure

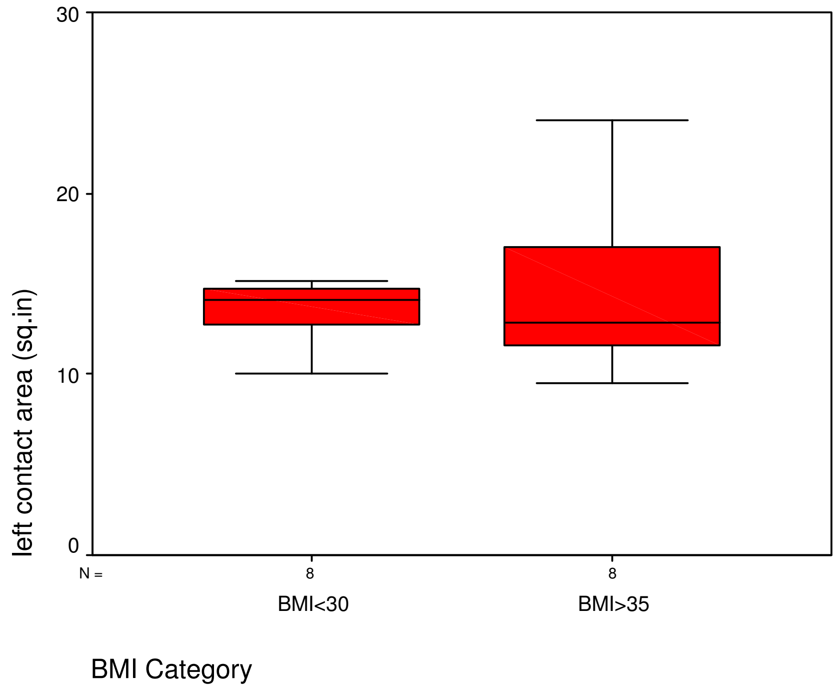


Figure 34 - Distribution for Normal and Obese by Left Arm Contact Area

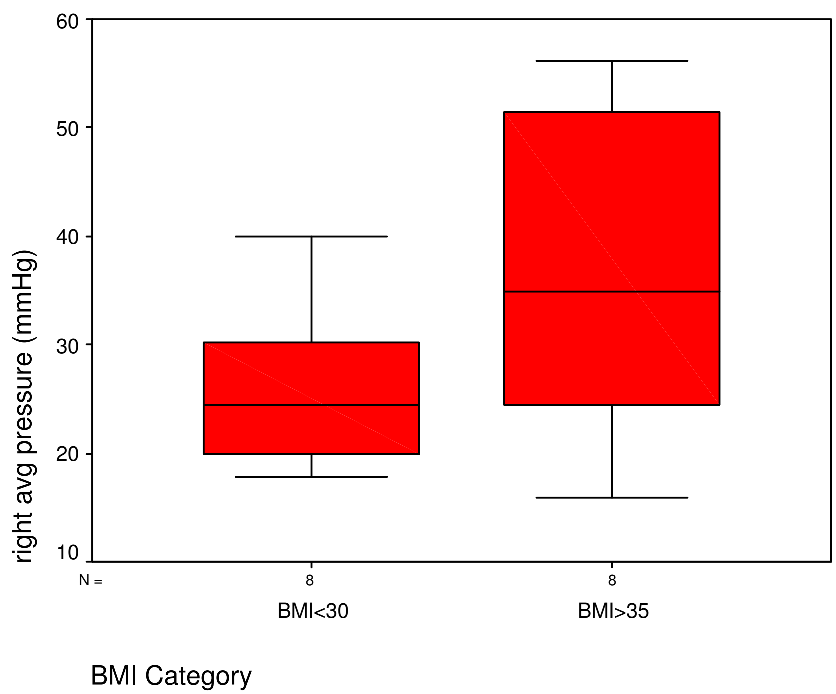


Figure 35- Distribution for Normal and Obese by Right Arm Average Pressure

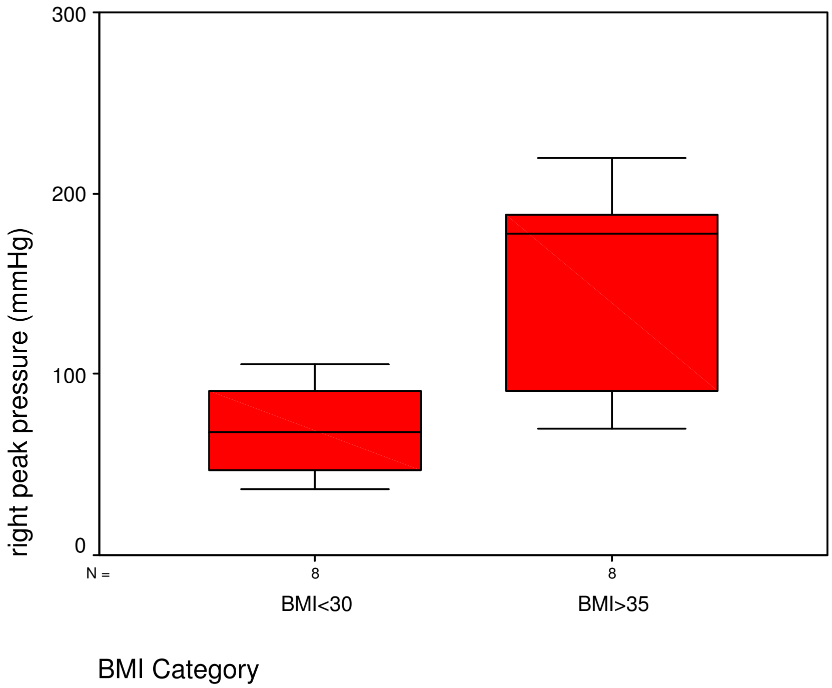


Figure 36- Distribution for Normal and Obese by Right Arm Peak Pressure

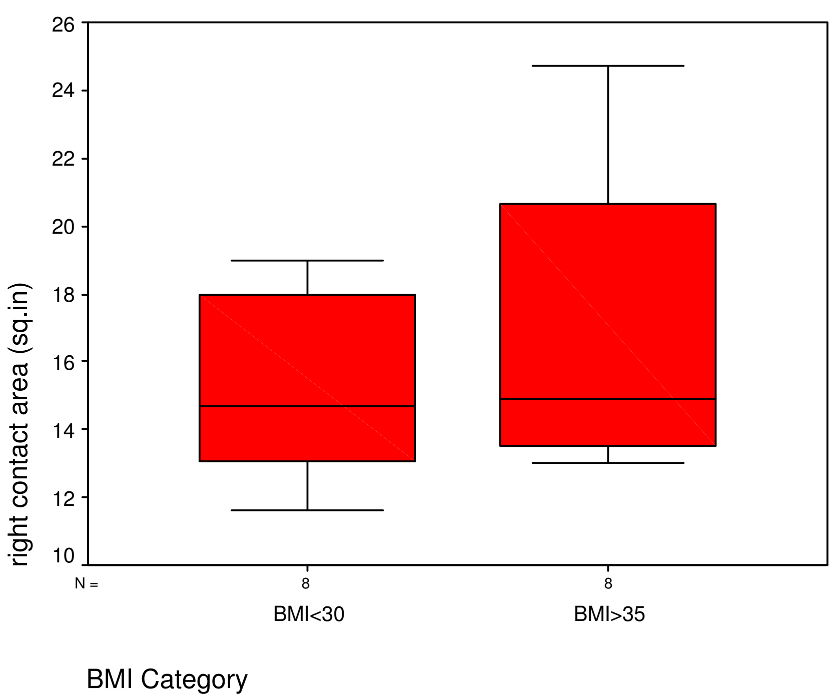


Figure 37- Distribution for Normal and Obese by Right Arm Contact Area

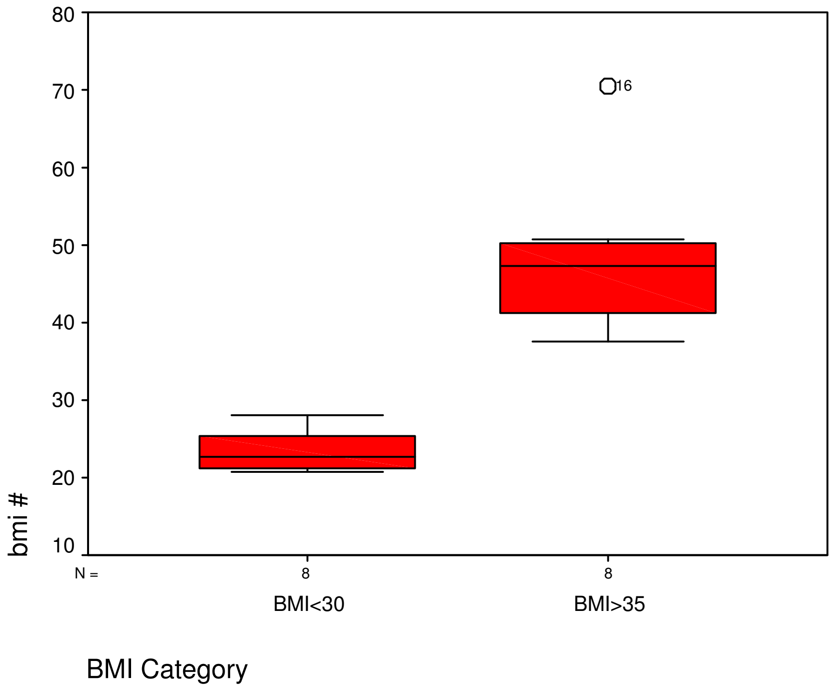


Figure 38- Distribution for Normal and Obese by BMI Number

Tables 16-17 show group statistics and the significance levels for the lab study arm rest parameters by BMI. These findings are consistent with the other arm data which indicates a strong need for further study of the actual forces for both groups.

Table 16- Group Statistics for Arm Pressure Lab Study by BMI

	BMI Category	N	Mean	Std. Deviation	Std. Error Mean
Left Avg Pressure	Normal	8	26.9375	5.98449	2.11584
	Obese	8	36.6000	10.81982	3.82539
Left Peak Pressure	Normal	8	61.5125	20.46778	7.23645
	Obese	8	103.4625	47.38894	16.75452
Left Contact Area (in2)	Normal	8	13.5625	1.75250	.61960
	Obese	8	14.5750	4.90968	1.73584
Right Avg Pressure	Normal	8	25.9000	7.72954	2.73280
	Obese	8	36.7250	14.97767	5.29541
Right Peak Pressure	Normal	8	69.1375	25.21756	8.91576
	Obese	8	150.6625	57.26352	20.24571
Right Contact Area (in2)	Normal	8	15.2625	2.81066	.99372
	Obese	8	16.9750	4.66468	1.64922

Table 17 - Independent Samples Test for Arm Pressure Lab Study by BMI

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Left Avg Pressure	Equal variances assumed	-2.210	14	**.044**	-9.6625	4.371	-19.03	-.2864
Left Peak Pressure	Equal variances assumed	-2.299	14	**.037**	-41.950	18.250	-81.09	-2.801
Left Contact Area (in2)	Equal variances assumed	-.549	14	**.591**	-1.0125	1.8431	-4.965	2.9405
Right Avg Pressure	Equal variances assumed	-1.817	14	**.091**	-10.825	5.9589	-23.60	1.9557
Right Peak Pressure	Equal variances assumed	-3.685	14	**.002**	-81.525	22.121	-128.9	-34.07
Right Contact Area (in2)	Equal variances assumed	-.889	14	**.389**	-1.7125	1.925	-5.842	2.4172

E. Conclusions

Arm pressure readings for this sample were found to be different for Left Average, Left Peak and Right Peak. However, it should be noted that for the obese group, peak pressures in both hands regularly exceeded 220mmHg. This is the maximum recording level of our device. Subsequently, while we know that differences do exist, we really do not know exactly what those differences are relative to one another. This indicates a need for further study, in situ, for obese workers with respect to arm rest use. Further, it should be noted that we learned more about how workers of different weight classes sit by reviewing the videos than we did by studying the pressures. Part of this is simple deduction born from poor statistical results and part of it was poor test procedures established without the benefit of hindsight.

What we learned in general with the two groups was that obese workers tend to approach the chair from an angle using more pressure on one arm and then using both while normals tend to approach both the seat and the arms evenly. This loading process, of one arm, and the front corner of a seat pan is very important to designers and engineers. Simply put, it means that several of our assumptions of even loading seen in traditional tests are not valid for the obese worker.

CHAPTER V
GENERAL CONCLUSIONS

This research addresses the interests of the furniture industry to study the effect of the changing office worker and work habits on seating design, associated with the shift in technology and body proportions that were not present in the 1970’s when current standards and designs were initiated. The research compared the office seating habits of normal and obese office workers to determine whether a difference in use patterns exists beyond the obvious force differences associated with heavier body weights. The purpose of the collection of this data was to create a basis for new standards used to validate design requirements of office seating in the areas of quality, durability and performance.

In the 1970’s, approximately 1 out of 50 office workers was over 225lbs. For that reason, this number was used as a critical part of many of the performance tests for office seating designed at that time. Today, with the 95^{th}%tile male exceeding 250lbs, we know that at least 1 in 15 Americans exceed the old 225lb level. A reality check of the offices studied in the field study was performed to see where fell into this standard. Using the old 225lb level, 1 of 7 office workers in an office with 35 of the 51 study participants would be considered outside of the current test maximum that was derived from old military anthropometric studies. Clearly this is too small a sample size to make any national claims about what has happened to our office work force but it is an accurate reflection of what at least one employer is faced with when making chair selections for employees. A full 20% of employees at that location are likely to be provided with inadequately scaled and tested seating that was designed for the comfort and use of a normal BMI person rather than for them.

A logical question to ask following this type of study is “where do we go from here”? I strongly believe that it is in the best interest of the furniture industry to first revise current tests to reflect the new proportions of people and to then develop a standard for obese seating products that will adequately test these products to ensure that they can deliver safe and effective seating for this growing part of our workforce.

Ideally, this test methodology would include simultaneous component testing using biomimetic test dummies rather than the current shot bags and mechanical plungers. This would of course be a dramatic change for an industry that is historically slow to change, but it would certainly result in a much higher caliber of product for the very demanding market of obese seating.

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APPENDIX A

XSENSOR™ SPECIFICATIONS

X3 PX100 SERIES SENSORS

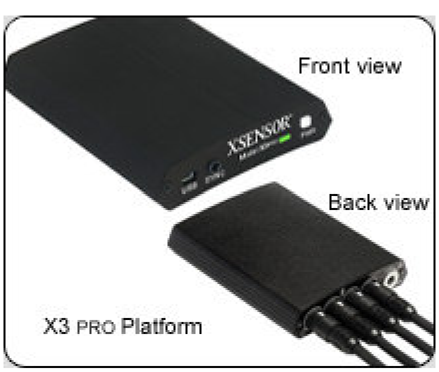
- Ultra flexible/conforming
- Large dimensions available (e.g. full-body)
- Low pressure range (<5 psi)
- Accurate and repeatable (+/- 10%)
- High spatial resolution (small as 5mm) Very durable
- Primarily used for human body interface applications

Sensors

Featuring durable sensors designed to withstand industrial testing conditions and to provide repeatable and accurate pressure distribution information, XSENSOR sensors in the Industrial System are ideal for testing automotive seating, tire treads, and door seals.

- Export functionality (export frames with comments based on statistical criteria, centre of gravity, place holders, etc.)
- Delayed recording
- Trigger recording
- Video capture and playback
- Sensor group templates
- Synchronization with other devices including time delay triggers

  - Less than 1mm thick, X3 PX100 sensor pads are a matrices of hundreds / thousands of sensors that wrap and flex around any contours
  - X3 PX100 sensor pads conform **like cloth** to the curves of the body and support surfaces, providing true dynamic images
  - No hard wires or cables in the active sensing area of X3 PX100 sensors
  - PX100 sensors are extremely conforming



APPENDIX B

CONSENT FORM

Office Worker Seating- Field Study

You have been asked to participate in a research study to learn more about the seating habits of office workers. You were randomly selected to be a possible participant because of your job tasks and work hours. A total of 50 participants have been selected to participate in this study. The purpose of this study is to determine overall seating habits of the general office population and to compare those same habits to smaller groups within that population by such things as gender and body size.

If you agree to be in this study, you will be asked to perform your normal daily duties while seated in a special test chair that will collect data relative to your use of your office chair for two 8-hour shifts. You will also be asked to complete a simple questionnaire that is attached to this form. There are no significant risks associated with this study and no discernible benefits either.

You will not receive monetary compensation for your participation. This study is confidential. Data will be maintained by and kept private by the primary researcher (Mark Benden). Only summary data will be presented and your name will never be tied to any general or specific data in any report that might be published. Your decision to participate will not affect your current or future relations with Texas A&M University. If you decide to participate, you are free to refuse to answer any of the question s that may make you uncomfortable. You can withdraw at any time without your relations with the University, job, benefits etc., being affected. You can contact Mark Benden 979-255-4177 or Dr. William Hyman 979-845-5593 with any questions about this study.

This research study has been reviewed by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research-related questions regarding subjects' rights, you can contact the Institutional Review Board through Ms. Angelia M. Raines, Director of Research Compliance, Office of the Vice President for Research at (979) 458-4067, araines@vprmail.tamu.edu.

Please be sure you have read the above information, asked questions and received answers to your satisfaction. You will be given a copy of the consent form for your records. By signing this document, you consent to participate in this study.

Signature of Participant:_________________________________Date:________

Signature of Investigator:________________________________Date:________

APPENDIX C
QUESTIONNAIRE

Office Worker Seating Lab and Field Study

Please circle correct or closest response or list as indicated:

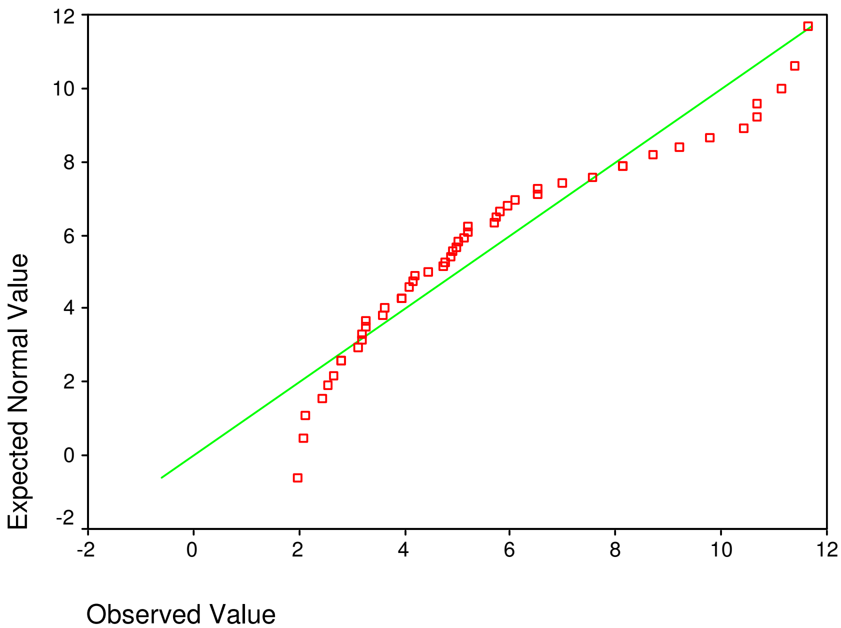
1. Gender: M F
2. Age:
3. Weight in lbs.
4. Height in inches:
5. Job task: Clerical/Support Technical Managerial
6. Job Title:
7. Race/Ethnicity:
8. Normal work hours:
9. Normal Seated work hours at primary desk:
10. Geographic quadrant within US: NE SE NW SW

Date tested:

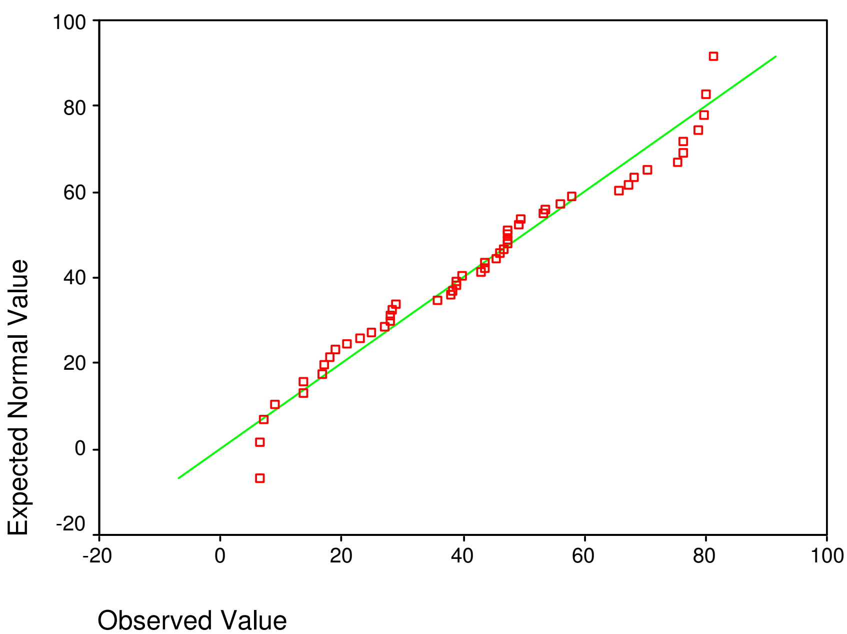
APPENDIX D

TESTS FOR NORMALITY OF FIELD DATA

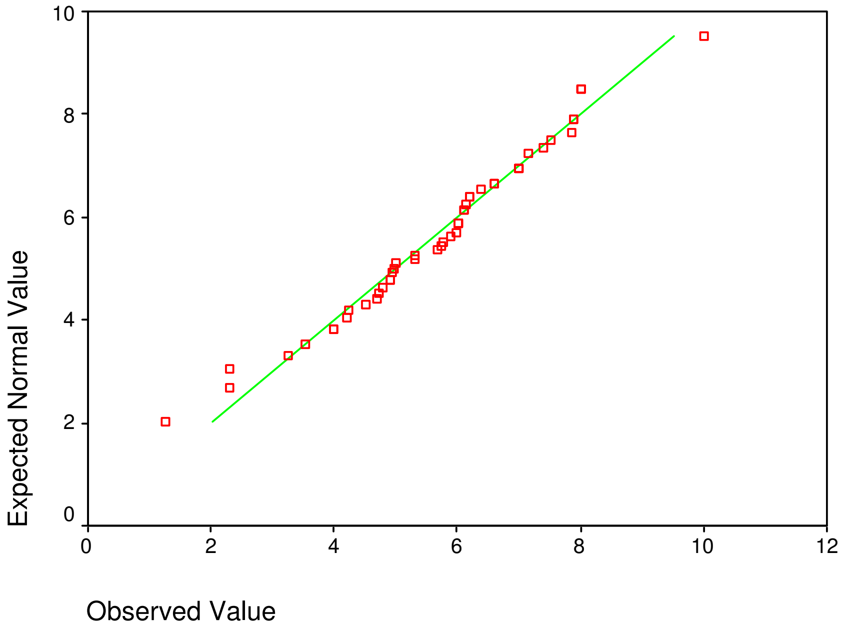
Normal Q-Q Plot of seats/hr



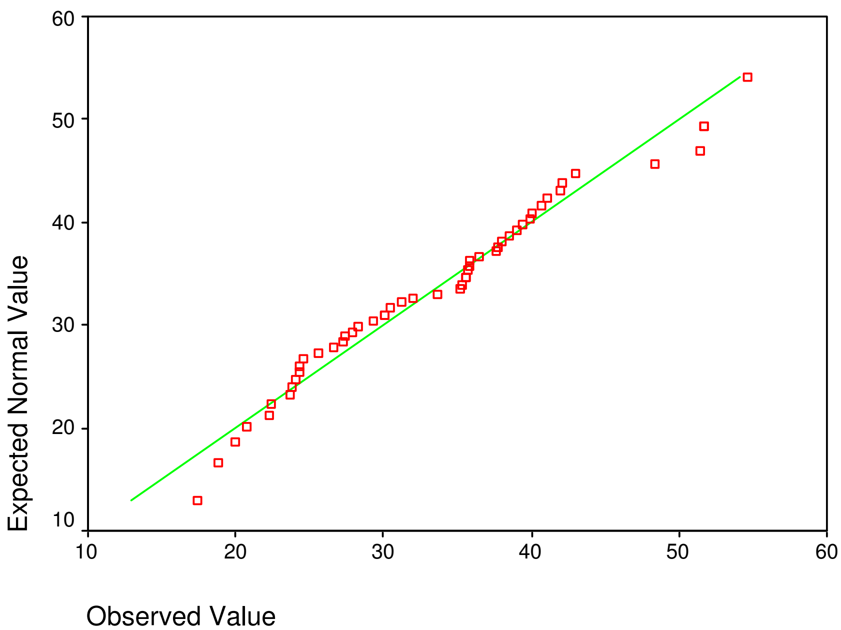
Normal Q-Q Plot of backs/hr



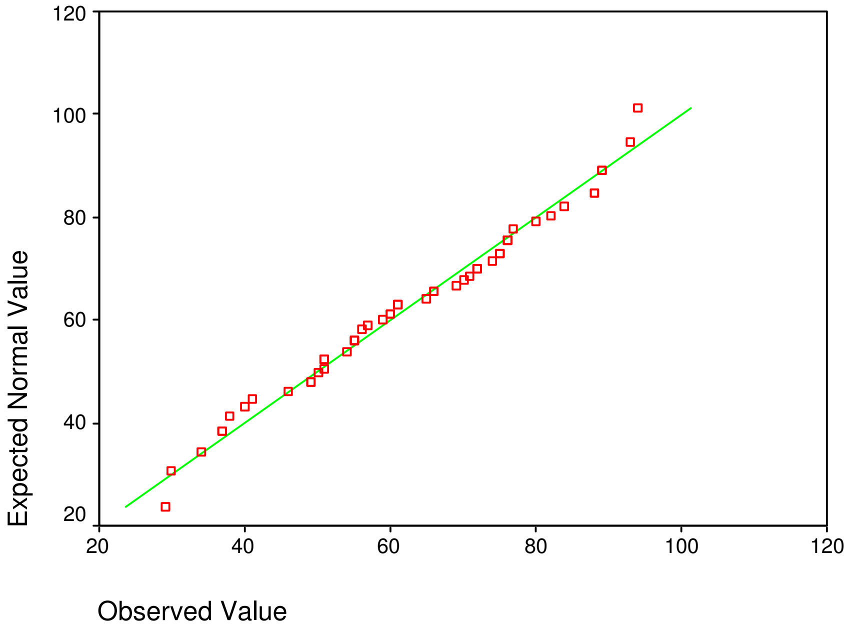
Normal Q-Q Plot of time in seat



Normal Q-Q Plot of bmi #

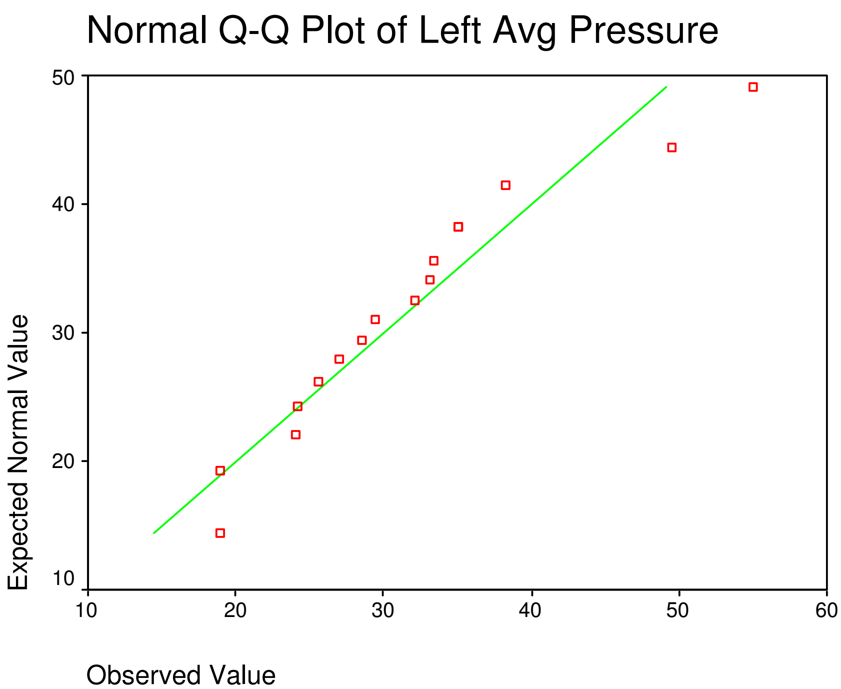


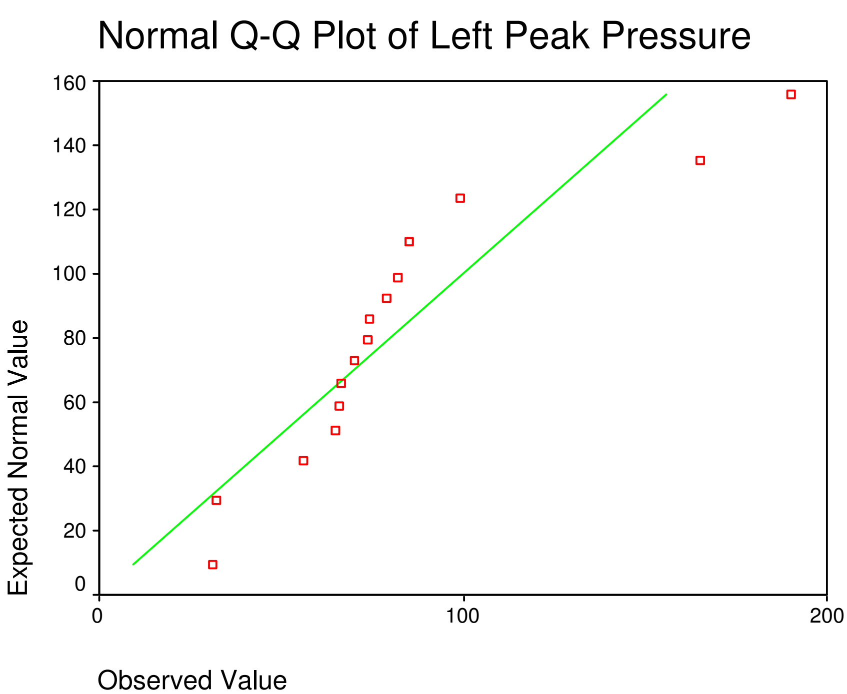
Normal Q-Q Plot of roll distance



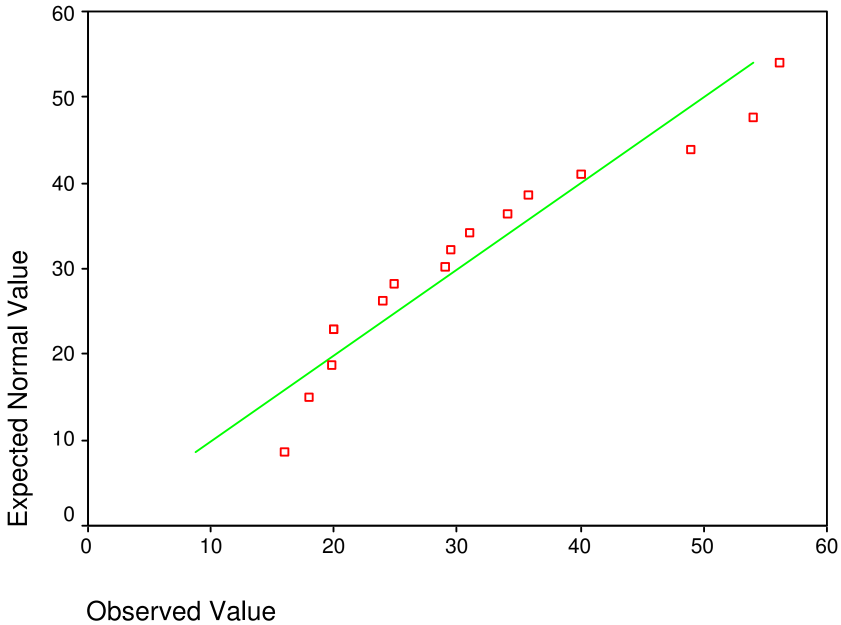
APPENDIX E

TESTS FOR NORMALITY OF LAB DATA

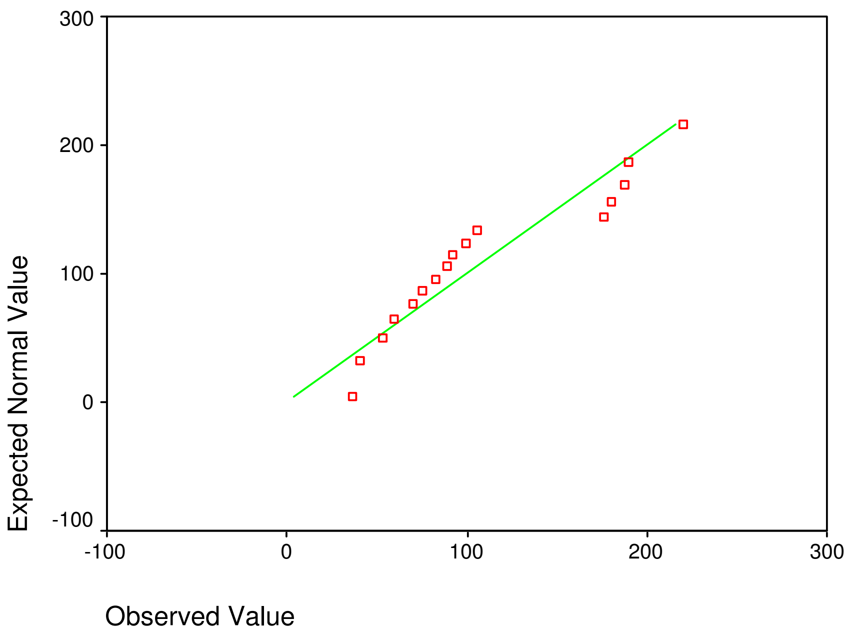


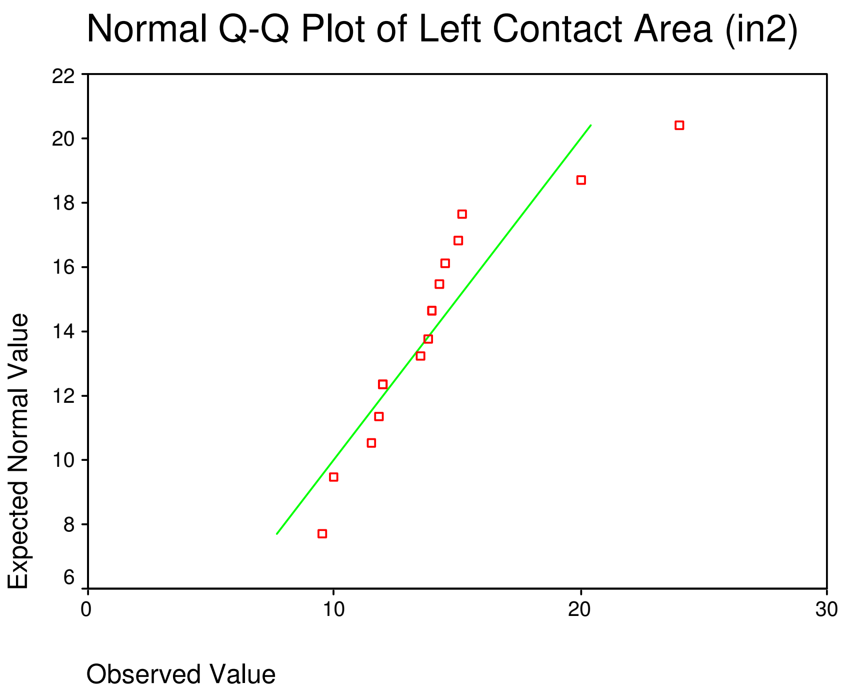


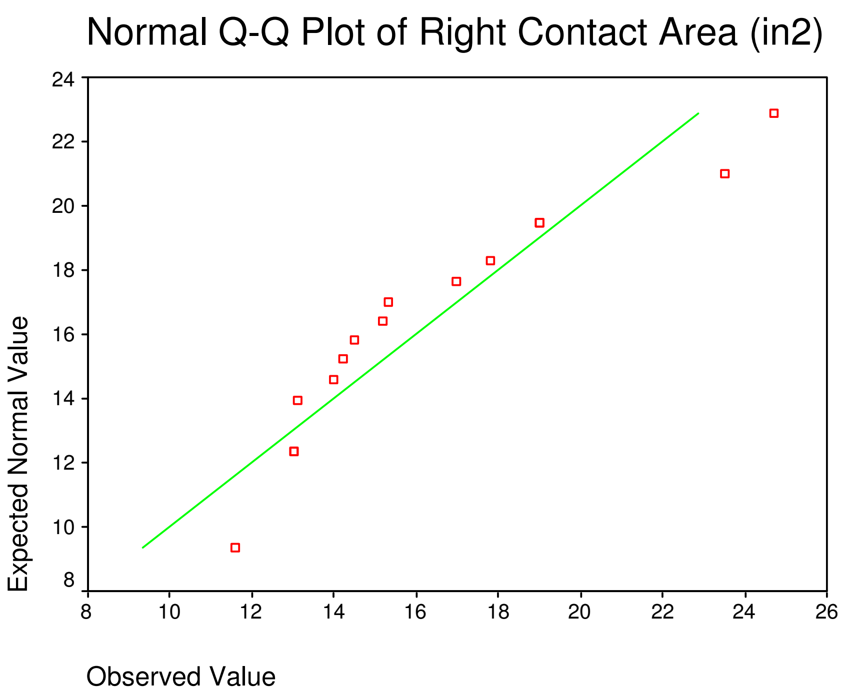
Normal Q-Q Plot of Right Avg Pressure

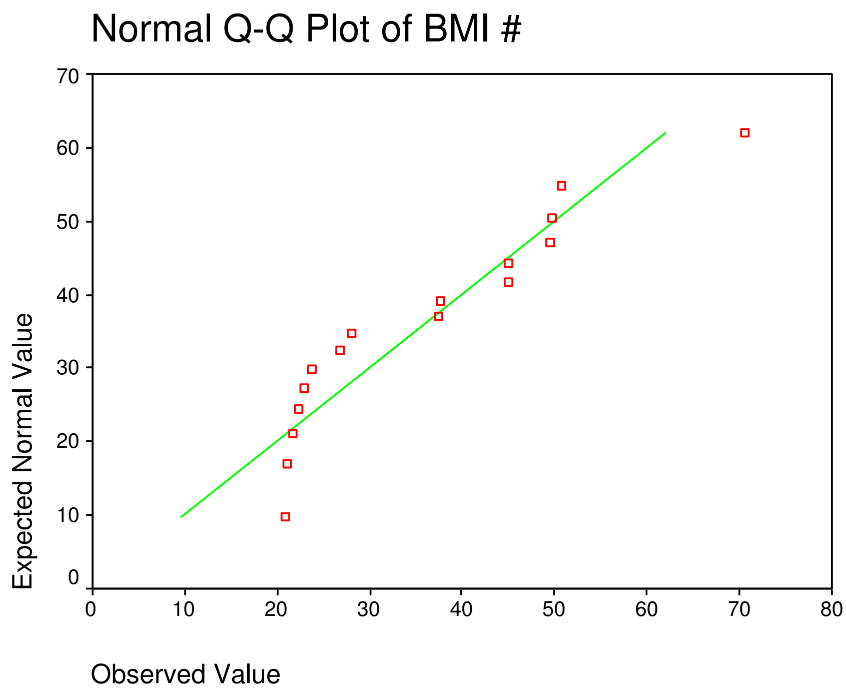


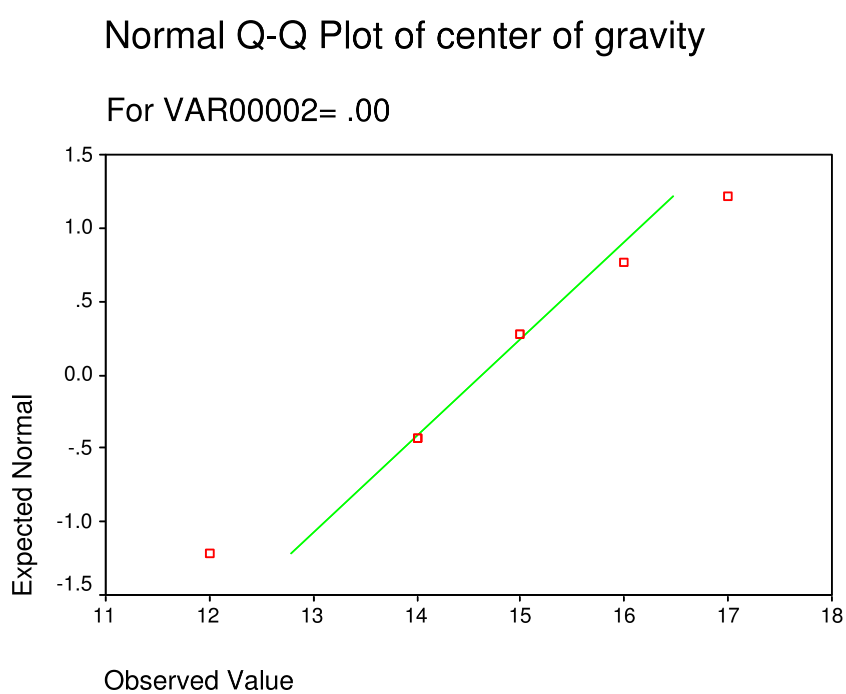
Normal Q-Q Plot of Right Peak Pressure




Normal Q-Q Plot of Left Contact Area (in2)
Expected Normal Value
22
20
18
16
14
12
10
8
6
0
10
20
30
Observed Value


Normal Q-Q Plot of Right Contact Area (in2)
Expected Normal Value
24
22
20
18
16
14
12
10
8
8
10
12
14
16
18
20
22
24
26
Observed Value


Normal Q-Q Plot of BMI #
Expected Normal Value
Observed Value
0
10
20
30
40
50
60
70
80


Normal Q-Q Plot of center of gravity
For VAR00002= .00
Expected Normal
Observed Value
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
11
12
13
14
15
16
17
18

APPENDIX F
RAW DATA EXAMPLE FROM THE FIELD STUDY

Frame #	Time	P1 Avg	P1 PEAK	P1 CONTACT (in^2)	P2 Avg	P2 PEAK	P2 CONTACT (in^2)	P1seat total	P2 Back Total
30979	22	33	4	20	21	1	0	0	0
30980	22	33	4	20	21	1	0	0	0
30981	22	33	5	20	21	1	0	0	0
30982	22	33	4	20	21	1	0	0	0
30983	22	33	5	20	21	1	0	0	0
30984	22	33	4	20	21	1	0	0	0
30985	22	33	5	20	21	1	0	0	0
30986	21	33	5	20	21	1	0	0	0
30987	21	33	5	20	21	1	0	0	0
30988	22	33	5	20	21	1	0	0	0
30989	22	33	4	20	21	1	0	0	0
30990	21	33	5	20	21	1	0	0	0
30991	21	33	5	20	21	1	0	0	0
30992	21	33	5	20	21	1	0	0	0
30993	21	33	5	20	21	1	0	0	0
30994	48	106	218	22	29	24	1	1	1
30995	45	91	225	24	39	70	0	1	1
30996	54	149	225	19	19	1	0	0	1
30997	54	153	225	20	21	4	0	0	1
30998	53	149	222	19	19	1	0	0	1
30999	53	149	222	19	19	1	0	0	1
31000	53	143	223	19	19	1	0	0	1

APPENDIX G

RAW DATA PAGE FROM ARM TEST IN LAB STUDY

Frame #	Time	Units	P1 Avg	P1 PEAK	P1 CONTACT (in²)	P2 Avg	P2 PEAK	P2 CONTACT (in²)
1	09/11/06 16:30:47.646 ms	mmHg	0	0	0	0	0	0
2	09/11/06 16:30:48.647 ms	mmHg	0	0	0	0	0	0
3	09/11/06 16:30:49.648 ms	mmHg	0	0	0	0	0	0
4	09/11/06 16:30:50.650 ms	mmHg	0	0	0	0	0	0
5	09/11/06 16:30:51.641 ms	mmHg	0	0	0	0	0	0
6	09/11/06 16:30:52.643 ms	mmHg	0	0	0	19.36	40	2.75
7	09/11/06 16:30:53.644 ms	mmHg	24.64	82	15.25	24.8	83	18.75
8	09/11/06 16:30:54.646 ms	mmHg	29.63	93	22.25	31.83	151	25.75
9	09/11/06 16:30:55.647 ms	mmHg	49.34	172	24	53.26	220	25.75
10	09/11/06 16:30:56.648 ms	mmHg	63.73	220	21.5	67.02	220	24.25
11	09/11/06 16:30:57.650 ms	mmHg	58.88	209	19.25	65.56	220	20.5
12	09/11/06 16:30:58.651 ms	mmHg	43.52	169	17.25	46.36	220	18.5
13	09/11/06 16:30:59.653 ms	mmHg	26.49	66	13.75	25.98	99	13
14	09/11/06 16:31:00.654 ms	mmHg	15.96	29	6.25	13.43	20	3.5
15	09/11/06 16:31:01.656 ms	mmHg	14.67	17	0.75	0	0	0
16	09/11/06 16:31:02.657 ms	mmHg	0	0	0	0	0	0
17	09/11/06 16:31:03.659 ms	mmHg	12.61	15	8.25	10.69	12	3.25
18	09/11/06 16:31:04.660 ms	mmHg	15.73	20	12.75	13.44	24	12.5
19	09/11/06 16:31:05.651 ms	mmHg	16.96	23	14.25	14.02	26	13
20	09/11/06 16:31:06.653 ms	mmHg	16.84	23	15.25	13.93	26	13.5
21	09/11/06 16:31:07.654 ms	mmHg	16.79	23	15.5	13.94	26	13.5
22	09/11/06 16:31:08.656 ms	mmHg	17.05	24	15.5	14.02	28	14.25
23	09/11/06 16:31:09.657 ms	mmHg	17.21	25	15.5	14.23	29	14
24	09/11/06 16:31:10.659 ms	mmHg	17.23	25	15.5	14	28	14.25

Frame #	Time	Units	P1 Avg	P1 PEAK	P1 CONTACT (in²)	P2 Avg	P2 PEAK	P2 CONTACT (in²)
25	09/11/06 16:31:11.660 ms	mmHg	14.08	19	12.25	10.31	12	4
26	09/11/06 16:31:12.662 ms	mmHg	0	0	0	0	0	0
27	09/11/06 16:31:13.663 ms	mmHg	0	0	0	11.6	14	1.25
28	09/11/06 16:31:14.664 ms	mmHg	20.59	38	8.5	25.98	54	13
29	09/11/06 16:31:15.666 ms	mmHg	52.98	116	15.5	57.24	149	18.75
30	09/11/06 16:31:16.657 ms	mmHg	0	0	0	0	0	0
31	09/11/06 16:31:17.659 ms	mmHg	0	0	0	0	0	0
32	09/11/06 16:31:18.660 ms	mmHg	0	0	0	0	0	0
33	09/11/06 16:31:19.662 ms	mmHg	0	0	0	0	0	0
34	09/11/06 16:31:20.663 ms	mmHg	0	0	0	0	0	0
35	09/11/06 16:31:21.664 ms	mmHg	0	0	0	0	0	0
36	09/11/06 16:31:22.666 ms	mmHg	0	0	0	0	0	0
37	09/11/06 16:31:23.667 ms	mmHg	0	0	0	0	0	0
38	09/11/06 16:31:24.669 ms	mmHg	0	0	0	0	0	0
		Totals	544.93	1408	289	561	1701	288
		Averages	28.63158	74.10526	15.21053	29.52632	89.52632	15.15789

APPENDIX H

FIELD DATA BY PARTICIPANT

Subject #	m/f	BMI group	Age	BMI #	Race	Job type
1771	0.00	1.00	40.00	43.04	c	c
1772	1.00	1.00	47.00	40.74	c	c
1773	1.00	1.00	34.00	35.77	c	t
1774	1.00	1.00	27.00	51.49	h	c
1775	1.00	1.00	36.00	37.59	a	c
1776	0.00	1.00	47.00	35.87	c	m
1777	1.00	1.00	34.00	36.49	a	t
1499	1.00	1.00	26.00	35.18	c	c
1961	1.00	1.00	38.00	42.00	h	c
1863	0.00	1.00	33.00	35.73	c	t
1962	1.00	1.00	25.00	40.00	c	m
1963	1.00	1.00	25.00	39.93	c	c
1964	0.00	1.00	34.00	39.45	c	t
1965	0.00	1.00	37.00	41.05	h	c
1966	0.00	1.00	45.00	51.68	a	c
1967	1.00	1.00	45.00	51.68	a	c
1968	1.00	1.00	56.00	38.01	c	c
1969	0.00	1.00	53.00	38.51	c	t
1830	1.00	1.00	42.00	42.06	c	c
1831	1.00	1.00	37.00	39.06	h	m
1832	0.00	1.00	36.00	30.13	c	c
1833	1.00	1.00	58.00	48.42	a	c
1834	0.00	1.00	23.00	35.56	c	c
1835	0.00	1.00	23.00	35.56	c	c
1836	0.00	1.00	28.00	35.26	c	t
1837	1.00	1.00	29.00	54.68	h	c
1838	1.00	1.00	37.00	37.76	c	m
1778	1.00	0.00	25.00	24.37	o	c
1779	1.00	0.00	35.00	24.03	h	t
1491	1.00	0.00	25.00	28.29	h	c
1492	1.00	0.00	36.00	17.47	c	t
1493	1.00	0.00	24.00	32.00	c	c
1494	1.00	0.00	46.00	27.45	c	m
1495	0.00	0.00	45.00	27.89	c	m
1496	1.00	0.00	37.00	24.56	c	c
1497	1.00	0.00	28.00	33.65	c	c
1498	0.00	0.00	38.00	27.26	c	c
1860	1.00	0.00	36.00	19.97	c	m
1861	0.00	0.00	45.00	30.13	a	t
1862	1.00	0.00	27.00	25.60	c	m
1864	0.00	0.00	56.00	23.63	c	c
1865	1.00	0.00	46.00	22.39	c	m
1866	1.00	0.00	59.00	26.57	c	c
1867	0.00	0.00	49.00	22.31	c	c
1868	0.00	0.00	25.00	20.80	c	c
1869	1.00	0.00	40.00	18.79	c	c
1940	1.00	0.00	30.00	30.41	c	t

Subject #	**m/f**	**BMI group**	**Age**	**BMI #**	**Race**	**Job type**
1941	1.00	0.00	40.00	24.36	c	m
1942	0.00	0.00	43.00	29.26	c	m
1943	0.00	0.00	38.00	23.75	c	m
1960	1.00	0.00	22.00	31.17	c	c

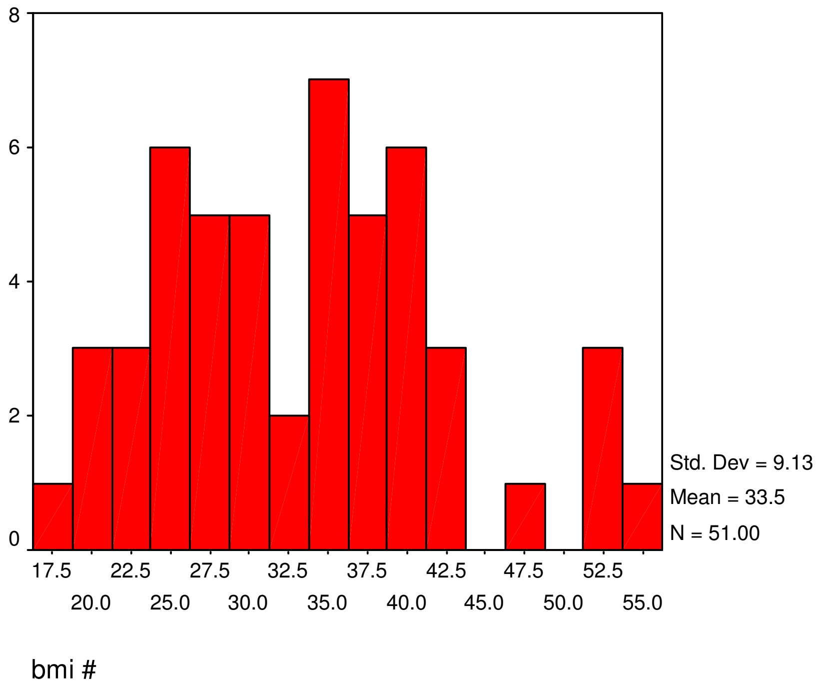
Subject #	back events	hrs of test	seats/ hr	backs/hr	seat time	% of shift seated
1771	485	6.37	278.11	76.16	4.23	0.66
1772	459	8.61	205.78	53.30	7.90	0.92
1773	312	6.33	280.09	49.29	4.90	0.77
1774	426	8.61	206.04	49.48	5.77	0.67
1775	679	8.61	206.16	78.86	8	0.91
1776	87	1.92	925.00	45.31	1.26	0.66
1777	588	7.37	241.11	79.78	7	0.90
1499	408	8.61	174.10	47.39	6.61	0.77
1961	195.00	7.00	280.14	27.86	6	0.86
1863	350	7.40	251.76	47.30	2.29	0.31
1962	53.00	8.03	244.33	6.60	4	0.46
1963	435	6.37	308.26	68.31	5.73	0.90
1964	460	8.61	228.08	53.42	7.90	0.92
1965	276	6.33	310.43	43.60	4.90	0.77
1966	500	8.61	228.34	58.07	5.99	0.70
1967	656	8.61	228.46	76.19	8	0.91
1968	204	7.50	262.40	27.20	4.50	0.60
1969	640	8.00	246.13	80.00	7	0.83
1830	407	8.61	212.54	47.27	7.40	0.86
1831	300	6.90	265.36	43.48	6.10	0.88
1832	145	8.61	212.78	16.84	6.10	0.71
1833	650	8.61	212.89	75.49	8	0.91
1834	100	7.40	247.84	13.51	6.00	0.81
1835	600	7.37	248.98	81.41	7	0.90
1836	240	8.61	213.24	27.87	6.61	0.77
1837	335	8.61	213.36	38.91	6	0.74
1838	567	8.61	213.47	65.85	6	0.70
1778	396	8.61	206.58	46.01	7.00	0.81
1779	370	8.59	207.17	43.09	6.20	0.72
1491	330	8.61	173.15	38.32	7.52	0.87
1492	402	8.61	173.29	46.69	4.79	0.56
1493	540	8.01	186.39	67.42	7.15	0.89
1494	142	8.28	180.43	17.15	3.54	0.43
1495	521	14.52	102.96	35.88	7.85	0.54
1496	327	14.28	104.76	22.90	9.99	0.70
1497	62	8.53	175.50	7.27	4.20	0.49
1498	641	9.11	164.43	70.36	6.20	0.68
1860	250	8.61	216.03	29.04	5.90	0.69
1861	75	3.00	620.33	25.00	2.31	0.77
1862	334	8.61	216.26	38.79	4.74	0.55
1864	344	8.61	216.49	39.95	4.94	0.57
1865	244	8.61	216.61	28.34	6.39	0.74
1866	164	8.61	216.72	19.05	6.15	0.71
1867	117	8.59	217.35	13.62	5.31	0.62

Subject #	back events	hrs of test	seats/ hr	backs/hr	seat time	% of shift seated
1868	76	8.57	217.97	8.87	4.97	0.58
1869	323	8.50	219.88	38.00	5.30	0.62
1940	55	8.60	225.58	6.40	5.69	0.66
1941	153	8.50	228.35	18.00	4.69	0.55
1942	143	6.90	281.45	20.72	3.26	0.47
1943	408	8.61	225.64	47.38	5	0.58
1960	458	8.16	240.20	56.13	4	0.44

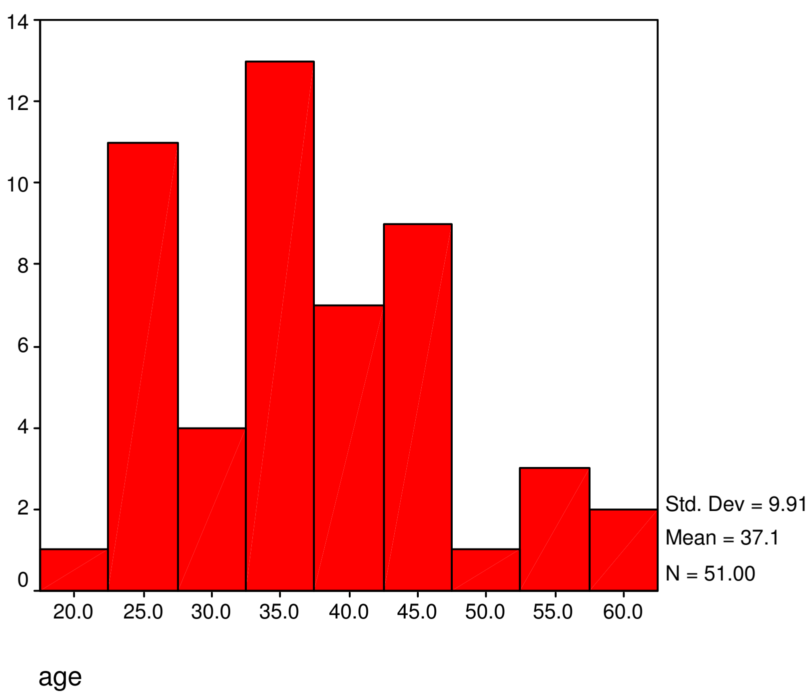
APPENDIX I

GRAPHS OF DISTRIBUTIONS FROM FIELD STUDY

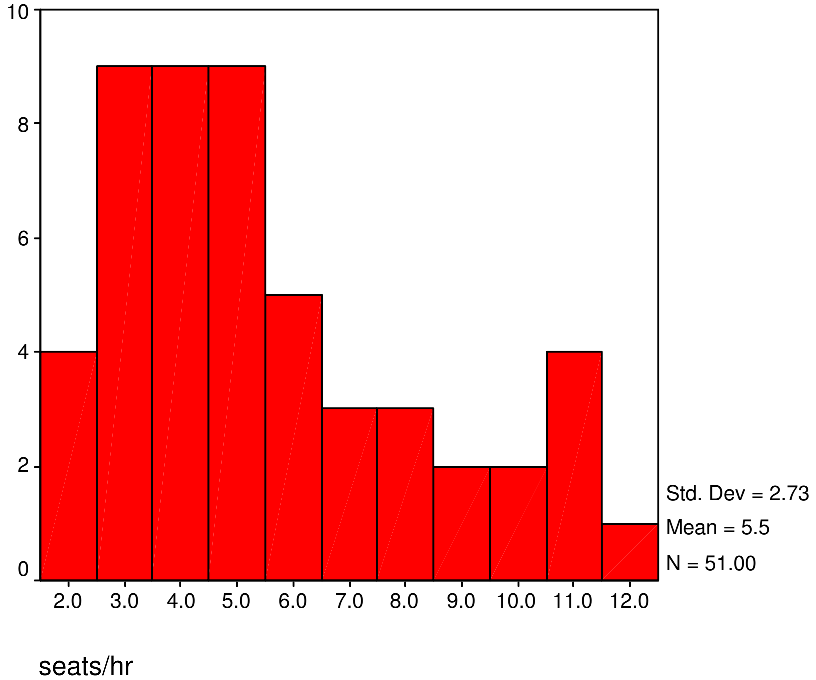
Number of Participants with BMI in certain ranges



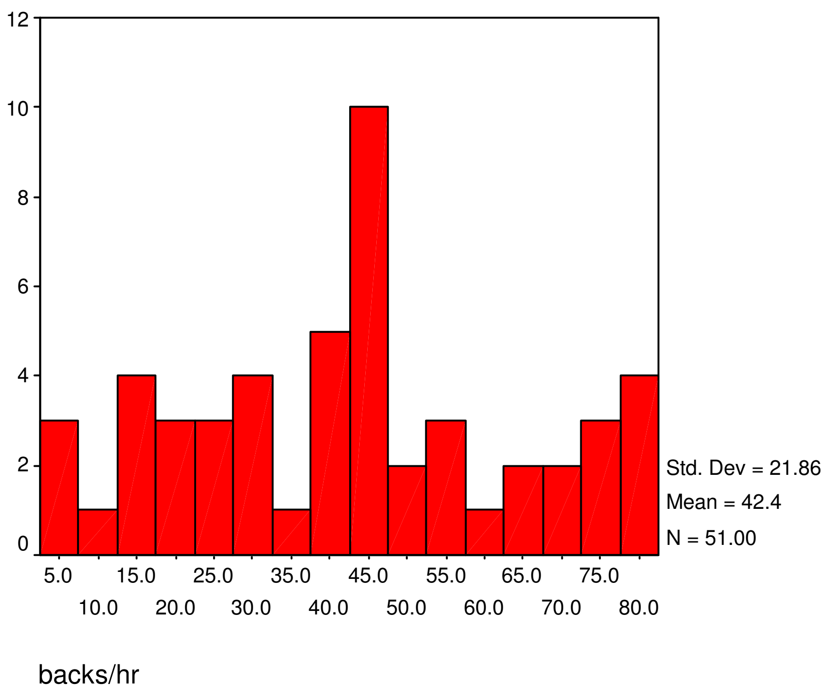
Number of Participants with Age in certain ranges



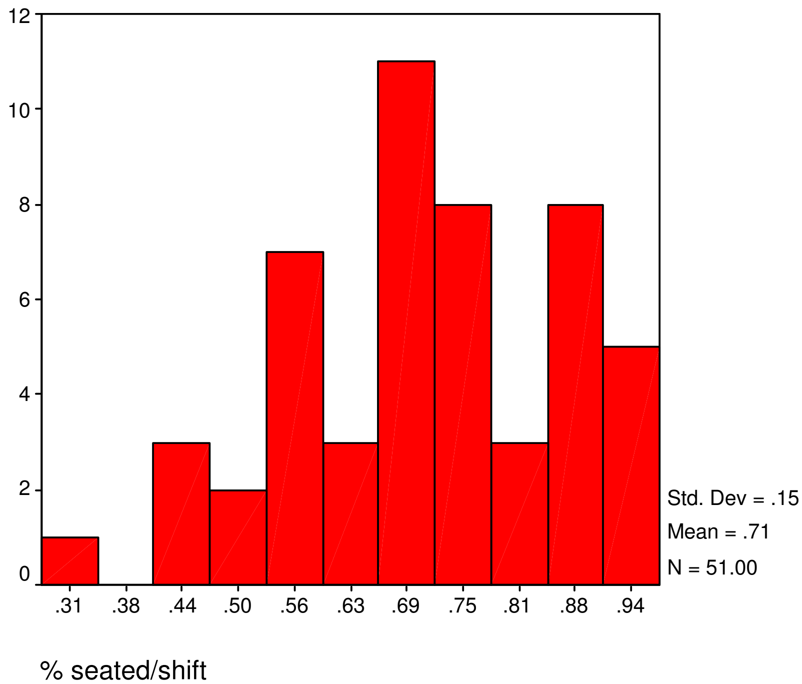
Distribution of Seats/Hr



Distribution of Backs/Hr



Distribution of Seat Time Per Shift as a Percentage of Shift



APPENDIX J

DESCRIPTIVE STATISTICS PER PARAMETER

	race			Statistic	Std. Error
bmi #	1.00	Mean		31.0230	1.19079
		95% Confidence Interval for Mean	Lower Bound	28.6079	
			Upper Bound	33.4380	
		5% Trimmed Mean		31.0996	
		Median		31.1700	
		Variance		52.465	
		Std. Deviation		7.24327	
		Minimum		17.47	
		Maximum		43.04	
		Range		25.57	
		Interquartile Range		12.3550	
		Skewness		-.155	.388
		Kurtosis		-1.149	.759
	2.00	Mean		40.0857	4.21342
		95% Confidence Interval for Mean	Lower Bound	29.7758	
			Upper Bound	50.3956	
		5% Trimmed Mean		40.1669	
		Median		41.0500	
		Variance		124.270	
		Std. Deviation		11.14766	
		Minimum		24.03	
		Maximum		54.68	
		Range		30.65	
		Interquartile Range		23.2000	
		Skewness		-.199	.794
		Kurtosis		-.924	1.587
	3.00	Mean		42.6650	3.72681
		95% Confidence Interval for Mean	Lower Bound	33.0849	
			Upper Bound	52.2451	
		5% Trimmed Mean		42.8606	
		Median		43.0050	
		Variance		83.335	
		Std. Deviation		9.12878	
		Minimum		30.13	
		Maximum		51.68	
		Range		21.55	
		Interquartile Range		16.7800	
		Skewness		-.268	.845
		Kurtosis		-2.106	1.741

seats/hr	1.00	Mean		5.9638	.45624
		95% Confidence Interval for Mean	Lower Bound	5.0385	
			Upper Bound	6.8891	
		5% Trimmed Mean		5.8540	
		Median		5.1800	
		Variance		7.702	
		Std. Deviation		2.77521	
		Minimum		2.13	
		Maximum		11.65	
		Range		9.52	
		Interquartile Range		4.3450	
		Skewness		.732	.388
		Kurtosis		-.625	.759
	2.00	Mean		5.1671	.43714
		95% Confidence Interval for Mean	Lower Bound	4.0975	
			Upper Bound	6.2368	
		5% Trimmed Mean		5.1346	
		Median		4.8800	
		Variance		1.338	
		Std. Deviation		1.15657	
		Minimum		3.95	
		Maximum		6.97	
		Range		3.02	
		Interquartile Range		2.4500	
		Skewness		.773	.794
		Kurtosis		-.813	1.587
	3.00	Mean		3.7533	1.38881
		95% Confidence Interval for Mean	Lower Bound	.1833	
			Upper Bound	7.3234	
		5% Trimmed Mean		3.4681	
		Median		2.5000	
		Variance		11.573	
		Std. Deviation		3.40189	
		Minimum		1.97	
		Maximum		10.67	
		Range		8.70	
		Interquartile Range		2.7000	
		Skewness		2.406	.845
		Kurtosis		5.836	1.741

backs/hr	1.00	Mean		38.8916	3.63802
		95% Confidence Interval for Mean	Lower Bound	31.5134	
			Upper Bound	46.2699	
		5% Trimmed Mean		38.3655	
		Median		38.7900	
		Variance		489.703	
		Std. Deviation		22.12922	
		Minimum		6.40	
		Maximum		81.41	
		Range		75.01	
		Interquartile Range		34.8350	
		Skewness		.273	.388
		Kurtosis		-.933	.759
	2.00	Mean		40.6771	2.54797
		95% Confidence Interval for Mean	Lower Bound	34.4425	
			Upper Bound	46.9118	
		5% Trimmed Mean		40.9002	
		Median		43.0900	
		Variance		45.445	
		Std. Deviation		6.74128	
		Minimum		27.86	
		Maximum		49.48	
		Range		21.62	
		Interquartile Range		5.2800	
		Skewness		-1.052	.794
		Kurtosis		2.102	1.587
	3.00	Mean		65.5650	8.74054
		95% Confidence Interval for Mean	Lower Bound	43.0967	
			Upper Bound	88.0333	
		5% Trimmed Mean		67.0289	
		Median		75.8400	
		Variance		458.383	
		Std. Deviation		21.40988	
		Minimum		25.00	
		Maximum		79.78	
		Range		54.78	
		Interquartile Range		29.2875	
		Skewness		-1.827	.845
		Kurtosis		3.096	1.741

% seated/shift	1.00	Mean		.6654	.02528
		95% Confidence Interval for Mean	Lower Bound	.6141	
			Upper Bound	.7167	
		5% Trimmed Mean		.6679	
		Median		.6600	
		Variance		.024	
		Std. Deviation		.15374	
		Minimum		.31	
		Maximum		.92	
		Range		.61	
		Interquartile Range		.2150	
		Skewness		-.085	.388
		Kurtosis		-.521	.759
	2.00	Mean		.7871	.03145
		95% Confidence Interval for Mean	Lower Bound	.7102	
			Upper Bound	.8641	
		5% Trimmed Mean		.7885	
		Median		.7700	
		Variance		.007	
		Std. Deviation		.08321	
		Minimum		.67	
		Maximum		.88	
		Range		.21	
		Interquartile Range		.1500	
		Skewness		-.107	.794
		Kurtosis		-1.863	1.587
	3.00	Mean		.8500	.03751
		95% Confidence Interval for Mean	Lower Bound	.7536	
			Upper Bound	.9464	
		5% Trimmed Mean		.8550	
		Median		.9050	
		Variance		.008	
		Std. Deviation		.09187	
		Minimum		.70	
		Maximum		.91	
		Range		.21	
		Interquartile Range		.1575	
		Skewness		-1.205	.845
		Kurtosis		-.429	1.741

a bmi # is constant when race = 4.00. It has been omitted.
b seats/hr is constant when race = 4.00. It has been omitted.
c backs/hr is constant when race = 4.00. It has been omitted.
d % seated/shift is constant when race = 4.00. It has been omitted.
1 = Caucasian, 2 = Hispanic, 3 = Black

Comparison of Job Type vs. Several Parameters

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
% seated/ shift	1	29	.7441	.13692	.02543	**.6921**	**.7962**	.44	.92
	2	10	.7210	.17929	.05670	.5927	.8493	.31	.92
	3	12	.6042	.13276	.03833	**.5198**	**.6885**	.43	.88
	Total	51	.7067	.15342	.02148	.6635	.7498	.31	.92
seats/hr	1	29	5.7793	2.89972	.53847	4.6763	6.8823	1.97	11.65
	2	10	5.3810	2.61551	.82710	3.5100	7.2520	2.44	10.67
	3	12	5.1283	2.57150	.74233	3.4945	6.7622	2.13	11.15
	Total	51	5.5480	2.73381	.38281	4.7791	6.3169	1.97	11.65
backs/hr	1	29	45.0948	23.03636	4.27774	36.3323	53.8574	7.27	81.41
	2	10	45.8840	22.87970	7.23520	29.5168	62.2512	6.40	80.00
	3	12	33.0450	16.37749	4.72778	22.6392	43.4508	6.60	65.85
	Total	51	42.4143	21.86449	3.06164	36.2648	48.5638	6.40	81.41
age	1	29	36.5862	11.63283	2.16016	32.1613	41.0111	22.00	59.00
	2	10	36.2000	7.39068	2.33714	30.9130	41.4870	28.00	53.00
	3	12	38.9167	7.21688	2.08333	34.3313	43.5021	25.00	47.00
	Total	51	37.0588	9.90840	1.38745	34.2720	39.8456	22.00	59.00
m or f	1	29	.6552	.48373	.08983	.4712	.8392	.00	1.00
	2	10	.5000	.52705	.16667	.1230	.8770	.00	1.00
	3	12	.6667	.49237	.14213	.3538	.9795	.00	1.00
	Total	51	.6275	.48829	.06837	.4901	.7648	.00	1.00
race	1	29	1.5517	.86957	.16148	1.2210	1.8825	1.00	4.00
	2	10	1.5000	.84984	.26874	.8921	2.1079	1.00	3.00
	3	12	1.0833	.28868	.08333	.8999	1.2667	1.00	2.00
	Total	51	1.4314	.78115	.10938	1.2117	1.6511	1.00	4.00

1 = Clerical, 2 = Technical, 3 = Managerial

ANOVA of Parameters by Job Type

		Sum of Squares	df	Mean Square	F	Sig.
% seated/shift	Between Groups	.169	2	.084	4.020	**.024**
	Within Groups	1.008	48	.021		
	Total	1.177	50			
seats/hr	Between Groups	3.944	2	1.972	.256	.775
	Within Groups	369.742	48	7.703		
	Total	373.686	50			
backs/hr	Between Groups	1382.165	2	691.083	1.473	.239
	Within Groups	22520.634	48	469.180		
	Total	23902.799	50			
age	Between Groups	55.272	2	27.636	.273	.762
	Within Groups	4853.551	48	101.116		
	Total	4908.824	50			
m or f	Between Groups	.203	2	.102	.416	.662
	Within Groups	11.718	48	.244		
	Total	11.922	50			
race	Between Groups	1.921	2	.960	1.612	.210
	Within Groups	28.589	48	.596		
	Total	30.510	50			

Comparison of BMI Category Descriptive Statistics

% seated/shift

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
BMI<35	24	.6350	.12701	.02592	.5814	.6886	.43	.89
BMI>35	27	.7704	.14847	.02857	.7116	.8291	.31	.92
Total	51	.7067	.15342	.02148	.6635	.7498	.31	.92

Caster Roll distance statistics by BMI Category

	bmi category	N	Mean	Std. Deviation	Std. Error Mean
roll distance	1.00	25	50.9520	14.05196	2.81039
	.00	25	73.7200	12.11239	2.42248

Caster Roll distance Independent Samples t –test by BMI Category

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
roll distance	Equal variances assumed	.090	.765	-6.136	48	.0001	-22.76	3.710	-30.22	-15.30

APPENDIX K

RAW DATA AND ANALYSIS FROM LAB STUDY

Participant	Height (in)	Weight (lbs.)	BMI	bmi category	Age	Gender	Seated Hip Breadth	Seated Elbow Height	Seated Elbow Breadth	Horizontal Acromium Distance
868	65	128	20.80	0.00	25	1	14.5	7	15	7
403	65	125	21.01	0.00	34	1	15	7	16	4
406	69	145	21.62	0.00	48	0	17	8	18	4
867	63	130	22.31	0	49	1	16	7.5	16.5	3.75
404	66	140	22.82	0.00	28	1	17	7	16.5	4
943	73	180	23.75	0	39	0	16.75	7.5	17	4.5
407	72	196	26.84	0.00	33	0	18	9	20	5
498	72	214	28	0	36	0	15.25	9	21.5	7
400	66	230	37.49	1.00	33	0	18.5	8.25	21.5	7.5
775	66	260	37.6	1	36	1	23	8	23	10
771	70	310	44.92	1.00	41	0	20.5	10.75	26.5	8
405	69	302	45.04	1.00	49	0	21	10	27	8.5
776	73	371	49.43	1.00	54	0	22	8.75	28	10.25
402	63	278	49.73	1.00	42	1	24	8.5	24	9.5
774	65	302	50.75	1.00	27	1	23	8	24	6.75
401	59	346	70.57	1.00	20	1	25	9.5	25	10.5
averages	**67.25**	**228.56**	**35.79**		**37.13**	0 male 1 female	**34.00**	**37.13**	**21.22**	**6.89**

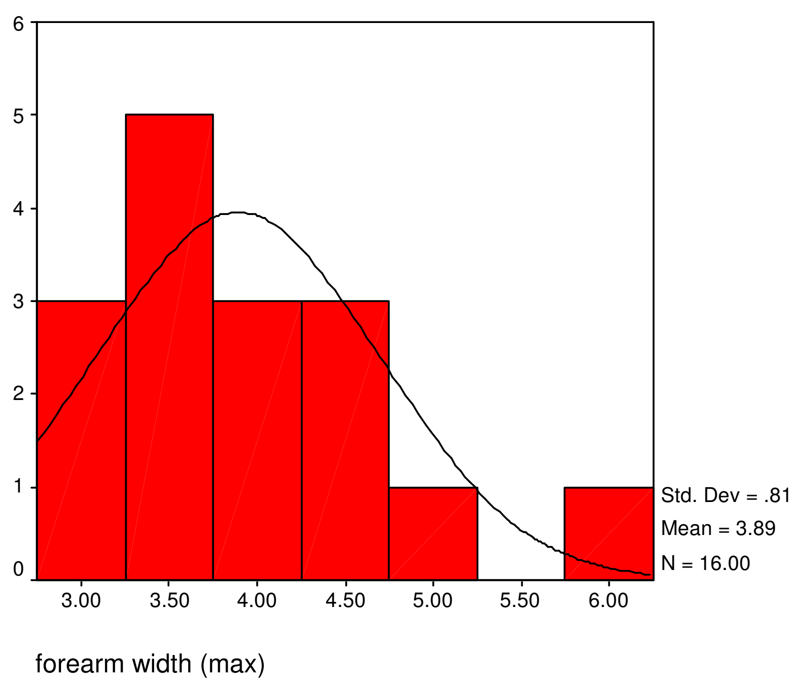
				left arm			right arm		
Participant	Seat Depth	Forearm Width	Center of Gravity	P1 Avg	P1 PEAK	P1 CONTACT (in^2)	P2 Avg	P2 PEAK	P2 CONTACT (in^2)
868	18	2.75	14	28.6	74.1	15.2	29.5	89.5	15.2
403	18	3	15	24.2	70	14.3	31	92	14.2
406	19	3.25	16	33.4	79	13.5	40	105.3	13
867	19	3	17	35	85	15	29	75.3	17
404	19	3.5	12	27	65	10	20	60	11.6
943	21.5	3.5	19	29.4	56	12	19.8	53	13.1
407	19	3.5	17	19	32	14.5	20	41	19
498	18.5	3.5	16	18.9	31	14	17.9	37	19
400	19.5	4	22	24.1	82	14	24.8	83	17.8
775	21	4	19	32.1	66.7	11.8	49	187.3	23.5
771	20	4.5	21	38.3	74	11.5	35.8	176	14.5
405	20.5	4.5	22	55	190	12	56.2	220	13
776	23.5	5	20	33.2	85	9.5	34	180	15.3
402	21	4.5	19	25.6	66	13.8	24	99	13
774	20	4	19	49.5	165	24	54	190	24.7
401	22	5.75	19	39	105	23	51	202	10.4
averages	**19.97**	**3.89**	**17.94**	mmHg	mmHg	(in^2)	mmHg	mmHg	(in^2)
	319.5	62.25	287						
				1 mmHg	= 0.01933 PSI				

Correlations

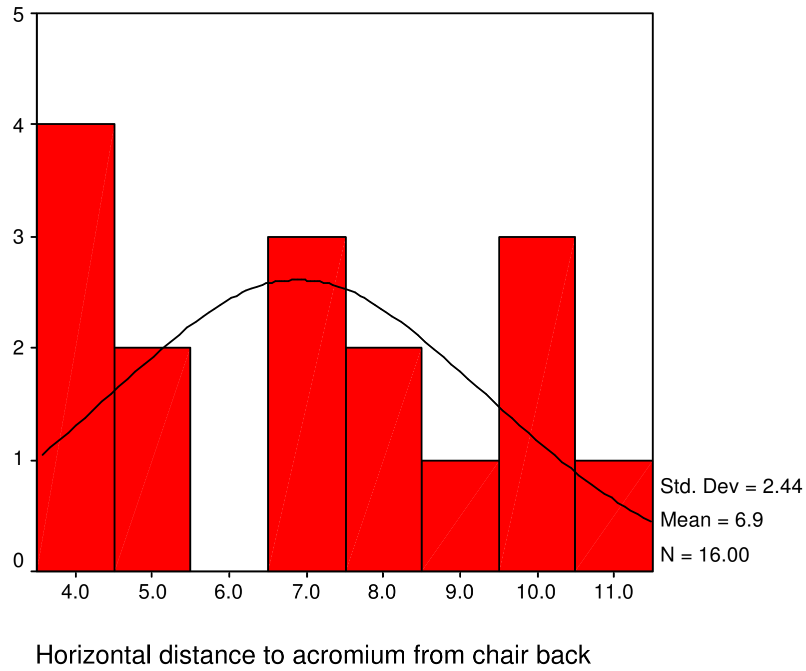
		height	bmi	seat depth	seated hip breadth	gender
height	Pearson Correlation	1	-.330	.097	-.300	-.824(**)
	Sig. (2-tailed)	.	.212	.720	.258	.000
	N	16	16	16	16	16
bmi	Pearson Correlation	-.330	1	.706(**)	.914(**)	.081
	Sig. (2-tailed)	.212	.	.002	.000	.766
	N	16	16	16	16	16
seat depth	Pearson Correlation	.097	.706(**)	1	.751(**)	-.147
	Sig. (2-tailed)	.720	.002	.	.001	.586
	N	16	16	16	16	16
seated hip breadth	Pearson Correlation	-.300	.914(**)	.751(**)	1	.158
	Sig. (2-tailed)	.258	.000	.001	.	.560
	N	16	16	16	16	16
gender	Pearson Correlation	-.824(**)	.081	-.147	.158	1
	Sig. (2-tailed)	.000	.766	.586	.560	.
	N	16	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed).

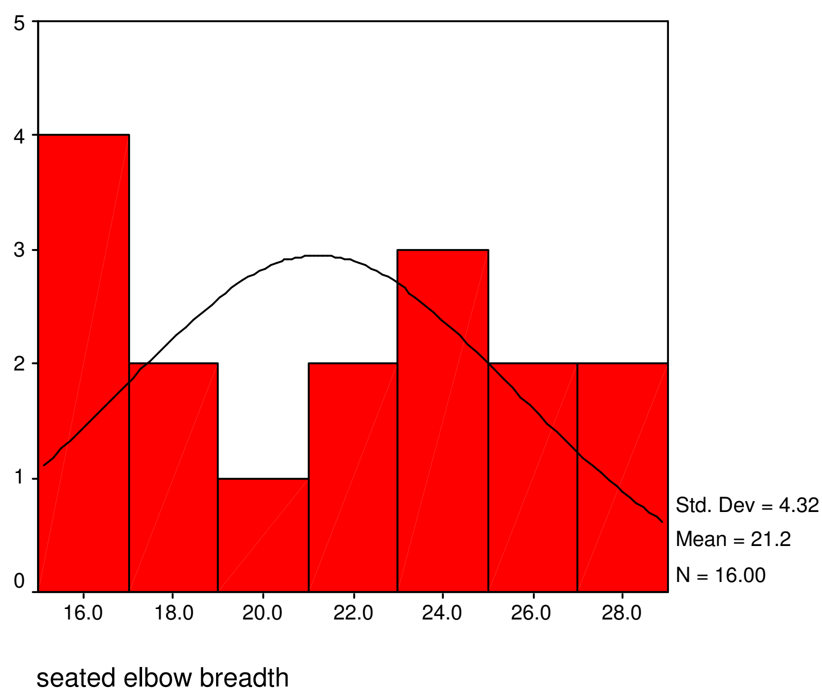
Histogram of Forearm Width for all Participants



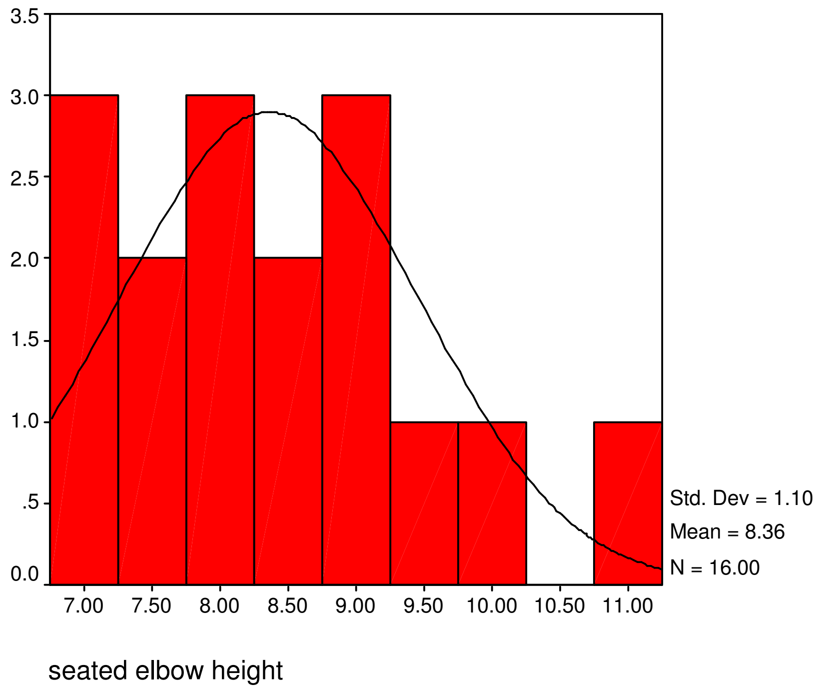
Histogram of Horizontal Distance to Acromium for all Participants



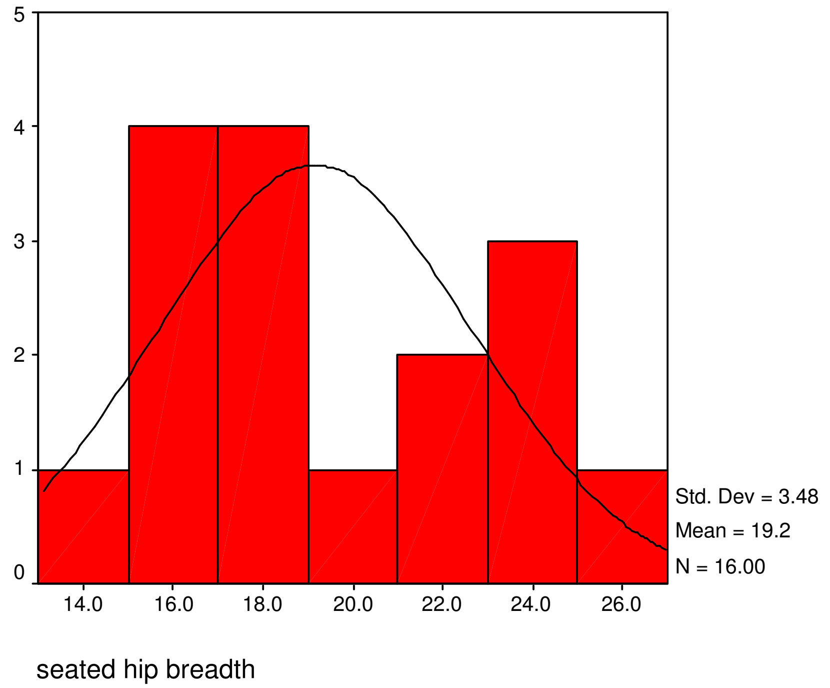
Histogram of Seated Elbow Breadth for all Participants



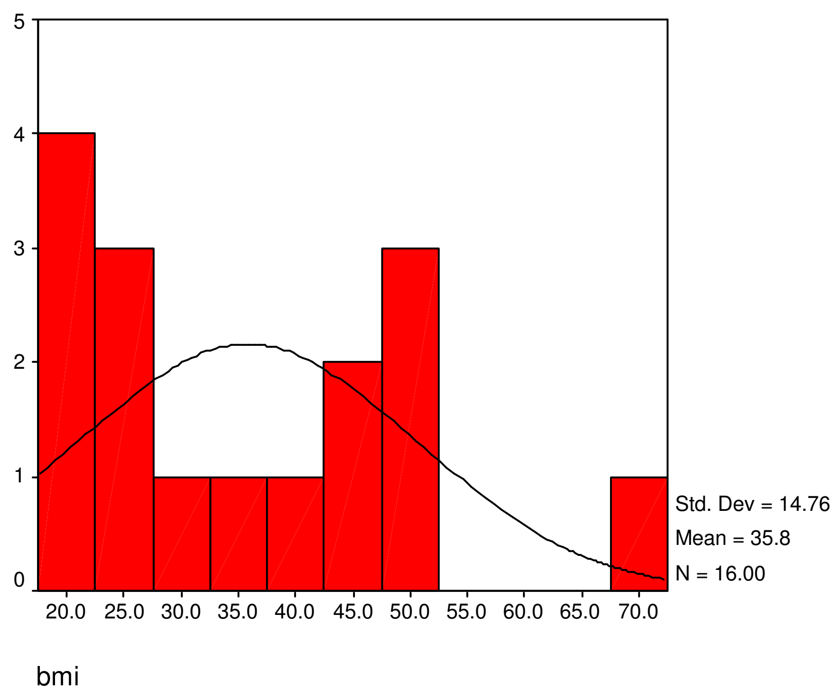
Histogram of Seated Elbow Height for all Participants



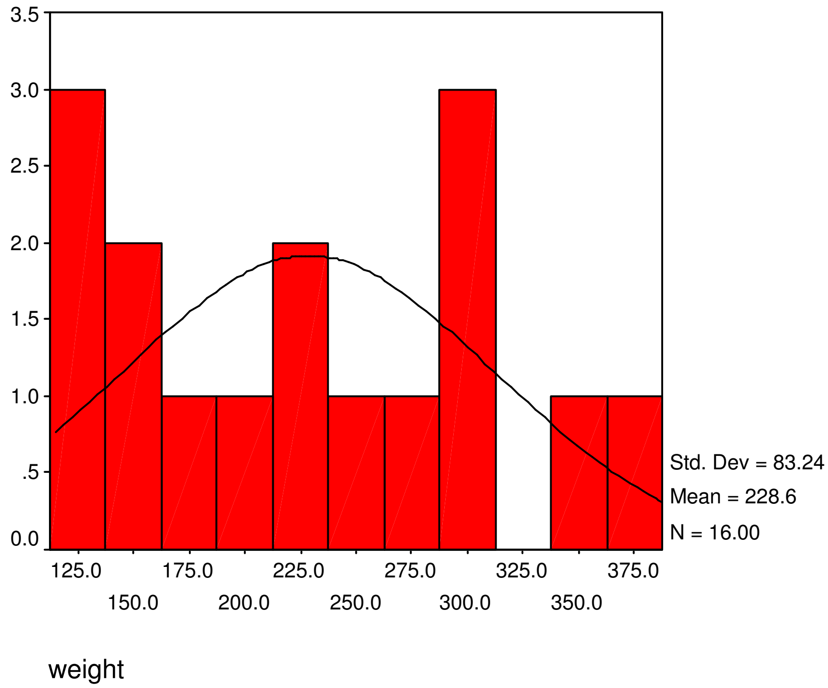
Histogram of Seated Hip Breadth for all Participants



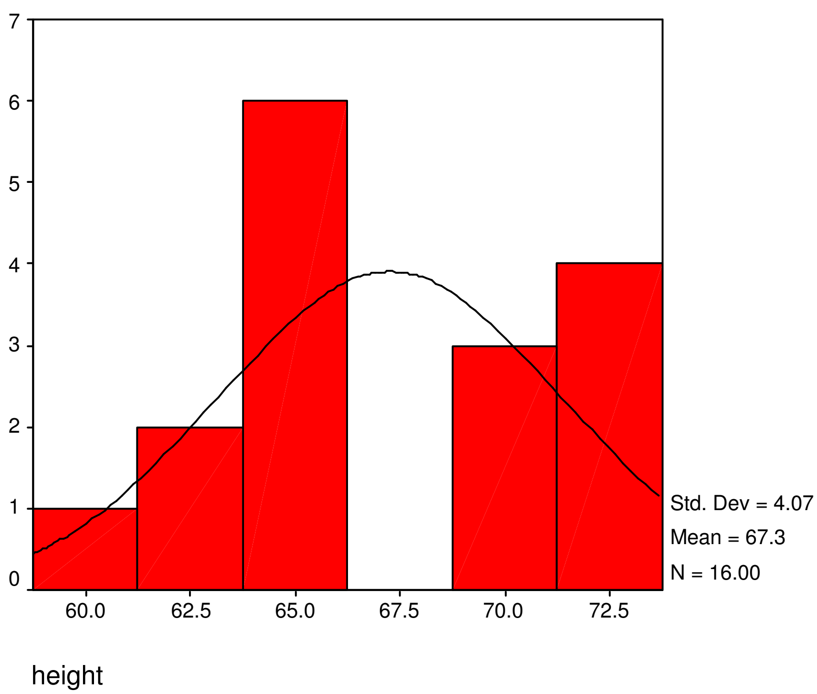
Histogram of BMI # for all Participants



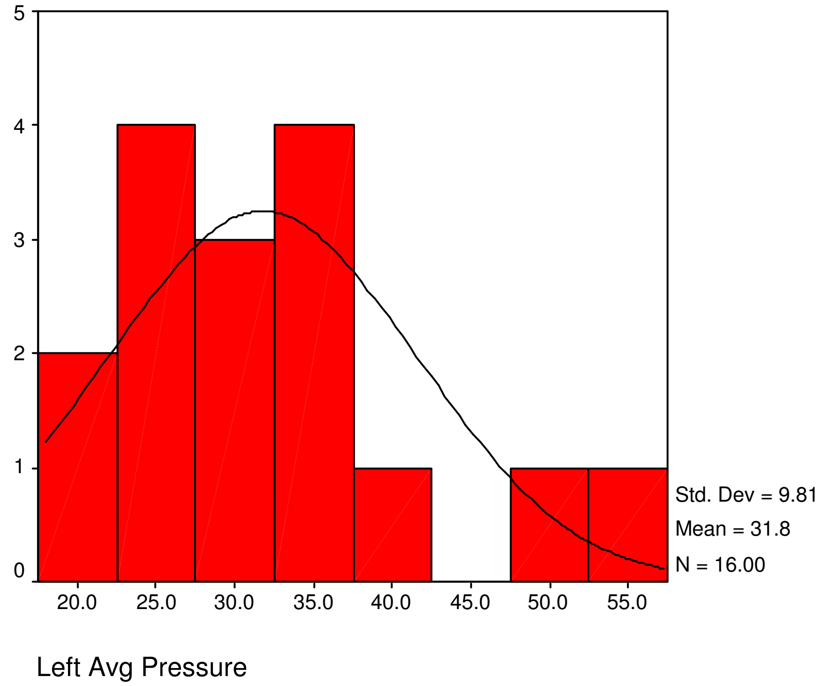
Histogram of Weight for all Participants



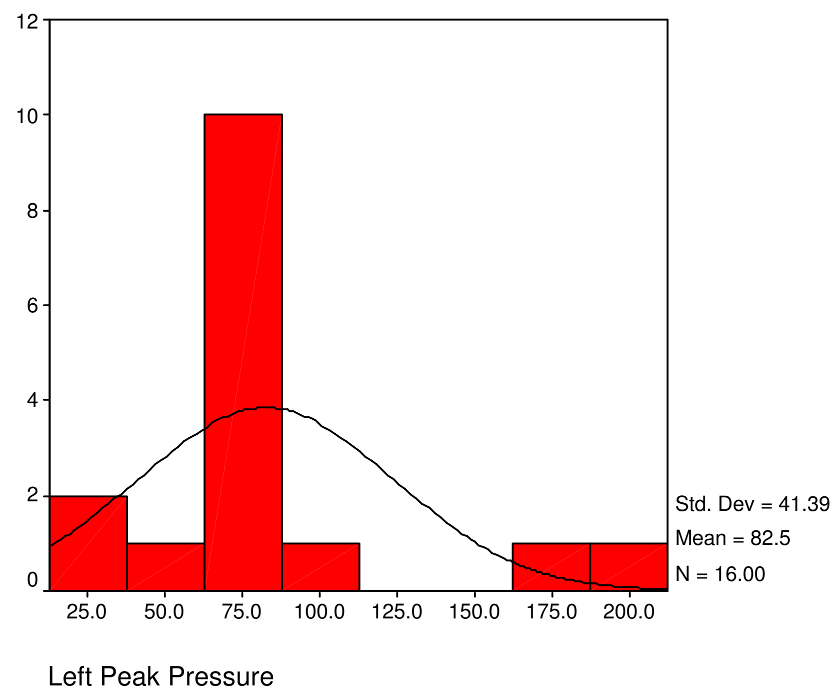
Histogram of Height for all Participants



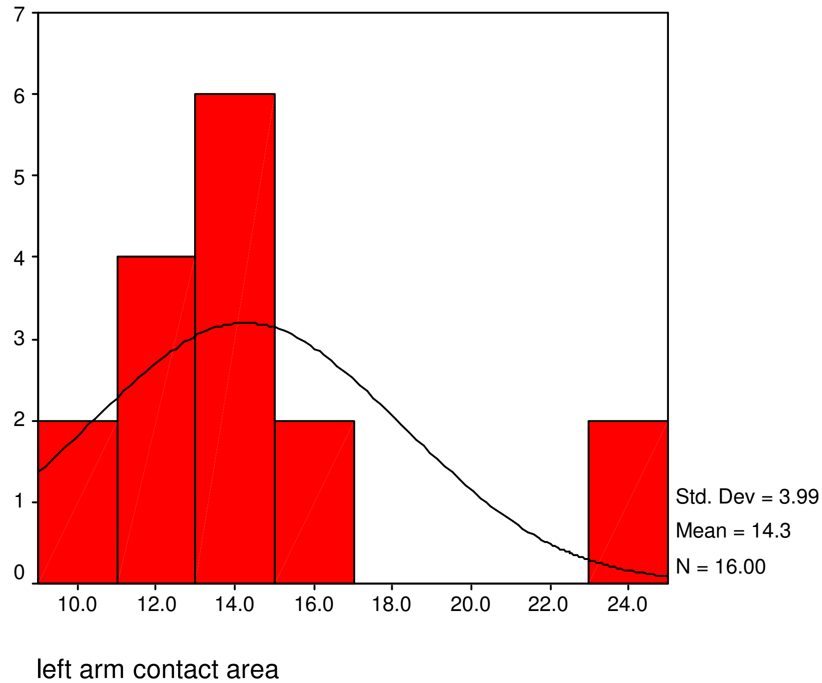
Left Arm Average Pressure Histogram
(Pressure in mmHg)



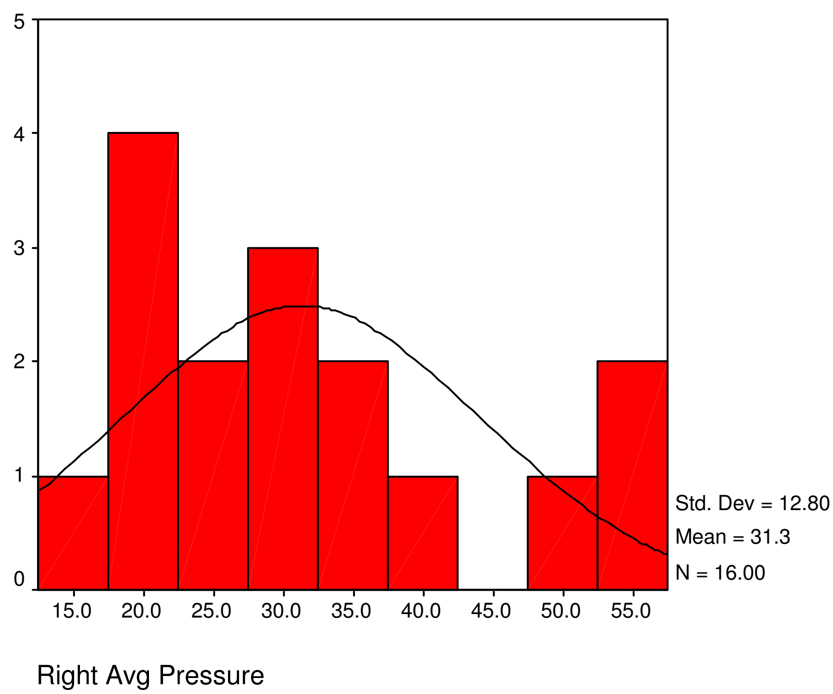
Left Arm Peak Pressure Histogram



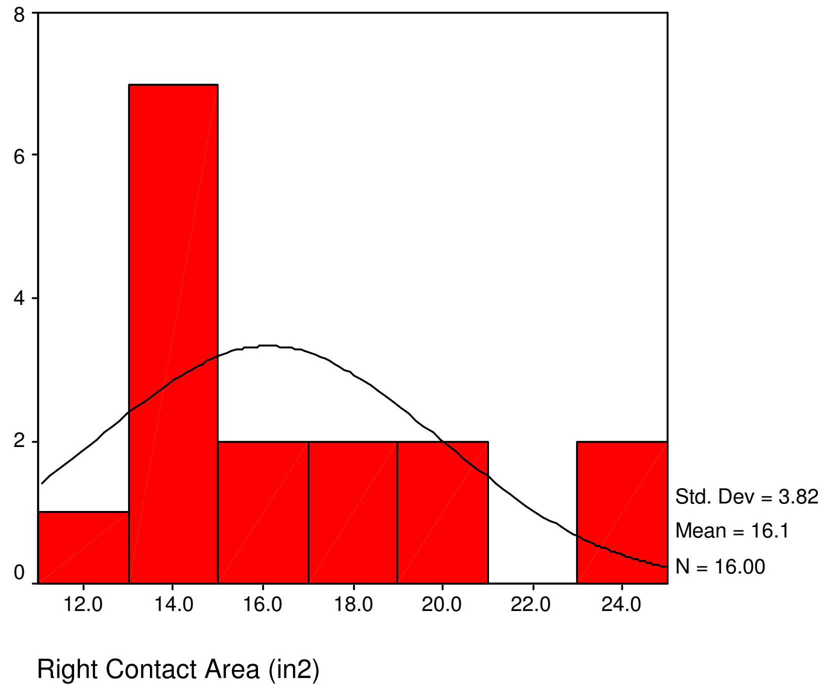
Left Arm Contact Area Histogram



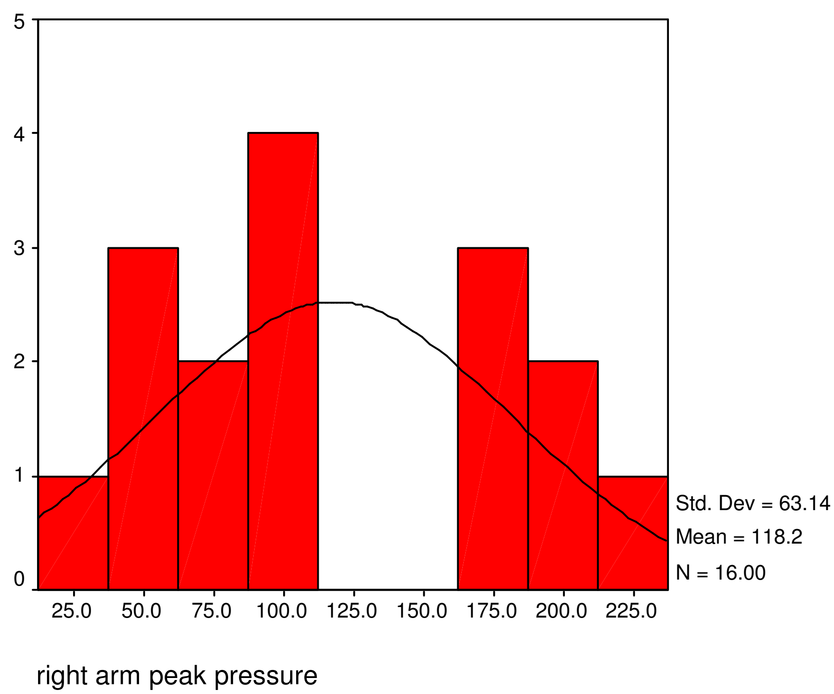
Right Arm Average Pressure Histogram



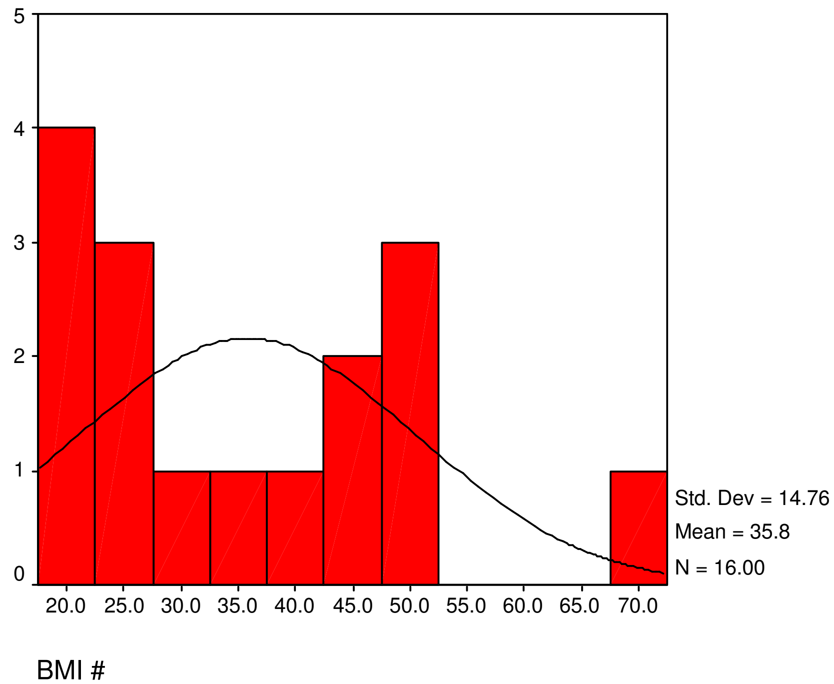
Right Arm Contact Area Histogram



Right Arm Peak Pressure Histogram



BMI # Histogram



VITA

Name: Mark E. Benden CPE

Address: 5713 Shellbournes Hill College Station, Texas 77845

Email Address: mark@igoergo.com

Education: B.S., Bioengineering, Texas A&M University 1990
M.S., Industrial Engineering, Texas A&M University 1992
Ph.D., Interdisciplinary Engineering, Texas A&M University 2006