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ANTHROPOMETRIC COMPARISONS BETWEEN *BODY MEASUREMENTS* OF MEN AND WOMEN (U)

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BIO-DYNAMICS CORPORATION

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
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This report documents some of the differences in the body proportions of men and women in the region of the torso and legs. The study utilized discriminate analysis to pinpoint multivariate differences and regression analysis to indicate the magnitude of these differences from an applications' standpoint. The coefficients and estimates from these analyses are presented. It appears that men and women are proportioned so differently that it should be nearly impossible to have a single sizing system for coverall or flight suit types of clothing or equipment.

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PREFACE

This study was carried out under contract F33615-86-C-0547 with the Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. Project scientists were Dr. Edward Schafer and Dr. Barry T. Bates, Bio-Dynamics Corporation. Ms. Kathleen M. Robinette, Human Engineering Division, Harry G. Armstrong Aerospace Medical Research Laboratory was contract monitor.

Mr. Shinwon Kim assisted in the computer analysis and contruction of tables. Mr. Richard H. Tromel edited the report and coordinated resources needed to complete the work.

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INTRODUCTION

With the increasing number of military occupation specialties open to female personnel, potential problems in the design and sizing of protective clothing and equipment have become apparent. These problems arise from the fact that most protective equipment and clothing now used by the armed forces were designed specifically for males. The improper fit of clothing and equipment can affect the safety, efficiency and productivity of personnel.

Recent studies (cf. McConville, Robinette and White; 1981) have documented the fact that anthropometric differences exist between genders which rule out the use of a "down-sized" male sizing system for females. The specific differences which preclude the "down-sizing" option are gender differences in proportionality among various body measurements.

Two possible solutions to the inadequacy of "down-sizing" male garments for use by females are:

1. Separate sizing system for females based upon observed female body measurements.

2. Single system that incorporates differences in body proportions based upon the values of a few key dimensions.

While the first option will likely produce garments with the best overall fit, the costs incurred in the production of two separate sets of garments which meet the same functional need are something to be avoided if possible. The second option offers a compromise between the inadequacy of a "down-sized" male system and the redundancy of a separate sizing system for each gender group. However, if such a system is to work, research must be conducted to identify where differences in proportionality occur, and which, if any, key body dimensions can vary with these observed differences.

Thus, the purpose of this study was to identify differences in the proportionality among body dimensions between sexes which could affect the design and development of an adequate sizing system. Specifically, this research report will focus on those body measurements that are known to be important in the design and sizing of coverall/flightsuit-type garments.

To better understand the differences in proportionality between genders, this research employed multiple discriminant analysis and multiple regression techniques. The discriminant analysis was used to identify key dimensions, i.e., body measures which appear to have the greatest proportional difference between sexes; while multiple regression was used to calibrate the relationships between selected key dimensions and other variables important to the proper fit of coverall/flightsuit-type garments.

Nineteen of the 20 variable means were statistically greater for the males with hip circumferences being equal. Practically all correlation coefficients (99.3%) were significantly ($p < 0.05$) different from zero with 28.9% having magnitudes equal to or greater than 0.71. The results were similar between data sets with generally high intercorrelations within the length measures and within the subset of circumference values and weight. Overall, the discriminant analyses indicated a considerable divergence from cross-gender proportionality. At least 14 variables entered each of the three models evaluated with five standardized coefficients being equal to or greater than 0.775. In addition, the signs of the coefficients were both positive (40%) and negative (60%) further indicating cross-gender disproportionality. The results of the regression analyses suggest that none of the three models were adequate for estimating the values of the independent variable nor effectively compensating for the general lack of cross-gender anthropometric proportionality. The two sets of models using stature as a predictor variable with weight and shoulder circumference produced a large number of models in which the estimated female values exceeded the corresponding male values indicating the inappropriateness of a "down-sized" male sizing system for females. The third model (hip and shoulder circumferences) partially alleviated this problem of disproportionality but the results still indicated a general lack of "goodness of fit".

CHAPTER I
BACKGROUND

This chapter contains a review of selected literature in order to provide the reader with background information. The review of anthropometric literature presented is divided into two anthropometric areas: a) total body and b) sex related. Since these areas are not mutually exclusive some reports are included in both sections.

Total Body Anthropometry

In the early part of this century, two extensive bibliographies were published which summarized the anthropometric literature available at that time. O'Brien, Peterson and Worner (1929) prepared a bibliography for the United States Department of Agriculture (USDA) on the relation of clothing to health. This bibliography contained references for studies of body measurements, anthropometrics and hygiene as they related to military and civilian clothing.

Shortly thereafter, O'Brien (1930) prepared an annotated list of literature references for the USDA on garment sizes and body measurements. The major finding of the report was that no scientifically determined measurements related to garment design had been published, with the exception of one study relative to uniform design. Basically, the only information available on the design of garments at that time was anthropometric information obtained from military records and physical development data gathered by physical educators. The report did provide a list of garment design-related literature for the following: children, adults, military, insurance companies and college students.

The studies by Gould (1930) and Jorgensen and Hatlestad (1940) provide examples of the early types of total body anthropometric information gathered by physical educators. Gould's article presents results from a study of southern female college student physiques based on recorded physical measurements of young college women from 1909 to 1928. The mean height of these women was found to be 63.34 inches, with the mean weight equal to 116.2 pounds. On the average, over three and a half years of college attendance, these subject gained an average of 0.30 inches in height and 0.90 pounds in weight. After comparing results to female students in northern colleges, it was found that both the height and weight of southern women was slightly less.

Jorgensen and Hatlestad (1940) obtained 28 overall body anthropometric measurements on 200 college women and 300 college men aged 18 to 20 years in an attempt to determine body build. Body build was defined as a width-depth-stature relationship within a person. The results presented no evidence to support the existence of distinct types or categories of body build in either males or females. Rather, there seemed to be a continuous distribution of body builds ranging from extreme lateral to extreme linear. Some indices were more useful than others. The indices which proved most valuable for men and women were: weight/height, chest girth/height and leg length/chest girth.

In an attempt to remedy the data inadequacies uncovered in earlier reports, O'Brien and her colleague Shelton (1941) conducted an extensive civilian survey involving the measurement of weight and 58 body dimensions used in garment and pattern construction on over 10,000 white women in the United States. A detailed statistical analysis of the results was conducted and presented to the USDA, Bureau of Home Economics. The intention was to discern key measurements critical to the design of women's garments. The results suggested that a stature (height) and weight combination would provide the best basis for classifying women's body types for the establishment of a standard system of garment and pattern sizes. The investigators also found that girth measurements had little relationship to vertical measurements. Finally, it was determined that the five measurements of weight, stature, bust, waist and hip circumference determine fairly completely the size and shape of a woman.

Thurstone (1946) used the multivariate statistical technique of factor analysis in an examination of 12 anthropometric measurements obtained from adult men. It was found that the correlations among the variables could be accounted for by a simple structure of four factors. Factor 1 was termed "head size" and was described by the measurements of head length, head breadth and head height. Factor 2, called "bone length", contained the variables of stature, sitting height, span and hand length. Factor 3, the "girth" factor, included shoulder breadth, hip breadth, chest breadth and chest depth. Factor 4 was titled "size of extremities" with the variables: stature, span, hand length and hand breadth loading on this factor.

A more recent report from the civilian literature summarizes a study by Hathaway and Foard (1960), again conducted for the USDA. It contains data on the height and weight of adults in the United States. The contents of this report are quite extensive, and include the following sections: average heights and weights related to age, average weights for age, data on men in military service, data from other countries compared to the United States and changes in the United States population between 1790 and 1950.

In addition to the studies on civilian populations, more extensive surveys have been conducted by the military. Several large scale studies have been periodically conducted to update the anthropometric data base (Churchill & Bernhardi, 1957; Hertzberg, Churchill, Dupertuis, White & Damon, 1963; Laubach, McConville, Churchill & White, 1977; McConville, Churchill, Churchill & White, 1977; Tebbetts, Churchill & McConville, 1977). The reports on the findings of these studies are primarily published as technical reports available upon request from the military. A large number of measurements have been taken in each of the studies.

A major problem with the anthropometric studies conducted through the late 1970's is the difficulty in consolidating the information from the various studies into usable form. An important advance was made to the study and use of the human anthropometric literature with the development of a data bank by the Aerospace Medical Research Laboratory (AMRL) (McConville, Churchill & Clauser, 1977). This data bank was established as a resource for designers, and incorporated raw data from most current large-scale anthropometric surveys in comparable format. Data from 30 large-scale anthropometric surveys representing a total sample of over 80,000 military and civilian men and women were consolidated.

McConville and Clauser (1978) provided a historical overview of collections of anthropometric data, as well as a listing of the current resources of the AMRL data bank. They suggested that segments of the population such as foreign women and ethnic subgroups in the United States are inadequately represented or missing from the data bank.

White (1978) prepared an excellent review and summary of the sources of anthropometric data in the United States military and civilian population of adults and children. He also provided a brief review of anthropometric data sources from various foreign counties. Human engineering factors and considerations are the primary topic of this literature summary. The lack of anthropometric data with regard to civilian populations was discussed as well as the shortcoming of using data from military populations as a basis for designing clothing and equipment for civilian populations. For example, the military population is, in general, a younger population, as well as a population with a smaller range of variation in body size and measurements. With respect to trends in human engineering, White suggested that one area with a strong need for applied anthropometry is in the design of clothing and apparel.

Some of the more recent military reports have attempted to address the need for applied anthropometry for the purpose of clothing design. Alexander and McConville (1979) discussed the series of height/weight sizing programs used by designers of protective clothing for United States Air Force (USAF) men. The original system of sizing was based on the 1950 sample of subjects who were 0.75 inches shorter and 10 pounds lighter on the average than the 1967 survey data used for the current sizing program. The 1967 sample was comprised of 2420 male officers on active flying status in the USAF, who were 98 percent white and ranged in age from 23 to 32 years. Excluding head, hand and foot measurements, 71 body dimensions were used. The report presents sizing tables for four, six, eight and twelve size programs alone with bivariate tables, summary statistics, percentile data and tariffs. The supporting text indicates that height and weight correlate well with many other body dimensions which are central to most design problems.

With regard to the choice of key sizing dimensions, the following decisions were made (Alexander & McConville, 1979). No single measurement was adequate for sizing garments because no single dimension is related closely to both lengths/heights and girths/breadths. Secondly, the designer should choose two or more key dimensions which need not correlate well with each other but should correlate well with other included measurements. For example, height and weight can be used as the key dimensions for the sizing of one piece flight garments. Finally, after the key dimensions are chosen, the designer must establish size intervals, dimensional data by size, design values and tariffs.

Robinette (1984) advocated a similar strategy for the design process. Development and use of anthropometric programs for the design of personal protective clothing and equipment were discussed and an anthropometric sizing system advocated as the basis for design via the following techniques. First, select one or two key dimensions. "Key" dimensions are described as those which collectively have a strong relationship with most of the other dimensions important to the item being designed. Second, divide the user sample into similar subgroups. Summarize the variability in the remaining dimensions and select design values for the key dimensions to accommodate the observed variance for each subgroup.

In summary, total body anthropometric data have been obtained primarily from military populations. Good data from civilian populations is relatively scarce. This is unfortunate since anthropometric data is foundational to the design of clothing, equipment and workspaces for both military and civilian population.

Sex Related Anthropometry

Much of the early work involving sex related anthropometry has been conducted on civilian populations. The previously described series of studies completed by O'Brien, as well as those by the early physical educators, included female populations in their investigations.

Other more recent work in the area of sexual dimorphism has been completed by physical anthropologists. De Villiers (1968) studied the skulls of South African Negroes. Significant sex differences were found. The results indicated that the male skull was larger in 46 out of the 51 dimensions measured. The sexual dimorphism of the skull of the South African Negro was found to be associated mainly with the mandible. Many cranial indices did not distinguish between males and females, but rather sexual differences were reflected in the mandibular indices. The most significant sex differences were: height of the mandibular ramus, breadth of the face, and, to a lesser degree, length and height of the cranial vault. Sex differences in the shape of the skull were found to be less pronounced, and reflective of the infantile characteristics of the female skull.

Factor analysis and discriminant function analysis were employed by Choi and Trotter (1975) in a study of race-sex differences among fetal skeletons. Twenty-one measurements on each of 115 American white and negro fetal skeletons were evaluated. The result indicated that the factor patterns of race-sex groups were similar. The discriminant analysis results showed that differences between the sexes were more marked than that between different races. The authors concluded that possible race and sex differences are less discernible among fetal skeletons than adult skeletons.

Bleibtreu and Taylor (1976) also used multivariate techniques (discriminant function analysis and canonical analysis) to categorize sexual dimorphism and racial groups. Boys and girls of four ethnic groups (N=637) were studied. Previous results in this area have indicated that the "best" metric predictors differ among ethnic groups of the same chronological age. The results of this study indicated that the most important sex discriminators for children were limb joint diameters and dimensions of the head and face (except for the American Indians). Head and face measures were found to be the only important linear measurements.

In the sex related anthropometric literature on military populations in the United States, the investigation reported by Churchill and Bernhardi (1957) on Women's Air Force (WAF) basic trainees served as a supplement to an original report in 1952 on WAF trainees. Based on 61 body dimension measurements, 1830 correlation coefficient pairings were obtained. Regression equations were provided for estimating all other dimensions.

Laubach, McConville, Churchill and White (1977) reported information from the first anthropometric survey of United States Army females in 30 years, involving 128 measurements on body size dimensions, 9 measurements of static strength, and 14 workspace dimensions. The purpose of the study was: to obtain and develop statistical data on female static muscle strength. The ultimate goal was to aid in the design of clothing, protective equipment, and workspace and industrial equipment. The first report in the series described the methodology involved, including landmarks used and procedures involved. The total series of measurements was divided into five separate groups. First, the core series included all 1331 subjects and 69 conventional body size measurements. Each of the remaining four series included approximately one-fourth of the subjects. Subseries 1 included approximately 24 additional conventional measures and several skinfold measurements. Subseries 2 involved 14 workspace measurements, while subseries 3 included 31 head and face measurements. Subseries 4 involved 9 strength measurements.

Another report on the results from an anthropometric survey of Army men and women was provided by McConville, Churchill, Churchill and White (1977). This survey involved 1331 United States Army women and 287 men. Subseries A included measurements of length, breadth and circumference of the head, while subseries C included head and face measurements.

One of the purposes for these extensive surveys is for the design of clothing and equipment for military men and women. Robinette, Churchill and McConville (1979) attempted to document true differences in body size and proportions between USAF men and women in relation to current design or changes in design. The data base used was the 1977 Army survey (McConville, Churchill, Churchill & White, 1977) of females and males. Fifty-six measurements were compared and evaluated with regard to the investigation of two main assumptions: 1) female body size can be represented by scaling down male body dimensions and 2) that males and females of approximately equal body weight and stature are approximately equal in all other proportions. The authors concluded that females cannot be represented accurately by scaling down male proportions and dimensions but that some height/weight samples indicate a degree of similarity between the sexes for selected dimensions. Among the dimensions which were the least comparable were those involving body tissue commonly associated with secondary sex characteristics (such as hip circumference, chest depth, and bicep circumference/flexed). Hand, foot and head dimensions were other subgroups that did not scale down satisfactorily for females or match the corresponding male values.

Alexander and McConville (1979) presented a series of height/weight sizing programs used by designers of protective clothing for USAF men. The sizing values were based on an analysis of 1967 survey data involving 71 dimensions, excluding head, hand and foot measurements. The authors stated that, for the purposes of a general sizing program, the significant proportional differences between the sexes cannot be reconciled by the assumption that females require simply smaller scaled sizes of the same garments worn by men.

The report prepared by McConville, Robinette and White (1981) documented research leading to the development of an integrated male/female sizing system incorporating the body size data of persons of both sexes and taking into account the areas of disproportionality between them. The concepts underlying the development of a sizing system are presented along with the problems. The actual sizing programs developed are presented in a format usable for designers and pattern makers in a separate report (Robinette, Churchill & Tebbetts, 1981).

The approach used in the study (McConville, Robinette & White, 1981) was to identify key sizing variables that exert some level of control on variations of body size and proportionality found between the sexes for dimensions critical to the fit and function of the clothing item being sized. Stature and shoulder circumference were identified as the basis for sizing upper body garments. Crotch height and hip circumference were established as key dimensions for lower body unisex sizing programs. A system of 20 sizes was selected as adequate for both upper and lower body clothing systems.

In summary, literature in the area of sex differences in anthropometric measurements indicates that significant differences do exist between the sexes. These differences must be identified and used in the design of equipment, clothing and workspaces that are to be used by both men and women.

CHAPTER II
PROCEDURES

This chapter contains sample and variable descriptions along with a description of the primary procedures used in the data analysis.

Sample Description

The data for the analysis were acquired from the AFAMRL Anthropometric Data Bank Library: Volume IX, 1977 Survey of Army Women. The data were taken from the anthropometric survey on U.S. Army women conducted during the winter of 1976-77 at four Army bases under the U.S. Army Research and Development Command, Natick, Massachusetts. The results of this survey are reported in the Anthropometry of Women of the U.S. Army-1977 which was published in five reports identified in the bibliography. In addition to information on the anthropometric characteristics of Army female personnel, there is also comparative data on a small sample of U.S. Army male personnel. Only data for white subjects were used in the analysis resulting in 970 female and 191 male data sets. All variables are expressed in millimeters except for weight which is in pounds. Rather than convert weight to metric units, pounds were retained to be consistent with the original data set.

Variable Descriptions

Twenty body dimensions were included in the analysis. These particular dimensions were selected because of their importance in ensuring proper fit of coverall/flightsuit type garments. The variables are identified in Table 1 and defined in Appendix A. Four measures known to be important were not included due to their absence from the sample (radiale-stylion length, acromion-radiale length, biacromial breadth and vertical trunk circumference).

Discriminant Analysis

Previous research has shown that when men and women are matched with regard to height and weight, the two most mismatched dimensions of body size are hip and shoulder circumference (Robinette, et al., 1979). Thus, if one desires to develop an integrated sizing system that adequately fits both genders, at the least, these two body dimensions must be

Table 1. Variables Used in Coverall/Flightsuit Analysis

1. Weight
2. Stature
3. Axilla Height
4. Bustpoint Height
5. Waist Height
6. Buttock Height
7. Sleeve Inseam
8. Sleeve Outseam
9. Shoulder Circumference
10. Sitting Height
11. Knee Height, Sitting
12. Hip Circumference
13. Biceps Circumference, Flexed
14. Waist Circumference
15. Back Arc, Bust
16. Intercye Front
17. Bust Circumference
18. Ankle Circumference
19. Waist Back Length
20. Back Arc, Waist

successfully fit. In addition, one needs to determine if there are other variables important to the adequate fit of flightsuit/coverall-type garments which exhibit differential proportionality across genders. Multiple discriminant analysis was used to identify these variables.

Multiple discriminant analysis is a particular procedure that is part of the general linear model. In the two-group situation (for example, males and females), this procedure is equivalent to multiple regression with a discrete variable having two levels (Kerlinger and Pedhazur; 1973: 377). The general form of the model is:

$$D_{ik} = d_{i1}z_{1k} + d_{i2}z_{2k} + \ldots + d_{ip}z_{pk} \quad \text{(EQ 1)}$$

where D_{ik} is the score for the k-th individual on discriminant function i, the d's are the standardized discriminant coefficients and the z's are the p independent variables in standard form. Given that there are only two groups of individual cases (males or females), there is only one discriminant function and Equation 1 reduces to the form:

$$D_k = d_1z_{1k} + d_2z_{2k} + \ldots + d_pz_{pk} \quad \text{(EQ 2)}$$

Thus, the discriminant function, for the two-group condition is little more than an estimated regression equation, with the only difference being the adjustmer of the data for the group and total sample centroids or means (Nie, et al., 1975: 443).

The following basic assumptions about the statistical nature of the data are important for discriminant analysis:

1. All variables are measured on an interval or ratio scale.

2. Data cases must be assignable into one of two or more mutually exclusive groups.

3. Discriminating variables cannot be linear combinations of one or more other discriminating variables used in the analysis.

4. Equality must exist between the population covariance matrices.

5. Populations from which the samples are drawn are multivariate normal (Klecka, 1980: 8-10).

In this application of discriminant analysis, stepwise inclusion of variables was used to identify body measurements which demonstrate significant disproportionality across gender groups. In addition, the stepwise procedure provides insight as to the relative importance of each measurement compared to all other variables in the model with regard to cross-gender disproportionality. That is, variables which enter the model early are judged more disproportionate than those which enter the model late.

Three specific analyses were performed on the data set in this study. In the first analysis, the two independent variables of stature and weight were forced into the discriminant function first. After this initial step, all remaining variables were allowed to enter the model based upon a statistically significant ($p < 0.05$) Mahalanobis Distance (D^2). In the second analysis, stature and shoulder circumference were forced into the model prior to the stepwise inclusion of all other variables. The inclusion criteria used in the first application was also used in this application. In the third analysis no variables were forced into the model and all variables were allowed to enter based upon the Mahalanobis Distance criteria used in applications one and two.

<u>Regression Analysis</u>

After identifying the most important variables in defining the disproportionality between males and females, the next step was to determine how these variables relate to other variables which are known to be important for proper fit of flightsuit/coverall garments. This was accomplished using multiple regression analysis procedures to estimate three sets of regression equations. Stature and weight, stature and shoulder circumference and the two highest loading variables from the unforced discriminant analysis were used as the independent variable pairs. The dependent variable set for each of the three sets of regression equations consisted of all other variables used in the analysis.

The basic assumptions of multiple regression analysis are:

1. All variables are measures on an interval or ratio scale.

2. Relationships between the independent and dependent variables are linear.

3. Residuals are normally distributed with equal variances across the ranges of the independent variables.

4. Residuals are not correlated with the independent variables in the model.

5. Populations from which the samples are drawn are multivariate normal (Blalock, 1979: 386-389).

All regressions were estimated using two forms of the model. The first form is:

$$Y = a + b_1X_1 + b_2X_2 \quad \text{(EQ 3)}$$

where Y is the dependent variable, the X's are the independent variables and the b's are the estimated partial regression coefficients and the a value is the intercept. This form of the model was estimated separately for males and females. The second form of the model is:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 \quad \text{(EQ 4)}$$

where Y is the dependent variable, X_1 and X_2 are the independent variables, X_3 is a dichotomous discrete variable representing gender with males assigned the value of zero and females assigned the value of one. X_4 and X_5 are cross-product interaction terms between sex and X_1 and X_2, respectively.

While Equation 3 is a predictive model, Equation 4 provides the information necessary to understand in what ways the structural relationships among various body dimensions vary across genders. Equation 5 is Equation 4 rewritten with comparable terms grouped:

$$Y = (a + b_3X_3) + (b_1X_1 + b_4X_4) + (b_2X_2 + b_5X_5) \quad \text{(EQ 5)}$$

Given that X_3 can take the value of 0 or 1 and that X_4 and X_5 are the products of X_3 and X_1, and X_3 and X_2, respectively, when X_3 equals zero Equation 5 reduces to Equation 3 since all product terms of X_3 also becomes zero. Thus, the estimated values of b_3, b_4 and b_5 illustrate the differences between female and male estimated values of a, b_1 and b_2, respectively. Thus, a significant b_3 indicates that the intercepts are different across genders, even after the effects of the independent variables have been accounted for. However, a significant b_4 or b_5 implies a difference between the independent and dependent variables across sexes. It is these differences that are of primary importance in this research.

In estimating both Equations 3 and 4 all relevant independent variables were allowed to enter the models simultaneously. Only the lack of sufficient tolerance precludes a variable from entering the model. In this application, a minimum tolerance level of 0.10 was used.

Equation 3 provides information as to the likely impact that differences between the sexes will have on the design and sizing of properly fitting garments. Male and female results were generated for each dependent variable for the various combinations of independent variables by inputing data values common to both males and females. The output of the male equation was then compared to the outcome of the female equation.

CHAPTER III
RESULTS AND CONCLUSIONS

This chapter contains the results of the analyses and an assessment of the likely impact that the findings will have on the proper design and fit of coverall/flightsuit garments.

Descriptive Statistics

Table 2 contains the means and standard deviations for the total sample as well as for each gender group. All mean values for males are greater than the corresponding measures for females with 19 of the 20 values being statistically greater ($p < 0.05$). However, it is noteworthy that mean hip circumferences for both gender groups are virtually the same (957.3 versus 956.7mm), suggesting some lack of cross-gender proportionality.

Tables 3, 4 and 5 contain the zero-order correlation coefficients for the male, female and total samples, respectively. An examination of these data indicate the presence of considerable multicollinearity. In each of the tables there are 190 cells. The numbers of coefficients significantly ($p < 0.05$) different from zero are 186 (97.9%) for the males and all values for the female and total samples. Overall, 28.9% of the coefficients had magnitudes equal to or greater than 0.71 indicating at least 50% common variance. The general pattern is for the length measures (heights, inseam and outseam) to correlate highly with each other (100% $\geq$ 0.71), while circumference values (except for ankle) correlate highly with one another and with weight (91.1% $\geq$ 0.71).

The presence of multicollinearity within the two blocks of variables noted above (length and circumference) could impact the analysis. With excessive multicollinearity, one of the basic problems of a stepwise procedure is that the order of entry into the model can be unstable across samples which come from the same population (Kachigan, 1982: 228).

The final aspect of the data contained in Tables 3, 4 and 5 is the similarity of results noted between genders. This is important since an assumption of discriminant analysis is that the correlation between any two predictor variables must be similar within the respective populations (Kachigan, 1982: 219).

Table 2. Means and Standard Deviations of All Variables Used in the Coverall/Flightsuit Analysis

Variables	Male Mean	Male Std Dev	Female Mean	Female Std Dev	Difference of Means t-value	Total Mean	Total Std Dev
Weight	1561.03	252.76	1318.05	183.99	15.59*	1358.02	216.48
Stature	1742.81	70.90	1632.29	64.18	21.37*	1650.47	77.10
Axilla Height	1312.28	60.71	1233.21	55.16	17.80*	1246.22	63.29
Bustpoint Height	1271.87	58.00	1182.27	55.48	20.25*	1197.01	65.01
Waist Height	1037.61	59.23	1013.49	50.74	5.83*	1017.46	52.97
Buttock Height	886.19	49.85	831.79	44.01	15.27*	840.74	49.32
Sleeve Inseam	478.77	26.73	446.75	24.39	24.79*	452.02	27.48
Sleeve Outseam	584.10	32.32	534.43	28.17	21.72*	542.60	34.25
Shoulder Circumference	1107.14	63.71	1001.24	52.06	24.71*	1018.67	66.87
Sitting Height	902.69	33.77	858.81	32.58	16.82*	866.03	36.58
Knee Height, Sitting	547.21	30.02	507.52	25.02	19.35*	514.05	29.79
Hip Circumference	957.30	63.74	956.67	61.27	0.13	956.77	61.66
Biceps Circumference, Flexed	310.30	27.62	267.59	22.44	23.37*	274.62	28.22
Waist Circumference	800.39	84.89	707.95	67.11	16.60*	723.16	78.22
Back Arc, Bust	455.66	34.72	420.39	30.62	31.33*	426.19	33.94
Intercye Front	364.95	19.61	330.82	17.09	24.60*	336.43	21.62
Bust Circumference	933.78	68.23	882.96	62.23	10.15*	891.32	65.97
Ankle Circumference	217.51	14.44	208.21	12.32	9.25*	209.74	13.15
Waist Back Length	455.67	31.65	410.49	26.04	21.10*	417.92	31.81
Back Arc, Waist	396.90	44.66	352.98	33.76	15.51*	360.21	39.29
	N = 191		N = 970			N = 1161	

* $p < 0.05$

Note: All measures are in millimeters except weight which is in tenths of pound.

Table 3. Correlation Matrix of Variables Used In Coverall/Flightsuit Analysis, Male Sample

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Weight	1.00																			
2. Stature	0.54	1.00																		
3. Axilla Height	0.49	0.97	1.00																	
4. Bustpoint Height	0.46	0.96	0.97	1.00																
5. Waist Height	0.32	0.86	0.86	0.86	1.00															
6. Buttock Height	0.43	0.90	0.90	0.90	0.87	1.00														
7. Sleeve Inseam	0.34	0.80	0.80	0.81	0.79	0.79	1.00													
8. Sleeve Cutseam	0.47	0.81	0.82	0.81	0.78	0.79	0.92	1.00												
9. Shoulder Circumference	0.86	0.34	0.28	0.27	0.17	0.24	0.23	0.34	1.00											
10. Sitting Height	0.48	0.77	0.69	0.67	0.51	0.56	0.47	0.49	0.32	1.00										
11. Knee Height, Sitting	0.57	0.89	0.89	0.89	0.82	0.84	0.80	0.82	0.37	0.51	1.00									
12. Hip Circumference	0.94	0.44	0.41	0.37	0.27	0.34	0.29	0.43	0.82	0.40	0.50	1.00								
13. Biceps Circumference, Flexed	0.82	0.21	0.14	0.12	0.00	0.12	0.03	0.16	0.83	0.24	0.24	0.77	1.00							
14. Waist Circumference	0.91	0.32	0.29	0.24	0.11	0.24	0.18	0.32	0.77	0.27	0.39	0.90	0.77	1.00						
15. Back Arc, Bust	0.83	0.29	0.25	0.22	0.08	0.21	0.19	0.30	0.83	0.27	0.33	0.79	0.77	0.79	1.00					
16. Intercye Front	0.67	0.43	0.41	0.39	0.29	0.37	0.28	0.36	0.70	0.38	0.44	0.63	0.53	0.54	0.53	1.00				
17. Bust Circumference	0.89	0.29	0.25	0.23	0.10	0.20	0.18	0.31	0.90	0.27	0.35	0.86	0.85	0.86	0.89	0.65	1.00			
18. Ankle Circumference	0.82	0.50	0.46	0.44	0.30	0.40	0.32	0.42	0.67	0.40	0.58	0.75	0.64	0.69	0.63	0.55	0.69	1.00		
19. Waist Back Length	0.52	0.51	0.48	0.43	0.18	0.32	0 31	0.35	0.37	0.57	0.41	0.48	0.36	0.45	0.38	0.35	0.37	0.44	1.00	
20. Back Arc, Waist	0.87	0.30	0.27	0.22	0.09	0.24	0.16	0.30	0.73	0.24	0.38	0.86	0.75	0.96	0.78	0.50	0.82	0.67	0.43	1.00

Note: Critical r value with $p < 0.05$ equals 0.14

Table 4. Correlation Matrix of Variables Used In Coverall/Flightsuit Analysis, Female Sample

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Weight	1.00																			
2. Stature	0.54	1.00																		
3. Axilla Height	0.53	0.97	1.00																	
4. Bustpoint Height	0.47	0.90	0.95	1.00																
5. Waist Height	0.45	0.90	0.90	0.88	1.00															
6. Buttock Height	0.52	0.87	0.89	0.87	0.86	1.00														
7. Sleeve Inseam	0.36	0.79	0.79	0.78	0.79	0.80	1.00													
8. Sleeve Outseam	0.43	0.81	0.80	0.80	0.79	0.79	0.88	1.00												
9. Shoulder Circumference	0.82	0.34	0.32	0.28	0.27	0.35	0.23	0.29	1.00											
10. Sitting Height	0.47	0.81	0.75	0.71	0.64	0.54	0.49	0.53	0.29	1.00										
11. Knee Height, Sitting	0.56	0.88	0.87	0.85	0.86	0.87	0.79	0.82	0.37	0.57	1.00									
12. Hip Circumference	0.90	0.42	0.41	0.35	0.34	0.39	0.25	0.31	0.70	0.39	0.42	1.00								
13. Biceps Circumference, Flexed	0.82	0.21	0.20	0.17	0.14	0.22	0.05	0.13	0.78	0.21	0.25	0.73	1.00							
14. Waist Circumference	0.79	0.22	0.24	0.17	0.07	0.27	0.12	0.17	0.74	0.16	0.26	0.69	0.70	1.00						
15. Back Arc, Bust	0.75	0.22	0.23	0.17	0.17	0.26	0.14	0.20	0.77	0.16	0.27	0.64	0.66	0.73	1.00					
16. Intercye Front	0.55	0.40	0.36	0.35	0.33	0.36	0.30	0.35	0.61	0.33	0.41	0.47	0.40	0.40	0.43	1.00				
17. Bust Circumference	0.81	0.25	0.25	0.18	0.19	0.28	0.14	0.21	0.83	0.20	0.29	0.70	0.73	0.79	0.85	0.50	1.00			
18. Ankle Circumference	0.63	0.37	0.35	0.32	0.32	0.32	0.24	0.27	0.43	0.35	0.40	0.54	0.52	0.35	0.38	0.31	0.37	1.00		
19. Waist Back Length	0.31	0.52	0.49	0.44	0.29	0.36	0.34	0.35	0.18	0.54	0.37	0.22	0.15	0.31	0.14	0.18	0.13	0.20	1.00	
20. Back Arc, Waist	0.76	0.20	0.21	0.15	0.07	0.25	0.11	0.16	0.72	0.14	0.24	0.67	0.68	0.94	0.75	0.38	0.77	0.34	0.30	1.00

Note: Critical r value with $p < 0.05$ equals 0.06

Table 5. Correlation Matrix of Variables Used In Coverall/Flightsuit Analysis, Total Sample

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Weight	1.00																			
2. Stature	0.63	1.00																		
3. Axilla Height	0.61	0.97	1.00																	
4. Bustpoint Height	0.57	0.95	0.96	1.00																
5. Waist Height	0.44	0.83	0.86	0.83	1.00															
6. Buttock Height	0.58	0.89	0.91	0.90	0.85	1.00														
7. Sleeve Inseam	0.46	0.83	0.83	0.83	0.77	0.84	1.00													
8. Sleeve Outseam	0.55	0.86	0.85	0.85	0.75	0.83	0.91	1.00												
9. Shoulder Circumference	0.85	0.54	0.49	0.49	0.29	0.48	0.42	0.52	1.00											
10. Sitting Height	0.56	0.84	0.79	0.77	0.61	0.63	0.58	0.63	0.48	1.00										
11. Knee Height, Sitting	0.64	0.91	0.90	0.89	0.81	0.89	0.83	0.87	0.55	0.65	1.00									
12. Hip Circumference	0.82	0.36	0.36	0.31	0.32	0.35	0.23	0.28	0.59	0.35	0.38	1.00								
13. Biceps Circumference, Flexed	0.85	0.44	0.40	0.40	0.18	0.38	0.27	0.39	0.86	0.40	0.45	0.61	1.00							
14. Waist Circumference	0.85	0.42	0.40	0.37	0.15	0.39	0.30	0.39	0.80	0.34	0.44	0.66	0.78	1.00						
15. Back Arc, Bust	0.80	0.39	0.37	0.34	0.20	0.37	0.29	0.37	0.81	0.32	0.41	0.62	0.74	0.78	1.00					
16. Intercye Front	0.67	0.59	0.54	0.55	0.36	0.50	0.47	0.55	0.75	0.51	0.58	0.41	0.62	0.57	0.56	1.00				
17. Bust Circumference	0.84	0.36	0.35	0.30	0.21	0.35	0.25	0.34	0.82	0.31	0.39	0.70	0.76	0.82	0.87	0.58	1.00			
18. Ankle Circumference	0.70	0.46	0.44	0.42	0.34	0.40	0.33	0.38	0.53	0.43	0.50	0.56	0.58	0.48	0.49	0.44	0.48	1.00		
19. Waist Back Length	0.49	0.65	0.61	0.59	0.31	0.48	0.48	0.53	0.46	0.65	0.54	0.23	0.43	0.49	0.35	0.45	0.30	0.34	1.00	
20. Back Arc, Waist	0.82	0.39	0.37	0.34	0.14	0.37	0.28	0.37	0.77	0.31	0.42	0.64	0.76	0.95	0.79	0.54	0.80	0.47	0.48	1.00

Note: Critical r value with $p < 0.05$ equals 0.06

Discriminant Analyses

Tables 6, 7 and 8 contain the results of the discriminant analyses for the model with no forced variables, the model in which weight and stature are the forced variables and the model in which shoulder circumference and stature are the forced variables, respectively. Each table is divided into two panels. The top panel contains the step in which each variable entered the model, the standardized discriminant coefficient for each variable that met the criteria for entering the model, the overall canonical correlation coefficient and the proportion of correctly classified cases for the model. The second part of the table contains the structural coefficients for each variable indicating its relationship with the estimated discriminant function.

The step entered indicates the relative discriminating strength of each variable after adjusting for all variables that have been previously entered into the model. For example, the results in Table 6 demonstrate that, as a single variable, shoulder circumference has the greatest discriminating strength of all the variables used in the analysis. In addition, once differences in shoulder circumference have been accounted for, hip circumference contributes the next greatest degree of discriminating strength. This process is repeated until all variables meeting the criteria for inclusion in the model are entered.

The standardized discriminant coefficients reflect the relative strength and the direction of the effect of each variable in the model after all variables meeting the inclusion criteria have entered. Thus, while shoulder circumference has the greatest discriminating power by itself, when combined with the other variables in the model it is only the sixth most influential measure. When all variables were entered into the model, stature became the most influential variable.

The sign of the standardized discriminant coefficient indicates which genders values are relatively larger and which are relatively smaller for the respective body dimensions. For example, while males are relatively taller and have relatively greater shoulder circumferences than females, females have proportionately greater waist heights as well as hip and bust circumferences.

Table 6. Discriminant Analysis of Selected Body Measures With Gender as the Dependent Variable and No Variables Forced into the Model

Independent Variables	Step Entered	Standardized Discriminant Coefficient
Stature	3	1.749
Waist Height	4	-1.183
Hip Circumference	2	-0.972
Bust Circumference	7	-0.783
Biceps Circumference, Flexed	5	0.778
Shoulder Circumference	1	0.490
Sleeve Outseam	6	0.386
Buttock Height	11	-0.286
Sitting Height	9	-0.271
Interscye Front	8	0.261
Back Arc, Bust	10	0.242
Waist Circumference	14	0.207
Waist Back Length	13	-0.143
Ankle Circumference	12	-0.106

Number of Males = 191
Number of Females = 970

Canonical Correlation = 0.87

Proportion Correctly Classified by Function

Males = 99.0%
Females = 99.2%

Table 6. Continued

Independent Variables	Structural Coefficient
Shoulder Circumference	0.404
Interscye Front	0.402
Biceps Circumference, Flexed	0.377
Sleeve Outseam	0.355
Stature	0.349
Waist Back Length	0.345
Bustpoint Height	0.314
Knee Height, Sitting	0.302
Axilla Height	0.297
Sleeve Inseam	0.279
Sitting Height	0.276
Waist Circumference	0.271
Back Arc, Waist	0.258
Weight	0.257
Buttock Height	0.249
Back Arc, Bust	0.232
Bust Circumference	0.166
Ankle Circumference	0.151
Waist Height	0.095
Hip Circumference	0.002

Table 7. Discriminant Analysis of Selected Body Measures With Gender as the Dependent Variable and Weight and Stature Forced into the Model

Independent Variables	Step Entered	Standardized Discriminant Coefficient
Stature	1	1.760
Waist Height	4	-1.179
Hip Circumference	3	-0.952
Biceps Circumference, Flexed	5	0.790
Bust Circumference	9	-0.775
Shoulder Circumference	8	0.492
Sleeve Outseam	6	0.386
Buttock Height	12	-0.287
Sitting Height	10	-0.269
Interscye Front	7	0.262
Back Arc, Bust	11	0.245
Waist Circumference	15	0.221
Waist Back Length	14	-0.144
Ankle Circumference	13	-0.098
Weight	2	-0.066

Number of Males = 191
Number of Females = 970

Canonical Correlation = 0.87

Proportion Correctly Classified by Function

Males = 99.0%
Females = 99.2%

Table 7. Continued

Independent Variables	Structural Coefficient
Shoulder Circumference	0.404
Interscye Front	0.402
Biceps Circumference, Flexed	0.377
Sleeve Outseam	0.355
Stature	0.349
Waist Back Length	0.345
Bustpoint Height	0.314
Knee Height, Sitting	0.301
Axilla Height	0.297
Sleeve Inseam	0.279
Sitting Height	0.276
Waist Circumference	0.271
Back Arc, Waist	0.258
Weight	0.255
Buttock Height	0.249
Back Arc, Bust	0.232
Bust Circumference	0.166
Ankle Circumference	0.151
Waist Height	0.095
Hip Circumference	0.002

Table 8. Discriminant Analysis of Selected Body Measures With Gender as the Dependent Variable and Stature and Shoulder Circumference Forced into the Model

Independent Variables	Step Entered	Standardized Discriminant Coefficient
Stature	2	1.749
Waist Height	4	-1.183
Hip Circumference	3	-0.972
Bust Circumference	7	-0.783
Biceps Circumference, Flexed	5	0.778
Shoulder Circumference	1	0.490
Sleeve Outseam	6	0.386
Buttock Height	11	-0.286
Sitting Height	9	-0.271
Interscye Front	8	0.261
Back Arc, Bust	10	0.242
Waist Circumference	14	0.207
Waist Back Length	13	-0.143
Ankle Circumference	12	-0.106

Number of Males = 191
Number of Females = 970

Canonical Correlation = 0.87

Proportion Correctly Classified by Function

Males = 99.0%
Females = 99.2%

Table 8. Continued

Independent Variables	Structural Coefficient
Shoulder Circumference	0.404
Interscye Front	0.402
Biceps Circumference, Flexed	0.377
Sleeve Outseam	0.355
Stature	0.349
Waist Back Length	0.345
Bustpoint Height	0.314
Knee Height, Sitting	0.302
Axilla Height	0.297
Sleeve Inseam	0.279
Sitting Height	0.276
Waist Circumference	0.271
Back Arc, Waist	0.258
Weight	0.257
Buttock Height	0.249
Back Arc, Bust	0.232
Bust Circumference	0.166
Ankle Circumference	0.151
Waist Height	0.095
Hip Circumference	0.002

The canonical correlation coefficient and the proportion correctly classified are measures of the adequacy of the overall discriminant function. As previously noted, when applying discriminant analysis to a two group situation, the procedure becomes analogous to multiple regression with a dichotomous dependent variable. The canonical correlation coefficient, in this case, is nothing more than the multiple regression correlation coefficient.

The proportion correctly classified by the function indicates the percent of all cases in the sample that would have been correctly classified by gender from the function if the actual sexes of the cases were unknown. Obviously, this has little practical application in this study other than as a measure of the power of the function.

The model with no forced variables (Table 6) is the one to which the others are compared. The first four variables to enter the model were shoulder circumference, hip circumference, stature and waist height. In all, 14 variables met the criteria for entry. A noteworthy exception was weight. The probable reason is that the first four variables are measures of circumference and stature which are very important dimensions of weight as evidenced by their linear relationship with weight (Tables 3-5). Overall, the model appears to have excellent discriminating power. Approximately 99 percent of all cases were correctly classified. In addition, the canonical correlation coefficient was 0.87.

Once all variables were entered in the model, the strength of shoulder circumference diminished to sixth place with a standardized discriminant coefficient of 0.490. By comparison, stature, the most important variable in the completed model, has a coefficient of 1.749.

With regard to the sign associated with each variable's standardized discriminant coefficient, women appear to have proportionately greater height measurements (waist, buttock and sitting heights) than males,with the exception of overall stature. Furthermore, the magnitude of the disproportionality is significant. For instance, the coefficient for waist height has the second greatest magnitude of all coefficients (-1.183). In addition to the height measures, females have proportionately larger hip, bust and ankle circumferences (-0.972, -0.783 and -0.106, respectively), as well as greater waist back length (-0.143).

In terms of designing flightsuits and coverall clothing, the lack of inter-gender proportionality between stature and waist height and hip and shoulder circumferences could be important. For example, the results contained in Table 8 suggest that a flight suit designed for a male but worn by a woman of the same height would be too large at the shoulders yet too small at the hips and chest/bust regions. In addition, the waist band would ride too low on the woman's torso.

A review of the structural coefficients in Table 6 indicates that the estimated discriminant function is not highly correlated with any particular variable. The greatest coefficient is 0.404. Thus, less than 20% of the total variance of the discriminant scores is shared by any one variable. Yet as previously noted in the analysis of the zero-order correlation coefficients, there appear to be two dimensions of the body to which a number of variables contribute: length and circumference. A review of the structural coefficients suggests that the estimated discriminant function is some linear combination of these two dimensions with the upper body circumferences being most dominant (shoulder circumference and interscye front) followed by various aspects of body length. Of note is the fact that the two variables most weakly associated with the estimated function are hip circumference and waist height, while shoulder circumference and stature are both moderately associated with the function (0.404 and 0.349, respectively). These relative differences in structural coefficients provide additional support to the earlier suggestion that the two major dimensions of inter-gender disproportionality are differences in proportionality between stature and waist height and between shoulder and hip circumference.

Table 7 contains the results of the discriminant analysis where weight and stature were forced into the model as the first two independent variables. A comparison of these data with the Table 6 results reveals little difference between the two. The two minor differences which do occur are the presence of one additional variable in the model (weight) and a change in the relative strength between two explanatory variables, bust circumference and bicep circumference. With weight forced into the model, the relative strength of bust circumference declines slightly. This is most likely the result of the high correlation between weight and this variable. No discernable differences between the performances of the two models were observed. That is, both have canonical correlation coefficients of 0.87 and the proportion correctly classified by the estimated functions is identical (99.1%). Finally, a comparison of the structural coefficients between the two models indicates a virtual correspondence in the mathematical structure of the two estimated discriminant functions. This is evident by the fact that the structural coefficients (the zero-order correlations coefficients between each independent variable and the estimated factor scores) are identical across the two models.

Table 8 contains the results of the analysis in which the independent variables of stature and shoulder circumference were initially forced into the model. Other than the step entered, the results of Table 8 are identical to those contained in Table 6 and very similar to the results of Table 7.

Overall, the results of the discriminant analyses indicate a considerable divergence from cross-gender anthropometric proportionality. For example, if there was perfect proportionality, only one variable would ever enter the discriminant function since all other variables would be mathematical transformations of that one variable. However, in these models, at least 14 variables entered, with five of the 14 having standardized discriminant coefficients of 0.775 or greater. In addition, the signs associated with each coefficient indicate the direction of the disproportionality. For example, after controlling for stature, women are likely to have a greater waist height and greater hip and bust circumferences while men are likely to have greater shoulder and biceps circumferences.

Bivariate Distribution Plots

Figures 1 through 6 contain gender-specific bivariate distribution plots for 1) weight by stature, 2) shoulder circumference by stature and 3) shoulder circumference by hip circumference. Each plot indicates the location of the male or female sub-samples across the two selected variables. In addition, those subjects incorrectly classified by the function are indicated with an "X".

A cross-gender comparison of the distribution of cases within each bivariate plot conforms to what one would expect given the proportional differences of the four variables used in the plots. That is, for stature, weight and shoulder circumference, the male cases tend to cluster at the larger end of the distribution, while the female cases are concentrated at the smaller end. Hip circumference values are more similar with nearly identical mean values and females exhibiting the largest values.

Due to the relatively small number of male cases in the sample and the fact that few cases were incorrectly classified, caution is warranted in drawing conclusions about differences

Figure 1. Bivariate Distribution Plot of Weight by Stature for Males

Stature (millimeters)

Weight (pounds)	< 1500	1500–1525	1525–1550	1550–1575	1575–1600	1600–1625	1625–1650	1650–1675	1675–1700	1700–1725	1725–1750	1750–1775	1775–1800	> 1800
< 105			1X		1									
105–110														
110–115														
115–120							1		4X	1				
120–125				1	2						2			
125–130					1						2	2	1	
130–135							1	4	3	4	2	1		
135–140					1	2		3	2	1	4	8	1	1
140–145									1	3		3	5	1
145–150							1		5	6	3	2	2	1
150–155							2	1		2	5	2	2	4
155–160							2	1	1		4	1		2
160–165						1			1		2	6	1	2
165–170									2		2	1	2	1
170–175								1		1	2			2
> 175							1		2	2	6	6	7	21

Note: Each "X" represents one incorrectly classified case.

Figure 2. Bivariate Distribution Plot of Weight by Stature for Females

Stature (millimeters)

Weight (pounds)	<1500	1500–1525	1525–1550	1550–1575	1575–1600	1600–1625	1625–1650	1650–1675	1675–1700	1700–1725	1725–1750	1750–1775	1775–1800	>1800
<105	6	8	12	8	9	5	6	1						
105–110	1	2	7	3	11	7	6	1						
110–115	1	2	9	15	13	10	10	5	8	1				
115–120	4		4	14	14	8	12	12	4	3				
120–125	3	3	9	11	19	21	21	11	7	3X	1			
125–130	1	4	6	11	16	19	12	17	9	5	1	2		
130–135			7	9	20	19	17	18	10	3	1	1		
135–140		2		5	15	18	17	21	13	9	5	1		
140–145			3	4	7	18	10	13	7X	4	7	3X	2	2
145–150			1	1	4	9	12	17	11	6	7			
150–155				2	1	3	9	11X	5	10	4	1	1	3
155–160					5	2	4	8	5	8X	5	2	1X	1X
160–165					1		5	4		7	4	5	1	
165–170						1		1		1	3	1		1
170–175							2		1	2	1			1
>175						4		1	5	4	3X	2	1	

Note: Each "X" represents one incorrectly classified case.

Figure 3. Bivariate Distribution Plot of Shoulder Circumference by Stature for Males

Stature (millimeters) × Shoulder Circumference (millimeters)

Shoulder Circumference (mm) \ Stature (mm)	<1500	1500–1525	1525–1550	1550–1575	1575–1600	1600–1625	1625–1650	1650–1675	1675–1700	1700–1725	1725–1750	1750–1775	1775–1800	>1800
<900														
900–925														
925–950														
950–975			1X											
975–1000					1				3X		1	1		
1000–1025										3	3	2	1	
1025–1050				1			2	1	4	2	1	4	1	2
1050–1075					2		2	2	2	7	3	4	5	3
1075–1100						1		4	3	2	7	5	1	3
1100–1125					2	1	1		5	3	6	6	3	2
1125–1150						1	1	2	1	1	6	3	4	7
1150–1175								1	2		2	2	4	7
>1175							2		1	2	5	5	2	11

Note: Each "X" represents one incorrectly classified case.

Figure 4. Bivariate Distribution Plot of Shoulder Circumference by Stature for Females

Stature (millimeters)

Shoulder Circumference (millimeters)	< 1500	1500–1525	1525–1550	1550–1575	1575–1600	1600–1625	1625–1650	1650–1675	1675–1700	1700–1725	1725–1750	1750–1775	1775–1800	> 1800
< 900		1	3	5	5	2	2	2						
900–925	3	3	5	1	11	4	7	2	1	1				
925–950	4	45	11	17	3	17	17	6	11	2		2		
950–975	3	3	11	20	27	26	24	18	15	6	1	1		2
975–1000	2	5	15	16	20	30	19	27	13	12X	7	5		1
1000–1025	1	3	5	11	23	37	28	37	17	12	8	1	2	1
1025–1050	3	2	3	5	21	10	20	23	11	15	15	6X	1	
1050–1075			4	5	10	10	12	13	8X	8X	5	1	1	2
1075–1100			1	2	1	4	8	9	6	6	4	4		1
1100–1125				1	4	2	5	4X	2	3	1	1		1X
1125–1150							1			1			1X	
1150–1175						1			1			1	1	
> 1175						1					1X			

Note: Each "X" represents one incorrectly classified case.

Figure 5. Bivariate Distribution Plot of Shoulder Circumference by Hip Circumference for Males

Hip Circumference (millimeters)

Shoulder Circumference (millimeters)	< 875	875–900	900–925	925–950	950–975	975–1000	1000–1025	1025–1050	1050–1075	1075–1100	1100–1125	1125–1150	1150–1175	> 1175
< 900														
900–925														
925–950														
950–975	1X													
975–1000	4X	1		1										
1000–1025	1	5	2	1										
1025–1050	2	5	8	2	1									
1050–1075	1	5	13	5	4	2								
1075–1100	1	7	3	7	5	2	1							
1100–1125		3	7	6	7	4	1		1					
1125–1150		1	3	6	6	4	4	1		1				
1150–1175					3	4	5	4	2					
> 1175					1	4	3	1	9	6	1	3		

Note: Each "X" represents one incorrectly classified case.

Figure 6. Bivariate Distribution Plot of Shoulder Circumference by Hip Circumference for Females

Hip Circumference (millimeters)

Shoulder Circumference (millimeters)	< 875	875–900	900–925	925–950	950–975	975–1000	1000–1025	1025–1050	1050–1075	1075–1100	1100–1125	1125–1150	1150–1175	> 1175
< 900	16	2	2											
900–925	17	11	3	5		2								
925–950	19	34	20	21	7		2	1						
950–975	18	22	45	34	23	6	6		3					
975–1000	7	16	32X	39	34	23	16	3	2					
1000–1025	1	3	19	31	54	38	22	13	4	1				
1025–1050	1	1	5	17X	36	35	18	14	2	6				
1050–1075	1	1	3	4	13	19X	14X	10	6	4	3	1		
1075–1100				2	2	8	11	5	8	1	1			
1100–1125					3	6XX	2	6	1	2		1	1	2
1125–1150					1X			1	1					
1150–1175							1	1			1			1
> 1175										1	1X			

Note: Each "X" represents one incorrectly classified case.

between the distributions of incorrectly classified cases across genders. However, if conclusions are reached, it appears that the incorrectly classified males represent more extreme cases than do the incorrectly classified females. This is evident by the fact that the misclassified females are located more within the overall female distribution than are the misclassified males. Furthermore, this relationship is consistent across the three sets of plots. Overall, only 2 (1.0%) of the 190 males and 8 (0.8%) of the 970 females were misclassified.

Regression Analyses

Thus far the analyses have illustrated a pronounced statistical deviation from anthropometric proportionality across genders. In addition, those variables most responsible for that lack of proportionality have been identified, i.e., stature, waist height, shoulder circumference and hip circumference. However, to provide the designer with information that can be used to improve the design and fit of coverall/flightsuit garments, more detail regarding the anthropometric differences between males and females must be documented. To obtain this necessary detail, regression analyses were employed. The results of these analyses are presented in Tables 9 through 13.

Tables 9, 10 and 12 contain the results of the regression analyses which estimate the relationships between the three different sets of two independent variables (stature and weight, stature and shoulder circumference, and shoulder circumference and hip circumference) and all other variables used in the analysis. In addition to the above sets of independent measures, the dummy variable sex (with males coded zero and females coded one) was also used in the estimations as were the cross-product interactions between sex and each of the two independent measures. The dummy variable sex and the two cross-product interactions were included in the analyses to provide insight as to the nature of the lack of proportionality. While significant estimated coefficients for the cross-product interactions indicate a lack of proportionality, a significant coefficient for the variable sex does not. Instead, a significant coefficient for sex only implies that the two genders differ with regard to the intercept even after controlling for the two independent measures. A complete listing of all male and female regression equations for all models is given in Tables 15-17, Appendix B.

Table 9. Regression Analysis of Coverall/Flightsuit Measures using Stature and Weight as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		WEIGHT		SEX		SEX-STATURE		SEX-WEIGHT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
Axilla Height	0.954	8082.03 *	D		-0.002	-0.86	12.927	10.16 *	64.526	115.56 *	D	
Bustpoint Height	0.923	4630.14 *	D		-0.018	-5.54 *	-1.336	-0.79	64.590	86.67 *	D	
Waist Height	0.813	1685.37 *	D		-0.025	-6.22 *	53.433	24.81 *	58.390	61.79 *	D	
Buttock Height	0.812	1672.83 *	D		0.007	1.75	13.030	6.48 *	45.920	52.03 *	D	
Sleeve Inseam	0.705	923.62 *	D		-0.014	-5.35 *	0.347	0.25	24.989	40.53 *	D	
Sleeve Outseam	0.763	1243.00 *	D		-0.002	-0.52	-9.859	-6.28 *	28.038	40.69 *	D	
Shoulder Circumference	0.809	1640.61 *	D		0.252	48.52 *	-58.782	-21.38 *	-9.812	-8.14 *	D	
Sitting Height	0.721	1000.82 *	D		0.007	2.02 *	1.328	0.73	30.361	38.07 *	D	
Knee Height, Sitting	0.842	2054.52 *	D		0.015	7.03 *	-0.013	-0.01	25.166	51.41 *	D	
Hip Circumference	0.823	1797.68 *	D		0.299	64.85 *	62.337	25.53 *	-6.737	-6.29 *	D	
Biceps Circ., Flexed	0.830	1895.05 *	D		0.119	57.55 *	-26.803	-24.51 *	-9.043	-18.85 *	D	
Waist Circumference	0.777	1350.80 *	D		0.346	52.83 *	-41.359	-11.91 *	-23.092	-15.15 *	D	
Back Arc, Bust	0.685	842.71 *	D		0.143	42.42 *	-13.627	-7.60 *	-9.221	-11.73 *	D	
Interscye Front	0.572	517.25 *	D		0.045	17.94 *	-19.146	-14.38 *	2.815	4.82 *	D	
Bust Circumference	0.754	1188.33 *	D		0.311	53.61 *	-3.108	-101.00	-19.507	-14.45 *	D	
Ankle Circumference	0.492	375.68 *	D		0.042	24.97 *	1.944	2.20 *	0.798	2.06 *	D	
Waist Back Length	0.478	355.11 *	D		0.015	3.67 *	-20.437	-9.45 *	14.721	15.52 *	D	
Back Arc, Waist	0.737	1083.56 *	D		0.172	47.96 *	-19.356	-10.20 *	-11.980	-14.39 *	D	

* $p < 0.05$

D : did not enter model due to insufficient tolerance

Table 10. Regression Analysis of Coverall/Flightsuit Measures using Stature and Shoulder Circumference as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		SHOULDER CIRCUMFERENCE		SEX		SEX-STATURE		SEX-SHOULDER CIRCUMFERENCE	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
Weight	0.806	1605.58 *	0.872	19.11 *	2.560	48.69 *	D		D		0.122	13.51 *
Axilla Height	0.955	8141.57 *	0.839	130.13 *	-0.027	-3.68 *	D		D		0.011	8.54 *
Bustpoint Height	0.922	4601.47 *	0.824	95.07 *	-0.048	-4.85 *	D		D		-0.004	-2.10 *
Waist Height	0.812	1667.64 *	0.734	66.73 *	-0.099	-7.83 *	D		D		0.047	21.39 *
Buttock Height	0.813	1682.57 *	0.599	58.66 *	0.019	1.68	D		D		0.140	6.96 *
Sleeve Inseam	0.699	897.89 *	0.307	42.48 *	-0.020	-2.40 *	D		D		-0.000	-0.18
Sleeve Outseam	0.763	1246.25 *	0.357	44.78 *	0.019	2.06 *	D		D		-0.008	-5.22 *
Sitting Height	0.721	999.02 *	0.400	43.23 *	0.016	1.53	D		D		0.002	1.11
Knee Height, Sitting	0.839	2011.01 *	0.340	59.40 *	0.035	5.35 *	D		D		0.002	1.40
Hip Circumference	0.567	507.68 *	0.185	9.55 *	0.684	30.59 *	D		D		0.092	23.91 *
Biceps Circ., Flexed	0.749	1153.49 *	-0.023	-3.44 *	0.358	45.89 *	D		D		-0.007	-5.56 *
Waist Circumference	0.642	695.76 *	-0.011	-0.49	0.967	37.54 *	D		D		0.009	1.92
Back Arc, Bust	0.677	810.21 *	0.017	-1.80	0.454	42.69 *	D		D		0.011	5.98 *
Interscye Front	0.632	664.75 *	0.059	9.41 *	0.186	25.70 *	D		D		-0.008	-6.42 *
Bust Circumference	0.739	1094.22 *	-0.284	-1.76	0.963	51.80 *	D		D		0.048	14.98 *
Ankle Circumference	0.346	205.12 *	0.051	10.11 *	0.088	14.97 *	D		D		0.005	5.44 *
Waist Back Length	0.476	351.89 *	0.207	18.76 *	0.042	3.27 *	D		D		-0.018	-8.35 *
Back Arc, Waist	0.608	601.20 *	-0.013	-1.10	0.480	35.44 *	D		D		0.005	2.29 *

* $p < 0.05$
D : did not enter model due to insufficient tolerance

Table 11. Regression Coefficient of Sex-Shoulder Circumference as a Percent of the Regression Coefficient of Shoulder Circumference

DEPENDENT VARIABLES	SHOULDER CIRCUMFERENCE		SEX-SHOULDER CIRCUMFERENCE		SEX-SHOULDER CIRCUMFERENCE AS A PERCENT OF SHOULDER CIRCUMFERENCE
	Coeff.	T-Ratio	Coeff.	T-Ratio	
Weight	2.560	48.69 *	0.122	13.51 *	4.77
Axilla Height	-0.027	-3.68 *	0.011	8.54 *	-39.86
Bustpoint Height	-0.048	-4.85 *	-0.004	-2.10 *	7.46
Waist Height	-0.099	-7.83 *	0.047	21.39 *	-46.99
Buttock Height	0.019	1.66	0.140	6.96 *	722.23
Sleeve Inseam	-0.020	2.40 *	-0.000	-0.18	1.25
Sleeve Outseam	0.019	2.06 *	-0.008	-5.22 *	-43.58
Sitting Height	0.016	1.53	0.002	1.11	12.50
Knee Height, Sitting	0.035	5.35 *	0.002	1.40	4.50
Hip Circumference	0.684	30.59 *	0.092	23.91 *	13.43
Biceps Circ., Flexed	0.358	45.89 *	-0.007	-5.56 *	-2.08
Waist Circumference	0.967	37.54 *	0.009	1.92	0.88
Back Arc, Bust	0.454	42.69 *	0.011	5.98 *	2.41
Interscye Front	0.186	25.70 *	-0.008	-6.42 *	-4.29
Bust Circumference	0.963	51.80 *	0.048	14.98 *	4.97
Ankle Circumference	0.088	14.97 *	0.005	5.44 *	6.25
Waist Back Length	0.042	3.27 *	-0.018	-8.35 *	-43.83
Back Arc, Waist	0.480	35.44 *	0.005	2.29 *	1.11

* $p < 0.05$

Table 12. Regression Analysis of Coverall/Flightsuit Measures using Shoulder and Hip Circumference as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		SHOULDER CIRCUMFERENCE		HIP CIRCUMFERENCE		SEX		SEX-SHOULDER CIRCUMFERENCE		SEX-HIP CIRCUMFERENCE	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
Weight	0.903	3581.94 *	1.299	23.98 *	2.027	41.77 *	D		D		-0.112	-13.62 *
Axilla Height	0.346	205.86 *	0.031	0.75	0.352	10.81 *	D		D		-0.079	-12.69 *
Bustpoint Height	0.356	214.60 *	0.032	0.77	0.304	9.61 *	D		D		-0.090	-14.15 *
Waist Height	0.133	60.11 *	0.016	0.41	0.271	7.72 *	D		D		-0.023	-3.84 *
Buttock Height	0.293	161.58 *	0.090	2.72 *	0.224	8.34 *	D		D		-0.046	-9.22 *
Sleeve Inseam	0.244	125.59 *	0.040	2.09 *	0.078	5.68 *	D		D		-0.029	-9.98 *
Sleeve Outseam	0.374	232.39 *	0.059	2.74 *	0.116	7.61 *	D		D		-0.045	-13.80 *
Stature	0.413	272.60 *	0.077	1.63	0.397	10.90 *	D		D		-0.106	-14.85 *
Sitting Height	0.323	185.78 *	0.013	0.56	0.202	10.49 *	D		D		-0.044	-12.07 *
Knee Height, Sitting	0.396	254.17 *	0.046	2.46 *	0.154	10.80 *	D		D		-0.038	-12.97 *
Biceps Circ., Flexed	0.785	1409.78 *	0.232	22.05 *	0.132	14.88 *	D		D		-0.019	-11.90 *
Waist Circumference	0.708	937.74 *	0.565	16.68 *	0.468	15.79 *	D		D		-0.035	-6.81 *
Back Arc, Bust	0.694	876.23 *	0.365	24.22 *	0.108	7.40 *	D		D		0.003	1.51
Interscye Front	0.607	597.87 *	0.180	16.53 *	0.027	4.04 *	D		D		-0.018	-9.62 *
Bust Circumference	0.762	1239.75 *	0.784	30.39 *	0.245	8.91 *	D		D		0.033	8.59 *
Ankle Circumference	0.396	254.26 *	0.027	3.31 *	0.101	14.01 *	D		D		-0.007	-5.54 *
Waist Back Length	0.337	197.57 *	0.023	1.11	0.100	7.25 *	D		D		-0.045	-14.34 *
Back Arc, Waist	0.667	774.18 *	0.286	15.73 *	0.223	13.95 *	D		D		-0.015	-5.37 *

* $p < 0.05$

D : did not enter model due to insufficient tolerance

Table 13. Regression Coefficient of Sex-Hip Circumference as a Percent of the Regression Coefficient of Hip Circumference

DEPENDENT VARIABLES	HIP CIRCUMFERENCE		SEX-HIP CIRCUMFERENCE		SEX-HIP CIRCUMFERENCE AS A PERCENT OF HIP CIRCUMFERENCE
	Coeff.	T-Ratio	Coeff.	T-Ratio	
Weight	2.144	41.77 *	-0.112	-13.62 *	-5.20
Axilla Height	0.420	10.88 *	-0.079	-12.69 *	-18.73
Bustpoint Height	0.381	9.61 *	-0.090	-14.15 *	-23.50
Waist Height	0.289	7.72 *	-0.023	-3.84 *	-7.94
Buttock Height	0.263	8.34 *	-0.046	-9.22 *	-17.64
Sleeve Inseam	0.103	5.68 *	-0.029	-9.98 *	-28.02
Sleeve Outseam	0.157	7.61 *	-0.045	-13.80 *	-28.91
Stature	0.489	10.90 *	-0.106	-14.85 *	-21.74
Sitting Height	0.240	10.49 *	-0.044	-12.07 *	-18.36
Knee Height, Sitting	0.186	10.60 *	-0.036	-12.97 *	-19.52
Biceps Circ., Flexed	0.148	14.89 *	-0.019	-11.90 *	-12.76
Waist Circumference	0.507	15.79 *	-0.035	-6.81 *	-6.88
Back Arc, Bust	0.106	7.40 *	0.003	1.51	3.26
Interscye Front	0.042	4.04 *	-0.016	-9.62 *	-37.99
Bust Circumference	0.218	8.91 *	0.033	8.59 *	15.39
Ankle Circumference	0.109	14.01 *	-0.007	-5.54 *	-6.31
Waist Back Length	0.143	7.25 *	-0.045	-14.34 *	-31.56
Back Arc, Waist	0.240	13.95 *	-0.015	-5 37 *	-6.15

* $p < 0.05$

Tables 11 and 13 are included in the analysis to better understand the extent of disproportionality across gender groups. In these tables, the estimated coefficients of the cross-product interactions are compared to the estimated coefficents of the measurement that is used in conjunction with sex to produce the cross-product variable. The comparisons of these coefficients illustrate the nature of the disproportionality between the two genders.

Table 9 contains the regression results in which stature and weight were used as independent variables. All models are significant, with 14 of the 18 models having coefficients of determination (R^2) in excess of 0.700. Neither stature nor the interaction of sex and weight attained sufficient tolerance levels to enter the models. However, the sex-stature interaction term was found to be significant for all 18 models. Weight was found to be significant for all variable models except axilla and buttock heights and sleeve outseam. Sex was not significant for bust, sitting and knee heights as well as sleeve inseam and bust circumference.

In terms of the direction of associations as measured by the significant regression coefficients, weight was found to be negatively correlated with the height and length measures with the exception of sitting and knee heights, and waist back length. However, all circumference and arc variables are positively associated with the independent variable weight.

With regard to the dichotomous variable sex (where males are coded zero and females are coded one), there are significant positive associations between this measure and axilla, waist and buttock heights and hip and ankle circumferences. On the other hand negative association exists between sex and shoulder, bicep and waist circumferences, sleeve outseam, back/bust, back/waist and interscye arcs and waist back length. The significant aspect of these signs in terms of anthropometric proportionality and the sex variable is that there appears to be a lack of consistency across types of measures. For example, sex is associated both positively and negatively with height and length measures as well as with circumferences and arcs.

The final variable in Table 9 to be discussed is the cross-product interaction between sex and stature. As noted earlier, this variable was significant for all models. In addition, the pattern of the signs of the coefficients illustrates the manner in which the lack of cross-gender proportionality affects male and female anthropometry. For example, males appear larger throughout the torso than females, once stature is controlled. Thus, a flight suit or coverall garment that is designed using a unisex model where stature and weight are the driving variables for estimating other important body dimensions is likely to fit too loosely on women and too tight on men.

Tables 10 and 12 contain the results of the regression analyses with stature and shoulder circumference and shoulder and hip circumferences as the independent variables, respectively. Of interest in both tables is the fact the sex never enters the models due to a lack of sufficient tolerance. Thus, in these two analyses gender differences have been accounted for by the independent variables and/or the cross-product interaction terms.

Stature, shoulder circumference, and sex-shoulder circumference interaction are the only terms to enter the estimated regression equations for the model using stature and shoulder circumference as the independent variables (Table 11). While all equations are significant, not all variables contribute significantly. Stature, shoulder circumference and sex-shoulder circumference interaction are significant for 14, 16 and 15 equations respectively. Stature is positively associated with all significant variables except biceps circumference, while shoulder circumference is positively associated with all variables other than axilla, bust and waist heights and sleeve inseam. The direction of association between the interaction term and the dependent variables is somewhat more complicated. Those estimated interaction coefficients that have negative signs include both height and length measures as well as circumference and arc dimensions. Specifically, bust height, sleeve outseam, biceps circumference, interscye front and waist back length all exhibit a negative sign.

Table 11 contains information as to the extent of gender differences in the relational calculus between shoulder circumference and the dependent variables. The far right column of the table depicts the coefficients for the cross-product as a percent of the coefficients for the variable shoulder circumference. In seven of the 18 models (axilla, waist, buttock, and sitting heights; sleeve outseam; waist back length; and hip circumference), the structural relationships between shoulder circumference and the independent variables for total sample and females differ by more than 10%. Furthermore, five of the seven differences are 40% or more. In one model, buttock height, the difference is more than 700%. However, in this particular model the coefficient between shoulder circumference and the dependent variable is statistically insignificant.

The signs associated with each of the coefficients for the cross-product interactions is also noteworthy. Once shoulder circumference and stature are controlled, women appear to have significantly greater weight; axilla, waist, and buttock heights; hip, bust, and ankle circumferences; as well as waist and bust back arcs. However, they have smaller bust heights, sleeve outseams, flexed biceps circumferences, interscye front, and waist back lengths.

Table 12 contains the regression analyses where shoulder and hip circumferences are used as the dependent variables. In these models the dichotomous gender variable and the cross-product interaction between sex and shoulder circumference fail to meet minimum tolerance levels and are excluded.

In Table 12 all 18 models are significant. However, only four of the models have coefficients of determination of 0.700 or greater. The estimated coefficients for hip circumference are significant for all 18 models, while the coefficients for shoulder circumference are significant for only 12. The coefficients for the hip circumference-sex interaction are significant for 17 models.

The consistency of the signs of the estimated regression coefficients is notable. In all models both shoulder and hip circumferences are positively related to the dependent measure, while the signs of the coefficients for the sex-hip circumference interaction are all negative with the exception of bust circumference.

Table 13 contains information illustrating the manner in which the structural coefficients between hip circumference and the independent variables vary across genders. There are 13 models where the estimated coefficients for the sex-hip circumference interaction are 10% or more of the corresponding coefficient for hip circumference. In 12 of the 13 models, the female coefficients are less than those for the total sample. Only in the model where bust circumference is the dependent variable is the estimated coefficient for women greater than that for the total sample, once shoulder circumference is controlled.

Thus far, the results from the regression analyses indicate that stature and weight are the best predictor variables of the anthropometric measures used in the analyses. This is evident by the greater proportion of models with coefficients of determination which exceed 0.700. However, the analyses also demonstrate a considerable lack of proportionality between stature and the dependent variables. In fact, stature fails to enter the models and only impacts the cross-product interaction with sex.

The models which use stature and shoulder circumference as predictor variables are slightly less adequate in their ability to account for variation in the dependent variables than those estimated using weight and stature. For example, while 14 of the weight and stature models had R^2 values of 0.700 or greater, only 10 of the 18 coefficients of determination associated with the shoulder circumference and stature models attained this magnitude. In this latter set of models shoulder circumference produces the lack of proportionality. The most interesting lack of proportionality occurs with regard to the prediction of height measures. In general, the analysis indicates that a unisex model using shoulder circumference and stature as predictor variables is likely to underestimate axilla, waist, and buttock heights for females, yet overestimate bustpoint height.

The final set of prediction models observed included hip and shoulder circumferences as the predictor variables. This set was characterized by having the lowest R^2 values with only four models achieving coefficients of determination of 0.700 or greater. Furthermore, hip circumference was the measure that interacted with sex. Yet, the pattern of interaction was considerably more consistent than that observed in the previous two sets of models. That is, the statistically significant estimated coefficients for the cross-product interaction of sex and hip circumference were all signed negative, with the exception of bust circumference.

Table 14 contains a summary of the differences in the output of the male and female specific regression models. A more detailed listing of the differences is provided in Tables 18 through 20, Appendix C. Three sets of sex specific prediction equations were used. The first set used stature and weight as predictor variables, the second used stature and shoulder circumference, while the third used hip and shoulder circumferences. Input data for these variables were obtained by selecting values common to both the male and female sub-samples. After estimating values for the dependent variables, corresponding female values were subtracted from the male estimates. Table 14 contains the extreme values obtained for each dependent variable.

When stature and weight were used as predictor variables, the greatest differences occurred for hip and shoulder circumferences and waist height. Other variables with differences in excess of 30mm include axilla and buttock heights, waist back length, and waist and flexed

Table 14. Maximum and Minimum Differences Between Male and Female Estimated Values From Separate Regression Models

Dependent Variables	Independent Variables: Stature & Weight		Stature & Shoulder Circumference		Hip & Shoulder Circumference	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Stature	-------	-------	-------	-------	142.94	75.38
Weight	-------	-------	-83.80	-191.29	262.55	16.94
Shoulder Circumference	67.08	50.11	-------	-------	-------	-------
Hip Circumference	-51.04	-177.37	-102.43	-95.38	-------	-------
Axilla Height	-8.58	-21.47	-17.87	-17.87	120.18	43.92
Waist Height	-40.92	-78.38	-62.67	-41.81	-12.68	-65.46
Bustpoint/Chest Height	3.39	-0.81	7.37	1.61	116.44	62.87
Buttock Height	-18.21	-54.37	-2.57	-33.94	76.74	18.09
Sitting Height	9.62	-6.38	7.01	-7.05	41.01	37.79
Knee Height, Sitting	1.55	-3.54	0.04	-5.98	64.08	14.78
Sleeve Inseam	0.28	-1.71	0.38	0.02	41.01	18.27
Sleeve Outseam	13.52	7.86	11.45	6.13	69.50	26.70
Waist Back Length	46.33	7.20	31.71	10.02	70.68	26.98
Waist Circumference	46.18	38.82	-1.17	-25.09	166.03	-55.13
Bust/Chest Circumference	14.23	-15.81	-49.30	-55.91	32.47	-13.86
Ankle Circumference	0.35	-3.87	-1.36	-11.43	13.13	2.86
Bicep Circumference, Flexed	31.77	20.44	12.45	4.96	23.15	11.97
Interscye Front	22.47	17.51	10.33	7.03	19.11	12.85
Back Arc, Bust/Chest	17.85	5.71	-9.91	-15.66	12.54	-14.13
Back Arc, Waist	24.71	16.50	-0.62	-15.17	84.18	-32.30

biceps circumferences. Axilla, waist and buttock heights and hip circumference are the only measures where the female model consistently predicts values greater than the male equations.

In the models which used stature and shoulder circumference as the predictor variables, five variables exhibit differences greater than 30mm. These include hip and bust/chest circumferences, waist and buttock heights, and waist back length, with hip circumference, waist height and bust/chest circumference having the greatest differences. The predicted values for females were consistently greater than those for males in 10 of the 18 models.

The final set of models employed hip and shoulder circumferences to predict the independent variables. In these models the greatest differences occurred in stature, axilla height, bustpoint/chest height, and waist circumference. All but four measures (ankle and flexed biceps circumferences, interscye front, and back arc, bust) exhibited differences greater than 30mm. In addition, waist height was the only variable for which the female estimated values always exceed the male values.

In summary, none of the three sets of models appear to 1) do an adequate job of estimating the values of the independent variables and 2) effectively compensate for the absence of cross-gender anthropometric proportionality. In the two sets of models where stature and weight and stature and shoulder circumference were used as predictor variables, the presence of disproportionality is evident by the relatively large number of measures in which the estimated female values exceed the corresponding male values. This presence implies that "down-sizing" of coverall type equipment designed and sized for men is inappropriate for female personnel. However, even though the set of models which rely on hip and shoulder circumferences as predictor variables partially alleviates this problem of disproportionality, the results indicate a general lack of "goodness of fit" of the estimated regression equations to the actual data as evidenced by the relatively low values of R^2 for the models.

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APPENDIX A

VARIABLE DESCRIPTIONS

The variable descriptions included in this Appendix are modified from figures shown in Tebbetts, Churchill & McConville (1980).

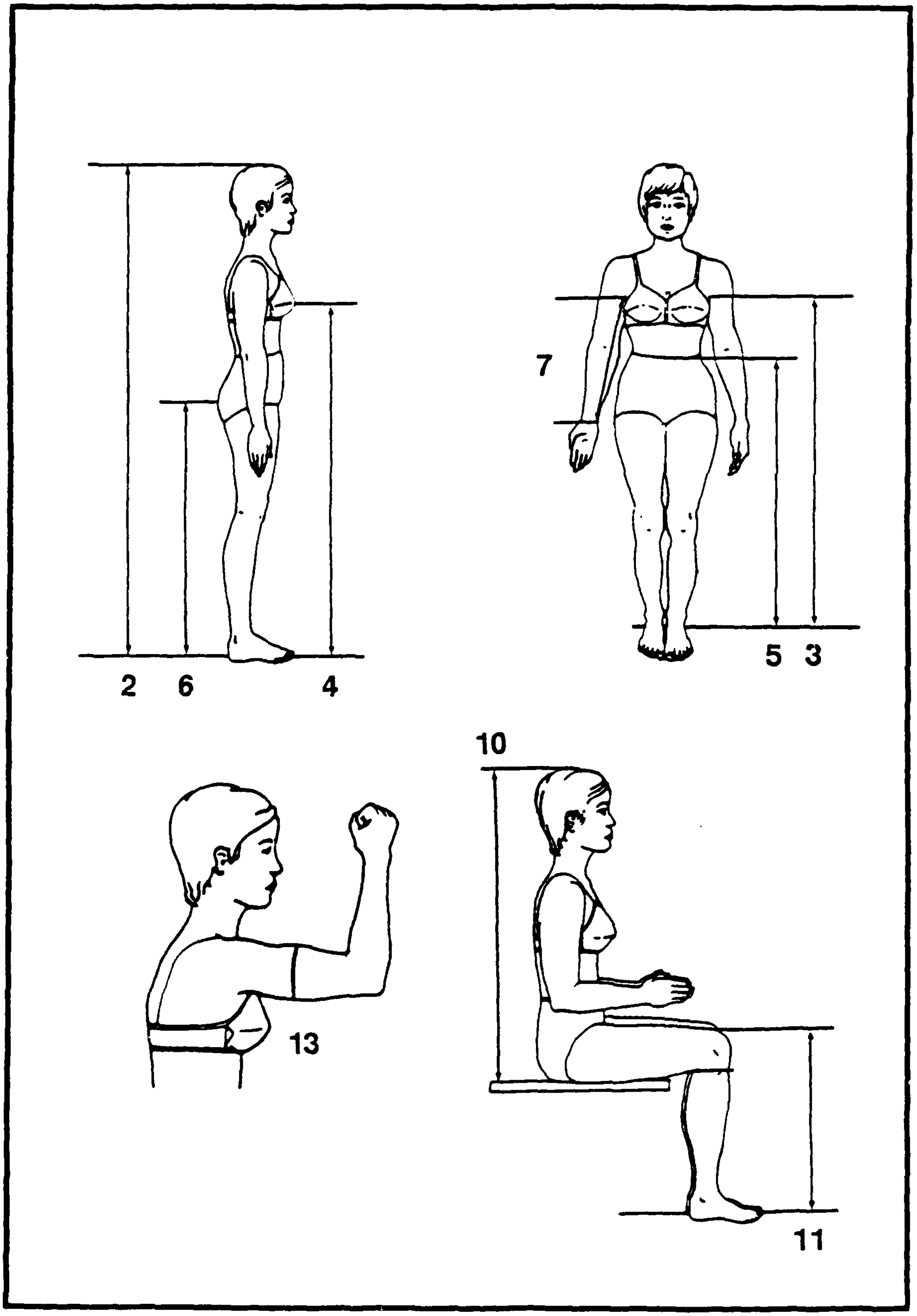

Figure 7. Variable Descriptions used for Coverall/Flightsuit Analysis

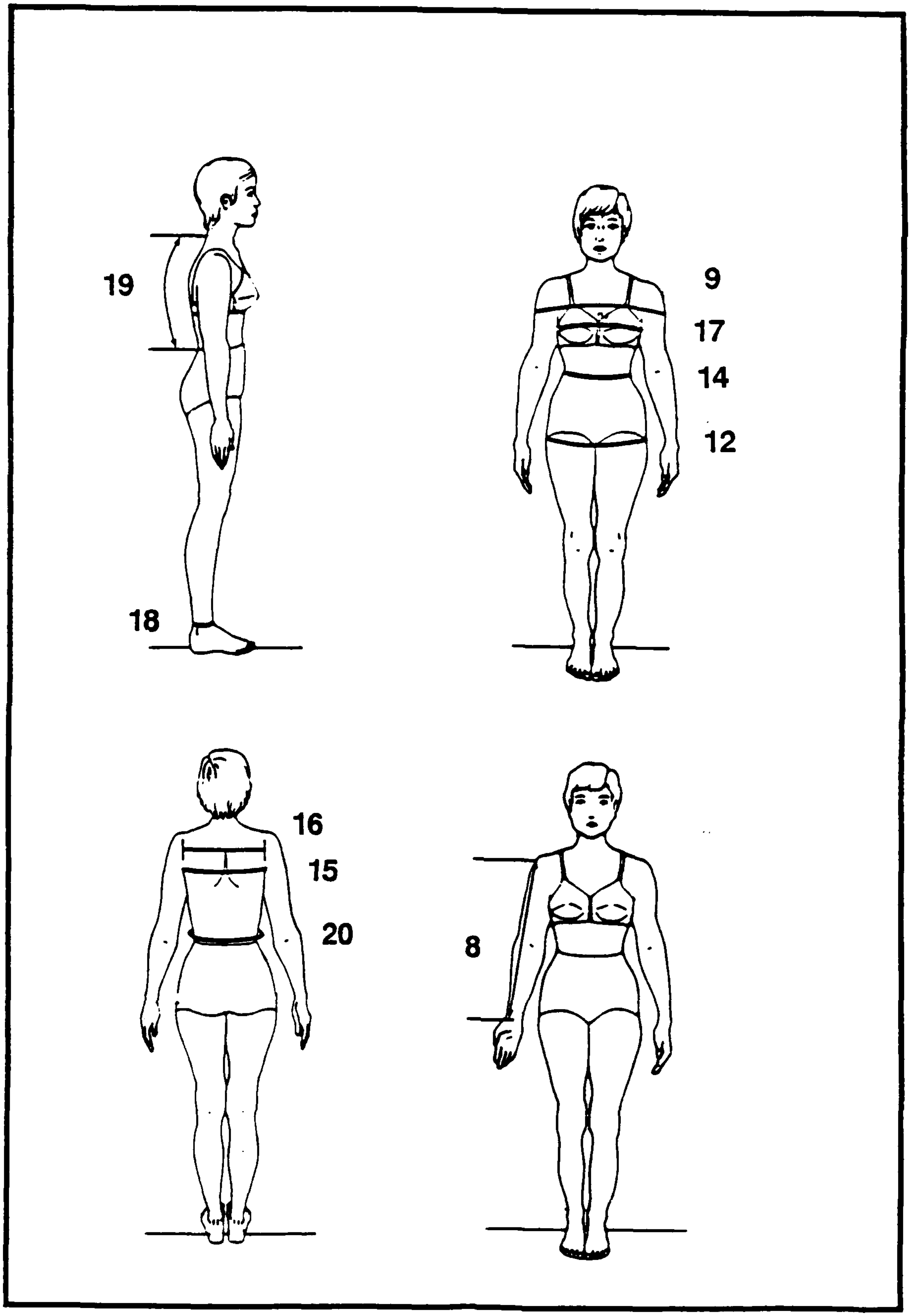

Figure 7 (Continued). Variable Descriptions used for Coverall/Flightsuit Analysis

1. WEIGHT: weight of subject wearing panties and bra (not pictured).

2. STATURE: vertical distance from floor to top of the head.

3. AXILLA HEIGHT: vertical distance from floor to armpit.

4. BUSTPOINT HEIGHT: vertical distance from floor to tip of the bra.

5. WAIST HEIGHT: vertical distance from floor to natural waist level.

6. BUTTOCK HEIGHT: vertical distance from floor to the point of maximum protrusion of the buttock.

7. SLEEVE INSEAM: distance from the anterior edge of the armpit to the little finger side of the wrist measured with the arm slightly abducted, the palm held forward, and the tape tense.

8. SLEEVE OUTSEAM: distance from acromial to the thumb side of the wrist; arm is slightly abducted, the palm held forward, and tape tense.

9. SHOULDER CIRCUMFERENCE: horizontal circumference of the shoulders at the level of the greatest lateral protrusion of the deltoid muscles.

10. SITTING HEIGHT: vertical distance from sitting surface top of the head.

11. KNEE HEIGHT, SITTING: *vertical distance from the footrest surface* to a point on the thigh 5 cm proximal to the anterior surface of the patella.

12. HIP CIRCUMFERENCE: maximum circumference of the hips at the level of the maximum posterior protrusion of the buttocks.

13. BICEPS CIRCUMFERENCE, FLEXED: circumference of the arm at the level of the maximal protrusion of the biceps, measured with the elbow flexed 90 degrees, the upper arm horizontal and the fist tightly clenched.

14. WAIST CIRCUMFERENCE: horizontal circumference of the waist at 'natural ' waist level.

15. BACK ARC, BUST: surface distance across the back between midaxillary lines at the level of the bra points.

16. INTERCYE FRONT: surface distance across the back between points midway between the posterior edges of armpits and acromial points.

17. BUST CIRCUMFERENCE: horizontal circumference if the trunk measured with the tape passing over the bra points.

18. ANKLE CIRCUMFERENCE: minimum circumference of the ankle.

19. WAIST BACK LENGTH: surface distance from the waist to cervical.

20. **BACK ARC, WAIST:** surface distance across the back between midaxillary lines at waist level.

APPENDIX B

MALE AND FEMALE REGRESSION EQUATIONS FOR ALL MODELS

Table 15. Regression Analysis of Coverall/Flightsuit Measures Using Stature and Weight as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		WEIGHT		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
AXILLA HEIGHT								
male	0.946	1640.71 *	0.854	49.16 *	-0.011	-2.32 *	-158.619	-5.90 *
female	0.941	7771.91 *	0.832	104.28 *	0.001	0.49	-126.217	-11.02 *
BUSTPOINT HEIGHT								
male	0.939	1441.95 *	0.830	47.05 *	-0.020	-4.11 *	-143.033	-5.24 *
female	0.887	3787.87 *	0.839	75.22 *	-0.017	-4.27 *	-165.230	-10.32 *
WAIST HEIGHT								
male	0.772	318.48 *	0.817	23.49 *	-0.050	-5.14 *	-307.295	-5.71 *
female	0.821	2215.94 *	0.741	57.72 *	-0.016	-3.64 *	-174.033	-9.45 *
BUTTOCK HEIGHT								
male	0.818	421.26 *	0.666	25.44 *	-0.016	-2.23 *	-248.651	-6.14 *
female	0.768	1599.42 *	0.577	45.53 *	0.015	3.33 *	-129.282	-7.11 *
SLEEVE INSEAM								
male	0.654	177.99 *	0.331	17.12 *	-0.015	-2.73 *	-74.374	-2.49 *
female	0.634	837.12 *	0.323	36.59 *	-0.014	-4.57 *	-61.302	-4.84 *
SLEEVE OUTSEAM								
male	0.669	190.17 *	0.364	15.95 *	0.004	0.67	-57.590	-1.63
female	0.667	968.34 *	0.364	37.52 *	-0.004	-1.15	-55.252	-3.96 *
SHOULDER CIRCUMFERENCE								
male	0.764	304.41 *	-0.158	-4.15 *	0.241	22.63 *	1005.658	17.07 *
female	0.695	1102.10 *	-0.122	-7.12 *	0.256	42.79 *	862.912	34.99 *

Table 15. Continued page 2 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		WEIGHT		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
SITTING HEIGHT								
male	0.601	141.36 *	0.344	13.09 *	0.012	1.66	284.954	7.02 *
female	0.666	965.84 *	0.405	36.06 *	0.006	1.43	189.746	11.76 *
KNEE HEIGHT, SITTING								
male	0.803	382.39 *	0.349	21.27 *	0.014	3.15 *	-82.980	-3.27 *
female	0.788	1802.16 *	0.322	46.77 *	0.015	6.08 *	-36.614	-3.71 *
HIP CIRCUMFERENCE								
male	0.904	881.87 *	-0.089	-3.65 *	0.252	37.01 *	718.094	19.07 *
female	0.816	2148.93 *	-0.094	-6.02 *	0.318	58.02 *	692.199	30.73 *
BICEPS CIRC, FLEXED								
male	0.758	294.78 *	-0.131	-7.83 *	0.110	23.52 *	366.147	14.17 *
female	0.756	1496.59 *	-0.116	-17.47 *	0.122	52.99 *	295.132	31.03 *
WAIST CIRCUMFERENCE								
male	0.876	662.46 *	-0.304	-8.27 *	0.353	34.19 *	779.983	13.70 *
female	0.678	1017.76 *	-0.297	-13.07 *	0.344	43.33 *	740.140	22.66 *
BACK CURVATURE, BUST								
male	0.736	262.50 *	-0.115	-5.24 *	0.132	21.53 *	449.040	13.23 *
female	0.607	746.04 *	-0.122	-10.67 *	0.148	36.94 *	425.265	25.82 *
INTERSCYE FRONT								
male	0.460	80.05 *	0.027	1.53	0.048	9.67 *	242.575	8.84 *
female	0.322	229.49 *	0.039	4.63 *	0.044	15.01 *	209.133	17.32 *

Table 15. Continued page 3 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		WEIGHT		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
BUST CIRCUMFERENCE								
male	0.854	548.16 *	-0.263	-8.19 *	0.282	31.33 *	951.847	19.16 *
female	0.709	1178.45 *	-0.256	-12.74 *	0.323	46.22 *	873.802	30.35 *
ANKLE CIRCUMFERENCE								
male	0.683	202.67 *	0.016	1.63	0.045	15.90 *	119.554	7.73 *
female	0.397	317.87 *	0.010	1.67	0.040	20.19 *	139.549	17.00 *
WAIST BACK LENGTH								
male	0.347	49.86 *	0.143	4.53 *	0.044	4.97 *	138.877	2.85 *
female	0.275	183.16 *	0.206	15.53 *	0.004	0.92	68.926	3.62 *
BACK CURVATURE, WAIST								
male	0.811	404.65 *	-0.159	-6.68 *	0.179	26.80 *	394.742	10.70 *
female	0.640	858.29 *	-0.153	-12.67 *	0.169	39.98 *	380.775	21.91 *

* $p < 0.05$
N (males) = 191
N (females) = 970

Table 16. Regression Analysis of Coverall/Flightsuit Measures using Stature and Shoulder Circumference as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
AXILLA HEIGHT								
male	0.947	1693.60 *	0.850	55.60 *	-0.060	-3.40 *	-105.800	-4.00 *
female	0.941	7777.60 *	0.840	117.50 *	-0.010	-0.95	-123.300	-10.30 *
BUSTPOINT HEIGHT								
male	0.937	1416.10 *	0.810	51.00 *	-0.060	-3.60 *	-69.300	-2.50 *
female	0.886	3773.10 *	0.830	82.80 *	-0.050	-3.80 *	-118.800	-7.10 *
WAIST HEIGHT								
male	0.755	294.20 *	0.760	23.80 *	-0.130	-3.70 *	-140.800	-2.50 *
female	0.820	2205.50 *	0.730	63.40 *	-0.040	-3.10 *	-130.100	-6.70 *
BUTTOCK HEIGHT								
male	0.816	421.50 *	0.650	27.90 *	-0.060	-2.30 *	-185.600	-4.50 *
female	0.768	1608.60 *	0.580	51.80 *	0.050	3.90 *	-177.300	-9.40 *
SLEEVE INSEAM								
male	0.639	169.10 *	0.310	17.60 *	-0.020	-1.00	-35.800	-1.20
female	0.627	814.80 *	0.310	38.60 *	-0.020	-2.10 *	-33.0	-2.50 *
SLEEVE OUTSEAM								
male	0.668	192.50 *	0.360	17.90 *	0.030	1.40	-83.400	-2.30 *
female	0.666	967.10 *	0.360	41.10 *	0.010	0.70	-54.300	-3.70 *
WEIGHT								
male	0.810	405.80 *	1.000	8.30 *	3.030	22.60 *	-3540.800	-16.80 *
female	0.757	1506.30 *	0.850	17.60 *	2.550	42.80 *	-2627.900	-32.40 *

Table 16. Continued page 2 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio		
SITTING HEIGHT								
male	0.595	140.40 *	0.360	15.10 *	0.040	1.40	241.900	5.90 *
female	0.665	964.40 *	0.410	40.10 *	0.010	1.10	175.700	10.40 *
KNEE HEIGHT, SITTING								
male	0.795	369.70 *	0.370	24.70 *	0.040	2.20 *	-129.500	-5.00 *
female	0.785	1770.50 *	0.330	54.10 *	0.040	4.80 *	-74.600	-7.20 *
HIP CIRCUMFERENCE								
male	0.712	236.40 *	0.160	4.40 *	0.760	18.40 *	175.900	-2.70 *
female	0.538	564.40 *	0.190	8.60 *	0.750	27.50 *	-111.100	-3.00 *
BICEPS CIRC, FLEXED								
male	0.704	227.40 *	-0.030	-2.00 *	0.380	20.60 *	-47.500	-1.70
female	0.612	766.00 *	-0.020	-2.80 *	0.340	37.60 *	-44.700	-3.60 *
WAIST CIRCUMFERENCE								
male	0.592	139.10 *	0.070	1.20	1.000	15.20 *	-429.900	-4.20 *
female	0.548	588.60 *	-0.030	-1.20	0.970	32.60 *	-212.500	-5.30 *
BACK CURVATTURE, BUST								
male	0.694	216.50 *	0.000	0.06	0.450	19.50 *	-49.700	-1.40
female	0.602	732.70 *	-0.020	-2.00 *	C.460	36.60 *	-11.100	-0.60
INTERSCYE FRONT								
male	0.535	110.20 *	0.060	4.10 *	0.190	11.90 *	45.300	1.80
female	0.415	344.40 *	0.060	8.50 *	0.180	20.40 *	58.800	5.00 *

Table 16. Continued page 3 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		STATURE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio		
BUST CIRCUMFERENCE								
male	0.821	437.20 *	-0.020	-0.60	0.980	27.90 *	-116.500	-2.10 *
female	0.691	1082.10 *	-0.030	-1.60	1.000	44.20 *	-74.800	-2.40 *
ANKLE CIRCUMFERENCE								
male	0.530	108.00 *	-0.060	5.90 *	0.130	10.60 *	-33.900	-1.80 *
female	0.248	160.40 *	0.050	8.70 *	0.080	11.70 *	44.900	4.70 *
WAIST BACK LENGTH								
male	0.299	41.50 *	0.190	6.70 *	0.110	3.50 *	-5.200	-0.10
female	0.273	182.60 *	0.210	17.90 *	0.000	0.30	61.600	3.10 *
BACK CURVATURE, WAIST								
male	0.542	113.60 *	0.030	0.98	0.500	13.80 *	-218.400	-3.80 *
female	0.524	534.30 *	-0.020	-1.80	0.480	31.30 *	-89.100	-4.20 *

* $p < 0.05$
N (males) = 191
N (females) = 970

Table 17. Regression Analysis of Coverall/Flightsuit Measures using Hip and Shoulder Circumference as Independent Variables

DEPENDENT VARIABLES	ADJ. R-SQUARED		HIP CIRCUMFERENCE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
AXILLA HEIGHT								
male	0.171	20.54 *	0.531	4.73 *	-0.167	-1.49	989.292	14.14 *
female	0.171	100.65 *	0.328	8.79 *	0.071	1.69	847.811	27.00 *
BUSTPOINT HEIGHT								
male	0.136	15.95 *	0.429	3.92 *	-0.106	-0.97	978.287	14.34 *
female	0.129	72.46 *	0.287	7.46 *	0.062	1.37	845.166	26.10 *
WAIST HEIGHT								
male	0.071	8.25 *	0.371	3.20 *	-0.145	-1.25	842.776	11.67 *
female	0.119	66.68 *	0.257	7.26 *	0.050	1.19	718.092	24.12 *
BUTTOCK HEIGHT								
male	0.111	12.84 *	0.338	3.53 *	-0.085	-0.89	657.566	11.06 *
female	0.168	98.61 *	0.209	6.99 *	0.128	3.63 *	504.311	20.09 *
SLEEVE INSEAM								
male	0.080	9.22 *	0.137	2.62 *	-0.014	-0.27	363.356	11.20 *
female	0.068	36.37 *	0.070	4.01 *	0.051	2.47 *	328.732	22.33 *
SLEEVE OUTSEAM								
male	0.179	21.64 *	0.242	4.06 *	-0.028	-0.47	383.355	10.34 *
female	0.106	58.68 *	0.099	5.02 *	0.075	3.21 *	364.463	21.89 *
WEIGHT								
male	0.915	1022.37 *	2.948	19.68 *	0.975	6.51 *	-2340.856	-25.09 *
female	0.879	3515.04 *	1.905	39.99 *	1.323	23.60 *	-1828.456	-45.67 *

Table 17. Continued page 2 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		HIP CIRCUMFERENCE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
SITTING HEIGHT								
male	0.157	18.64 *	0.225	3.58 *	-0.012	-0.19	700.221	17.84 *
female	0.157	91.08 *	0.199	8.94 *	0.021	0.78	647.926	34.64 *
KNEE HEIGHT, SITTING								
male	0.253	33.22 *	0.290	5.51 *	-0.063	-1.20	339.246	10.34 *
female	0.190	114.71 *	0.135	8.09 *	0.065	3.29 *	312.982	22.22 *
STATURE								
male	0.195	24.04 *	0.569	4.40 *	-0.084	-0.65	1290.687	16.04 *
female	0.179	106.84 *	0.374	8.65 *	0.111	2.18 *	1163.664	32.01 *
BICEPS CIRC, FLEXED								
male	0.719	244.62 *	0.113	3.80 *	0.269	9.06 *	-96.024	-5.19 *
female	0.676	1011.50 *	0.134	14.11 *	0.225	20.11 *	-85.743	-10.74 *
WAIST CIRCUMFERENCE								
male	0.812	410.92 *	1.116	14.91 *	0.102	1.36	-380.510	-8.17 *
female	0.608	752.44 *	0.382	12.22 *	0.636	17.29 *	-294.009	-11.19 *
BACK CURVATURE, BUST								
male	0.729	256.87 *	0.182	4.95 *	0.305	8.29 *	55.346	-2.42 *
female	0.619	788.45 *	0.098	6.97 *	0.374	22.63 *	-47.974	-4.06 *
INTERSCYE FRONT								
male	0.502	96.69 *	0.053	1.87	0.174	6.17 *	122.377	6.99 *
female	0.375	13.51 *	0.024	2.40 *	0.180	15.25 *	127.181	15.06 *

Table 17. Continued page 3 of 3

DEPENDENT VARIABLES	ADJ. R-SQUARED		HIP CIRCUMFERENCE		SHOULDER CIRCUMFERENCE		CONSTANT	
	R-SQ	F-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio	Coeff.	T-Ratio
BUST CIRCUMFERENCE								
male	0.860	585.71 *	0.378	7.28 *	0.658	12.70 *	-156.632	-4.85 *
female	0.715	1214.56 *	0.228	9.21 *	0.803	27.61 *	-138.934	-6.69 *
ANKLE CIRCUMFERENCE								
male	0.574	129.13 *	0.145	7.59 *	0.032	1.65	43.476	3.65 *
female	0.301	209.64 *	0.095	12.47 *	0.024	2.61 *	93.247	14.48 *
WAIST BACK LENGTH								
male	0.224	28.47 *	0.265	4.68 *	-0.032	-0.57	237.201	6.72 *
female	0.050	26.27 *	0.078	4.14 *	0.028	1.26	307.726	19.39 *
BACK CURVATURE, WAIST								
male	0.749	284.22 *	0.569	12.50 *	0.046	1.02	-198.562	-7.01 *
female	0.573	652.47 *	0.177	10.77 *	0.322	16.67 *	-138.058	-10.11 *

* $p < 0.05$
N (males) = 191
N (females) = 970

APPENDIX C

ESTIMATED DIFFERENCES BETWEEN MALES AND FEMALES FOR ALL INDEPENDENT VARIABLES, FOR ALL MODELS

NOTE: All Dimensions in millimeters; negative values indicate larger female dimensions.

Table 18. Estimated Male minus Female Computed Values with Stature and Weight as Dependent Variables

		Stature			
Axilla Height		1592	1653	1715	1776
Weight	1256	-12.71	-11.33	-9.96	-8.58
	1487	-15.63	-14.25	-12.88	-11.50
	1718	-18.55	-17.17	-15.80	-14.42
	1949	-21.47	-20.09	-18.72	-17.34
Waist Height		1592	1653	1715	1776
Weight	1256	-54.94	-50.27	-45.59	-40.92
	1487	-62.75	-58.08	-53.40	-48.73
	1718	-70.57	-65.89	-61.21	-56.54
	1949	-78.38	-73.70	-69.03	-64.35
Bustpoint Height		1592	1653	1715	1776
Weight	1256	3.39	2.85	2.30	1.75
	1487	2.54	1.99	1.45	0.90
	1718	1.69	1.14	0.59	0.04
	1949	0.84	0.29	-0.26	-0.81
Buttock Height		1592	1653	1715	1776
Weight	1256	-32.80	-27.94	-23.08	-18.21
	1487	-39.99	-35.13	-30.27	-25.40
	1718	-47.18	-42.32	-37.45	-32.59
	1949	-54.37	-49.50	-44.64	-39.78
Sleeve Inseam		1592	1653	1715	1776
Weight	1256	-1.21	-0.71	-0.22	0.28
	1487	-1.37	-0.88	-0.39	0.11
	1718	-1.54	-1.05	-0.55	-0.06
	1949	-1.71	-1.21	-0.72	-0.23

Table 18. Continued page 2 of 4

Sleeve Outseam		Stature			
		1592	1653	1715	1776
Weight	1256	7.86	7.86	7.85	7.85
	1487	9.75	9.74	9.74	9.74
	1718	11.64	11.63	11.63	11.63
	1949	13.52	13.52	13.52	13.52

Shoulder Circumference		Stature			
		1592	1653	1715	1776
Weight	1256	67.08	64.87	62.67	60.47
	1487	63.62	61.42	59.22	57.02
	1718	60.17	57.97	55.76	53.56
	1949	56.71	54.51	52.31	50.11

Sitting Height		Stature			
		1592	1653	1715	1776
Weight	1256	5.05	1.24	-2.57	-6.38
	1487	6.57	2.76	-1.05	-4.86
	1718	8.10	4.29	0.48	-3.33
	1949	9.62	5.81	2.00	-1.81

Knee Height, Sitting		Stature			
		1592	1653	1715	1776
Weight	1256	-3.46	-1.79	-0.12	1.55
	1487	-3.48	-1.82	-0.15	1.52
	1718	-3.51	-1.85	-0.18	1.49
	1949	-3.54	-1.87	-0.21	1.46

Hip Circumference		Stature			
		1592	1653	1715	1776
Weight	1256	-52.06	-51.72	-51.38	-51.04
	1487	-67.10	-66.76	-66.42	-66.08
	1718	-82.14	-81.80	-81.46	-81.12
	1949	-97.18	-96.84	-96.50	-96.16

Table 18. Continued page 3 of 4

Biceps Circ, Flexed		Stature			
		1592	1653	1715	1776
Weight	1256	31.77	30.85	29.93	29.01
	1487	28.91	27.99	27.07	26.16
	1718	26.05	25.14	24.22	23.30
	1949	23.20	22.28	21.36	20.44

Waist Circumference		Stature			
		1592	1653	1715	1776
Weight	1256	40.08	39.66	39.24	38.82
	1487	42.11	41.69	41.27	40.85
	1718	44.15	43.73	43.31	42.89
	1949	46.18	45.76	45.34	44.92

Back Arc, Bust		Stature			
		1592	1653	1715	1776
Weight	1256	16.45	16.92	17.39	17.85
	1487	12.87	13.34	13.81	14.27
	1718	9.29	9.76	10.22	10.69
	1949	5.71	6.18	6.64	7.11

Interscye Front		Stature			
		1592	1653	1715	1776
Weight	1256	19.69	18.96	18.23	17.51
	1487	20.61	19.89	19.16	18.43
	1718	21.54	20.81	20.09	19.36
	1949	22.47	21.74	21.01	20.29

Bust Circumference		Stature			
		1592	1653	1715	1776
Weight	1256	14.23	13.77	13.31	12.85
	1487	4.68	4.22	3.76	3.30
	1718	-4.88	-5.34	-5.80	-6.25
	1949	-14.43	-14.89	-15.35	-15.81

Table 18. Continued page 4 of 4

Ankle Circumference		Stature 1592	1653	1715	1776
Weight	1256	-3.87	-3.45	-3.03	-2.62
	1487	-2.88	-2.46	-2.05	-1.63
	1718	-1.89	-1.47	-1.06	-0.64
	1949	-0.90	-0.48	-0.07	0.35

Waist Back Length		Stature 1592	1653	1715	1776
Weight	1256	18.90	15.00	11.10	7.20
	1487	28.04	24.14	20.25	16.35
	1718	37.19	33.29	29.39	25.49
	1949	46.33	42.43	38.53	34.63

Back Arc, Waist		Stature 1592	1653	1715	1776
Weight	1256	17.58	17.22	16.86	16.50
	1487	19.96	19.60	19.24	18.88
	1718	22.34	21.98	21.62	21.26
	1949	24.71	24.35	23.99	23.63

Table 19. Estimated Male minus Female Computed Values with Stature and Shoulder Circumference as Dependent Variables

		Stature			
Axilla Height		1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-9.75	-8.90	-8.05	-7.20
	1064	-12.45	-11.61	-10.76	-9.91
	1120	-15.16	-14.32	-13.47	-12.62
	1175	-17.87	-17.02	-16.18	-15.33
		Stature			
Waist height		1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-47.88	-45.85	-43.83	-41.81
	1064	-52.81	-50.78	-48.76	-46.74
	1120	-57.74	-55.72	-53.69	-51.67
	1175	-62.67	-60.65	-58.62	-56.60
		Stature			
Bustpoint Height		1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	7.37	6.41	5.46	4.50
	1064	6.40	5.45	4.49	3.54
	1120	5.44	4.48	3.53	2.57
	1175	4.47	3.52	2.56	1.61
		Stature			
Buttock Height		1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-15.05	-10.89	-6.73	-2.57
	1064	-21.34	-17.19	-13.03	-8.87
	1120	-27.64	-23.48	-19.32	-15.17
	1175	-33.94	-29.78	-25.62	-21.46
		Stature			
Sleeve Inseam		1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	0.03	0.15	0.26	0.38
	1064	0.03	0.14	0.26	0.37
	1120	0.03	0.14	0.26	0.37
	1175	0.02	0.14	0.25	0.37

Table 19. Continued page 2 of 4

Sleeve Outseam		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	6.13	6.52	6.91	7.30
	1064	7.51	7.90	8.29	8.69
	1120	8.89	9.29	9.68	10.07
	1175	10.28	10.67	11.06	11.45

Weight		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-191.29	-181.98	-172.68	-163.37
	1064	-164.77	-155.46	-146.15	-136.85
	1120	-138.25	-128.94	-119.63	-110.33
	1175	-111.72	-102.42	-93.11	-83.80

Sitting Height		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	3.05	-0.31	-3.68	-7.05
	1064	4.37	1.01	-2.36	-5.73
	1120	5.69	2.33	-1.04	-4.41
	1175	7.01	3.65	0.28	-3.09

Knee Height, Sitting		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-5.79	-9.58	-1.90	0.04
	1064	-5.85	-3.91	-1.96	-0.02
	1120	-5.92	-3.97	-2.03	-0.08
	1175	-5.98	-4.03	-2.09	-0.14

Hip Circumference		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-97.31	-99.02	-100.72	-102.43
	1064	-96.67	-98.37	-100.08	-101.79
	1120	-96.03	-97.73	-99.44	-101.15
	1175	-95.38	-97.09	-98.80	-100.51

Table 19. Continued page 3 of 4

Biceps Circ, Flexed		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	7.35	6.55	5.76	4.96
	1064	9.05	8.25	7.45	6.66
	1120	10.75	9.95	9.15	8.36
	1175	12.45	11.65	10.85	10.05

Waist Circumference		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-25.09	-18.89	-12.69	-6.49
	1064	-23.32	-17.12	-10.91	-4.71
	1120	-21.54	-15.34	-9.14	-2.94
	1175	-19.77	-13.57	-7.37	-1.17

Back Arc, Bust		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-13.96	-12.61	-11.26	-9.91
	1064	-14.53	-13.18	-11.82	-10.47
	1120	-15.09	-13.74	-12.39	-11.04
	1175	-15.66	-14.30	-12.95	-11.60

Interscye Front		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	7.03	7.11	7.19	7.28
	1064	8.05	8.13	8.21	8.29
	1120	9.07	9.15	9.23	9.31
	1175	10.08	10.16	10.24	10.33

Bust Circumference		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-51.37	-50.68	-49.99	-49.30
	1064	-52.88	-52.19	-51.50	-50.81
	1120	-54.39	-53.70	-53.01	-52.33
	1175	-55.91	-55.22	-54.53	-53.84

Table 19. Continued page 4 of 4

Ankle Circumference		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-11.43	-10.57	-9.72	-8.87
	1064	-8.92	-8.07	-7.22	-6.37
	1120	-6.41	-5.56	-4.71	-3.86
	1175	-3.91	-3.06	-2.21	-1.36

Waist Back Length		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	13.49	12.33	11.17	10.02
	1064	19.56	18.41	17.25	16.09
	1120	25.64	24.48	23.32	22.17
	1175	31.71	30.56	29.40	28.24

Back Arc, Waist		Stature 1591.6	1653.2	1714.8	1776.4
Shoulder Circumference	1009	-15.17	-11.77	-8.37	-4.98
	1064	-13.71	-10.32	-6.92	-3.52
	1120	-12.26	-8.86	-5.47	-2.07
	1175	-10.81	-7.41	-4.02	-0.62

Table 20. Estimated Male minus Female Computed Values with Shoulder and Hip Circumferences as Dependent Variables

Axilla Height		Hip Circumference			
		898	958	1018	1078
Shoulder Circumference	1009	83.64	95.82	108.00	120.18
	1064	70.40	82.58	94.76	106.94
	1120	57.16	69.34	81.52	93.70
	1175	43.92	56.10	68.28	80.46

Waist Height		Hip Circumference			
		898	958	1018	1078
Shoulder Circumference	1009	-33.02	-26.24	-19.46	-12.68
	1064	-43.83	-37.05	-30.27	-23.49
	1120	-54.65	-47.87	-41.09	-34.31
	1175	-65.46	-58.68	-51.90	-45.12

Bustpoint Height		Hip Circumference			
		898	958	1018	1078
Shoulder Circumference	1009	90.91	99.42	107.93	116.44
	1064	81.57	90.07	98.58	107.09
	1120	72.22	80.73	89.24	97.74
	1175	62.87	71.38	79.89	88.40

Buttock Height		Hip Circumference			
		898	958	1018	1078
Shoulder Circumference	1009	53.63	61.33	69.03	76.74
	1064	41.78	49.49	57.19	64.89
	1120	29.94	37.64	45.34	53.04
	1175	18.09	25.79	33.49	41.20

Sleeve Inseam		Hip Circumference			
		898	958	1018	1078
Shoulder Circumference	1009	29.06	33.04	37.03	41.01
	1064	25.46	29.45	33.43	37.42
	1120	21.87	25.85	29.84	33.82
	1175	18.27	22.26	26.24	30.23

Table 20. Continued page 2 of 4

Sleeve Outseam		Hip Circumference 898	958	1018	1078
Shoulder Circumference	1009	43.79	52.36	60.93	69.50
	1064	38.09	46.66	55.23	63.80
	1120	32.40	40.96	49.53	58.10
	1175	26.70	35.27	43.84	52.41

Weight		Hip Circumference 898	958	1018	1078
Shoulder Circumference	1009	74.77	137.36	199.96	262.55
	1064	55.49	118.08	180.68	243.28
	1120	36.21	98.81	161.40	224.00
	1175	16.94	79.53	142.13	204.72

Sitting Height		Hip Circumference 898	958	1018	1078
Shoulder Circumference	1009	43.21	44.79	46.38	47.96
	1064	41.41	42.99	44.57	46.15
	1120	39.60	41.18	42.76	44.35
	1175	37.79	39.38	40.96	42.54

Knee Height, Sitting		Hip Circumference 898	958	1018	1078
Shoulder Circumference	1009	36.17	52.99	54.77	64.08
	1064	29.04	38.34	47.64	56.95
	1120	21.91	31.21	40.52	49.82
	1175	14.78	24.08	33.39	42.69

Stature		Hip Circumference 898	958	1018	1078
Shoulder Circumference	1009	107.68	119.43	131.18	142.94
	1064	96.91	108.67	120.42	132.17
	1120	86.15	97.90	109.66	121.41
	1175	75.38	87.14	98.89	110.65

Table 20. Continued page 3 of 4

		Hip Circumference			
Biceps Circ, Flexed		898	958	1018	1078
Shoulder Circumference	1009	15.74	14.48	13.22	11.97
	1064	18.21	16.95	15.70	14.44
	1120	20.68	19.43	18.17	16.91
	1175	23.15	21.90	20.64	19.38

		Hip Circumference			
Waist Circumference		898	958	1018	1078
Shoulder Circumference	1009	33.93	77.96	122.00	166.03
	1064	4.25	48.28	92.31	136.34
	1120	-25.44	18.59	62.62	106.65
	1175	-55.13	-11.10	32.93	76.96

		Hip Circumference			
Back Arc, Bust		898	958	1018	1078
Shoulder Circumference	1009	-2.51	2.50	7.52	12.54
	1064	-6.39	-1.37	3.65	8.67
	1120	-10.26	-5.24	-0.22	4.80
	1175	-14.13	-9.11	-4.10	0.92

		Hip Circumference			
Interscye Front		898	958	1018	1078
Shoulder Circumference	1009	13.98	15.69	17.40	19.11
	1064	13.60	15.31	17.02	18.73
	1120	13.22	14.93	16.64	18.36
	1175	12.85	14.56	16.27	17.98

		Hip Circumference			
Bust Circumference		898	958	1018	1078
Shoulder Circumference	1009	5.02	14.17	23.32	32.47
	1064	-1.27	7.88	17.03	26.18
	1120	-7.57	1.58	10.73	19.88
	1175	-13.86	-4.71	4.44	13.58

Table 20. Continued page 4 of 4

		Hip Circumference			
Ankle Circumference		898	958	1018	1078
Shoulder Circumference	1009	2.86	5.84	8.83	11.81
	1064	3.30	6.28	9.27	12.25
	1120	3.74	6.73	9.71	12.69
	1175	4.18	7.17	10.15	13.13

		Hip Circumference			
Waist Back Length		898	958	1018	1078
Shoulder Circumference	1009	36.99	48.22	59.45	70.68
	1064	33.66	44.88	56.11	67.34
	1120	30.32	41.55	52.77	64.00
	1175	26.98	38.21	49.44	60.67

		Hip Circumference			
Back Arc, Waist		898	958	1018	1078
Shoulder Circumference	1009	13.64	37.15	60.67	84.18
	1064	-1.67	21.84	45.35	68.87
	1120	-16.98	6.53	30.04	53.56
	1175	-32.30	-8.78	14.73	38.24