GRIP STRENGTH OF TELECOMMUNICATION WORKERS THIRTY TO FORTY YEARS OF AGE

by

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TABLE OF CONTENTS

LIST OF TABLES. iv

LIST OF FIGURES vi

Chapter

I. INTRODUCTION. 1

II. LITERATURE REVIEW 5

Grip Strength as a Function of Age. 5

Grip Strength as a Function of Gender 7

Grip Strength as a Function of Handedness . . . 9

Grip Strength as a Function of Body Height. . . 11

Grip Strength as a Function of Body Weight. . . 12

Grip Strength as a Function of Somatotype . . . 12

Grip Strength as a Function of Hand Anthropometry 13

Strength Test of the Fingers. 14

Grip Strength as a Function of Occupation . . . 16

Summary 18

Problem 20

III. THE STUDY 22

Subjects. 22

Variables 22

Procedures and Equipment. 23

AC
801
I=3
1986
No.172
cop.2

TABLE OF CONTENTS

LIST OF TABLES. iv

LIST OF FIGURES vi

Chapter

I. INTRODUCTION. 1

II. LITERATURE REVIEW 5

Grip Strength as a Function of Age. 5

Grip Strength as a Function of Gender 7

Grip Strength as a Function of Handedness . . . 9

Grip Strength as a Function of Body Height. . . 11

Grip Strength as a Function of Body Weight. . . 12

Grip Strength as a Function of Somatotype . . . 12

Grip Strength as a Function of Hand Anthropometry 13

Strength Test of the Fingers. 14

Grip Strength as a Function of Occupation . . . 16

Summary 18

Problem 20

III. THE STUDY 22

Subjects. 22

Variables 22

Procedures and Equipment. 23

Preliminary Activities. 23
Grip Strength Test. 24
Anthropometric Measurements 26

Experimental Design 27

IV. ANALYSIS AND RESULTS. 31

Analysis. 31

Results 33

Anthropometry 33
Gender. 38
Handedness. 40
Space Setting 42

V. CONCLUSIONS 47

Recommendations 48

LIST OF REFERENCES. 49

APPENDIX. 52

LIST OF TABLES

1.1 Hand Injuries 1979-1984, A Large Telecommunications Plant. 1

1.2 National Safety Council 1984 Accident Facts . . 2

1.3 Examples of Cumulative Trauma Disorders of the Hand 3

3.1 Split-Split-Plot Design 30

4.1 Analysis of Variance. 32

4.2 Average Hand and Arm Anthropometry (50 Male and 50 Female Subjects) 34

4.3 Pearson Correlation Coefficients Male Major Hand to Grip Strength (50 Male Subjects--Major Hand) 35

4.4 Pearson Correlation Coefficients Male Minor Hand to Grip Strength (50 Male Subjects--Minor Hand) 36

4.5 Pearson Correlation Coefficients Female Major Hand to Grip Strength (50 Female Subjects--Major Hand) 37

4.6 Pearson Correlation Coefficients Female Minor Hand to Grip Strength (50 Female Subjects--Minor Hand) 38

4.7 Average Grip Strength Comparison by Gender (50 Male and 50 Female Subjects). 39

4.8 Maximum and Minimum Strength Recorded at Each Setting (50 Male and 50 Female Subjects) 40

4.9 Average Grip Strength with Comparison of the Major and Minor Hand (50 Male and 50 Female Subjects) 41

4.10 Minor Hand Equal to or Stronger than the Major Hand (50 Male and 50 Female Subjects) 42

4.11 Distribution of Hand Grip Space Setting and Occurrence of Maximum Grip Strength (50 Male and 50 Female Subjects) 44

4.12 Critical Range Groups of Space Settings (100 Subjects). 45

4.13 Comparison of the Space Setting on the Jamar Hand Dynamometer with a Cylindrical Handle (Inches) 45

LIST OF FIGURES

1. Jamar Hand Dynamometer 25
2. Anthropometric Measuring Equipment 28
3. Daily Schedule 29
4. Critical Range Grouping. 43
5. Data Sheet 53
6. Hand Width 54
7. Hand Length. 55
8. Hand Thickness 56
9. Middle Finger Length 57
10. Wrist Circumference. 58
11. Forearm Circumference. 59
12. Height 60
13. Weight 61

CHAPTER I

INTRODUCTION

The hand is used in nearly all physical work activities and is the recipient of more work injuries than any other part of the body except the trunk. In 1983 there were 360,000 disabling injuries to the hand and fingers (Accident Facts, 1984). Accident statistics in some industries suggest that cumulative hand trauma disorders (CHTD) result in up to 50 percent of the total hand injuries as listed in Table 1.1.

Table 1.1

Hand Injuries 1979-1984, A Large Telecommunications Plant

Year	CHTD	Total Hand Injuries	Population
1979	102	233	7155
1980	61	128	6892
1981	48	128	6524
1982	117	190	6191
1983	99	169	4827
1984	19	88	6553

CHTD = 48%.

Hands and fingers accounted for 19 percent of all disabling injuries (Accident Facts, 1984) and 10 percent of all compensation claims (See Table 1.2).

Table 1.2

National Safety Council
1984 Accident Facts

Body Part	% Cases	% Compensation
Eyes	5	1
Head	6	6
Arms	9	7
Trunk	32	42
Hands	5	3
Fingers	14	6
Legs	13	13
Feet	4	2
Toes	2	1
General	10	19

Table 1.2: Data indicates that hand and finger accidents are one of the most common sites of worker injuries.

Of the major industry groups, manufacturing has the highest rate of workers' compensation claims for cumulative repetitive trauma to the hand and wrist (Accident Facts, 1984). Some of the most common cumulative trauma disorders to the hand are listed in Table 1.3.

Table 1.3

Examples of Cumulative Trauma Disorders of the Hand

DeQuervain's Disease	Tenosynovitis
Game Keeper's Thumb	Stenosing-tenosynovitis
Epicondylitis	Stenosing-tenosynovitis-creptans
Ganglionic Cysts	Arthritis
Tendinitis	Fatigue
Synovitus	Raynaud's Syndrome
Carpal Tunnel Syndrome	Bursitis
Peritendinitis	Trigger Finger
Ulnar Tunnel Syndrome	Trigger Thumb

In the last twenty years much research and investigation has gone into cumulative hand trauma disorders. Literature before this time dealt mainly with diagnosis and treatment. Investigation and research include many areas such as: hand anthropometry, disorders of the hand, optimum handle size, strength of the fingers, grip strength, biomechanical hand aspects and hand movements. A great number of studies showed very little overall correlation between grip strength and other measures of bodily strength (Laubach, Kroemer, and Thordsen, 1972). It, therefore, has been accepted that grip strength is an anthropometric criterion of its own standing and value. Other studies show a high correlation of grip

strength to height and weight (Schmidt and Toews, 1970). This leads one to conclude further studies are necessary. Of interest are the studies which were made concerning physical stress level associated with manual materials handling. The Job Severity Index (JSI), reported by Ayoub et al. (1978), demonstrates "worker capacity is a predicted quantity which is a function of measurable human characteristics including strength and body size." This gives cause for investigation and research concerning hand anthropometry as a function of grip strength, which may be a measurable human characteristic to be used as a predictor of hand injury caused by cumulative repetitive trauma.

Much is known of anthropometry and strength. Not enough is known concerning anthropometry and strength as they apply to industrial workers. Human Factors Engineering demands an indepth investigation, as a preventive measure, of the large number of hand cumulative repetitive disorders suffered by the industrial population. This paper is intended as a step in that direction.

CHAPTER II

LITERATURE REVIEW

One of the most reliable, safe, easily administered and economical measures of human strength is the grip strength measured by a hand dynamometer. For this reason it has been the choice of many investigators and is a popular choice of strength test batteries. Correlations of grip strength of the human body have been the subject of many studies. Those dealing with healthy mature adults during the prime of life are of primary interest here. Other studies are of interest only as they pertain to identifying these parameters. The following review is of the body of knowledge published from studies of grip strength as a function of: age, sex, height, weight, body type, hand and arm anthropometry, finger strength, dominant hand and employment.

Grip Strength as a Function of Age

Swanson, Matev and de Groot (1970) using the Jamar hand dynamometer adjusted to 2.5 inches recorded grip strength of 50 male and 50 female subjects (200 hands) ranging from 17 to 60 years of age. They were distributed

according to occupation in three main groups: skilled, sendentary and laborer. All were in good health. The male group showed rather constant strength between ages 20 and 50 years. The female group maximal strength was recorded between ages 30 and 40 years. Schmidt and Toews (1970) using a Jamar hand dynamometer with 1.5 inch hand grip spacing recorded grip strength of 1,128 normal male and 80 normal female subjects ranging in age from 18 to 62 years. The data from this study show that grip strength increases from 18 to 32 years of age and then decreases gradually to 62 years. This seems to indicate that grip strength increases to the third decade, then decreases slowly as the individual ages. After age 32 grip strength becomes inversely proportional to age. An evaluation of a small group of women revealed that except for smaller grip strength means, the same relationships for grip strength as found in the male population probably were present.

Bookwalter (1950) analyzed grip strength in 3,250 left hands and 3,316 right hands in males ages 9 to 24. The right mean grip strength of males revealed slow, regular progression from 9 to 14. Progression accelerated from 14 to 16 with the greatest increase at 16 years. Beyond that progression was slower, but regular through 23 years, with a rise occurring at the last interval, 24 years and up. There tended to be a plateau beyond

16 years, although it was less pronounced than for the left hand. Nemethi (1952) reported that (one thousand subjects of both sexes ages 18 to 65 representing various skills and tested for grip in both hands), in the early age group, 19 and below, the average grip was similar to that found in the late age group, 40 and up. Grip reached its maximum between ages 25 and 40.

Everett and Sills (1952) measured grip strength (using a Narragansett dynamometer), stature, somatotype components and hand anthropometry in 400 students ranging in age from 14 to 29 years (less than 6 percent over 20 years of age). They reported a zero order correlation of age to grip at .4694. Age ranked sixth behind weight, hand width, height, hand length, and finger length. For the subjects who were tested they concluded age had little influence upon grip strength. This indicates that subjects under 20 would present some special problems when used in studies concerning grip. Bowers (1961), who used subjects 18 to 24 years reported that the correlation of age with hand grip strength failed to reach significance.

Grip Strength as a Function of Gender

Schmidt and Toews (1970) found, as would be expected, females had less grip strength than males. This was also the finding of every other study comparing male to female strength. The exact difference of any given muscle group

is the subject of existing controversy. The age range of the 80 women applicants tested was 18 to 52 years. Three trials with each hand produced an average of 69.8 pounds grip in the major hand and 63.9 pounds grip in the minor hand, with an average difference of 5.9 pounds. Average grip strength was proportional to height and weight and was found to increase with age up to 40 years and decrease thereafter. It is interesting to note that in 16 persons (20.0 percent), grip strength in the minor hand was equal to or exceeded that of the major hand. Nordgren (1972), in a study of 23 female student laboratory assistants ages 17-24 years with no symptoms of any disease or handicap, found females to be 53 percent as strong as males (no details given of the male population studied) in the right hand grip and 56 percent as strong in the left hand. Laubach (1976), in his review of nine papers with the primary objective to investigate the statement that women's muscle strength is, in general, about two-thirds that of men, found that the mean percentage of women's total body strength was 63.5 percent of men's total body strength. In comparing grip to body strength, Asmussen and Heeboll-Nielson (1961) found females' grip strength to be 67 percent that of males', which is a close comparison to the mean percentage of total body strength.

Grip Strength as a Function of Handedness

Swanson, Matev and de Groot (1970) in their study made a comparison between the major and minor hands. They reported the gripping strength of the minor hand was the same as, or higher than, the major hand in 29 percent of the individuals examined. However, the grip of the major hand was always found to be the stronger for heavy manual workers. The chuck pinch of the minor hand was as strong as, or stronger than, that of the major hand in 50 percent of the males and 54 percent of the females tested. This finding was also true of 40 percent of the manual workers. The same difference in strength between the major and minor hands was demonstrated for lateral pinch. In 12 percent of the individuals examined the left hand was dominant. Of these 12 persons, 8 or 67 percent had a stronger grip with the minor hand.

On the average, grip strength of the minor hand was found to be 5.4 percent weaker in males and 8.9 percent weaker in females. The strength of pinch of the minor hand was weaker by 4 percent in males and 6 percent in females. The data obtained in this study indicate that there is less difference in strength of the major and minor hands than has generally been thought.

Schmidt and Toews (1970) found the average grip strength in the major hand was 113.1 pounds, with a range of 65 to 165 pounds, and a standard deviation of 16.3

pounds. Minor hand grip strength averaged 109.6 pounds, had a range of 60 to 165 pounds, with a standard deviation of 16.5 pounds. On the average, the difference in grip strength between the major and minor hand was only 3.5 pounds, with a standard deviation of 5.5 pounds, and was normally distributed. The value of p for the difference in means of major and minor hands was greater than 99.99. An interesting finding was the fact that the average major/minor grip strength ratio was 1.030, it was normally distributed with a range of 0.840 to 1.300, and a standard deviation of 0.054. Thus, 22.6 percent of the men tested had a ratio of less than 1.00, which means 22.6 percent were stronger in their minor hand. In addition, 5.4 percent of the men had major/minor ratio of 1.0, meaning that grip strength was equal bilaterally in these subjects.

Bookwalter (1950) comparing the left hand to the right hand grip strength stated that the left hand grip shows more irregularity and variability than the right hand grip. The left hand mean grip strengths were less than the right hand mean grip strengths for every age group. The difference at regular increments ranged from 5 to 14 pounds.

Toews (1964) in his study of grip strength, which included 231 male employees of the Kaiser Steel Corporation, 22 to 66 years, and 61 male high school students,

14 to 18 years of age concluded that the tested population failed to exhibit a grip-strength difference (major versus minor) of 10 percent with the major hand predominating. He found a greatly dispersed pattern which was presented when the major hand grip was plotted against the minor hand grip, and that 26 percent of the population tested had less grip strength in the major than in the minor hand.

Nemethi (1952) found the average grip of the female to be far below that of the male. There was a greater percent difference between the right and left hands of females, indicating a more unilateral usage in females.

Grip Strength as a Function of Body Height

Schmidt and Toews (1970) reported that in general, grip strength was directly associated with body height, up to 75 inches. Everett and Sills (1952) found height ranked third in the zero order correlation with hand grip strength behind weight and hand width. Height caused the greatest decrease in two of the partial correlations, and was included in the highest multiple correlation of each order except the second. It was evident that the variables of weight, height, the mesomorphic component, and anthropometric measurement of the hand all contributed to the higher multiple correlations with hand grip strength.

Grip Strength as a Function of Body Weight

Everett and Sills (1952) report the highest correlation of eleven variables studied was that of body weight (.66). They concluded weight correlated the highest with hand grip strength, caused the greatest decrease in most of the partial correlations when it was held constant, and was included in the highest multiple correlations of each order. Throughout the correlational analysis it was evident that weight, and anthropometric measurement of the hand, height and mesomorphy were the most influential variables in the prediction of hand grip strength. Bowers (1961) found the correlation of weight and grip strength, for each of the three dynamometers, was considerably lower than the .66 correlation coefficient between weight and hand grip strength found by Everett and Sills (1952).

Grip Strength as a Function of Somatotype

Everett and Sills (1952) classified body type into mesomorphy (muscular), endomorphy (heavy), and ectomorphy (thin). The mesomorphic variable positively correlated with grip strength. This result has been substantiated in other studies. Ectomorphy and endomorphy were not good indicators of grip strength. Laubach and McConville (1969) found that when body weight was constant, somatotype components of endomorphy and ectomorphy were not related to

muscle-strength measurements, however, the mesomorphic component still showed six significant correlations with muscle strength. When taking first-order partial correlations (stature held constant), endomorphy and mesomorphy correlated slightly higher than ectomorphy with muscle strength, while ectomorphy correlated with all of the muscle-strength measures.

Grip Strength as a Function of Hand Anthropometry

Everett and Sills (1952) measured hand width, hand length, palm length and finger length. Subjects sat in a desk chair. The stylion of the right arm was marked with a skin pencil and the subject then placed his hand with fingers extended on a piece of paper so that the stylion was at the edge of the paper. The paper was marked at the end of the dactylion (middle finger), at the base of the fingers between the index and middle finger, and at the most lateral projections of the distal heads of the second and fifth metacarpals. From these marks the hand measurements were obtained by the use of a flat caliper.

This method facilitated testing and also reduced the amount of time needed to test each subject. After the hand measurements were obtained, the grip strength of the right hand was tested on a Narragansett dynamometer. Each subject was given three trials and the best result used. The intercorrelations for the hand measurements indicated,

for the most part, substantial relationships. Palm length did not, however, correlate well with hand length and finger length. Weight had the highest correlation. Hand width had the second highest correlation with hand grip strength while hand length and finger length ranked fourth and fifth. Hand width caused substantial decreases in the partial correlations, while finger length was included in the highest fourth order multiple correlation.

Strength Test of the Fingers

Kroemer and Gienapp (1970) measured forces exerted by the thumb on thirty-one male rated U.S. Air force pilots, twenty-nine of whom were right-handed. The pilots exerted their largest instantaneous forces with the right thumb at alpha=0 degrees (upright), 30 degrees, 60 degrees, and 90 degrees. The subjects were not stimulated to exert extreme force, nor did the subjects get an immediate feedback on his performance. No competition between subjects took place. The force exertion was self-paced taking between 1 and 2 seconds.

With paired data, forces exerted at alpha=0 degrees and 30 degrees were not significantly different from each other, also, the forces at 60 degrees and 90 degrees did not differ. Generally, there was a trend of increased force with increased flection of the thumb. The simple correlation coefficient between grip strength and thumb

force at alpha=0 degrees was 0.49, and between grip strength and force at alpha=90 degrees was 0.41.

Swanson, Mateo and de Groot (1970) using an electronic pinch meter based on the strain gage principle recorded the chuck pinch (three-digit pinch), pulp (fingertip) pinch with separate fingers, and lateral pinch. The pinch object was a disk measuring 2.2 cm diameter and 0.5 cm thick. Little difference was noted in the strength of the grasp and pinch regardless of whether the test was performed in a standing or sitting position, or the extremity was supported or not. Pinch forces in the supported position were generally lower. A small difference in strength of pinch was observed between the sedentary and manual workers. The minimal to maximal strength of chuck pinch recorded for the major hand was 6.0 to 14.5 kg in the male group and 4.0 to 10.0 kg in the female group. The middle finger pinch was the strongest for both hands in males and females. Pinch with digit V was half as strong as pinch with digits II or III. The weakest separate pinch observed in the male group was 2.0 kg for digit V and the strongest was 11.8 kg for digit III. Among the females the weakest value was 1.3 kg with digit V and the strongest 7 kg with digit III.

For the lateral pinch test, the pinch meter was held between the pulp of the thumb and the lateral aspect of the index finger. The manual worker group recorded the

highest figures. The range of lateral pinch strength with the major hand of males was 14.5 to 6.0 kg. The female group showed a maximal strength of 9.0 kg and a minimal strength of 4.0 kg for the major hand. Little difference was found in average major and minor hand strengths for both chuck and lateral pinches. There was demonstrated a strength decrease of 6 percent for the major hand and 7 percent for the minor hand when the extremity examined was supported rather than free. The female group showed a similar decrease of 9 percent for the major hand and 10 percent for the minor hand. Bowers (1961) reported that the correlations showed that each of the factors--length of hand, length of middle finger, and length of the proximal phalanx of the middle finger--was significantly related to hand grip strength. The correlation of the factors of forearm girth, wrist girth, hand width, body weight, and height with hand grip strength were all significant at the one percent level of confidence.

Grip Strength as a Function of Occupation

Toews (1964), in his study of male employees of Kaiser Steel Corporation and high school students, divided workers into three different job groups representing 74 separate job classifications based on type of work performed. Job group 1 included 57 employees, 23 to 61 years of age with an average age of 42.8 years. Men in this job

class performed no work requiring the use of an active grip. Job group 2 included 76 employees, 21 to 66 years of age with an average age of 41.9 years. Men in this group used a moderate grip often, but seldom applied a maximum grip. Job group 3 included 98 employees, 20 to 61 years of age with an average age of 37.2 years. The work done by this group required the application of moderate grip often and maximum grip occasionally. It was found by this study that, among the population tested, a difference in grip strength existed between the major and the minor hand. The average differences between the major and the minor hand strength of the three job classes 1, 2, and 3 were found to be 6.2 percent, 6.2 percent, and 5.2 percent, respectively. When the participants' grasping power was statistically analyzed, the average difference between the major and the minor hand for the combined test group was 5.8 percent, with the major hand predominating. The control group's average grip strength was less than that of any of the three job classes of the test group, nevertheless, the average percent of difference between the major and the minor hand of the two groups closely paralleled one another.

Nemethi's (1952) study consisted of one thousand individuals representing males and females 18 to 65 years of age, from various groups of skilled, semi-skilled and unskilled labor which were tested for gripping power. He

reported male office workers ranked next to female workers in lack of arm development and that while skilled, semi-skilled and unskilled laborers did not differ greatly, there was a difference between supervisory or office workers and the other three classes of workers. Swanson, Mateo and de Groot (1970) classified occupations into skilled, sedentary and manual. They found that skilled and sedentary males recorded similar figures and that the forces recorded by the manual workers were not significantly higher. Taken separately, manual workers recorded the highest figures, 56.1 kg for the major hand and 49.3 kg for the minor hand.

Summary

Much research has been done on the subject of grip strength. Interest has been shown using handles of various sizes and shapes by researchers as Ayoub and Lo Presti (1971), Cochran and Riley (1982), and Natarajan, Cochran and Riley (1984). Much has been resolved concerning the optimum handle size and shape. Shape is an important variable and comparisons will be made of the Jamar hand dynamometer handle and a cylindrical handle, even though shape is not the subject of this study. Measuring the strength of an industrial population who uses the handles and correlations of their strength and anthropometry is in need of further study.

Studies have been made using different hand dynamometers at several different settings using a wide range of subjects. Montoye and Faulkner (1963) used a Stoelting dynamometer with seven settings at 0.5 cm intervals. Everett and Sills (1952) used a Narragansett (a standard spring steel type gripping device manufactured by Sklar) with no mention of setting. The Jamar dynamometer was used by Toews (1964) with no mention of a setting. Toews used the Jamar because it was introduced by Bechtol (1954) and in 1956 was recommended by the Subcommittee for the Study of Grasping Power of the Committee on Industrial Health and Rehabilitation of the California Medical Association as the most acceptable instrument manufactured at the time for quantitative measurement of grasping power. Toews and Schmidt (1950) chose a 1.5 inch setting using the Jamar. Swanson, Matev and de Groot (1970) used the Jamar set at 2.5 inches.

Bowers (1961) compared the Stoelting, Narragansett and cable tensiometer and found length of hand, length of middle finger and length of the proximal phalanx of the middle finger were significantly related to hand grip strength. He found slightly higher correlations for strength involving hand length and finger length on adjustable dynamometers versus nonadjustable.

The subjects used have ranged in age from four years (Montoye and Faulkner, 1963), to 66 years of age (Toews,

1964). Nemethi (1952) found age, sex and occupation should be considered when predicting grip strength. He found grip strength reached its maximum between ages 25-40 years. Swanson, Matev and de Groot (1970) found men's grip strength to hold constant between ages 20-50 years and women's grip strength to hold constant between ages 30-40 years. Schmidt and Toews (1970) found grip strength to increase up to 32 years of age and decrease gradually thereafter to 62 years of age.

Problem

There is the need for a study using a standard adjustable hand dynamometer. At least four different types of hand dynamometers have been used (Stoelting, Narragansett, Tensiometer and a Jamar). A mature, industrial population should be used to determine grip strength at different space settings to be of maximum benefit to the industrial engineer, ergonomist and safety engineer. Determination should be made as to the significance of space settings as it affects strength measurements using an adjustable hand grip dynamometer. Settings of 1.50 and 2.50 inches have been used on a Jamar hand dynamometer with no mention of space settings in other studies. Montoye and Faulkner (1961) used a Stoelting at settings between 4.25 and 6.50 cm. No one has tested the full range from 1.25 to 2.50 inches in one study. Correlations should be made

on hand and arm anthropometry at each of the settings to determine the relationships, if any, to grip strength. Correlations have not been done using multiple space settings in a single study. The range of settings should be broad enough to determine the efficient limits of the industrial population's hand strength.

CHAPTER III

THE STUDY

Subjects

One hundred subjects were chosen from volunteers at AT&T's Shreveport Works. Volunteers were contacted using personnel records which list employees by sex, occupation and birth date. Fifty men and fifty women were chosen between the ages of 30 to 40 years. Subjects were in good health with no injuries, illnesses or deformities to the upper extremities. Excluded from the study were maintenance workers, supervisory personnel and office workers in an effort to eliminate those subjects who may have jobs which require under or overuse of their grip strength. Ambidextrous persons were also excluded.

Variables

The dependent variable was the force gripped on the Jamar dynamometer. The independent variables were task and operator related. The task related variables were the hand space settings on the Jamar dynamometer of 1.25, 1.50, 1.75, 2.00, 2.25 and 2.50 inches. The operator variables were major/minor hand and the anthropometric

measurements of gender, age, weight, height, wrist circumference, forearm circumference, hand thickness, hand width, hand length, and middle finger length.

The values of all variables were selected based on their use in past investigations and previous studies so the results of this study may be easily compared to them.

Procedures and Equipment

Preliminary Activities

The subjects were given a brief description of the study and their participation requirements. They were questioned about their state of health, particularly about the hands and arms. A visual inspection of the hands and arms was made for deformities or signs of injury. Subjects were allowed to grip the Jamar hand dynamometer at that time. Upon acceptance into the study, company medical records were checked to verify there were no past injuries or other medical problems which would eliminate them from the study. An appointment was made to report for the experiment during the working day.

When the subject reported for the experiment a detailed explanation was given for participation. The data sheet (Appendix,Figure 5) was completed during the experiment.

Grip Strength Test

A Jamar hand dynamometer, model 1A manufactured by Asimon Engineering Company, 1818 Franklin Street, Santa Monica, California 90404, pictured in Figure 1, was used to measure grip strength. Two handles identical to the original handle were machined from aluminum with the exception that one handle was made to fit so that the spacing was 0.25 inch oversized. This allowed the space setting to be set in 0.25 inch increments by the use of both handles. Six hand space settings (1.25, 1.50, 1.75, 2.00, 2.25 and 2.50 inches) were used for each hand.

Settings for the dynamometer were selected at random. The hand to be tested first at that setting was also selected at random. Both hands were tested at each setting before resetting the dynamometer. This procedure was used to avoid systematic errors.

The subjects were asked to hold the dynamometer free of support with their arm at their side, elbow flexed at 90 degrees, and to apply a steady maximum force and release. This single effort was recorded. The order of events was:

a) The hand to be tested first was determined by random selection.

b) The dynamometer setting was determined by random selection and the dynamometer set.

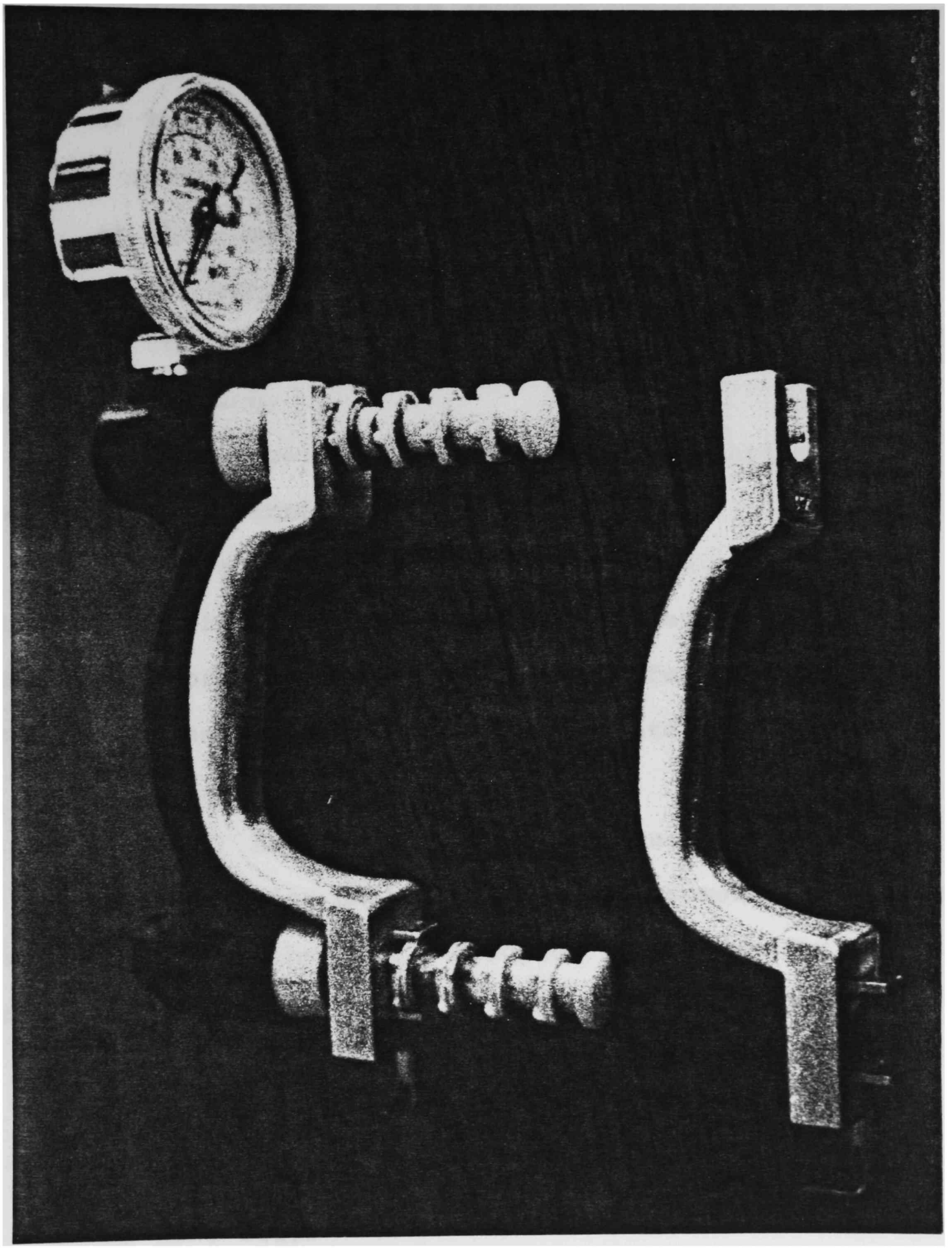

Figure 1: Jamar Hand Dynamometer

c) The dynamometer was given the subject in the hand determined at random. Grip strength was measured on a one attempt basis.

d) The dynamometer was taken from the subject and the reading recorded.

e) The dynamometer was given the subject in the other hand and the grip tested.

f) The dynamometer was taken from the subject and the reading recorded.

g) The procedure was repeated in (a) through (f) until all six settings were recorded.

There was a minimum of three minutes between grip tests involving each individual hand to avoid fatigue. The length of time the subject exerted force on the dynamometer at each recording was approximately 3 seconds.

Anthropometric Measurements

The following anthropometric measurements were taken and recorded on the data collection form (Appendix, Figure 5):

a) Hand length

b) Metacarple III length

c) Hand width

d) Hand thickness

e) Wrist circumference

f) Forearm circumference

g) Height

h) Weight

The equipment used was an anthropometric kit manufactured by GPM and marketed by Pfister Import-Export, Inc., Carlstadt, New Jersey 07072 and is pictured in Figure 2. The procedures used for taking the measurements are given in the Appendix (Figures 6 through 13).

Experimental Design

The design of the experiment had the data collection running in a one hour cycle with each subject completing the experiment in each cycle. The complete cycle schedule can be seen in Figure 3. As can be seen adequate rest was given between grip tests so the subjects did not fatigue. The tests were administered in random order to eliminate any systematic errors due to order. The total time of data collection was twenty working days with each subject putting in about an hour. Table 3.1 describes an exerpimental design.

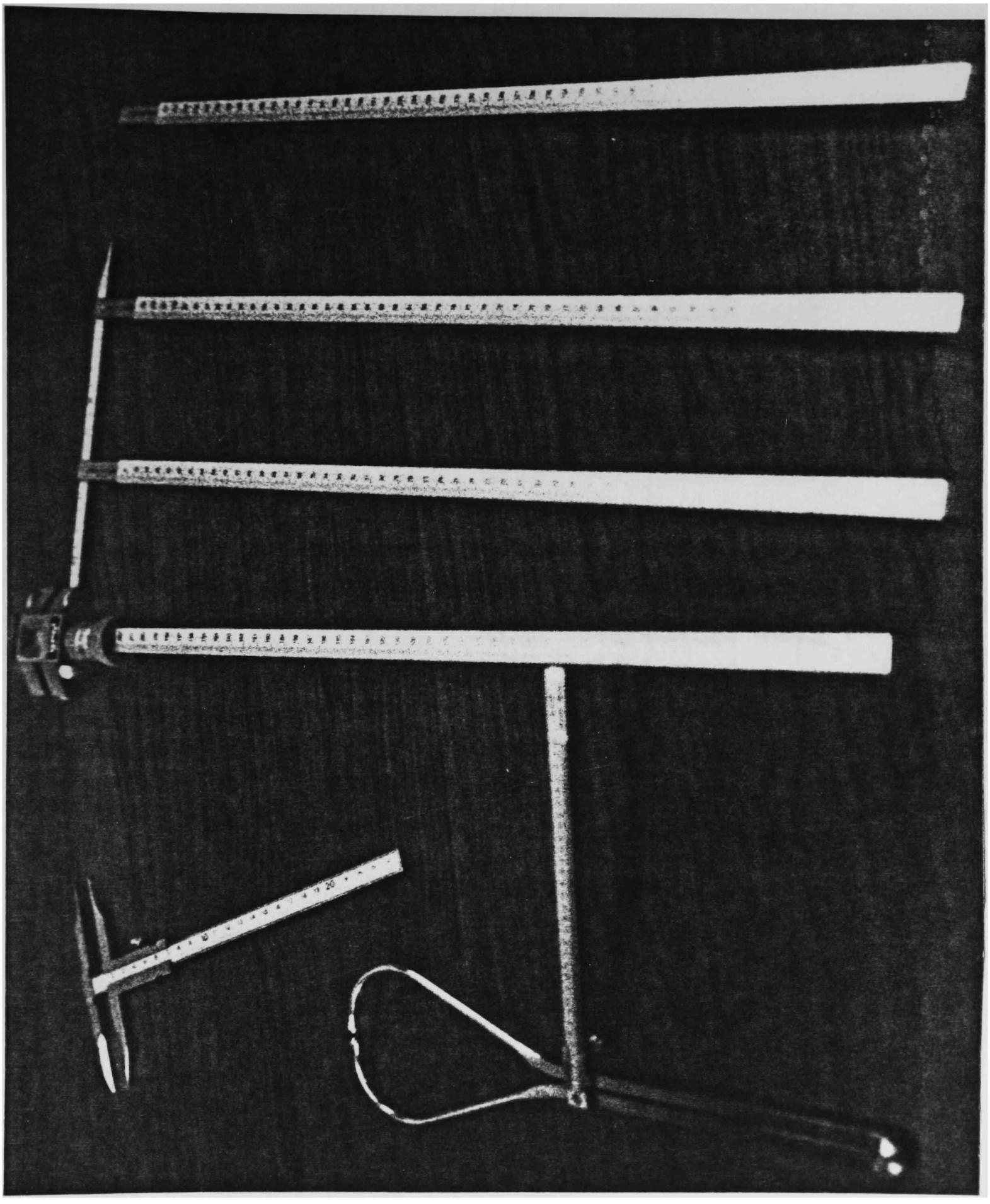

Figure 2: Anthropometric Measuring Equipment

Daily Schedule

Time (minutes)	Event
0:00	Preliminary
0:05	Grip (designated hand)
0:06	Grip (other hand)
0:07	Set dynamometer
0:10	Grip (designated hand)
0:11	Grip (other hand)
0:12	Set dynamometer
0:15	Grip (designated hand)
0:16	Grip (other hand)
0:17	Set dynamometer
0:20	Grip (designated hand)
0:21	Grip (other hand)
0:22	Set dynamometer
0:25	Grip (designated hand)
0:26	Grip (other hand)
0:27	Set dynamometer
0:30	Grip (designated hand)
0:31	Grip (other hand)
0:32	Anthropometry
0:45	Complete paper work
0:60	Repeat above procedure

Figure 3: Daily Schedule

Table 3.1

Split-Split-Plot Design

	Hand											
	Major Hand (settings)						Minor Hand (settings)					
	1	2	3	4	5	6	1	2	3	4	5	6
Male	1						1					
	.						.					
	.						.					
	.	(subjects)					.	(subjects)				
	.						.					
	.						.					
	50						50					
Female	1						1					
	.						.					
	.						.					
	.	(subjects)					.	(subjects				
	.						.					
	.						.					
	50						50					

N = 1200

CHAPTER IV

ANALYSIS AND RESULTS

Analysis

The Statistical Analysis System (SAS, 1972), SAS Institute, SAS version 5.08 was used for analysis of all data. The data are summarized by the means, standard deviations, maximum and minimum values for all of the variables. Correlations were run on all of the independent variables using the Pearson Correlation Coefficients. A level of significance of alpha=0.05 was used for all analysis.

Table 4.1 gives values for the analysis of variance to examine the effects of gender, handedness, and space setting as tested using the Null Hypothesis. H0-There is no statistically significant difference between (gender, handedness, or space setting). Hl-There is a statistically significant difference between (gender, handedness, or space setting). The Null Hypothesis was rejected.

Table 4.1

Analysis of Variance

Anova	Source	Degree of Freedom	Sum of Squares	F Value	Signif-icant Effect
Whole Plot					
	Gender	= 1	715506	2566.09	*
	Subjects	= 49	655	2.35	
	Gender * Subjects	= 49	3429	12.30	
Split Plot					
	Hand	= 1	20766	74.48	*
	Hand * Subject	= 49	130	.47	
	Hand * Gender	= 1	124	.45	
	Hand * Gender * Subject	= 49	1255	4.50	
Split-Split-Plot					
	Space	= 5	152871	109.65	*
	Space * Subject	=245	848	.61	
	Space * Gender	= 5	17970	12.89	
	Space * Gender * Subject	=245	136	.10	
	Space * Hand	= 5	160	.11	
	Space * Hand * Subject	=245	152	.11	
	Space * Gender * Hand	= 5	306	.22	
	Space * Hand * Gender * Subject	=245	206	.15	
	Total	=1199			

* Alpha=0.05.

Results

Anthropometry

Anthropometric data were gathered primarily to establish data for the beginning of a separate study, which will examine the possible correlations of hand and arm anthropometry and cumulative hand trauma disorders. Anthropometric data are presented in Table 4.2 to define the anthropometry of the subjects used in this study. Measurements are given in cm with the standard deviation given directly below in ( ). All data are normally distributed as revealed by the Shapiro-Wilk Statistic Test, which tests the Null Hypothesis.
HO-The input data values are random samples from a normal distribution. H1-The input data values are not random samples from a normal distribution. The test statistics show that the scores in the strength test data came from a normal distribution. Typical values of W = .98 and a p>.74 were recorded and therefore the Null Hypothesis (HO) is accepted.

Table 4.2

Average Hand and Arm Anthropometry
(50 Male and 50 Female Subjects)

	Anthropometric Measurement cm Note: Standard Deviation in ( )			
	Male		Female	
Body Part	Major	Minor	Major	Minor
Hand Length	19.078 (.975054)	19.144 (1.04475)	17.456 (.813448)	17.50 (.847566)
Metacarple III Length	8.244 (.538388)	8.284 (.533896)	7.564 (.436947)	7.596 (.450379)
Hand Width	9.252 (.438104)	9.092 (.49108)	8.062 (.38539)	7.958 (.409624)
Hand Thickness	3.152 (.178703)	3.076 (.191194)	2.846 (.733794)	2.766 (.729722)
Palm Length	10.83 (.579447)	10.86 (.657453)	9.88 (.492805)	9.884 (.502386)
Wrist Circumference	18.11 (.918573)	17.842 (.963431)	15.842 (.914975)	15.702 (.944693)
Forearm Circumference	31.686 (2.06546)	30.888 (2.00424)	26.53 (2.33738)	26.354 (2.42447)
Height	175.758 (6.00215)		162.026 (6.72509)	
Weight (lbs.)	177.94 (26.092)		138.76 (26.5711)	

The correlation between the measured grip strength and hand and arm anthropometry is low, as can be seen by looking at the values given in Tables 4.3 through 4.6. A general statement can be made that the larger the space

setting on the dynamometer the greater the correlation. The males tend to have higher R values than the females. The following four tables give the Pearson Correlation Coefficients for the male major and minor hand, and the females major and minor hand.

Table 4.3

Pearson Correlation Coefficients
Male Major Hand to Grip Strength
(50 Male Subjects--Major Hand)

Body Part (Major Hand)	Grip Strength at Each Space Setting on the Jamar Dynamometer (inches)					
	1.25	1.50	1.75	2.00	2.25	2.50
Length	.1732	.3221	.4349	.5865	.5890	.6636
	.2291	.0226	.0016	.0001	.0001	.0001
Width	.2869	.3148	.4737	.4924	.5015	.5467
	.0434	.0260	.0005	.0003	.0002	.0001
Thickness	.1980	.2781	.4964	.4700	.4405	.5549
	.1680	.0505	.0002	.0006	.0014	.0001
Metacarple III Length	.1548	.3666	.4694	.5614	.6042	.6217
	.2832	.0088	.0006	.0001	.0001	.0001
Wrist Circumference	.3399	.3598	.4381	.5227	.5122	.6175
	.0157	.0103	.0015	.0001	.0001	.0001
Forearm Circumference	.2368	.2925	.4241	.4954	.4970	.5907
	.0978	.0393	.0021	.0003	.0002	.0001

Note: Top figure = R.

Table 4.4

Pearson Correlation Coefficients
Male Minor Hand to Grip Strength
(50 Male Subjects--Minor Hand)

Body Part (Minor Hand)	Grip Strength at Each Space Setting on the Jamar Dynamometer (inches)					
	1.25	1.50	1.75	2.00	2.25	2.50
Length	.2834 .0458	.43622 .0015	.49538 .0003	.57515 .0001	.69182 .0001	.67719 .0001
Width	.43380 .0016	.51351 .0001	.58415 .0001	.52551 .0001	.55578 .0001	.57207 .0001
Thickness	.42506 .0021	.56331 .0001	.62571 .0001	.53976 .0001	.55566 .0001	.58345 .0001
Metacarple III Length	.22242 .1205	.41633 .0026	.46717 .0006	.56633 .0001	.65327 .0001	.66457 .0001
Wrist Circumference	.37346 .0076	.44912 .0011	.48329 .0004	.51079 .0002	.58587 .0001	.58989 .0001
Forearm Circumference	.40041 .0040	.44823 .0011	.59198 .0001	.60483 .0001	.60574 .0001	.65352 .0001

Note: Top figure = R.

Table 4.5

Pearson Correlation Coefficients Female
Major Hand to Grip Strength
(50 Female Subjects--
Major Hand)

Body Part (Major Hand)	Grip Strength at Each Space Setting on the Jamar Dynamometer (inches)					
	1.25	1.50	1.75	2.00	2.25	2.50
Length	.00988 .9457	.24173 .0908	.40722 .0033	.47308 .0005	.49547 .0003	.50862 .0002
Width	.15942 .2688	.42816 .0019	.56477 .0001	.52816 .0001	.62195 .0001	.52888 .0001
Thickness	.03763 .7953	.14389 .3188	.11077 .4438	.06900 .6340	.04643 .7489	.05443 .7073
Metacarple III Length	.01727 .9053	.25470 .0743	.36418 .0093	.37508 .0073	.43300 .0017	.45381 .0009
Wrist Circumference	.16079 .2646	.35978 .0103	.48293 .0004	.56119 .0001	.51758 .0001	.53805 .0001
Forearm Circumference	.23269 .1039	.39237 .0048	.53668 .0001	.50698 .0002	.56527 .0001	.47930 .0004

Note: Top figure = R.

Only first order correlations were calculated since it is more convenient to perform a hand grip strength test, than to measure the hand, to determine hand grip strength.

Table 4.6

Pearson Correlation Coefficients Female
Minor Hand to Grip Strength
(50 Female Subjects--
Minor Hand)

Body Part (Minor Hand)	Grip Strength at Each Space Setting on the Jamar Dynamometer (inches)					
	1.25	1.50	1.75	2.00	2.25	2.50
Length	-.01185	.35722	.35915	.38503	.47581	.44424
	.9349	.0109	.0104	.0058	.0005	.0012
Width	.10148	.42249	.47548	.48351	.50244	.55814
	.4832	.0022	.0005	.0004	.0002	.0001
Thickness	-.09072	-.0009	-.01505	.05211	-.06891	.0547
	.5309	.9946	.9174	.7193	.6344	.7056
Metacarple III Length	.10008	.40265	.40700	.43507	.47668	.45402
	.4892	.0037	.0034	.0016	.0005	.0009
Wrist Circumference	.00972	.26201	.34520	.33941	.35226	.35531
	.9466	.0661	.0141	.0159	.0121	.0173
Forearm Circumference	.17754	.33290	.42743	.37889	.34342	.32412
	.2174	.0182	.0020	.0067	.0146	.0217

Note: Top figure = R.

Gender

The average age of the subjects was 35.82 years for males and 35.12 years for females. The average grip strength for both male and female subjects using either hand reached its maximum between 1.75 and 2.25 inches. The average difference between male and female maximum grip strength was 56 percent (obtained by summing all the

male and female readings in the three space settings of 1.75, 2.00 and 2.25, in which the maximum grip was reached and in which there is no significant difference, then dividing the female sum by the male sum). Table 4.7 compares the genders by setting.

Table 4.7

Average Grip Strength Comparison by Gender
(50 Male and 50 Female Subjects)

Setting (Inches)	Grip Strength (lbs.)					
	Major Hand			Minor Hand		
	Male	Female	% f/m	Male	Female	& f/m
1.25	87.04	54.14	62.2	80.56	44.90	55.7
1.50	111.40	67.62	60.7	102.06	59.62	58.4
1.75	131.38	76.56	58.3	122.60	68.28	55.7
2.00	130.98	74.44	56.8	119.82	66.36	55.4
2.25	128.82	72.20	56.1	119.38	65.72	55.1
2.50	119.10	66.88	56.2	110.52	60.84	55.1

Table 4.8 gives the high and low strength range of the study population. The range extends from the weakest grip strength recorded of 21 lbs. by a female using the minor hand at the 1.25 inch setting to the strongest effort of 212 lbs. by a male using the minor hand at the 2.25 inch setting. The maximum strength recorded by a female was 118 lbs. using the major hand at the 1.75 inch setting.

The weakest grip recorded for the males was 38 lbs. at the 1.25 inch setting made by both the major and minor hand.

Table 4.8

Maximum and Minimum Strength Recorded at Each Setting
(50 Male and 50 Female Subjects)

Setting (inches)	Grip Strength (lbs.)							
	Major Hand				Minor Hand			
	Male		Female		Male		Female	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1.25	130	38	85	23	137	38	68	21
1.50	150	67	109	39	147	63	92	39
1.75	179	87	118	45	169	76	102	40
2.00	179	90	111	50	168	71	102	39
2.25	188	78	109	54	212	70	94	44
2.50	175	75	97	41	173	74	85	36

Handedness

Table 4.9 records the average strength at each space setting for males and females for both hands and compares the major hand with the minor hand giving the percent difference. This data should be of primary interest in that it reveals to the design engineer and ergonomist the grip strength of a healthy working population at their peak strength years. As can be seen, maximum strength is obtained between 1.75 and 2.25 inches. It makes a

significant difference if the settings are over or under this range.

Table 4.9

Average Grip Strength with Comparison of the Major and Minor Hand (50 Male and 50 Female Subjects)

	Grip Strength (lbs.)					
	Male Hand			Female Hand		
Setting (Inches)	Major	Minor	% mi/mj	Major	Minor	% mi/mj
1.25	87.04	80.56	92.5	54.14	44.90	82.9
1.50	111.40	102.06	91.6	67.62	59.62	88.2
1.75	131.38	122.60	93.3	76.56	68.28	89.2
2.00	130.98	119.82	91.5	74.44	66.36	89.2
2.25	128.82	119.38	92.7	72.20	65.72	91.0
2.50	119.10	110.52	92.8	66.88	60.84	91.0

Not one subject in a hundred tested had their maximum grip strength at the 1.25 inch setting. Only 2 percent of the maximum grip strength was recorded at the 1.50 inch setting. Subjects complained of difficulty gripping the 1.25 inch setting. Some complaints of being too small were expressed using the 1.50 inch setting, particularly among the male subjects. No complaints of too small or too large were made in settings of 1.75 to 2.50 inches.

Table 4.10 gives the percent of the industrial population whose minor hand has as strong or stronger grip strength than their major hand. As a whole, the minor hand is equal to or stronger than the major hand in 28 percent of the males and 22 percent of the females.

Table 4.10

Minor Hand Equal to or Stronger than the Major Hand
(50 Male and 50 Female Subjects)

Setting	1.25"	1.50"	1.75"	2.00"	2.25"	2.50"
Male	36%	28%	34%	24%	26%	26%
Female	14%	20%	22%	22%	22%	24%

Figure 4 is a graphic representation of grip strength of the male major and minor hand, and the female major and minor hand at each space setting. The average for all hands is also shown. Values are taken from Tables 4.2 and 4.3.

Space Setting

Table 4.11 gives the setting at which the maximum strength was obtained by a subject for all six settings.

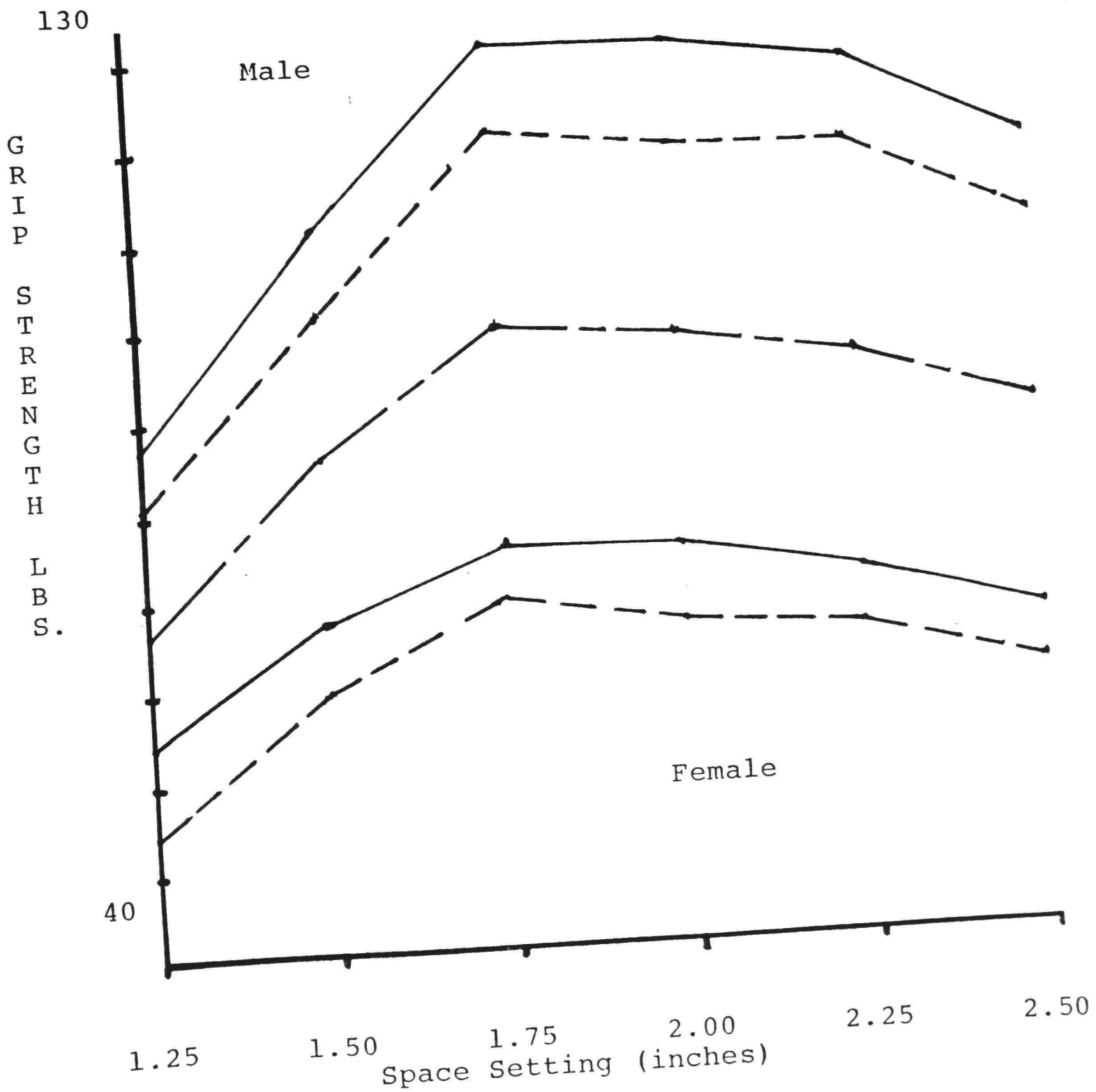

Figure 4: Critical Range Grouping

Table 4.11

Distribution of Hand Grip Space Setting and Occurrence of Maximum Grip Strength (50 Male and 50 Female Subjects)

Setting (Inches)	% of Total	Number Recorded			
		Male Hand		Female Hand	
		Major	Minor	Major	Minor
1.25	0	0	0	0	0
1.50	2	1	0	1	2
1.75	48	26	27	26	25
2.00	27	17	12	17	11
2.25	21	11	14	6	16
2.50	2	1	0	1	2

(Some Subjects had maximums in more than one setting.)

Table 4.12 gives the critical range groupings as determined by the Duncan's Multiple Range Test. There is no significant difference between the space settings of 1.75, 2.00 and 2.25 inches, where the maximum strength is obtained. The second highest grip strength was recorded at 2.50 inches. The third highest was recorded at the 1.50 inch space setting with the lowest recording for grip strength at 1.25 inch setting. The male groupings were identical with the female groupings.

Table 4.12

Critical Range Groups of Space Settings
(100 Subjects)

Settings (Inches)					
1.25 (66.660)	1.50 (85.175)	1.75 (99.720)	2.00 (97.900)	2.25 (96.530)	2.50 (89.335)
D	C	A			B

Note: Descending order A, B, D, D. Mean ( )
t-test data: Alpha = 0.05, DF 1152, T = 1.96203, LSD 3.2762

Much work has been done by other researchers using handles of various shapes. Table 4.13 gives the measurement of the perimeter of the handle of the Jamar hand dynamometer and makes a comparison to a cylindrical handle with the same perimeter (or circumference). The diameter of the cylindrical handle was calculated by dividing the perimeter of the dynamometer by 3.1416. See Figure 1 for a picture of the shape of the Jamar hand grip dynamometer.

Table 4.13

Comparison of the Space Setting on the Jamar
' Hand Dynamometer with a Cylindrical Handle
(Inches)

Setting	Perimeter	Diameter of an Equivalent Circle
1.25	3.75	1.19
1.50	4.27	1.36
1.75	4.79	1.52
2.00	5.31	1.69
2.25	5.83	1.86
2.50	6.30	2.01

Ayoub and Lo Presti (1971) found grip strength to reach a maximum at a 1.50 inch diameter cylindrical handle, which compares favorably with the findings of this study.

CHAPTER V

CONCLUSIONS

1. Settings less than 1.50 inches can effect strength measurements as much as 34 percent lower than at settings of 1.75 inches.

2. There is no significant difference in the grip strength between the psace settings of 1.75, 2.00 and 2.25 inches on the Jamar hand grip dynamometer.

3. Maximum grip strength occurs at 1.75 to 2.25 inch settings on a Jamar hand grip dynamometer for both male and female in major or minor hand.

4. There is no significant difference between the ratio of strength of the major and minor hand in males 30-40 years of age compared to females of that age.

5. Seven to ten percent is a close approximation for strength difference between the major and minor hand.

6. On the average, males are stronger than females in all space settings in both the major and minor hand.

7. On the average, the female grip strength is 56 percent as strong as the male grip strength.

8. The minor hand is equal to or stronger than the major hand in 28 percent of the males and 22 percent of the females.

9. Single correlations between hand or arm anthropometry and grip strength are low.

10. The expected maximum average grip strength for a male telecommunications worker 30-40 years of age is 131.38 lbs. in the major hand and 122.60 lbs. in the minor hand.

11. The expected maximum average grip strength for a female telecommunications worker 30-40 years of age is 76.56 lbs. in the major hand and 68.28 lbs. in the minor hand.

Recommendations

It is recommended that future studies be made using only left-handed subjects. Four left-handed females and nine left-handed males were used in this study. Of the males, 67 percent had a stronger grip in their right hand and of the females, 50 percent had a stronger grip in their right hand. This leads one to question, if in a right hand oriented society, the percentage for the left-handed population, having a minor hand equal to or stronger than the major hand, is not much higher than in the right-handed population.

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APPENDIX

ROOM TEMPERATURE _____

last first mi

NAME: _____

SOCIAL SECURITY #: _____

OCCUPATION: _____

SEX: M F MAJOR HAND: R L

AGE: _____ HEIGHT: _____cm WEIGHT: _____ lbs.

ANTHROPOMETRY (cm)

	right	left
HAND LENGTH	_____	_____
METACARPLE III LENGTH	_____	_____
HAND WIDTH	_____	_____
HAND THICKNESS	_____	_____
WRIST CIRCUMFERENCE	_____	_____
FOREARM CIRCUMFERENCE	_____	_____

JAMAR DYNAMOMETER RECORDINGS (lbs.)

SETTING (INCHES)	right	left
1.25	_____	_____
1.50	_____	_____
1.75	_____	_____
2.00	_____	_____
2.25	_____	_____
2.50	_____	_____

Figure 5: Data Sheet

HAND WIDTH

LANDMARK: None

INSTRUMENT: Sliding caliper

POSITION OF SUBJECT: Subject sits, right hand flat on a table, palm down. The fingers are together and straight but not hyperextended.

PROCEDURE: With a sliding caliper, measure the breadth of the hand between metacarpal-phalangeal joints II and V.

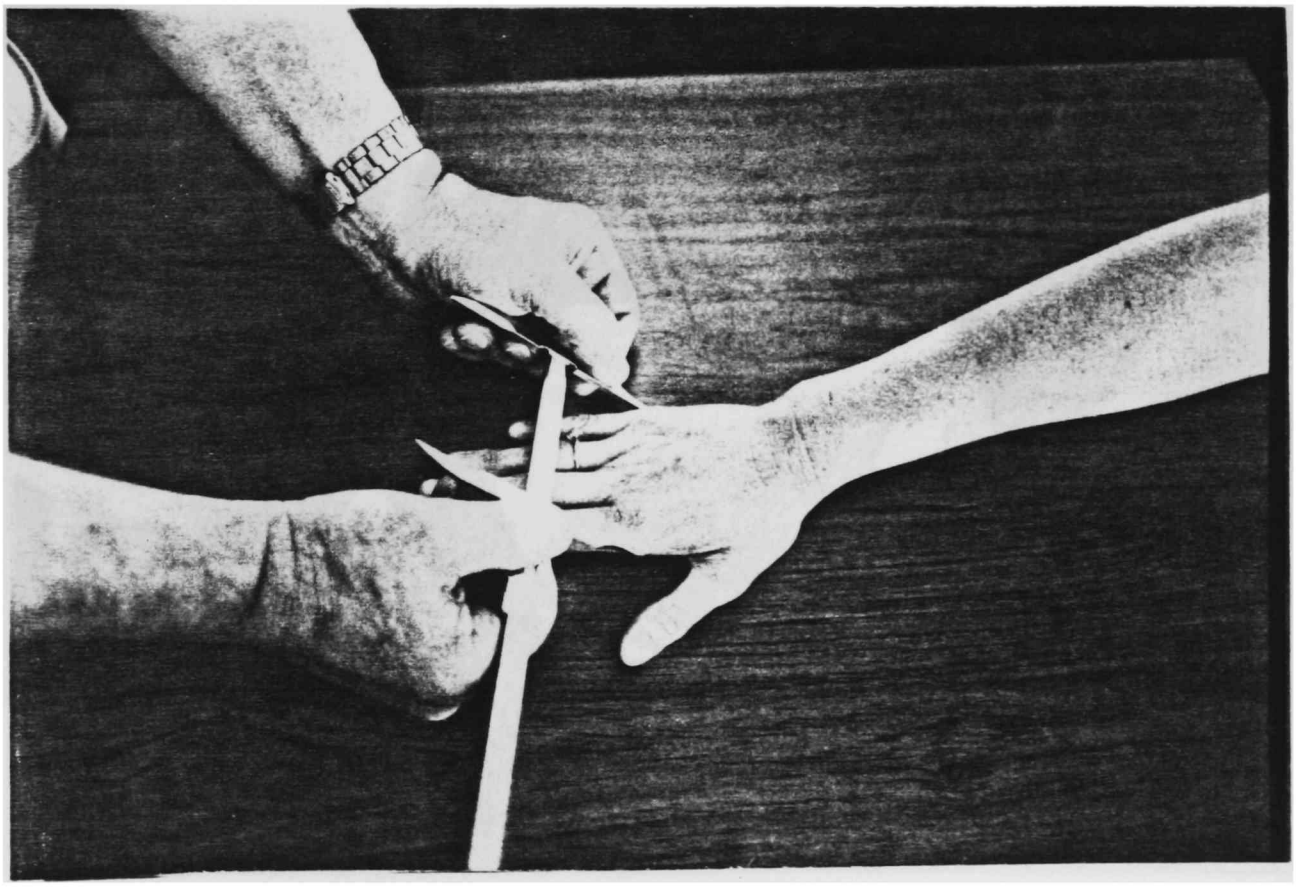

Figure 6: Hand Width

HAND LENGTH

LANDMARK: Wrist

INSTRUMENT: Sliding caliper

POSITION OF SUBJECT: Subject sits, right hand flat on a table, palm up. The fingers are together and straight but not hyperextended.

PROCEDURE: With the bar of a sliding caliper parallel to the long axis of the hand, measure the distance from the wrist landmark to dactylion.

Figure 7: Hand Length

HAND THICKNESS AT METACARPALE III

LANDMARK: Metacarpale III

INSTRUMENT: Outside caliper

POSITION OF SUBJECT: Subject sits, with ulnar edge of the hand resting on a table with the hand held so the palmar surface is in the vertical plane. The fingers are together and straight but not hyperextended.

PROCEDURE: With an outside caliper, measure the maximum distance between the dorsal and palmar surfaces of the knuckle of the middle finger where it joins the palm.

Figure 8: Hand Thickness

MIDDLE FINGER LENGTH

LANDMARK: Dactylion

INSTRUMENT: Sliding caliper

POSITION OF SUBJECT: Subject sits, right hand flat on a table, palm up. The fingers are together and straight but not hyperextended.

PROCEDURE: With the bar of a sliding caliper parallel to the long axis of the hand, measure the distance from the middle finger crotch level to the dactylion.

Figure 9: Middle Finger Length

WRIST CIRCUMFERENCE

LANDMARK: Base of hand

INSTRUMENT: Tape

POSITION OF SUBJECT: Subject sits, upper arm at side, lower arm in the horizontal plane and extended forward with the hand held in a relaxed position.

PROCEDURE: With a tape held in a plane perpendicular to the long axis of the lower arm, measure the circumference of the wrist at the distal crease.

Figure 10: Wrist Circumference

FOREARM CIRCUMFERENCE

LANDMARK: Lower arm circumference level

INSTRUMENT: Tape

POSITION OF SUBJECT: Subject sits, lower arm held so its long axis is perpendicular, elbow flexed 90 degrees, fist tightly clenched.

PROCEDURE: With a tape held in a plane perpendicular to the long axis of the lower arm, measure the circumference of the forearm at its maximum protrusion.

Figure 11: Forearm Circumference

HEIGHT

LANDMARK: None

INSTRUMENT: Anthropometer

POSITION OF SUBJECT: Subject stands erect, head in the Frankfort plane, heels together, and weight distributed equally on both feet with shoes removed.

PROCEDURE: With the arm of the anthropometer firmly touching the scalp, measure the vertical distance from the standing surface to the top of the head.

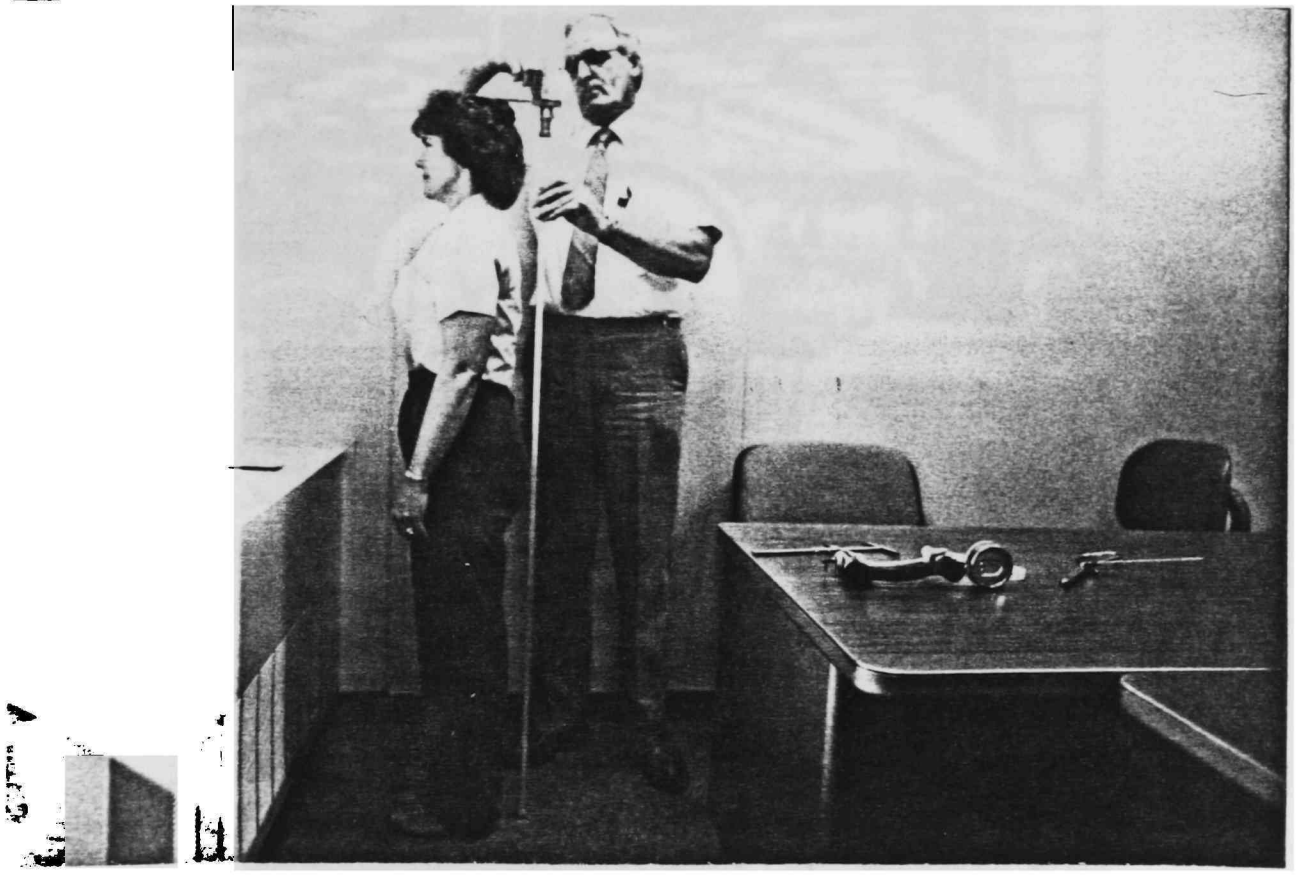

Figure 12: Height

WEIGHT

LANDMARK: None

INSTRUMENT: Toledo Scales Model 2181

POSITION OF SUBJECT: Subject stands on center of scale platform wearing street clothes (including shoes).

PROCEDURE: Read scale to within one pound and record.

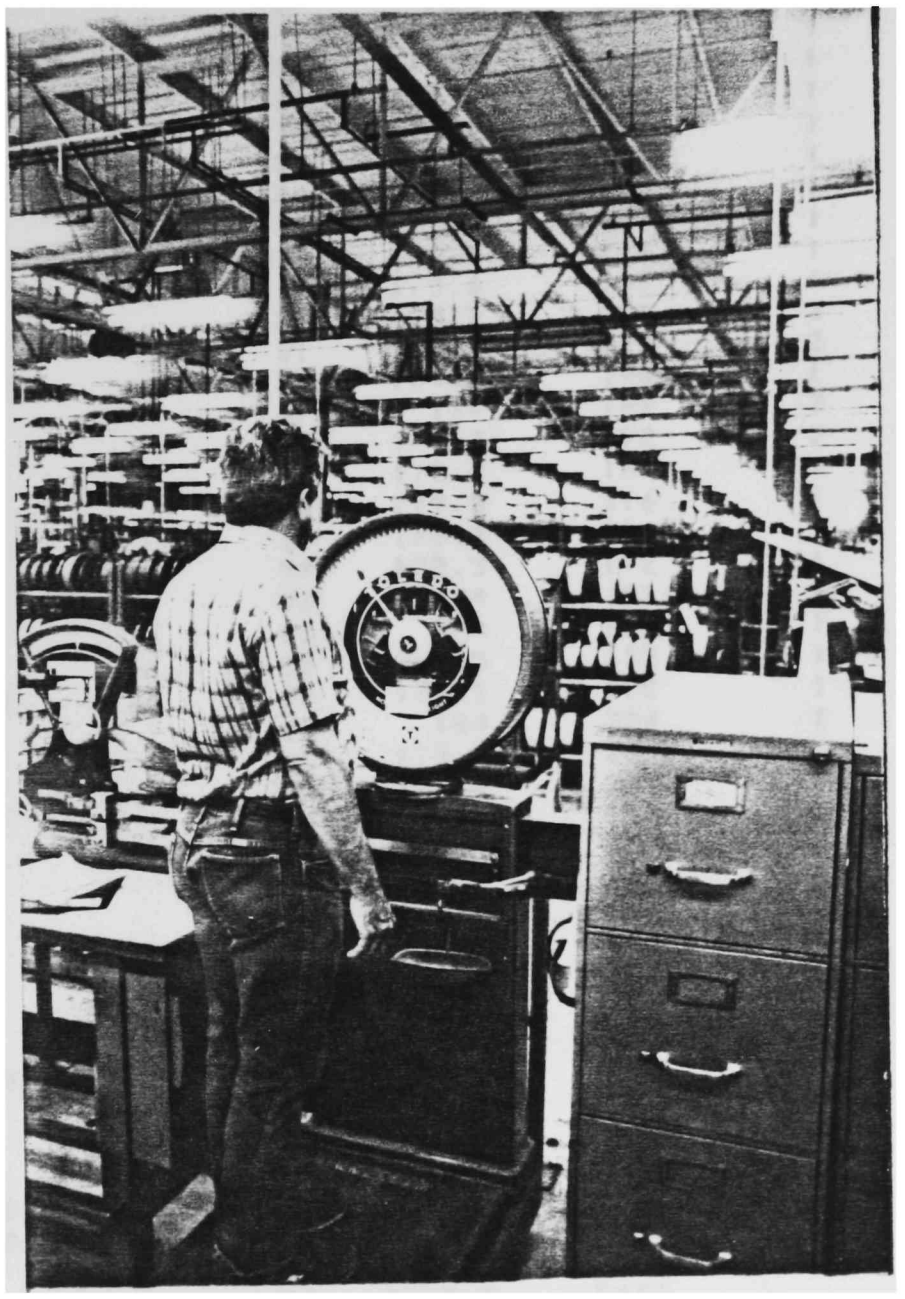

Figure 13: Weight

DATA (MALE)

	A	B	C	D	E	F	G	H
1	S/SN	SEX	AGE	HEIGHT	WEIGHT	MAJOR HD DHD	LGT	DMETA 3
2	1533M		39	172.7	150	2	18	7.8
3	9825M		37	179	177	1	19	8.5
4	7460M		35	166.6	176	1	17.9	7.6
5	8013MB		34	175.3	199	1	19.2	8
6	1087M		35	168.7	152	1	18.4	7.9
7	1221M		35	172.1	155	1	18.9	8.3
8	2440M		35	179.5	162	1	19.3	8.2
9	3002M		35	182	157	1	20.2	9.2
10	3197M		37	170.3	167	1	18.4	7.6
11	4861MB		37	169	165	1	19.8	8.6
12	9715M		34	177.1	166	1	19.1	8.1
13	7304M		35	179.6	222	1	20	8.4
14	7146M		39	178.7	174	1	19.3	8.3
15	1529M		33	160.9	148	1	16.6	7.1
16	9712M		31	171	175	1	18.3	7.8
17	7113M		34	172	188	1	18.7	8.7
18	8901M		36	186.3	225	1	19.9	8.6
19	3593M		39	183.4	196	1	19.3	8.1
20	8029M		37	175.6	157	1	19.5	9
21	683M		39	178.2	250	2	19.8	8.2
22	400M		31	180.1	193	2	18.9	8.1
23	6724MB		37	184.6	240	1	22.4	10.1
24	2417M		37	179	189	2	20.2	8.7
25	2863M		38	177.7	202	2	19.4	8.4
26	8135M		38	173.3	162	1	19.2	8.6
27	8659M		37	170.8	216	1	18.8	7.8
28	2494M		38	168.3	206	1	17.2	7.9
29	9924M		39	172.3	172	1	19.3	8.9
30	1561M		33	174	151	1	19.2	8.3
31	5667M		32	174	165	1	19.6	8.6
32	3138M		39	168.5	155	1	17.5	7.4
33	1367MB		33	189.2	180	1	20.5	8.7
34	5573M		39	184	224	1	19.5	7.8
35	6532M		37	173.1	164	1	18.7	8
36	693M		35	176.9	202	1	20.6	8.5
37	1145M		34	176.2	165	2	19.9	8.6
38	3640M		34	180.9	192	1	18.6	8.2
39	6368M		34	167.9	135	1	17.3	7.2
40	4235M		36	175.6	189	1	17.8	7.2
41	808M		36	169.5	150	1	19.2	8.2
42	4761M		38	176.1	169	1	18.3	7.7
43	2081M		37	178.3	170	2	18.7	8.1
44	133M		38	187.7	158	2	19.3	8.2
45	4973MB		36	166	136	1	20.3	9
46	923M		38	182.9	184	1	18.6	8.1
47	2153M		35	172.5	177	1	19.2	8.6
48	1936M		35	181.6	170	2	18.7	8.1
49	1807MB		34	178.7	190	1	19.2	8.5
50	7072MB		33	173	142	1	19.3	8.4
51	4934M		34	177.2	188	1	18.9	8.3
52	SUM	1791		8787.9	8897		953.9	412.2
53	AVERAGE	35.82		175.758	177.94		19.078	8.244
54	STD DEV			6.00215	26.092		.975054	.538388
55	VARIANCE			36.0258	680.792		.950731	.289861

DATA (MALE)

	I	J	K	L	M	N	O	P
1	DHD WID	DHD THIK	DWRIST	DFORARM	DPLM LGT	SHD LGT	SMETA 3	SHD WID
2	8.9	2.9	16.9	30.4	10.2	18.2	7.7	8.7
3	9.5	3.2	18.4	32.8	10.5	19	8.6	9
4	9.4	3.2	17.6	30.9	10.3	18.4	8	9.1
5	9.3	3.2	19	35.1	11.2	19.4	8.3	9
6	8.6	3.1	17.2	31.9	10.5	18.6	7.8	8.4
7	9.4	3.1	17.9	32.9	10.6	18.4	8.3	9.3
8	8.7	3	17.6	31.2	11.1	19.4	8.2	8.6
9	9.6	3.2	18.4	28.6	11	20.2	9.1	9.4
10	9.2	3	18.1	31.3	10.8	18.6	7.6	9.2
11	9.4	3.3	17.9	32.1	11.2	20	8.8	9
12	9.4	3.2	17.9	31.3	11	18.8	8	9.3
13	9.9	3.4	19.6	34.7	11.6	19.8	8.4	10
14	9.3	3.2	18.2	31.8	11	19.1	8.4	9.5
15	8.4	2.6	15.8	27.5	9.5	16.6	7.3	8
16	9.2	3.1	18.1	31.5	10.5	18.4	8.2	9.1
17	9.8	3.2	18.1	31.9	10	18.5	8.6	9.4
18	10	3.5	19.9	36	11.3	19.1	8.7	9.8
19	8.6	3.2	17.9	34.5	11.2	19.2	8.3	8.5
20	9.4	3.2	17.6	29.8	10.5	19.8	9.1	9.1
21	9.4	3.5	18.9	34.2	11.6	19.9	8.1	9.4
22	9.5	3.3	17.8	32.4	10.8	19	8.1	9.3
23	11	3.5	21.4	38.2	12.3	23.7	10.2	10.9
24	8.6	2.9	17.6	31.9	11.5	19.5	8.7	8.5
25	9	3	18.5	31.2	11	19.5	8.4	9
26	9.1	3.1	17.1	31.6	10.6	18.7	8.4	8.8
27	9.3	3.2	18.9	34.5	11	18.6	7.8	9.3
28	9.4	3.2	18.1	33.4	9.3	17.6	7.8	9.3
29	9.2	3.1	17.9	32.7	10.4	19.3	8.8	8.7
30	9.4	3.1	17.9	29.8	10.9	19.3	8.4	9.4
31	8.9	3.1	17.2	30.2	11	19.5	8.6	8.5
32	8.6	3.3	17.2	29.8	10.1	17.7	7.7	8.4
33	9.4	3.1	19.1	31.8	11.8	20.6	8.6	9.2
34	9.6	3.2	18.6	31.7	11.7	19.5	7.8	9.5
35	9	3.1	17.3	30.2	10.7	18.9	8.2	8.7
36	9.3	3.1	19.8	33.9	12.1	20.4	8.5	9.4
37	9.7	3.3	19	31.3	11.3	20.1	8.6	10
38	9.1	3.2	18.2	31.2	10.4	18.6	8	8.9
39	8.8	2.7	16.4	28	10.1	16.8	7	8.5
40	8.9	3.1	18	32.1	10.6	18.1	7.2	8.5
41	9.2	3.1	17.9	29.3	11	19	8.1	9
42	9.1	3.2	18.2	30.9	10.6	18.8	7.9	9
43	9.4	3.3	17.6	29.8	10.6	19.3	8.3	9.2
44	9.4	3.1	18.3	30.6	11.1	19.4	8.2	9.4
45	9.1	3.4	18.3	30.3	11.3	20.1	9.1	9.1
46	9	3.2	17.8	31.2	10.5	18.9	8.3	9
47	9.4	3.4	18.9	33.6	10.6	19.7	8.7	9.3
48	8.6	2.9	18	31.2	10.6	19	8	8.5
49	9.2	3.1	17.6	31.3	10.7	19.8	8.6	9
50	9.3	2.9	17.2	27.7	10.9	19.4	8.5	9.2
51	9.7	3.1	18.7	32.1	10.6	19	8.2	9.3
52	462.6	157.6	905.5	1584.3	541.7	957.2	414.2	454.6
53	9.252	3.152	18.11	31.686	10.834	19.144	8.284	9.092
54	.438104	.178703	.918573	2.06546	.579447	1.04475	.532896	.49108
55	.191935	.0319347	.843776	4.26613	.335759	1.09149	.285045	.241159

DATA (MALE)

	Q	R	S	T	U	V	W	X
1	SHD THIK	SWRIST	SFORARM	SPLM LGT	D1.25	D1.50	D1.75	D2.00
2	2.9	17.1	30.6	10.5	79	97	124	119
3	3.1	19	32.2	10.4	90	113	123	126
4	3	17.2	29.3	10.4	100	97	137	124
5	2.9	18.8	33.2	11.1	102	105	147	140
6	2.9	16.7	30.8	10.8	97	92	139	128
7	3.1	17.2	31.4	10.1	95	141	155	151
8	3	17.9	30.3	11.2	90	135	121	145
9	3.2	17.6	27.7	11.1	92	119	141	131
10	3	18.2	29.7	11	81	109	120	120
11	3.1	17.7	31.2	11.2	76	106	124	120
12	2.9	17.6	30.2	10.8	92	127	154	158
13	3.3	19.2	34.2	11.4	123	148	179	170
14	3.1	17.6	31	10.7	111	116	163	160
15	2.5	15.7	26.3	9.3	73	70	89	90
16	3	17.6	30.5	10.2	75	112	131	124
17	3.2	17.6	30.9	9.9	85	124	140	143
18	3.5	19.4	34.5	10.4	100	101	145	124
19	3.1	17.6	32.5	10.9	79	125	132	142
20	3.1	17.2	29.2	10.7	112	150	173	164
21	3.3	18.4	34.5	11.8	73	86	131	131
22	3.3	18.5	31.1	10.9	72	99	122	122
23	3.5	21.4	37.2	13.5	92	126	158	179
24	3.1	17.6	30.9	10.8	69	106	122	128
25	3.1	18.3	30.3	11.1	124	150	139	142
26	3.1	16.7	30.9	10.3	56	89	133	125
27	3.3	18.6	33.2	10.8	81	121	126	133
28	3.1	17.8	32.4	9.8	83	105	118	125
29	2.9	17.6	31.9	10.5	108	124	129	130
30	3.1	17.7	30.8	10.9	130	111	137	146
31	3	16.9	29.1	10.9	85	125	150	143
32	3.1	17.3	29	10	83	104	112	108
33	3	18.3	30.8	12	84	106	131	137
34	3.3	18.2	31.5	11.7	107	131	142	153
35	3	17.1	29.7	10.7	57	90	105	126
36	3	18.9	33.1	11.9	92	107	118	128
37	3.4	18.9	32.1	11.5	85	105	119	126
38	3	18.1	30.3	10.6	96	123	145	124
39	2.5	15	26.8	9.8	89	107	110	100
40	3	17.3	29.7	10.9	73	81	96	95
41	3.1	17.6	28.2	10.9	76	95	87	104
42	3.2	18.2	30.7	10.9	74	111	135	131
43	3.2	17.8	30.9	11	79	107	112	103
44	3.1	17.6	29.1	11.2	112	129	156	149
45	2.9	18.1	30.2	11	71	101	136	139
46	3.1	17.6	31	10.6	67	105	131	122
47	3.2	17.9	32.5	11	102	147	157	154
48	3	18.1	32	11	75	91	105	109
49	3.1	17.6	30.8	11.2	80	110	134	143
50	2.8	17.1	27.2	10.9	38	67	98	94
51	3.1	19	30.8	10.8	87	124	133	121
52	153.8	892.1	1544.4	543	4352	5570	6569	6549
53	3.076	17.842	30.888	10.86	87.04	111.4	131.38	130.98
54	.191194	.963431	2.00424	.657453	17.7603	19.037	19.8565	19.3533
55	.0365551	.9282	4.017	.432245	315.427	362.408	394.281	374.551

DATA (MALE)

	Y	Z	AA	AB	AC	AD	AE	AF
1	D2.25	D2.50	S1.25	S1.50	S1.75	S2.00	S2.25	S2.50
2	115	100	98	113	126	116	118	112
3	130	120	93	119	129	127	123	122
4	123	100	94	90	122	106	122	76
5	140	140	76	92	113	136	132	121
6	116	123	73	75	126	122	125	98
7	138	132	94	122	140	131	124	119
8	145	141	80	110	127	142	147	131
9	138	121	60	110	118	116	125	118
10	115	103	65	92	100	106	107	91
11	114	110	85	128	135	132	122	120
12	152	132	93	104	132	143	127	125
13	174	164	120	147	169	146	135	140
14	152	142	94	115	152	158	143	152
15	107	75	51	64	76	71	76	55
16	118	111	70	102	119	100	93	93
17	137	127	86	110	129	135	120	112
18	137	127	86	97	132	130	129	128
19	131	121	57	85	117	124	131	108
20	167	142	85	118	127	127	130	128
21	122	131	95	109	130	137	113	118
22	127	111	91	112	132	134	132	115
23	188	175	101	128	162	168	212	173
24	136	122	87	121	135	138	132	130
25	145	125	116	120	130	120	118	114
26	127	119	60	80	114	110	113	110
27	133	122	59	81	106	94	99	99
28	115	106	73	104	125	118	111	108
29	136	122	98	100	124	126	125	118
30	129	112	137	140	160	155	154	127
31	140	110	81	110	125	120	120	95
32	98	96	74	93	108	98	93	90
33	129	125	70	86	108	101	100	114
34	140	130	114	129	155	133	140	108
35	119	107	67	78	112	108	115	105
36	124	113	72	102	116	109	109	101
37	122	124	85	115	137	129	132	113
38	136	133	70	80	120	113	123	106
39	110	102	56	72	80	76	70	74
40	97	92	73	86	104	97	103	96
41	107	96	74	86	87	88	95	88
42	115	102	69	106	121	124	110	105
43	111	106	79	106	109	101	97	97
44	141	141	93	111	142	127	113	113
45	137	134	62	83	112	126	126	104
46	124	111	62	82	110	105	118	106
47	154	136	91	135	150	136	140	127
48	100	92	65	99	103	108	101	111
49	146	140	66	90	132	136	140	136
50	78	85	38	63	80	87	80	84
51	106	104	90	103	112	101	106	92
52	6441	5955	4028	5103	6130	5991	5969	5526
53	128.82	119.1	80.56	102.06	122.6	119.82	119.38	110.52
54	20.0313	19.1495	18.827	19.3036	19.9796	20.2864	22.2939	19.8908
55	401.253	366.704	354.456	372.629	399.184	411.538	497.016	395.642

DATA (FEMALE)

	A	B	C	D	E	F	G	H
1	S/SN	SEX	AGE	HEIGHT	WEIGHT	MAJOR HD	DHD LGT	DMETA 3
2	2547F		36	153	142	1	15.9	6.6
3	3587F		39	163.2	154	1	18.2	8.3
4	8783F		30	174	145	1	18.4	7.8
5	4131F		39	172.2	145	1	18	7.4
6	902FB		38	161.9	147	1	18.2	7.6
7	9867F		32	173.6	133	2	18.2	8.3
8	4845F		37	169.8	132	1	17.9	7.7
9	5775F		33	159.1	124	1	17	7.8
10	2872F		34	163.8	117	1	17	7.4
11	5143F		31	157.4	165	1	17.2	7.5
12	5814F		32	162.2	218	1	18.7	8.3
13	160F		37	165	150	1	18.2	7.7
14	1607F		38	166.2	189	1	18.3	7.7
15	1319F		31	177.6	210	1	18.1	8.1
16	3086F		34	164	131	1	17.4	7.8
17	1750F		38	156.5	112	1	16.2	7.1
18	3474F		35	150.6	105	1	16	7
19	8220F		37	161	131	1	18.1	8
20	9317F		31	166.9	132	1	17.2	7.6
21	2930F		34	157.3	113	1	16.6	6.7
22	384FB		34	158	155	1	17.9	7.7
23	5773F		34	159.6	141	2	17.5	7.6
24	1591FB		37	155	156	2	17.1	7.4
25	51F		38	162.8	178	1	17.1	7.3
26	8989FB		37	146	110	1	16.7	6.9
27	4191FB		34	158.1	142	1	17.9	7.7
28	96F		39	167.7	121	1	17.2	7.7
29	2124F		32	160.5	103	1	16.3	6.9
30	6466FB		33	155.4	133	1	18.6	8.2
31	1880FB		36	162	148	1	17.3	7.5
32	3721F		32	164.3	110	1	16.6	7.2
33	2960F		36	153.8	116	2	16	7.2
34	1173F		32	162.5	125	1	16.6	7
35	1212F		34	157.3	145	1	17.8	7.7
36	4678F		34	177	112	1	17.6	7.5
37	1967F		32	160.3	112	1	17.3	7.8
38	9662F		38	161.1	107	1	16.9	7.2
39	2386F		39	155.8	110	1	16.3	7.2
40	237F		34	162	189	1	17.6	7.5
41	9540FB		38	162.1	148	1	18.1	7.9
42	4111FB		34	159.3	145	1	17.5	7.7
43	1853FB		38	156.5	106	1	18.4	8.2
44	7030F		37	168.6	143	1	18.2	8.3
45	586FB		30	160.5	130	1	17.7	7.5
46	672F		39	175	160	1	18.6	7.8
47	2276FB		37	163.5	172	1	19	8.2
48	5239F		39	153.4	120	1	15.7	6.7
49	291F		35	168.9	136	1	17.9	7.3
50	1773F		31	161	115	1	17.2	7.6
51	1646FB		37	158	155	1	17.4	7.4
52	SUM		1756	8101.3	6938		872.8	378.2
53	AVERAGE		35.12	162.026	138.76		17.456	7.564
54	STD DEV			6.72509	26.5711		.813448	.436947
55	VARIANCE			45.2269	706.023		.661698	.190922

DATA (FEMALE)

	I	J	K	L	M	N	O	P
1	DHD WID	DHD THIK	DWRIST	DFORARM	DPLM LGT	SHD LGT	SMETA 3	SHD WID
2	7.9	2.6	15.8	27	9.3	15.8	6.6	7.8
3	8.5	2.7	15.8	26.3	9.9	18.4	8.2	8.1
4	8.1	2.8	16.9	28.8	10.6	18.5	7.9	8.2
5	7.9	2.7	15.6	27	10.6	18	7.5	7.7
6	8.7	2.9	16.9	27.6	10.6	18.4	7.7	8.7
7	8.7	2.6	15.7	27.1	9.9	18.8	8.5	8.5
8	8.3	2.7	15.9	26.2	10.2	17.9	7.7	8.1
9	7.9	2.7	15.2	25.2	9.2	16.9	7.8	7.5
10	7.7	2.7	15.1	24.3	9.6	17	7.4	7.6
11	7.7	2.6	16.4	29.8	9.7	17	7.5	7.7
12	8.5	3.1	17.6	30.7	10.4	18.7	8.3	8.4
13	8	2.8	16.4	26.7	10.5	18.2	7.6	8.2
14	8.7	2.9	17.1	31.9	10.6	18.2	7.4	8.7
15	8.4	2.8	17	31	10	18.6	8.4	8.4
16	7.8	3	15.5	27.2	9.6	17.4	7.7	7.8
17	7.4	2.5	14.2	24.7	9.1	16.4	7.1	7.3
18	7.5	2.5	14.8	23.9	9	16	6.9	7.2
19	8.4	2.7	16.4	26.1	10.1	18.2	8	8.4
20	8.1	7.8	15.4	25.2	9.6	17.3	7.5	8.1
21	7.4	2.7	14.2	23.9	9.9	16.3	6.6	7.2
22	8.3	3.1	17.1	28.5	10.2	18	7.7	8.1
23	8.1	2.8	16	28.3	10.1	17.5	7.6	8
24	7.8	3	15.9	28.3	9.7	16.8	7.2	7.9
25	8.1	2.7	16.4	29.2	9.8	17.1	7.4	7.9
26	7.1	2.5	15.4	26.8	9.8	16.7	7.3	7.2
27	8.1	2.8	15.9	27.6	10.2	17.6	7.7	7.9
28	8.2	2.6	15.8	25.1	9.5	17	7.7	8.1
29	7.8	2.6	15.2	23.2	9.4	16.6	7.1	7.5
30	8.2	2.8	16.4	26.9	9.6	18.7	8.3	8.2
31	7.8	3	16.1	28.2	9.8	17.5	7.6	7.7
32	7.4	2.7	14.1	23.7	9.4	16.8	7.3	7.2
33	8.3	2.6	14.9	25.2	8.8	16.1	7.1	8
34	8.2	2.6	15.1	23.6	9.6	16.9	7.2	8.1
35	8.5	2.8	15.7	27	10.1	17.7	7.9	8.3
36	8.2	2.5	15.1	22.3	10.1	17.6	7.4	7.8
37	7.8	2.6	14.9	23.7	9.5	17.5	7.8	7.8
38	7.9	2.6	15.2	22.9	9.7	16.8	7.3	7.8
39	7.7	2.6	15.2	25.1	9.1	16.3	7.2	7.6
40	8.3	3	18.9	32.6	10.1	17.5	7.5	8.4
41	8.3	3	15.8	26.7	10.2	18.4	7.9	7.9
42	8	2.8	15.8	24.3	9.8	17.8	7.9	7.8
43	7.9	2.6	15.9	23.3	10.2	18.5	8.3	8
44	8.6	2.8	15.8	26.7	9.9	18.5	8.4	8.5
45	8.3	3	16	25.9	10.2	17.6	7.6	8.2
46	8.2	2.8	16.5	27.8	10.8	18.4	7.7	8.4
47	8.7	2.9	17.7	27.9	10.8	18.7	8.2	8.8
48	7.4	2.5	15.1	26.2	9	15.6	6.8	7.4
49	7.7	2.7	15.5	25.8	10.6	17.7	7.2	7.5
50	8.3	2.6	15.4	24.8	9.6	17.5	7.6	8.2
51	8.3	2.9	15.4	28.3	10	17.6	7.6	8.1
52	403.1	142.3	792.1	1326.5	494	875	379.8	397.9
53	8.062	2.846	15.842	26.53	9.88	17.5	7.596	7.958
54	.38539	.733794	.914975	2.33738	.492805	.847566	.450379	.409624
55	.148527	.538453	.83718	5.446337	.242857	.718367	.202841	.167792

DATA (FEMALE)

	Q	R	S	T	U	V	W	X
1	SHD THIK	SWRIST	SFORARM	SPLM LGT	D1.25	D1.50	D1.75	D2.00
2	2.6	15.8	26.5	9.2	54	62	66	66
3	2.6	16.2	26.2	10.2	62	72	94	82
4	2.7	16.4	27.6	10.6	85	96	106	109
5	2.6	15.8	27.6	10.5	30	52	66	77
6	2.7	17	27.1	10.7	55	74	94	80
7	2.6	15.6	27.5	10.3	50	72	92	64
8	2.7	15.9	25.8	10.2	46	58	73	72
9	2.6	15.1	24.2	9.1	50	64	66	67
10	2.6	14.9	24	9.6	61	63	62	62
11	2.4	15.4	29.2	9.5	50	72	85	86
12	3	17.3	30.7	10.4	80	80	93	81
13	2.9	16.7	26.7	10.6	31	39	49	50
14	2.8	17.3	31.9	10.8	58	85	97	93
15	2.8	16.9	30.2	10.2	82	109	118	111
16	2.8	15.2	26.2	9.7	60	71	76	75
17	2.5	14.2	26.6	9.3	60	67	72	65
18	2.5	14.5	22.9	9.1	32	44	52	56
19	2.6	16.2	25.1	10.2	43	59	58	67
20	7.7	15.7	25.1	9.8	44	73	78	72
21	2.5	14.1	23.2	9.7	56	61	66	58
22	2.9	16.7	29.2	10.3	74	89	88	98
23	2.8	16.1	27.3	9.9	60	74	82	80
24	2.9	15.8	28.4	9.6	59	77	87	79
25	2.8	16.1	27.9	9.7	52	61	74	69
26	2.5	15.1	26.2	9.4	36	51	65	63
27	2.8	15.8	28.2	9.9	65	72	79	87
28	2.6	15.4	25.1	9.3	66	80	90	84
29	2.5	14.9	21.9	9.5	67	73	77	80
30	2.9	16.4	27.8	9.4	56	62	66	62
31	2.7	16	28.3	9.9	45	56	63	66
32	2.5	14.2	22.9	9.5	55	67	69	62
33	2.6	14.6	24.8	9	53	61	66	65
34	2.5	15.1	24	9.7	71	68	72	73
35	2.7	15.3	27	9.8	42	64	73	74
36	2.4	15.1	23.6	10.2	35	71	72	84
37	2.5	14.9	23.5	9.7	62	61	63	63
38	2.5	14.4	21.9	9.5	62	71	75	72
39	2.6	15	24.5	9.1	57	75	69	62
40	3	19	33	10	58	68	80	80
41	2.8	16.3	25.3	10.5	30	52	67	61
42	2.8	15.4	24.1	9.9	55	67	75	64
43	2.7	15.2	23.7	10.2	23	44	45	65
44	2.7	15.8	26.8	10.1	43	62	83	85
45	2.7	16.1	26.1	10	80	94	101	90
46	2.7	16.3	28.2	10.7	55	70	80	78
47	2.9	17.2	27.8	10.5	34	78	101	105
48	2.3	14.9	26.8	8.8	42	46	59	54
49	2.6	15.1	25.7	10.5	53	47	70	66
50	2.5	15.2	25.1	9.9	65	64	81	72
51	2.7	15.5	28.3	10	63	83	93	86
52	138.3	785.1	1317.7	494.2	2707	3381	3828	3722
53	2.766	15.702	26.354	9.884	54.14	67.62	76.56	74.44
54	.729722	.944639	2.42447	.502386	14.2055	13.7379	14.9423	13.6594
55	.532494	.892445	5.87804	.252392	201.796	188.73	223.272	186.578

DATA (FEMALE)

	Y	Z	AA	AB	AC	AD	AE	AF
1	D2.25	D2.50	S1.25	S1.50	S1.75	S2.00	S2.25	S2.50
2	64	55	36	44	58	57	55	54
3	86	75	39	72	75	72	72	72
4	97	95	46	92	94	92	92	83
5	65	72	25	45	56	71	64	72
6	91	76	44	60	79	78	79	71
7	90	75	59	81	90	84	94	79
8	60	66	40	59	56	58	56	57
9	63	60	38	39	57	58	58	48
10	62	56	45	52	70	65	60	56
11	70	71	36	69	74	76	70	56
12	81	70	68	75	76	77	76	62
13	55	41	21	52	43	39	45	37
14	93	70	35	53	67	52	58	60
15	109	97	63	91	102	102	89	85
16	77	70	40	66	75	70	70	60
17	63	63	53	58	66	63	58	58
18	54	50	29	43	44	46	49	43
19	65	69	32	50	62	67	66	64
20	67	65	35	54	61	66	56	62
21	60	46	42	52	54	46	52	40
22	84	78	67	83	98	90	81	72
23	79	72	54	71	79	75	74	72
24	82	74	55	71	80	79	68	62
25	72	59	44	48	52	57	56	52
26	71	70	40	51	63	60	67	57
27	84	75	50	61	62	72	77	66
28	82	76	52	74	80	73	63	69
29	71	67	45	61	65	74	69	68
30	61	62	66	66	72	67	65	60
31	62	60	37	46	56	41	46	44
32	55	59	47	58	68	60	57	53
33	69	61	55	63	65	67	69	62
34	66	61	56	62	65	71	61	54
35	66	67	40	54	65	66	54	55
36	79	74	46	58	70	67	73	68
37	62	55	53	53	60	60	60	55
38	63	65	41	59	60	60	64	59
39	57	56	66	62	67	57	61	60
40	75	76	47	54	72	71	66	63
41	86	55	24	42	51	50	62	36
42	55	57	45	58	69	59	56	51
43	46	57	29	40	40	45	44	49
44	83	72	33	58	80	76	81	77
45	86	80	49	70	89	76	77	72
46	76	72	41	56	70	68	70	67
47	91	91	33	68	83	82	86	79
48	53	47	39	40	55	45	50	39
49	70	61	45	47	55	56	65	52
50	76	70	61	65	74	70	75	73
51	76	73	59	75	90	85	70	77
52	3610	3344	2245	2981	3414	3318	3286	3042
53	72.2	66.88	44.9	59.62	68.28	66.36	65.72	60.84
54	13.2634	11.3814	11.5816	12.6182	13.7909	13.3703	11.8011	11.9136
55	175.918	129.536	134.133	159.22	190.188	178.766	139.267	141.933

DATA LEGEND

1	Right handed
2	Left handed
B	Black
D	Dominant (Major)
F	Female
M	Male
S	Subdominant
FORARM	Forearm
HD	Hand
LGT	Length
META 3	Metacarple III
PLM	Palm
SUB. NO.	Subject number
THIK	Thickness
WID	Width

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_____	Ted McKenzie
Student's signature	Student's signature
_____	August 5, 1986
Date	Date