SECULAR CHANGE IN THE KNEE JOINT AND THE EFFECTS OF OBESITY

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SECULAR CHANGE IN THE KNEE JOINT AND THE EFFECTS OF OBESITY

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ABSTRACT

SECULAR CHANGE IN THE KNEE JOINT AND THE EFFECTS OF OBESITY

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In America, there have been well-documented trends of rising obesity in the past 30 years and a steady increase in stature during the 20th century. Proposed explanations for these increases in body weight and stature include changes in nutrition, over-nutrition, healthcare, sanitation, and socioeconomic status, as well as reduced incidence of infectious disease during early growth. Of interest to anthropologists is how excessive body weight affects the skeletal system. The purpose of this study is to: (1) determine if there is a secular change in the articular surfaces of the knee joint, (2) determine if there are differences between normal weight and obese individuals in the articular surfaces of the knee joint, and (3) examine if the secular change in body mass is a causal factor in the secular trends in the size and shape of the articular surfaces of the knee joint. Twenty-one measurements from the femur and tibia were collected and analyzed from 162 skeletons from the Robert J. Terry Collection, William M. Bass Donated Skeletal Collection, and the Texas State Donated Skeletal Collection. Body Mass Index was calculated for each individual using the CDC equation. The data were then subjected to statistical analyses to determine whether there has been secular change in the size and shape of the knee and to determine if obesity is a significant causal factor. The results of these analyses indicate a secular trend in several of the dimensions of the femur and tibia, and that there are differences between normal weight and obese individuals in some of these dimensions. However, the results are suggestive but inconclusive as to whether or not obesity is a factor in the secular trend. The results of this study support a growing body of literature that indicates obesity may have a significant effect on skeletal morphology.

CHAPTER I

INTRODUCTION

Statement of the Problem

In the past two centuries, Americans have significantly increased in stature and body weight with corresponding changes in skeletal size and shape (Agostini and Ross 2011, Driscoll 2010, Meadows Jantz and Jantz 1995, Meadows Jantz and Jantz 1999, Moore 2008, Moore and Schaefer 2011, Trotter and Gleser 1958). These observed changes have primarily been linked to changes in nutrition and over-nutrition, healthcare, sanitation, socioeconomic status, reduced physical activity, and reduced incidence of infectious disease during early growth (Driscoll 2010, Flegal et al. 2002, Ogden et al. 2006, Wescott and Jantz 2005). Of interest to anthropologists is documenting these secular trends and understanding the effects of changes in stature and body weight on the human skeleton. While many trends in the skeleton have been documented over the past several decades, there is still a need for more research on how the extremes of body mass affect the skeletal elements involved in weight bearing functions. The aim of this research is to study the knee joint in relation to the secular trend of rising obesity using metric methods in order to determine if there is a correlation between excessive body mass and differences in dimensions of the knee joint.

Purpose

The purpose of this study is three fold. First, it will be determined if there is secular change in the size and shape of the bony elements of the knee joint. Second, whether or not there are significant differences in knee joint size and shape between individuals of normal body weight and obese individuals will be investigated. Finally, if a secular change exists, the data will be analyzed to investigate if this trend is due to increasing obesity.

General Research Problem

Measurements of the distal femur and the proximal tibia will be obtained from skeletons from the 19th and 20th centuries and tested for secular change in the dimensions of these elements. Next, the sample will be separated into normal weight and obese individuals based on the body mass index (BMI). Measurements will be used to examine if there is a difference between normal weight and obese individuals. Finally, the correlations between secular trends and the pattern of rising obesity will be examined to test if obesity has a causal effect. Therefore, the research questions and hypotheses examined in this study are as follows:

Research Question A:

Is there a secular trend in femoral and tibial size and shape at the knee joint?

Null Hypothesis A1: There is no significant change in femoral and tibial size of the knee joint.

Null Hypothesis A2: There is no significant secular change in the shape of the articular surface at the knee joint.

Research Question B:

Is there is significant difference in femoral and tibial size and shape between normal weight individuals and obese individuals?

Null Hypothesis B1: There is no significant difference in femoral and tibial size between normal BMI and obese individuals.

Null Hypothesis B2: There is no significant difference in femoral and tibial shape between normal BMI and obese individuals.

Research Question C:

Is there a correlation between the secular trends in body weight and the size and shape of the femur and tibia?

Null Hypothesis C1: There is no correlation between the secular trends and differences between normal weight and obese individuals in the measurements.

Literature Review

Secular trends have been documented in the skeletal system in recent times, including in the cranium, pelvis, femur and tibia. Jantz (2001) demonstrated that over the past two centuries in the United States the skull has become longer, narrower and higher. Wescott and Jantz (2005) later showed the increase in cranial height is associated with the shape of the cranial base and therefore primarily associated with changes occurring in the first decade of life. Driscoll (2010) found that the pelvis is also changing over time with dimensional changes in the pelvic inlet, pelvic outlet, and bi-iliac breadth. In particular, the pelvic inlet size has increased in the anterior-posterior direction; the pelvic outlet has increased in the medio-lateral direction; and the bi-iliac breadth has become narrower (Driscoll 2010). Meadows Jantz and Jantz (1995, 1999) conducted several studies on the femur and tibia that demonstrate not only increases in length, but also that the femur and tibia are changing allometrically (i.e. proportionally in rate of change) and that the tibia is changing more than the femur.

The National Health and Nutrition Examination Survey (NHANES) periodically surveys the United States population for a variety of information, including ancestry and age, and measures individuals for height and weight. NHANES then analyzes the data that they collect for trends in the population's health. One of the trends that they have discovered is an increase in the number of obese individuals in the population, especially since the 1980s (Flegal et al. 2002, Ogden et al. 2006). In particular, they have found that between 1960 and 1980 the percentage of obese individuals was relatively stable, but since the 1980s the prevalence of obesity has doubled in adults to 32.2% in 2004, and the prevalence of overweight children has tripled to 17.1% in 2004 (Flegal et al. 2002, Ogden et al. 2006). NHANES has also found trends within rising obesity. Specifically, they have documented a trend in which the increase in prevalence of obesity is more significant in men than in women, and that for the period of 1999-2004 there was no significant increase of obesity in women (Ogden et al. 2006). They also note that there are differences between the ancestry groups for women, but less so for men (Ogden et al. 2006).

The NHANES results indicate two trends that would affect the weight bearing joints of the skeleton: (1) there is a trend in adults for an increased prevalence of obesity, and (2) there is a trend in subadults for increased weight. According to Wolf's Law, in the general sense of it, bone will adapt to the mechanical loads that are placed on it (Ruff et al. 2006). Therefore, increased stress placed on the bone by excess weight will have an effect on the bone in terms of trabecular orientation, cortical thickness, and other properties such as shape. However, the factors of age will act upon the bone in different ways due to the differences in the bony reaction that occur in developing or growing bones and mature bone. For example, studies have demonstrated that articular surface size and shape change little during adulthood and are correlated with body mass by the age of 18, the age at which the skeleton is often considered to be mature (Lieberman et al. 2001, Ruff et al. 1991). As Lieberman and colleagues (2001) demonstrated with their study, bone reacts to the mechanical strains placed on them during growth by adapting the shape of the bone and through bone growth to better withstand the strains applied to them while in adults the bone is responding to the new or added strains through remodeling. Ruff et al. (1991) also concluded this and expanded on it by demonstrating that the diaphyseal cross-sectional geometry is more apt to change in response to added mechanical loading strains than articular surface sizes, such as the femoral head which was the main articular surface that they examined. However, it is unknown at this time if there have been significant secular changes in the articular surfaces of the knee joint or how these changes correlate with increases in body mass.

Since the rising trend in obesity is seen in sub-adults as well as adults, a secular change is expected in distal femur and proximal tibia articular and diaphyseal size and shape that correlates with the secular trend in obesity. Changes in diaphyseal morphology in relation to body mass have been documented by several researchers (Agostini and Ross 2011, Moore 2008, Ruff et al. 1991). Agostini and Ross (2011) and Moore (2008) both found that the femoral diaphysis changed in the medio-lateral direction with increased body mass. Ruff et al. (1991) found similar results and showed that while the diaphysis changed, the femoral head dimensions did not change.

There have been other correlations made between obesity and skeletal morphology in the lower limbs. Moore (2008) and Moore and Schaefer (2011) found a correlation between increased bone density and increased body mass. This correlation is explained by Frost (1997) in his review of the forces that cause modeling and remodeling on bone. Here Frost explains that the larger muscle forces required in movement for obese individuals causes bone mass to increase in order to sustain such forces. However, if an obese individual were to become inactive, then their bone mass would decrease in response to the lack of forces acting on it (Frost 1997).

Moore (2008) and Moore and Schaefer (2011) also discovered that obese individuals are more likely to have diffuse idiopathic skeletal hyperostosis in the spine and osteoarthritis at the knee, especially at the medial tibia (Moore 2008, Moore and Schaefer 2011). These studies illustrate some of the ways in which increased weight affects the skeleton, particularly in weight bearing bones and joints, and are important to our understanding of the dynamics of the skeletal system in response to added loading and stress.

Some studies have focused on the knee joint and its response to obesity, but they have been limited in their scope. DeVita and Hortobagyi (2003) conducted a study in which lean mass individuals (normal weight) and obese individuals were recorded walking on a force plate with reflectors on them at specific locations in order to determine whether or not the torque and power at the knee and ankle changed between the weight categories. Their results indicated that obesity is not associated with knee joint torque and power because obese individuals adjust their gait to reduce the load on the knee joint, thus producing less torque and power at the knee joint, but more at the ankle. They demonstrate that obese individuals alter their gait to help in carrying the extra weight. The differences in gait between normal weight and obese individuals should affect the articular surfaces in the knee joint.

This hypothesis is supported by another study which found that the compression forces put on a bone directly correlates with the size of the articular facets as the force is transmitted from the proximal articular surfaces to the distal articular surfaces (Pal and Routal 1991). Based on these results, Pal and Routal (1991) concluded that the area of the articular surface is proportional to the amount of force it resists. It can then be surmised that the extra compression forces applied to the articular surfaces of the knee joint from added weight in obese individuals would result in larger articular surfaces. However, as Pal and Routal (1991) indicated, the knee is subject to other types of forces correlated with the range of movement at the knee that could impact how the compression forces affect the articular surfaces in size, shape, and area.

In summary, previous research has focused on either secular trends or the effects of obesity. While secular trends in femur and tibia length have been studied, the knee has not been studied for secular changes. Much of the research conducted on the effects of obesity have focused on long bone shaft morphology and bone density. Other studies looking at the biomechanical effects of weight on weight-bearing joints have provided some insight on various properties, such as torque and bending moments affecting long bones and joints. This study aims to examine both secular trends and obesity effects together to determine if obesity is a causal factor in the secular trends, particularly those in the legs and at the knee.

CHAPTER II

MATERIALS AND METHODS

Materials

The sample consists of adult American White male and females born in the 19th and 20th centuries from three skeletal collections: the Robert J. Terry Collection (Terry Collection) at the Smithsonian's U.S. National Museum of Natural History in Washington, DC (Hunt and Albanese 2005), the Texas State University Donated Skeletal Collection (TX State Collection) in San Marcos, TX, and the William M. Bass Donated Skeletal Collection (Bass Collection) at the University of Tennessee in Knoxville, TN (Shirley et al. 2011). The 19th century individuals were obtained from the Terry Collection and the 20th century individuals from the Terry Collection, TX State Collection, and Bass Collection. Due to the availability and preservation of the 19th century samples, only one 19th century female was measured. The sample consists of 162 individuals (Table 2.1) and represents 83 normal weight and 60 obese individuals. American White males and females are represented in roughly equal numbers in the sample.

Table 2.1. Sample Composition

Sex	19th Century	20th Century		Total
	Normal Weight	Normal Weight	Obese Weight	
Male	18	37	32	87
Female	1	46	28	75
Total	19	83	60	162

Sample Selection

The sample was selected to avoid differences associated with confounding variables, such as ancestry, age at death, lower limb pathology, and preservation quality of the skeleton. Differences between ancestry groups in morphology and metrics have been documented for a number of traits. Therefore, the ancestral differences in shape were controlled for by only examining individuals classified as American White. While studying only one ancestry group eliminates the need to conduct multiple tests to determine if there are differences between the groups in the knee joint or to conduct the same tests separately on each group, it also constrains the scope and applicability of this study. The results of this study will therefore only be applicable to American White males and females. This is in part due to the fact that the pattern of obesity in American Whites is different from that of other ancestry groups. In general, American Whites tend to be less obese than American Blacks and Mexican Americans (Flegal et al. 2002, Ogden et al. 2006). While the changes on the skeleton due to obesity are biomechanical changes, and thus should span across ancestry groups and populations, this study errs on the side of caution to avoid unforeseen confounding variables related to ancestry group dimorphism.

Morphological changes in the skeleton associated with chronological age or disease, especially related to osteoarthritis and bone degeneration, can result in increased variation in the sample and decrease accuracy of the measurements. Age was controlled for by initially sampling individuals between 20 and 50 years of age at the time of death. However, for the subset sample of females, the maximum age had to be increased to 60 years for normal weight and obese individuals due to the insufficient number of available samples less than 50 years of age. Likewise, for the subset sample of males, the maximum age had to be increased to 55 years for both normal weight and obese individuals. All individuals were examined for pathology of the lower limbs. Individuals with pathology such as healed breaks, severe osteoarthritis, and severe bone growth were excluded from the sample. Individuals in the older age ranges were therefore chosen to avoid osteoarthritic growth and other age related pathology that would affect measurement accuracy. Increasing the age range for these subsets allowed for the necessary sample size to be obtained without including individuals with age-induced abnormalities at the knee joint.

Poorly preserved bones with defects and breaks on the surfaces of the bones could cause uncertainty in the measurements taken, especially when located on the articular surfaces of the proximal tibia and distal femur. To control for uncertainty due to poor preservation, individuals who did not have well preserved and/or complete lower limbs were excluded.

Procedure and Equipment

The twenty-one measurements collected were primarily dimensions of the distal portion of the femur and proximal portion of the tibia. See Appendix A for the list of measurements taken and their definitions. The lengths and midshaft diameters on both the femur and tibia were also measured. The measurements were taken primarily from the left elements (right elements were used when the left was unavailable) and were taken according to the definitions in Zobeck (1983), Bass (2005), and Ruff (2002) using standard osteometric equipment (osteometric board and digital sliding calipers) (Table 2.2). Additionally, three measurement definitions were developed for the current study by the author: the tibia intercondylar tubercle distance (ITD), tibia posteriolateral epiphyseal thickness (PLET), and tibia posteriomedial epiphyseal thickness (PMET) (Fig. 2.1 and Appendix A).

Table 2.2. Measurements and Abbreviations

Measurement	**Abbreviation**	**Reference**
Femur Anterior-Posterior Diameter of the Lateral Condyle	APL	Zobeck 1983
Femur Anterior-Posterior Diameter of the Medial Condyle	APM	Zobeck 1983
Tibia Anterior-Posterior Diameter at the Nutrient Foramen	APN	Bass 1987
Femur Anterior-Posterior Diameter at the Midshaft	APS	Bass 1987
Femur Bicondylar Breadth	BCB	Zobeck 1983
Tibia Maximum Breadth of the Proximal Epiphysis	BPE	Zobeck 1983
Femur Epicondylar Breadth	FEB	Zobeck 1983
Femur Maximum Length	FML	Bass 1987
Tibia Intercondylar Tubercle Distance	ITD	Harrington 2013
Tibia Anterior-Posterior Breadth of the Lateral Condyle	LAPB	Ruff 2002
Femur Lateral Condyle Mediolateral Breadth	LCML	Ruff 2002
Tibia Mediolateral Breadth of the Lateral Condyle	LMLB	Ruff 2002
Tibia Anterior-Posterior Breadth of the Medial Condyle	MAPB	Ruff 2002
Femur Medial Condyle Mediolateral Breadth	MCML	Ruff 2002
Tibia Mediolateral Diameter at the Nutrient Foramen	MLN	Bass 1987
Femur Mediolateral Diameter of the Midshaft	MLS	Bass 1987
Tibia Mediolateral Breadth of the Medial Condyle	MMLB	Ruff 2002
Tibia Posteriolateral Epiphyseal Thickness	PLET	Harrington 2013
Tibia Posteriomedial Epiphyseal Thickness	PMET	Harrington 2013
Tibia Condylo-Malleolar Length	TML	Zobeck 1983
Femur Maximum Vertical Diameter of the Head	VHD	Zobeck 1983

Figure 2.1. ITD (left; superior view, anterior facing top), PLET (middle; posterior-lateral view, superior facing left), PMET (right; posterior view, superior facing left)

Intraobserver and interobserver tests were conducted on the three measurements developed for this study to determine whether these dimensions could be measured consistently and accurately. Ten females and ten males were measured for the intraobserver analysis, five females and five males from the Terry Collection and five females and five males from the Bass Collection. The individuals were chosen from the sample set using a random number generator on MS Excel®. Each individual was measured three times on different days. For the interobserver test, five donations were chosen from the TX State Collection and were measured by two volunteers and the author. The volunteers were only given the definitions of the measurements to be taken with no instruction or aid from the author. Error analysis (see statistical analyses section below) was used to test for intraobserver and interobserver error in the three measurements that were defined by the author (ITD, PLET, and PMET).

In order to be able to analyze the data for shape differences in the knee joint, shape ratios of the femoral condyles and the tibial condyles were calculated. This was done by dividing one condylar breadth measurement by the other for each condyle (see

Table 2.3). Similar ratios were created for the femur distal shape and midshaft shapes of the femur and tibia. This will allow the shape of the condyles and midshafts to be analyzed for differences between the sample groups.

Table 2.3. Shape Ratio Formulae

Ratio	Abbreviation	Formula
Femur Lateral Condyle Shape	FLCS	APL/LCML
Femur Medial Condyle Shape	FMCS	APM/MCML
Femur Distal Shape	FDS	APL/BCB
Tibia Lateral Condyle Shape	TLCS	LAPB/LMLB
Tibia Medial Condyle Shape	TMCS	MAPB/MMLB
Femur Midshaft Shape	FMS	APS/MLS
Tibia Shaft Shape at Nutrient Foramen	TNS	APN/MLN

Height, weight, age at death, and ancestry group data were collected for each individual. For some of the individuals in the Terry Collection, stature and body weight were either not available or significantly below normal due to the age and long disease history of the individuals (Hunt and Albanese 2005). If weight was not available or considered to be associated with wasting as indicated by long-term illnesses and extremely low body masses, body mass was estimated using the femoral head diameter formulae created by Ruff and coworkers on a Boston reference sample (Ruff et al. 1991). Femoral head size has been shown to be a good predictor of weight in normal weight individuals due to its function as part of a weight bearing joint (Ruff 2003, Auerbach and Ruff 2004). The equations for body mass estimation are listed in Table 2.4.

In cases where stature was not available, height was estimated using the 19th and 20th century femoral maximum length formulae provided in FORDISC 3.1 (Ousley and

Jantz 2005). The 19th century equations are based on samples from the Terry Collection and the World War Two Collection (Trotter and Gleser 1952). It must be noted that one of the reference samples, the Terry Collection, is taken from the collection on which the equations are being used. This should not affect the accuracy of the estimates. The 20th century equations are based on the Forensic Databank samples from the Bass Collection and positively identified forensic cases (Ousley and Jantz 1998). The FORDISC 3.1 equations for height estimation are listed in Table 2.4 (Ousley and Jantz 2005).

Table 2.4. Estimation Equations

Estimation	**Equation**	**Source**
White Male Body Mass	(2.741*VHD – 54.9) *0.9	Ruff 2001
White Female Body Mass	(2.426*VHD – 35.1) *0.9	Ruff 2001
19th Century White Male Height	0.26197*FML + 50.845	FORDISC 3.1
19th Century White Female Height	0.24809*FML + 53.748	FORDISC 3.1
20th Century Male Height	0.22808*FML + 67.995	FORDISC 3.1
20th Century Female Height	0.25012*FML + 53.641	FORDISC 3.1

Due to the fact that many of the individuals in the Terry Collection were ill and bedridden for a period of time before their death and thus lost weight, the cadaver weights for these individuals are not reflective of their average adult living weight (Hunt & Albanese 2005). To compound the problem more, the cadavers lost water weight and muscle mass while being stored in coolers and morgues before being transferred to the Washington University Medical School (Hunt & Albanese 2005). Therefore the weights of individuals from the Terry Collection which have given weights that are unusually low, were estimated using the Ruff et al. (1991) equation (see above). For those individuals whose records included weight information, the estimated weights and recorded weights were compared (see Figure 2.2). The average difference between the estimated and recorded weights is 19.3kg (~43lbs). There are no known studies that demonstrate that joint size or shape changes due to decreased mobility.

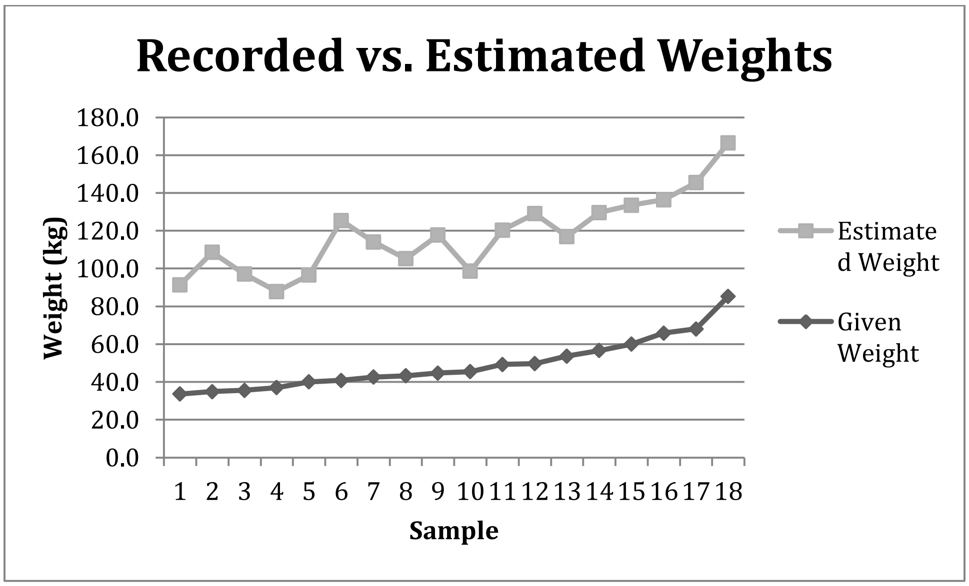


Figure 2.2. Plot of Recorded Versus Estimated Weights

The height and weight of each individual was used to determine if their weight is normal or obese according to the standard body mass index (BMI) (CDC 2011). To calculate BMI, the mass of an individual is divided by the square of their height (equation from CDC 2011):

$$BMI = \frac{mass(kg)}{\left(height(m)\right)^2}$$

Normal weight is in the range of 18.5-24.9 BMI and obese is 30+ BMI (CDC 2011).

Statistical Analyses

The statistical analyses were conducted using MS Excel® and SAS 9.3® software (SAS Institute Inc. 2012). Both descriptive and interpretive statistics were conducted. A percent error was calculated via MS Excel® for the intraobserver and interobserver studies. The following equation was used:

$$\%\ \text{Error} = \frac{\sum_{i=1}^{N} \left| x_{i1} - x_{i2} \right| / N}{\left(\bar{X}_1 + \bar{X}_2 \right) / 2} \bullet 100$$

Where: $\left| x_{i1} - x_{i2} \right|$ is the absolute difference between a measurement value obtained at trial 1 and a measurement value obtained at trial 2 (the same was done between trail 1 and 3, and trial 2 and 3); $\bar{X}_1$ is the mean value obtained at trial 1 (or 2) for a measurement; $\bar{X}_2$ is the mean value obtained at trial 2 (or 3) for a measurement; and N is the number of cases. The percentage error between the trials for each measurement were obtained and averaged for an overall percentage error for each measurement. The acceptable error percentage was set at 5% for all three measurements.

Analysis of variance (ANOVA) was conducted using SAS 9.3. It was used to test several of the statistical hypotheses, including sexual dimorphism and differences between normal and obese individuals. A one-way ANOVA determines if the variance between group means is significant or not by analyzing the variation within groups and the variation between groups. If the variation between groups is greater than the variation within the groups, then the differences between the group means are statistically significant. In order to use ANOVA, the data must be normally distributed and the variances of the groups must be homogeneous. To test if the data are normally distributed, the data for each measurement was plotted as frequencies in MS Excel®.

An analysis of co-variance (ANCOVA) was also performed via SAS 9.3 on the data to test for the presence of a secular trend and was performed for the pooled sexes and the individual sexes. ANCOVA uses a combination of ANOVA and linear regressions to compare groups. Regression analysis examines how the dependent variable changes when the independent variable varied. The ANCOVA not only determined whether a significant difference existed between sub-groups in measurements, but it also plotted this in a regression model. This test used sex and year of birth as the independent variables. This test allowed for a continuous trend through time to be detected. This is important since the 19th century sample is small and restricted to the last thirty years of the century whereas the 20th century sample spans over 80 years of the century.

CHAPTER III

RESULTS

Intra- and Inter-Observer

In order for the measurements created for this study, the tibia intercondylar distance (ITD), tibia posteriolateral epiphyseal thickness (PLET), and tibia posteriomedial epiphyseal thickness (PMET), to be considered reliable, the percent error must be below 5%. The results of the error analysis are below this accuracy limit (Table 3.1). Thus these three measurements are considered to be consistent and reliable within an observer over multiple trials as well as between observers when measuring the same sample.

Table 3.1. Intraobserver and Interobserver Percent Error Rates

Measurement	Intraobserver (%)	Interobserver (%)
ITD	3.89	1.8
PLET	0.08	0.7
PMET	0.12	1.3

Sample Characteristics

The mean, standard deviation (SD), and the range (given as the minimum and maximum) are provided in Appendix C for all of the variables. Tables 3.2 and 3.3 provide the sample characteristics for the age, body mass index (BMI), year of birth (YOB), and stature (STAT) for females and males.

Table 3.2. Descriptive Statistics for Females

Variable	Mean	SD	Minimum	Maximum
Age	47.71	9.45	29	60
BMI	28.38	9.45	18.70	57.40
YOB	1941	22.17	1870	1979
STAT	1.63	0.07	1.47	1.83

Table 3.3. Descriptive Statistics for Males

Variable	Mean	SD	Minimum	Maximum
Age	43.85	6.95	26	55
BMI	28.21	8.58	19.50	57.50
YOB	1940	30.98	1876	1982
STAT	1.75	0.08	1.53	1.96

Sexual Dimorphism

The results of the ANOVA comparing the sexes show that there is sexual dimorphism in both size and shape. The only three measurements that were not statistically significant were body mass index (BMI p=0.9048), femoral midshaft shape (FMS p=0.2955), and tibia shaft shape at the nutrient foramen (TNS p=0.0681) (see Appendix C). Males exhibit larger values than females for all significant variables except the shape variables femur lateral condyle shape (FLCS), femur medial condyle shape (FMCS), femur distal shape (FDS), tibia lateral condyle shape (TLCS), and tibia medial condyle shape (TMCS). There are no significant interactions between sex and category or sex and century that could have affected the results of ANOVA.

Secular Trends

The results of the ANCOVA with sex and year of birth as the variables show significant relationships between year of birth and the following variables when the sexes are pooled: stature (STAT), weight (WGHT), body mass index (BMI), femur maximum length (FML), femur anterior-posterior diameter at the midshaft (APS), femur anterior-posterior diameter of the later condyle (APL), femur epicondylar breadth (FEB), tibia anterior-posterior diameter at the nutrient foramen (APN), tibia mediolateral breadth of the lateral condyle (LMLB), tibia maximum breadth of the proximal epiphysis (BPE), tibia condylo-malleolar length (TML), tibia lateral condyle shape (TLCS), tibia medial condyle shape (TMCS), femur midhsaft shape (FMS), and tibia shaft shape at the nutrient foramen (TNS) (see Table 3.4, see Fig. 3.1 for STAT, BMI, FML, and TML, see Appendix C for graphs). While the femur anterior-posterior diameter of the medial condyle (APM) is not strictly significant, it is almost significant at p=0.0676 and thus also will be considered in the discussion. There is a significant interaction between birth year and sex for the femur medial condyle mediolateral breadth (MCML), tibia intercondylar tubercle distance (ITD), femur medial condyle shape (FMCS), and tibia lateral condyle shape (TLCS) (see Fig. 3.2).

When the sexes are divided, males and females exhibit differences in the overall trend. There are significant correlations in females between birth year and the following: WGHT, BMI, FML, APS, femur mediolateral diameter of the midshaft (MLS), MCML, femur bicondylar breadth (BCB), FEB, APN, tibia anterior-posterior breadth of the lateral condyle (LAPB), LMLB, ITD, BPE, TML, and TLCS (see Table 3.4, see Appendix C for graphs). While the femur medial condyle shape (FMCS) is not strictly significant for females, it is almost significant at p=0.0521 and is thus considered in the discussion. There are significant relationships in males between birth year and STAT, WGHT, BMI, FML, APS, FEB, BPE, TML, FMCS, TLCS, FMS, and TNS (see Table 3.4, see

Appendix C for graphs).

Table 3.4 Significant Results for Secular Trends Through Year of Birth

Measurement	P-value for Females	P-value for Males	P-value for Pooled Sexes	Interaction of Year of Birth and Sex
STAT	0.1586	0.0017	0.0032	0.4173
WGHT	0.0002	0.0008	<0.0001	0.2742
BMI	0.0003	0.0041	<0.0001	0.0950
FML	0.0334	0.0056	0.0012	0.8749
APS	<0.0001	0.0298	<0.0001	0.1219
MLS	0.0400	0.8542	0.1121	0.0729
APL	0.0835	0.1130	0.0314	0.8970
APM	0.0964	0.2799	0.0676	0.6280
MCML	0.0038	0.2074	0.2297	0.0056
BCB	0.0477	0.5595	0.0791	0.2999
FEB	0.0221	0.0492	0.0050	0.7238
APN	0.0228	0.1002	0.0065	0.4260
LAPB	0.0327	0.4924	0.0745	0.3707
LMLB	0.0285	0.0868	0.0085	0.5831
ITD	0.0451	0.1800	0.3684	0.0165
BPE	0.0075	0.0329	0.0009	0.4058
TML	0.0012	<0.0001	<0.0001	0.6858
FMCS	0.0521	0.0308	0.6736	0.0048
TLCS	0.0001	0.0046	<0.0001	0.0369
TMCS	0.1351	0.1389	0.0134	0.7251
FMS	0.1609	0.0192	0.0134	0.9177
TNS	0.1759	0.0396	0.0232	0.9576

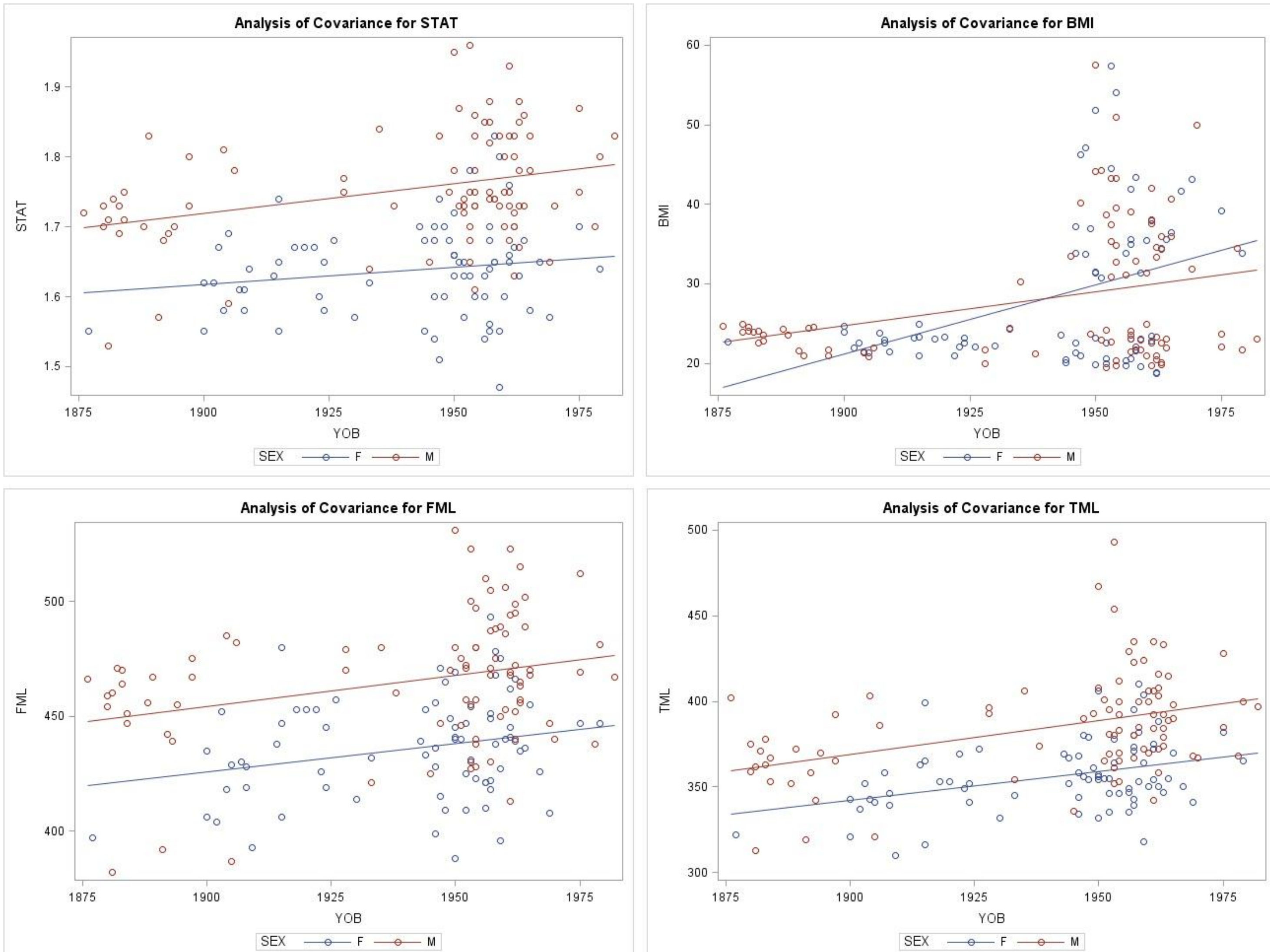


Figure 3.1. Year of birth secular trend for STAT, BMI, FML, and TML

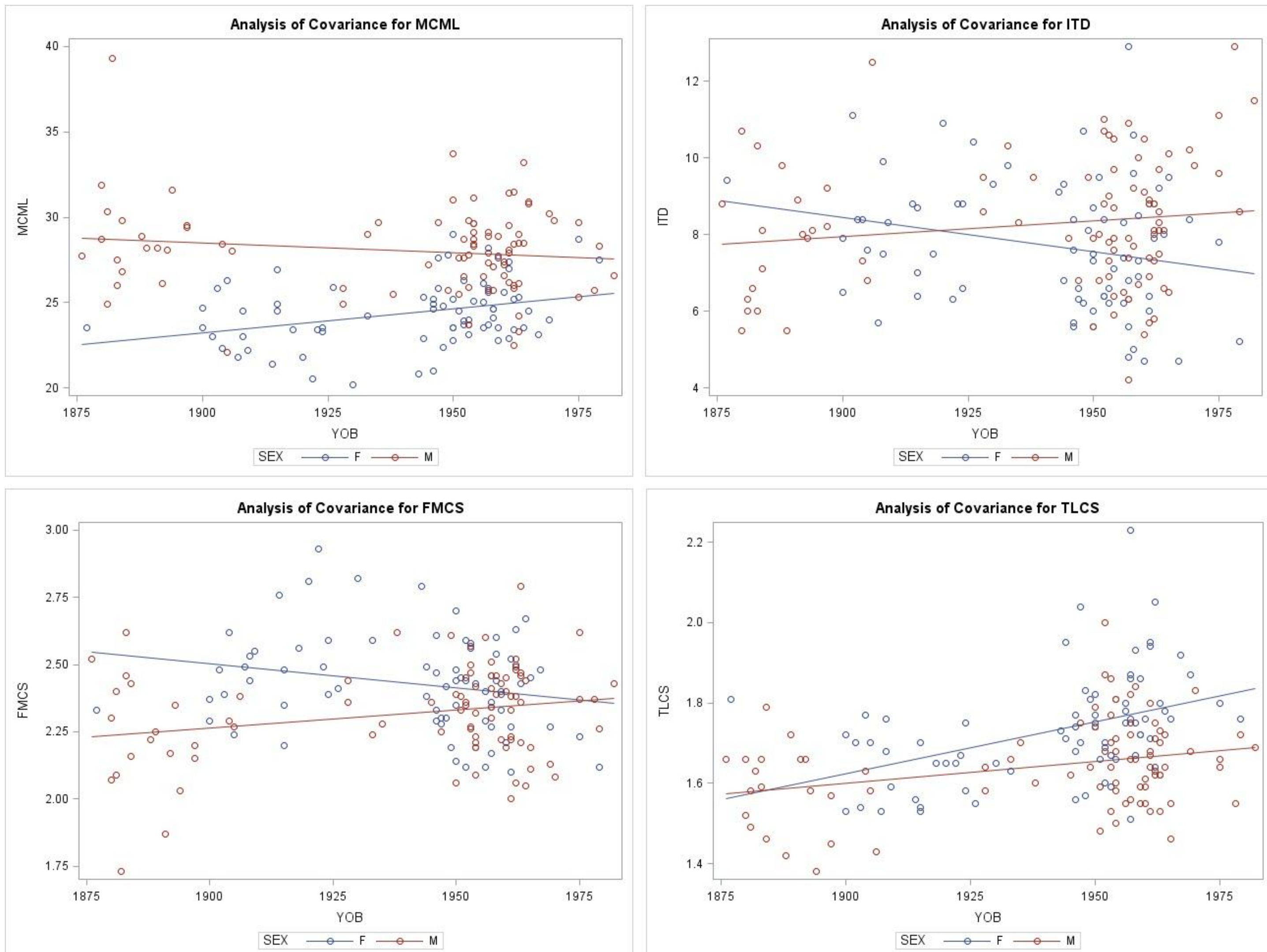


Figure 3.2. Year of Birth Secular Trends

Differences Between Normal Weight and Obese Weght

Body Mass Index

The results of the secular trend analyses have demonstrated that there is a secular trend in the body mass index (BMI) for both females and males. Flegal et al. (2002) and Ogden et al. (2006) have both demonstrated that obesity has been rising over time. The results presented here support their findings by showing that BMI has been increasing for both sexes (see Fig. 3.3). It should be noted that while both sexes are increasing, females show a higher increase than males.

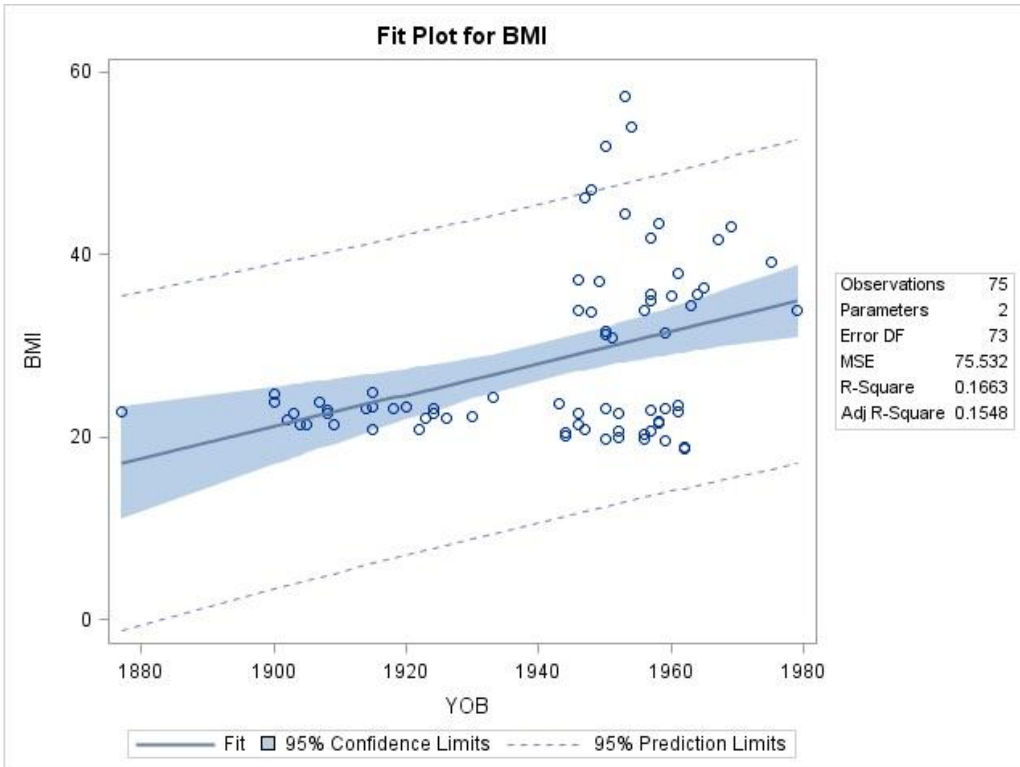
Females

The results of the two-way ANOVA performed for the females between BMI categories that the femur mediolateral diameter of the midshaft (MLS $p=<0.0001$), tibia anterior-posterior diameter at the nutrient foramen (APN $p=0.0312$), femur medial condyle shape (FMCS $p=0.0220$), and femur midshaft shape (FMS $p=0.0375$) are significantly different between the normal weight and obese categories (see Fig. 3.4). The femur anterior-posterior diameter at the midshaft (APS $p=0.0572$), femur distal shape (FDS $p=0.0651$), and tibia lateral condyle shape (TLCS $p=0.0606$) are almost significant at the 0.05 level.

Males

The results of the two-way ANOVA performed for the males between BMI categories are that APS ($p=0.0217$), MLS ($p=<0.0001$), femur medial condyle mediolateral breadth (MCML $p=0.0284$), and APN ($p=0.0337$) are significantly different between the normal weight and obese BMI categories (see Fig. 3.5). The posteriolateral epiphyseal thickness of the proximal tibia (PLET $p=0.0511$), FMCS ($p=0.0625$), and

FMS (p=0.0658) are almost significant at the 0.05 level.



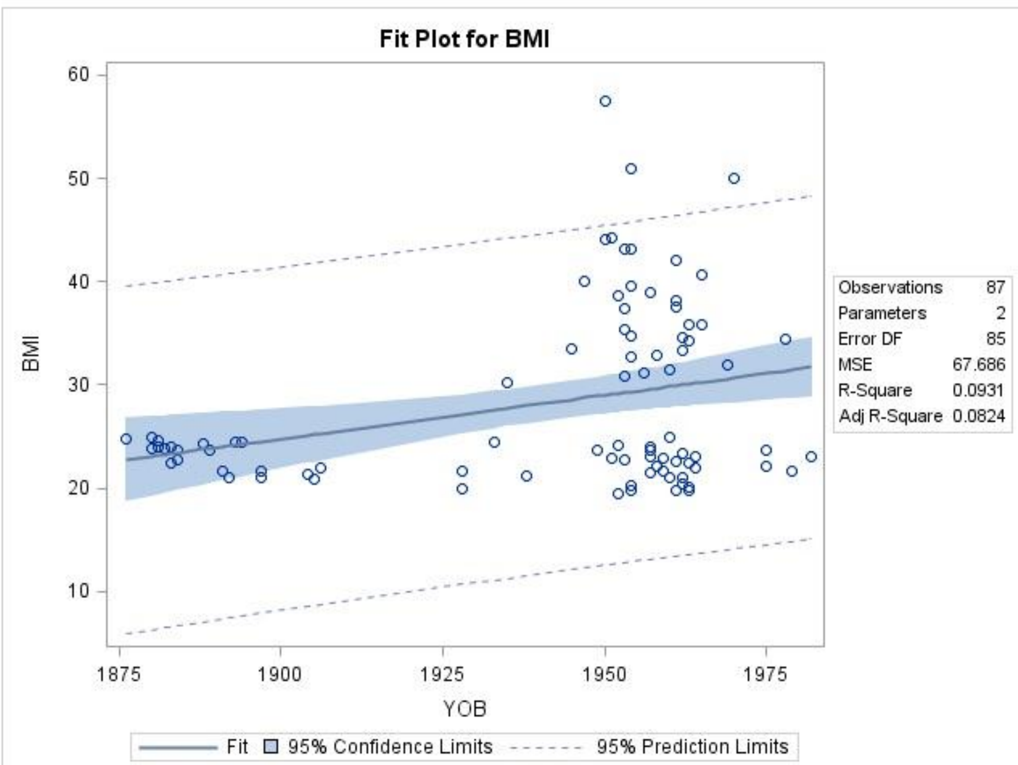


Figure 3.3. BMI Secular Trends for Females (top) and Males (bottom)

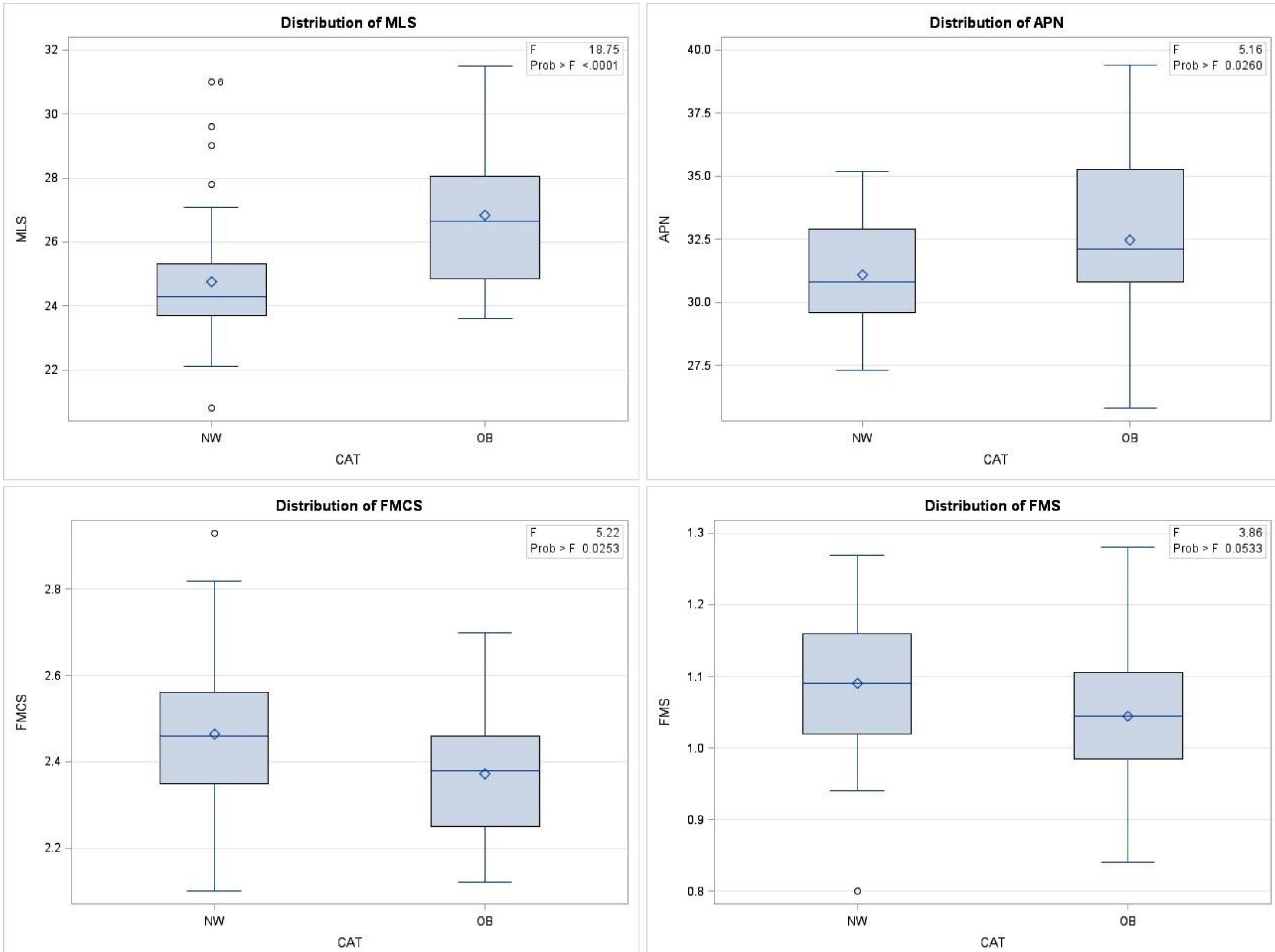


Figure 3.4. Significant Differences Between Normal Weight and Obese Females for MLS, APN, FMCS, and FMS

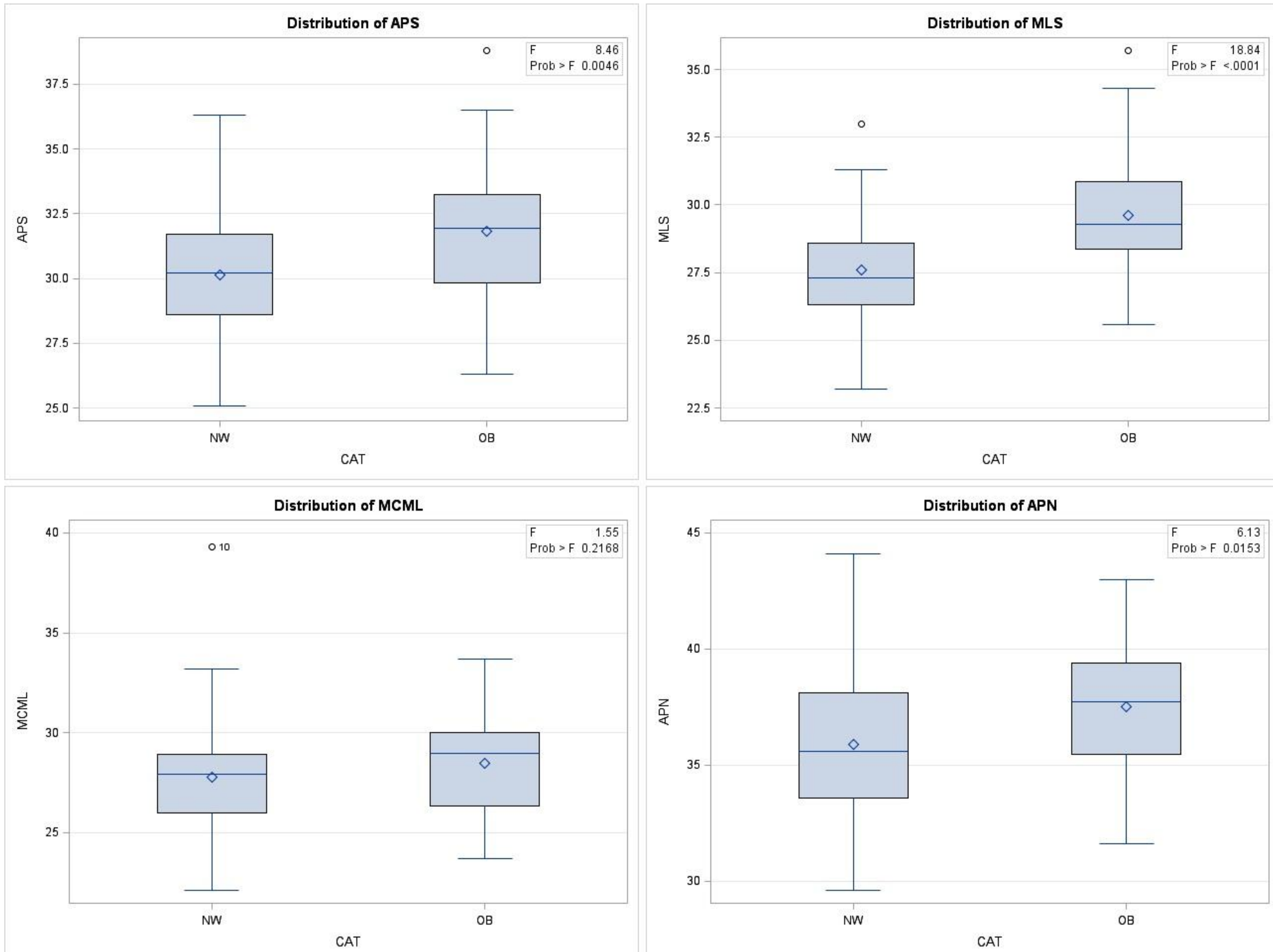


Figure 3.5. Significant Differences Between Normal Weight and Obese Females for APS, MLS, MCML, and APN

CHAPTER IV

DISCUSSION

Sexual Dimorphism

It was expected that there would be sexual dimorphism for the measurements taken since sexual dimorphism has been observed for a variety of aspects in the human form. It is interesting that femur midshaft shape (FMS) and tibia shaft shape at the nutrient foramen (TNS) show no significant sexual dimorphism while the individual measurements that make up these shape ratios have highly significant sexual dimorphism. This indicates that while the measurements are different between the sexes, the shape is relatively the same. Researchers have generally attempted to link lower-limb morphology to subsistence strategy and sexual division of labor. For example, Ruff (1987) argued that the differences in the femoral and tibial midshaft shapes between hunter-gatherers, agriculturalists, and modern industrial groups are a factor of the difference of mobility of the sexes between these groups. Differences in mobility between the sexes in each group is a function of the sexual division of labor, with men performing tasks that require more travel than women in hunter-gatherer societies, men performing increasingly sedentary tasks in agricultural societies, and men and women performing relatively equal tasks in terms of mobility in modern industrial societies (Ruff 1987). While mobility, specifically walking versus jogging/running, has been demonstrated to correlate with the anterior-posterior dimension of the femur and tibia, there are other variables that likely account for midshaft morphology, such as genetics, climate, terrain, and age at which adult activities begin (Wescott 2006). Nonetheless, it does appear that the reduced sexual division of labor in modern industrial societies is one of the factors contributing to the reduced sexual dimorphism in the midshaft shapes of the femur and tibia (Ruff 1987, Wescott 2006). Since there are significant differences between the sexes in the measurements and shape ratios, it is expected that the results of the secular trend and the body mass index analysis would also show a difference between the sexes.

Secular Trends

The fact that secular trends are present is not surprising. Secular trends have been documented in the skeletal system for the cranium (Jantz 2001, Wescott and Jantz 2005), pelvis (Driscoll 2010), and the femur and tibia (Meadows Jantz and Jantz 1995, 1999). Secular change in long bone length was expected based on previous studies (Meadows Jantz and Jantz 1995, 1999) and changes in diaphyseal size and shape were likely based on secular trends in the pelvis (Driscoll 2010).

Driscoll (2010) found that the pelvis is increasing in the anterior-posterior direction in the pelvic inlet, in the mediolateral direction in the pelvic outlet, and an increased subpubic angle for both females and males. Driscoll (2010) also observed that there is a decrease in bi-iliac breadth in the pelvis, suggesting that our bipedal efficiency is decreasing, possibly due to increased reliance on technology for transportation and cultural preferences. Such changes, particularly in the bi-iliac breadth, predict changes in lower limbs.

There are several measurements that exhibit a secular trend in the pooled sexes for year of birth. Stature (STAT), femur maximum length (FML), and tibia condylemalleolar length (TML) are among those with a secular trend through the birth years. This is not surprising since Meadows Jantz and Jantz (1995, 1999) have demonstrated an increase in height and femur and tibia lengths over the past 150 years. Meadows Jantz and Jantz (1999) have also noted that while both the femur and tibia exhibit change through time, changes in the tibia are more pronounced than those in the femur. In the century and year of birth analyses, TML is more significant than FML. Thus, the results of this study support their conclusions on rates of change in the tibia and femur.

The anterior-posterior dimension of the femur (APS) and the femoral midshaft shape (FMS) also exhibit secular change through the birth years for the pooled sexes with APS increasing and FMS increasing in the anterior-posterior direction. Since the AP bending strains increase in relation to increased lower-limb length and there is a significant trend in FML, it is not surprising that these trends would be present in the year of birth analysis (Gruss 2007). Gruss (2007) demonstrated that during the stance phase of walking, individuals with longer lower-limbs had increased anterior-posterior bending stresses at the femoral and tibial midshafts, knee, and ankle. Therefore, as the femur increased in length through time, so did APS and FMS in correlation with it. A later study also looking at the correlation between lower limb length and anterior-posterior/mediolateral bending stresses took into account the added weight that comes with added height (Shaw and Stock 2010). When the measurements were standardized for lean body mass, the significance between limb length and anterior-posterior diameter of the femur found by Gruss (2007) no longer held significance. The results obtained by Shaw and Stock (2010) indicate that the extra body mass associated with being taller is not a cause of the increased anterior-posterior bending stresses that result in larger anterior-posterior diameters of longer femurs (Shaw and Stock 2010). However, Shaw and Stock (2010) did not account for extra fat weight associated increases in body mass index. Therefore, it is possible that the observed increase in the anterior-posterior diameter of the femoral midshaft, and therefore FMS, could have resulted from a combination of increased length and body mass.

In addition to these measurements, there are several measurements with secular trends for birth years, both for pooled sexes and the individual sexes. Which measurements are significant differs between the females, males, and pooled sexes. These differences could be caused by the differences in sample sizes between the females and males. Another possible factor is the sexual dimorphism in size and shape between the sexes for the measurements examined. With males generally being larger, it would take a larger change in the measurements for them to become significant.

There are some interesting patterns in the results that indicate that the sexes are changing in different areas of the knee. Both sexes show significant secular trends for the femur and tibia length (FML and TML) and the midshaft of the femur (APS). This corresponds with previous research in stature and long bone length increases (Meadows Jantz and Jantz 1995, Meadows Jantz and Jantz 1999) and in the correlation between long bone length and the anterior-posterior dimension of the femur (Gruss 2007, Shaw and Stock 2010). Females also show significant trends in the midshaft dimensions of the femur in the mediolateral direction (MLS) and the tibia in the anterior-posterior direction (APN) that males do not. In general, MLS and APN are increasing over time in females. Shaw and Sock (2010) determined that the bi-iliac breadth is correlated with mediolateral dimensions of the femoral shaft. In particular, it was demonstrated that as the bi-iliac breadth widens, so does the mediolateral dimensions of the femur. Based on this, one could conclude that the increase in MLS is in part a product of bi-iliac widening. However, Driscoll (2010) documented a narrowing of the bi-iliac breadth in her research on secular trends in the pelvis. Therefore, the trend in MLS is not correlated with bi-iliac breadth in this case. While Driscoll (2010) did not investigate whether or not bi-acetabular breadth changed, it is possible that such a change is occurring. If a change in the bi-acetabular breadth is occurring, this could have a greater impact on MLS and will need to be investigated in future research. It is also possible that the trend in MLS is correlated with the rise of obesity since MLS is significantly different between normal weight and obese females. The increase in APN is a factor of increased height, as it was for the femur. Gruss (2007) and Shaw and Stock (2010) demonstrated that the increased anterior-posterior bending forces associated with increased lower limb length causes an increase in the anterior-posterior dimensions of the tibia and is not associated with the extra lean body weight incurred by having increased height.

Only males demonstrate a significant change in the femoral and tibial midshaft shapes (FMS and TNS). Both of these shape ratios are increasing, indicating that the femur and tibia are becoming more anterior-posteriorly elongated. Since males are increasing in APS, it was not surprising the FMS showed a secular trend. However, for the tibia, neither the anterior-posterior (APN) nor the mediolateral (MLN) of the tibial shaft at the nutrient foramen were significant. This suggests that the shape ratio TNS is capturing a change that is occurring that the individual measurements did not. This could be a result of the fact that since males are generally larger than females, it will take a larger change in the measurements for them to become significant. APN, FMS, and TNS do show a significant trend when the sexes are pooled, probably owing to the significance of these measurements in one of the sexes.

Females are changing more than males in the knee as evidenced by the significant secular trends for females, but not for males, at the femur medial condyle in the mediolateral direction (MCML), distal femur breadth (BCB), tibia lateral condyle in both the anterior-posterior and mediolateral directions (LAPB and LMLB), and tibia intercondylar tubercle distance (ITD). There are two possible explanations for females showing these changes when males do not. One possibility is that females are becoming obese at an earlier age than males. This would mean that their skeletons would have a longer period of time to adjust to the added weight from being obese. The other possibility is that since females are smaller than males, the added weight from being obese would have a greater effect on the bones than in males. Finally, since there has been little change in obesity among females between 1999 and 2004, it is possible that the effects of obesity are already established in the skeletal remains examined, but is just starting to change in males.

Both sexes do demonstrate a secular trend present in the femur epicondylar breadth (FEB), suggesting that males are changing at the distal femur, which supports Moore (2008) and Agostini and Ross (2011). Also, while females are showing more secular trends in the dimensions of the knee, both sexes have a significant secular trend in the shape of the knee at the tibia lateral condyle (TLCS). In addition to this, males show another secular trend in shape at the knee for femur medial condyle (FMCS). This suggests that females are changing in both size and shape. However, males appear to be changing primarily in shape, suggesting that the individual measurements are not capturing the change occurring while the shape ratios are showing the change for males.

There are some possible explanations for the differences between females and males in the secular trends. One potential explanation is that females show a more significant secular trend in BMI than do males (p=0.0003 and p=0.0041 respectively), indicating that the skeleton of females are under more weight-induced stresses than males. However, Ogden et al. (2006) reported in their results that females are increasing in obesity less than males. The conflict between the results presented here and Ogden and coworkers' (2006) results could be a product of the sample size and strict sampling methods employed in the current study. The sample used here was not randomly chosen and represents only a portion of the United States population (see Assumptions and Limitation section below). Therefore, this sample is not congruent with the NHANES sample used by Ogden and coworkers (2006), but rather represents a subset. Nonetheless, the steeper BMI trend in females found here combined with the fact that females are smaller than males in size and muscle mass could cause a larger stress in the load-bearing joints of females. Since males have larger muscle mass, their skeletons may have already incorporated the changes for greater body mass. Therefore, the steeper trend in BMI observed for females and the lack of preexisting capabilities for increased body mass could be causing females to change more than males in the lower limbs. However, it must be noted that it is unknown for how long the individuals in this study were obese or what periods in their life they were obese.

Differences Between Normal Weight and Obese Individuals

It is possible that the secular trends observed in the knee are associated with changes in stature and body weight. To investigate this possible cause, the differences between individuals with normal and obese BMI were examined. The majority of the differences between the normal weight and obese individuals lie in the midshafts of the femur in the anterior-posterior and mediolateral dimensions and the shape (APS, MLS, and FMS), and the tibia in the anterior-posterior dimension (APN). In females, MLS, APN, and FMS have significant differences between normal weight and obese individuals and APS is almost significant. In males, APS, MLS, and APN are significant and FMS is almost significant for differences between normal weight and obese individuals.

These results support previous research done by various authors that show similar results (Agostini and Ross 2011, Moore 2008, Moore and Schaefer 2011, Ruff et al. 1991). Agostini and Ross (2011) found that the greatest difference between normal weight and obese individuals in the midshaft was in the mediolateral direction when examining the femur. Ruff and colleagues (1991) also found that femur diaphyseal dimensions were more correlated with body mass than femoral head dimensions. Moore (2008) and Moore and Schaefer (2011) found that while the mediolateral dimension was significantly different, the difference was more pronounced when looking at body weight rather than the BMI. Specifically, they found that the widening of the femur in the mediolateral direction was greatest in individuals more than 115kg (Moore and Schaefer 2011). This could be a function of the added stresses that extra weight puts on the femur. Since the femur is angled such that the distal end of the femur is closer to the midline than the proximal end (angled in the mediolateral direction), the extra weight in obese individuals would be putting more mediolateral stress on the femur in comparison to normal weight individuals having the same femur length. Therefore, it was expected that

MLS would be significantly different between normal weight and obese categories for both sexes.

For the femur, APS was also significant for males and almost significant for females. This suggests that the femoral midshaft is significantly different in both directions, not just in the mediolateral dimension as the previous research has indicated. Increases in the anterior-posterior diameter of the midshaft could be the result of the increased length of the femur (Gruss 2007). As femur length increases, the anterior-posterior bending strains also increase (Gruss 2007, Shaw and Stock 2010). Therefore, it would be expected that APS might increase in relationship to increases in femoral length (FML), as seen in the secular trends discussed above. Yet, Shaw and Stock (2010) demonstrated that the extra weight correlated with increased height is not affecting the anterior-posterior bending stresses in the femur. However, added weight from being taller is not added weight from being obese. Therefore, obese individuals are probably placing greater bending stresses on the femora than are normal BMI individuals with the same length femur. This increased bending stress in obese individuals, however, may not be anterior-posterior bending stress. Wescott and Zephro (2012) demonstrated in their study that the mediolateral widening of the femoral shaft is correlated with femoral head diameter (FHD), and thus body mass. This supports the results of both previous research (discussed above) and the current study. Moreover, they discovered that the anterior-posterior widening of the femoral shaft was more correlated with femoral length (FML) for both sexes, but was also correlated with FHD in males. This suggests that the increase in APS in obese males found here is partially a result of the added weight from being obese. More research on this topic needs to be conducted in order to determine the types of stresses that added weight from obesity puts on the weight bearing bones of the body.

Meadows Jantz and Jantz (1999) have noted that while both the femur and tibia exhibit change through time, changes in the tibia are more pronounced than those in the femur. Therefore, it is surprising that most of the research published thus far has been focused on the femur with few studies including the tibia in their analysis. Based on Meadows Jantz and Jantz's (1999) observation that the tibia changes as well as the femur, it was expected that the tibial shaft dimensions at the nutrient foramen (APN) would show significant differences. However, if the results from Shaw and Stock (2010) are taken into account, one would not necessarily expect significant differences in the tibial diaphysis. Once again, here is a situation in which added weight from being taller is not added weight from being obese. Obese individuals are placing greater bending stresses on the tibia than are normal BMI individuals with the same length tibia. In both sexes, the APN is significantly different between normal weight and obese individuals with this dimension increasing in obese individuals. These results indicate that while the femur is changing in the both directions, the tibia is primarily changing in the anterior-posterior direction.

The results for the articular surfaces of the distal femur and proximal tibia are different between females and males. For the femur, females show a significant difference in the femur medial condyle shape (FMCS) between normal weight and obese individuals while males are not quite significant for this shape ratio. One possible factor in the difference between females and males in FMCS is that males are significantly larger and therefore would need a larger change in either anterior-posterior diameter of the medial condyle (APM) or medial condyle mediolateral breadth (MCML) of the femur in order to make this shape ratio significantly different. Males are significant for MCML while females are not. This suggests that in females, the individual measurements are not changing enough to capture the changes occurring that the shape ratio captures. In males, the change in MCML, while significant, is not enough to be captured by the shape ratio. Females are also almost significant in the femur distal shape (FDS) while males are not. Neither the femur anterior-posterior diameter of the lateral condyle (APL) nor the femur bicondylar breadth (BCB) are significant or close to significant for either sex. This indicates that the shape ratio is capturing a change in the distal femur that the individual measurements do not.

Ruff (2003) has shown that the tibia proximal mediolateral dimension is a good predictor of anthropoid body mass. While his study was geared toward anthropoids rather than humans, it is a prominent study in the area of body mass estimation and provides a base from which to work. It is therefore surprising that there were no significant differences for the mediolateral measurements of the proximal tibia between normal weight and obese individuals for either sex. However, this could be a product of the biomechanical differences between anthropoids and humans. At the proximal tibia, there are a few nearly significant measurements for the proximal tibia. For females, the tibia lateral condyle shape (TLCS) is almost significant and males are almost significant for the tibia posteriolateral epiphyseal thickness (PLET). These results suggest that females are exhibiting more shape changes in the proximal tibia articular surfaces than males, but that males are showing epiphyseal thickness changes on the posterior-medial side. The increased thickness of the joint could be a result of increased body mass, but this is the first study to examine the correlation between body mass and epiphyseal thickness.

It is interesting to note here that the tibia medial condyle is not showing any significant or nearly significant differences between normal weight and obese individuals. This means that the differences observed in the femur medial condyle is not mirrored in the tibia as expected. However, the reason for this is unknown at this time.

When it comes to gait, DeVita and Hortobagyi (2003) demonstrated that normal weight and obese individuals have a different gait when walking. In particular, they found that obese individuals adjusted their gait to redirect the torque placed on the knee to the ankle (DeVita and Hortobagyi 2003). Thus, obese individuals may not be adding additional stress to the knee joint. Future studies should focus on changes in the distal tibia and the ankle.

Is the Rise of Obesity Correlated with the Secular Trend?

The rise of obesity appears to be correlated with some of the secular trends observed in the femur and tibia. In particular, the midshaft dimensions and shape are significant for a secular trend and for differences between normal weight and obese individuals (MLS and APN in females, and APS in males). This indicates that obesity is a contributing factor to the secular change observed. This can be explained by the biomechanics of bone and the surrounding muscle and ligamentous tissues that work on the bone. The extra weight puts more strain on the bone causing the bone to respond and remodel its structure to accommodate the increased muscle strain caused by the added weight.

It is less clear if obesity is affecting the knee joint. It is possible that obesity is a contributing factor in the secular trend observed for the femur medial condyle shape (FMCS) in females. It is also possible that obesity is a contributing factor in the secular trend observed for femur medial condyle mediolateral breadth (MCML) in males. Other measurements show a secular trend, but are not quite significantly different between normal weight and obese individuals (TLCS in females, and FMS in males). The secular trend observed in these measurements might be influenced by BMI trends, but it is unclear at this time how much obesity is actually affecting such trends.

Part of the reason for the uncertainty of the correlation between obesity and secular trend is due to the fact that there are many more trends than there are differences between normal weight and obese individuals at the knee joint. If obesity is a causal factor in the secular trend, then why does it only show up for the select few variables seen here? More research will need to be conducted on the correlation between the secular trends observed in the skeleton and those observed in body mass to determine the extent of the effects that obesity has on the skeletal trends. Better data on how long individuals have been obese and at what age they became obese is needed to tease out the causal effects of obesity on morphological changes of the femur and tibia.

Assumptions and Limitations

There are a few assumptions that are made in this study that need to be addressed. The first is in relation to the individuals in the collections used. In selecting the Terry, Bass, and Texas State Collections, it is assumed that they are representative of the larger population from which they originated. The Terry Collection is primarily composed of cadavers from medical schools. Many of the cadavers used in medical schools in the 19th century were unclaimed individuals from morgues, and therefore often from the lower socioeconomic classes (Hunt and Albanese 2005). This presents a bias in the segments of society (social classes) represented by the individuals in this collection, and thus the 19th

century population that it represents.

The Texas State and Bass Collections are composed of bodies donated by the individuals or their families, and therefore represent both higher social classes, generally the middle classes, and the same social class as the Terry Collection. The earlier donations received at the Bass Collection were in fact Medical Examiner donations of unclaimed and unknown individuals (Shirley et al. 2011). Therefore, as with the Terry Collection, a portion of the individuals at the Bass Collection are of the lower class. This presents a bias in the segments of society that is represented by the individuals in these collections. The different sources of the collections could also affect the time-dependent trends in the data that do not reflect trends in the population that is represented by the samples.

The sample sizes of the subgroups also constrain the research. There are fewer females than males and fewer obese individuals than normal weight individuals. This could skew the results in favor of one or the other group. The earlier birth years are also less represented than the middle to later birth years when the distribution of year of births are plotted. In particular, the 19^{th} century sample size is very small, 19 individuals, but spans the last thirty years of the century. Therefore, it is probable that the majority of the secular trends observed in this study are primarily in the 20^{th} century. However, most of the secular trends associated with obesity are occurring later in the 20^{th} centrury so this may not be a biasing factor. Larger sample sizes will need to be gathered in the future to confirm the results obtained in this study and to expand the scope of interpretations.

Since the data were only collected from American White individuals, the results of this study are only applicable to this population. Part of the reason for this limitation is that American Whites show different patterns of obesity than other ancestry groups as demonstrated by Flegal et al. (2002) and Ogden et al. (2006). Future research will need to be conducted on other ancestry groups to determine if the results of this study will be similar to those of other groups.

Since the sample was constricted by excluding obese individuals showing pathological conditions at the knee, it is possible that part of the obese population is not being sampled. As discussed in the Methods and Materials chapter, this was to eliminate any discrepancies in the measurements caused by bony growth and remodeling due to pathology such as osteoarthritis. However, as Moore (2008) and Moore and Schaefer (2011) demonstrated, obesity correlates with such pathology. Therefore, excluding obese individuals with pathology limits the scope of the study in terms of the subsample of the obese population being selected.

Finally, another limitation of this study is that weight at or just prior to death is used. This means that the BMI calculated for each individual only represents the last portion of their lives. It is possible that some of the obese individuals were not obese for very long prior to death. In the same manner, normal weight individuals could have been obese for a period of their lives and lost the weight before death. Finally, the age at which a person becomes obese could have a significant effect on the morphology of the knee. Individuals that were obese as children or juveniles would be expected to show greater changes than individuals that became obese as adults. Due to this limitation, it is likely that there is some noise in the data created by fluctuations in weight in the individuals and the period of their lives that the weight at death represents. This noise could be causing reduced significance in the results of some measurements or inflating the significance in the results of other measurements. Therefore, while this study provides a stepping-stone in the analysis of the effects of obesity on the skeletal system and secular trends, more in-depth research needs to be conducted to verify the results of this study.

CHAPTER V

CONCLUSION

This study aimed to determine whether or not secular trends are present in the articular surfaces of the knee joint, whether or not differences exist between normal weight and obese individuals at the knee joint, and whether or not the rise in obesity is a causal factor in the secular trends observed at the knee joint. To investigate these points of inquiry, the femur and tibia of skeletons from the Robert J. Terry Collection, William M. Bass Donated Skeletal Collection, and Texas State University Donated Skeletal Collection were measured. These measurements were then subjected to various statistical analyses that allowed for the determination of secular trends, and dimorphism between normal weight and obese individuals.

The results helped to answer some of the research questions addressed in this study. The first research question addressed whether or not secular trends are present in the femur and tibia. The results do show that there are significant secular trends observed in the bony elements of the femur and tibia at the knee joint. While both null hypotheses were rejected, it must be noted that the results showed that females are changing more than males overall. The second question asked was whether or not there were significant differences between normal weight and obese individuals in the femur and tibia. The results indicated that there are differences between normal weight and obese individuals, and thus both null hypotheses were again rejected. However, there are not many differences and most of the significant differences are found in the midshaft, not the articular surfaces of the knee joint. Also, which measurements and shape ratios are significantly different between normal weight and obese individuals vary between females and males. Finally, the third question posed here was whether or not the rise of obesity could be a factor in the secular trends observed in the knee joint. The results are such that while it is possible that there is some correlation between obesity and the secular trends observed at the knee joint, it is unclear if this is the case since there are so few measurements that are significant between NW and OB individuals. The results did support previous research on the effects of obesity on the shaft dimensions of the femur and tibia and showed a correlation between these dimensions and the secular trends observed. Since obesity rates do not increase significantly until the 1980s and the latest birth year used in this study is 1982, it is possible that the true effects of obesity will not be observable until late 20th and early 21st century birth cohorts are available. However, the results do support the results of diaphyseal cross-sectional geometry that suggest that diaphyseal size and shape are more sensitive to mechanical loading than articular surface size and shape (Ruff et al. 2006, Ruff et al. 1991).

It is certainly clear that obesity is affecting the skeleton in many ways as evidenced by the significant differences in the results between normal weight and obese individuals. Thus, this study adds to the literature on the subject of obesity effects on the skeleton. However, the correlation between obesity and secular trends is unclear despite the interesting results found here. Future research will need to be conducted to determine the extent that obesity plays a role in the secular trends observed in the lower limb.

APPENDIX A

TERMS AND DEFINITIONS

Femur:

1. Femur Epicondylar Breadth (FEB) – Measured over the most outstanding points of the epicondyles, parallel to the infracondylar plane (Zobeck, 1983).
2. Femur Bicondylar Breadth (BCB) – Greatest breadth across the condyles (transverse condylar breadth) taken at a point in the middle of each condyle (posteriorly) (Zobeck 1983).
3. Femur Anteroposterior Diameter of Lateral Condyle (APL) – The projected distance between the most posterior point on the lateral condyle and lip of the patellar surface taken perpendicular to the axis of the shaft (Zobeck 1983).
4. Femur Anteroposterior Diameter of Medial Condyle (APM) – The projected distance between the most posterior point on the medial condyle and the lip of the patellar surface taken perpendicular to the axis of the shaft (Zobeck 1983).
5. Femur Lateral Condyle Mediolateral Breadth (LCML) – The breadth of the lateral condyle measured at the most posteriorly projecting point (Ruff 2002).
6. Femur Medial Condyle Mediolateral Breadth (MCML) – The breadth of the medial condyle measured at the most posteriorly projecting point (Ruff 2002).
7. Femur Maximum Length (FML) – The maximum length of the femur from the most proximal point on the head to the most distal point on the condyles. Place the distal condyles against the fixed vertical foot of the board and move the

moveable vertical foot to the femoral head. Raise the bone slightly and move until maximum length is obtained (Bass 1987). Femur Anteroposterior Diameter of the Midshaft (APS) – The diameter of the femur at the midshaft in the anterior-posterior direction. Locate the midshaft point via the osteometric board. Measure maximum anterior-posterior diameter (Bass 1987).

8. Femur Mediolateral Diameter of the Midshaft (MLS) – The diameter of the femur at the midshaft in the mediolateral direction. Taken at right angle to APS (Bass 1987).
9. Femur Maximum Vertical Diameter of Head (VHD) – The greatest vertical diameter in the vertical plane passing through the axis of the neck (Zobeck 1983).

Tibia:

1. Tibia Maximum Breadth of the Proximal Epiphysis (BPE) – Maximum distance between the medial and lateral condyles (Zobeck 1983).
2. Tibia Anteroposterior Breadth of Lateral Condyle (LAPB) – The breadth of the lateral condyle as measured from the most posterior point to the most anterior point of the condyle (Ruff 2002).
3. Tibia Anteroposterior Breadth of Medial Condyle (MAPB) – The breadth of the medial condyle as measured from the most posterior point to the most anterior point of the condyle (Ruff 2002).
4. Tibia Mediolateral Breadth of Lateral Condyle (LMLB) – The breadth of the lateral condyle as measured from the most lateral to the most medial point of the condyle (Ruff 2002).

5. Tibia Mediolateral Breadth of the Medial Condyle (MMLB) – The breadth of the medial condyle as measured from the most lateral to the most medial point of the condyle (Ruff 2002).
6. Tibia Intercondylar Tubercle Distance (ITD) – The projected distance between the lateral side of the medial intercondylar tubercle and the medial side of the lateral intercondylar tubercle taken at the crests of the tubercles (Harrington 2013).
7. Tibia Posteriolateral Epiphyseal Thickness (PLET) – The distance (thickness) between the most distal portion of the fibular articular face to the superior plateau of the lateral condyle (Harrington 2013).
8. Tibia Posteriomedial Epiphyseal Thickness (PMET) – The distance between the line demarking the distal attachment of the epiphysis at the posteriomedial curvature of the condyle to the superior plateau of the condyle (Harrington 2013).
9. Tibia Condylo-Malleolar Length (TML) – End of malleolus against the vertical wall of the osterometric board, bone resting on its dorsal surface with its long axis parallel with the long axis of the board, block applied to the most prominent part of the lateral half of the lateral condyle (Zobeck 1983).
10. Tibia Anteroposterior Diameter at the Nutrient Foramen (APN) – Maximum anterior-posterior diameter of the shaft at the nutrient foramen (Bass 1987).
11. Tibia Mediolateral Diameter at the Nutrient Foramen (MLN) – Maximum medial-lateral diameter of the shaft at the nutrient foramen (Bass 1987).

APPENDIX B

Table B.1. Data

CATKEY	Sex	Age	YOB	Stature	Weight	BMI	Category	FML	APS	MLS	VHD
D01-2009	M	49	1960	1.80	68.2	21.0	NW	506.0	28.9	27.5	48.5
D01-2011	M	40	1970	1.73	149.7	50.0	OB	440.0	31.1	30.7	45.5
D03-2009	M	31	1978	1.70	100.0	34.5	OB	438.0	32.1	28.8	45.6
D06-2011	F	53	1957	1.56	102.3	41.9	OB	422.0	28.1	26.6	38.9
D07-2010	M	46	1964	1.86	79.5	23.0	NW	502.0	33.4	33.0	52.4
D07-2012	F	53	1958	1.65	59.0	21.7	NW	468.0	29.5	24.3	41.2
P000012R	F	41	1900	1.55	57.5	23.9	NW	406.0	23.8	23.5	40.8
P0000229	M	41	1883	1.73	67.0	22.5	NW	470.0	33.2	26.4	47.2
P0000274	M	45	1880	1.73	74.4	24.9	NW	459.0	32.9	30.7	50.2
P0000275	F	47	1877	1.55	54.7	22.7	NW	397.0	23.9	25.3	39.5
P0000332	M	50	1876	1.72	73.4	24.7	NW	466.0	36.3	31.3	49.8
P000034R	M	44	1894	1.70	71.0	24.5	NW	455.0	30.8	27.6	48.8
P0000380	M	44	1882	1.74	72.7	23.9	NW	471.0	31.6	30.2	49.5
P0000415	M	47	1880	1.70	69.0	23.9	NW	454.0	25.8	25.4	48.0
P000041R	F	41	1908	1.61	58.4	22.6	NW	428.0	26.9	27.1	41.2
P0000453	M	42	1884	1.71	68.5	23.6	NW	447.0	31.2	30.3	47.8
P0000546	M	40	1888	1.70	70.5	24.3	NW	456.0	27.7	28.3	48.6
P0000564	M	48	1881	1.53	57.7	24.6	NW	382.0	25.1	30.0	43.4
P0000596	M	48	1881	1.71	70.2	24.0	NW	460.0	29.3	27.0	48.5
P0000641	M	38	1892	1.68	59.1	21.0	NW	442.0	28.2	27.7	44.0
P0000755	M	36	1893	1.69	69.7	24.4	NW	439.0	30.1	28.6	48.3
P0000849	M	47	1884	1.75	69.7	22.8	NW	451.0	30.2	27.9	48.3
P0000872	M	48	1883	1.69	68.0	24.0	NW	464.0	26.6	27.2	47.6
P0000918	M	40	1891	1.57	53.2	21.6	NW	392.0	28.1	25.6	41.6
P0000983	F	30	1902	1.62	52.5	21.9	NW	404.0	24.3	22.6	38.5
P0001089	M	43	1889	1.83	78.6	23.6	NW	467.0	32.6	31.1	51.9
P000111R	M	38	1905	1.59	53.0	20.8	NW	387.0	25.5	26.0	41.5
P0001427	M	38	1897	1.80	67.5	21.0	NW	475.0	28.0	31.1	47.4
P0001563	F	29	1933	1.62	63.6	24.3	NW	432.0	27.7	23.4	43.6
P0001564	M	30	1933	1.64	65.5	24.4	NW	421.0	31.3	27.4	46.6
P0001566	F	33	1926	1.68	62.3	22.1	NW	457.0	30.5	24.8	43.0
P0001572	F	45	1914	1.63	61.9	23.2	NW	438.0	24.8	25.3	42.8
P0001574	F	49	1915	1.74	63.2	20.9	NW	480.0	28.8	25.1	43.4
P0001579	F	49	1915	1.65	68.2	24.9	NW	447.0	27.8	25.6	45.7
P0001580	F	45	1918	1.67	64.3	23.1	NW	453.0	27.9	23.8	43.9
P0001582	F	46	1915	1.55	56.2	23.3	NW	406.0	24.9	23.7	40.2
P0001594	F	40	1924	1.65	63.2	23.2	NW	445.0	24.1	24.8	43.4

Table B.1. Data Continued

CATKEY	APL	LCML	APM	MCML	BCB	FEB	APN	MLN	LAPB	LMLB	MAPB	MMLB
D01-2009	69.3	29.5	65.3	26.6	78.2	83.0	35.6	23.5	42.8	26.6	43.9	26.4
D01-2011	62.2	26.3	62.0	29.8	78.6	82.0	36.1	25.4	43.9	24.0	47.4	28.3
D03-2009	58.7	24.5	60.9	25.7	74.4	82.0	39.3	26.4	35.1	22.7	46.5	26.5
D06-2011	56.9	25.6	55.6	25.6	66.1	70.0	35.6	21.5	34.3	22.7	40.8	23.5
D07-2010	71.9	29.5	67.9	33.2	83.4	84.0	41.3	25.5	44.5	27.2	55.3	28.3
D07-2012	65.1	25.3	63.9	24.6	71.5	79.0	33.7	21.2	36.0	21.6	46.8	23.8
P000012R	55.5	22.5	53.9	23.5	65.9	72.0	28.4	20.3	31.9	20.8	39.6	22.6
P0000229	65.6	27.8	67.7	27.5	77.9	83.0	37.9	25.3	38.3	24.1	49.9	27.6
P0000274	66.6	33.2	66.0	31.9	81.5	85.0	37.4	25.2	43.1	28.4	50.4	30.0
P0000275	55.5	21.2	54.7	23.5	63.5	71.0	29.5	20.9	35.1	19.4	42.5	23.1
P0000332	68.6	26.3	69.8	27.7	76.5	88.0	38.6	27.3	42.6	25.6	49.6	26.8
P000034R	67.0	28.6	64.1	31.6	82.1	84.0	36.0	28.2	39.6	28.7	48.4	28.0
P0000380	64.9	31.6	68.1	39.3	76.9	85.0	36.9	29.3	40.7	24.9	50.0	27.4
P0000415	66.5	27.6	66.1	28.7	75.7	83.0	35.3	22.3	38.5	23.2	48.6	28.5
P000041R	60.7	22.9	59.9	24.5	67.3	75.0	33.2	20.8	36.5	20.7	40.9	22.8
P0000453	65.2	27.6	64.5	29.8	78.6	83.0	38.1	25.8	43.6	24.4	50.0	26.7
P0000546	65.6	25.3	64.1	28.9	75.3	83.0	36.7	24.2	34.3	24.2	47.0	27.3
P0000564	59.6	23.8	59.7	24.9	70.9	77.0	32.7	20.0	35.2	23.7	43.1	27.5
P0000596	66.5	30.5	63.3	30.3	77.0	80.0	31.7	23.9	42.9	27.1	45.3	29.5
P0000641	59.7	24.6	56.7	26.1	73.1	79.0	30.4	25.9	40.4	24.4	46.6	26.7
P0000755	63.1	29.3	65.9	28.1	76.3	83.0	37.5	24.2	34.5	21.8	48.1	28.3
P0000849	64.6	29.6	65.0	26.8	76.5	83.0	33.2	23.4	33.2	22.7	44.7	24.0
P0000872	63.7	29.8	68.0	26.0	76.8	83.0	34.9	21.8	42.3	25.5	43.6	24.9
P0000918	55.5	25.0	52.6	28.2	71.8	79.0	34.9	25.2	35.3	21.3	39.7	25.0
P0000983	56.6	22.3	57.1	23.0	66.8	71.0	29.6	21.2	32.1	18.9	40.0	22.0
P0001089	69.6	31.6	63.5	28.2	83.2	89.0	39.1	23.5	50.1	29.1	50.7	26.3
P000111R	51.3	22.5	50.1	22.1	65.4	70.0	29.6	20.7	32.8	20.8	38.7	22.7
P0001427	69.0	30.2	64.7	29.4	77.8	85.0	40.4	22.6	38.6	26.6	47.7	27.6
P0001563	62.7	24.5	62.7	24.2	70.9	78.0	29.6	23.8	36.1	22.2	40.0	22.6
P0001564	66.6	30.5	65.1	29.0	80.0	84.0	37.7	28.2	42.5	25.6	46.9	26.8
P0001566	64.6	25.2	62.5	25.9	70.4	77.0	33.7	25.8	34.6	22.3	45.0	23.1
P0001572	58.6	23.4	59.0	21.4	65.1	74.0	30.6	22.4	34.2	21.9	39.9	23.6
P0001574	60.9	26.7	59.2	26.9	70.2	73.0	34.5	21.2	36.7	24.0	42.1	24.0
P0001579	65.0	24.5	61.8	24.9	70.4	77.0	31.5	23.4	37.0	24.0	43.7	24.6
P0001580	60.7	26.0	59.9	23.4	63.4	75.0	32.1	23.0	35.1	21.3	44.0	23.6
P0001582	58.6	24.4	57.6	24.5	64.9	72.0	28.5	19.1	34.9	20.5	40.5	21.8
P0001594	63.1	25.0	60.8	23.5	67.6	78.0	28.5	19.1	34.1	21.6	43.7	22.3

Table B.1. Data Continued

CATKEY	ITD	PLET	PMET	BPE	TML	FLCS	FMCS	FDS	TLCS	TMCS	FMS	TNS
D01-2009	9.1	24.3	19.2	77.0	406	2.35	2.45	0.89	1.61	1.66	1.05	1.51
D01-2011	9.8	22.6	18.6	79.0	367.0	2.37	2.08	0.79	1.83	1.67	1.01	1.42
D03-2009	12.9	22.4	17.3	75.0	368	2.40	2.37	0.79	1.55	1.75	1.11	1.49
D06-2011	5.6	18.7	14.7	65.0	339	2.22	2.17	0.86	1.51	1.74	1.06	1.66
D07-2010	8.1	29.7	19.9	84.0	415	2.44	2.05	0.86	1.64	1.95	1.01	1.62
D07-2012	10.6	20.4	13.5	71.0	382.0	2.57	2.60	0.91	1.67	1.97	1.21	1.59
P000012R	7.9	17.6	15.3	67.0	321.0	2.47	2.29	0.84	1.53	1.75	1.01	1.40
P0000229	10.3	24.7	19.3	78.0	378.0	2.36	2.46	0.84	1.59	1.81	1.26	1.50
P0000274	5.5	23.4	17.5	82.0	375.0	2.01	2.07	0.82	1.52	1.68	1.07	1.48
P0000275	9.4	17.5	16.6	66.0	322.0	2.62	2.33	0.87	1.81	1.84	0.94	1.41
P0000332	8.8	24.9	18.9	80.0	402.0	2.61	2.52	0.90	1.66	1.85	1.16	1.41
P000034R	8.1	22.6	19.7	80.0	370.0	2.34	2.03	0.82	1.38	1.73	1.12	1.28
P0000380	6.6	20.5	18.9	78.0	371.0	2.05	1.73	0.84	1.63	1.82	1.05	1.26
P0000415	10.7	20.8	18.2	79.0	359.0	2.41	2.30	0.88	1.66	1.71	1.02	1.58
P000041R	9.9	24.5	17.1	69.0	339.0	2.65	2.44	0.90	1.76	1.79	0.99	1.60
P0000453	7.1	25.8	19.2	78.0	367.0	2.36	2.16	0.83	1.79	1.87	1.03	1.48
P0000546	9.8	23.0	19.0	76.0	352.0	2.59	2.22	0.87	1.42	1.72	0.98	1.52
P0000564	6.0	20.9	14.9	73.0	313.0	2.50	2.40	0.84	1.49	1.57	0.84	1.64
P0000596	6.3	23.4	19.3	76.0	362.0	2.18	2.09	0.86	1.58	1.54	1.09	1.33
P0000641	8.0	19.7	17.0	76.0	358.0	2.43	2.17	0.82	1.66	1.75	1.02	1.17
P0000755	7.9	21.6	20.0	78.0	342.0	2.15	2.35	0.83	1.58	1.70	1.05	1.55
P0000849	8.1	24.4	17.8	75.0	353.0	2.18	2.43	0.84	1.46	1.86	1.08	1.42
P0000872	6.0	20.5	19.8	77.0	363.0	2.14	2.62	0.83	1.66	1.75	0.98	1.60
P0000918	8.9	16.9	16.1	71.0	319.0	2.22	1.87	0.77	1.66	1.59	1.10	1.38
P0000983	11.1	18.7	15.5	66.0	337.0	2.54	2.48	0.85	1.70	1.82	1.08	1.40
P0001089	5.5	22.5	23.3	81.0	372.0	2.20	2.25	0.84	1.72	1.93	1.05	1.66
P000111R	6.8	17.1	13.5	66.0	321.0	2.28	2.27	0.78	1.58	1.70	0.98	1.43
P0001427	9.2	24.9	16.5	81.0	392.0	2.28	2.20	0.89	1.45	1.73	0.90	1.79
P0001563	9.8	22.0	16.9	72.0	345.0	2.56	2.59	0.88	1.63	1.77	1.18	1.24
P0001564	10.3	23.0	19.2	82.0	354.0	2.18	2.24	0.83	1.66	1.75	1.14	1.34
P0001566	10.4	22.7	16.8	73.0	372.0	2.56	2.41	0.92	1.55	1.95	1.23	1.31
P0001572	8.8	18.9	16.8	69.0	363.0	2.50	2.76	0.90	1.56	1.69	0.98	1.37
P0001574	6.4	22.7	17.7	71.0	399.0	2.28	2.20	0.87	1.53	1.75	1.15	1.63
P0001579	8.7	16.6	18.4	71.0	365.0	2.65	2.48	0.92	1.54	1.78	1.09	1.35
P0001580	7.5	19.9	13.8	70.0	353.0	2.33	2.56	0.96	1.65	1.86	1.17	1.40
P0001582	7.0	19.6	14.0	65.0	316.0	2.40	2.35	0.90	1.70	1.86	1.05	1.49
P0001594	8.8	23.6	16.5	68.0	352.0	2.52	2.59	0.93	1.58	1.96	0.97	1.49

Table B.1. Data Continued

CATKEY	Sex	Age	YOB	Stature	Weight	BMI	Category	FML	APS	MLS	VHD
P0001598	M	33	1928	1.75	66.5	21.7	NW	470.0	25.8	25.5	47.0
P0001599	F	41	1924	1.58	56.6	22.6	NW	419.0	27.3	24.5	40.4
P0001608	F	43	1920	1.67	64.9	23.3	NW	453.0	29.6	25.6	44.2
P0001612	F	41	1923	1.60	56.6	22.1	NW	426.0	28.1	22.1	40.4
P0001614	F	38	1922	1.67	58.4	20.9	NW	453.0	25.8	23.9	41.2
P0001617	F	35	1930	1.57	54.9	22.2	NW	414.0	21.3	20.8	39.6
P0001618	M	38	1928	1.77	62.6	19.9	NW	479.0	30.9	25.1	45.4
P000161R	F	50	1900	1.62	65.1	24.7	NW	435.0	25.8	26.9	44.3
P000289R	F	47.0	1904.0	1.6	53.6	21.4	NW	418.0	24.7	23.4	39.0
P000301R	M	36	1904	1.81	69.7	21.3	NW	485.0	29.5	28.7	48.3
P000306R	F	50	1903	1.67	62.5	22.5	NW	452.0	27.1	24.1	43.1
P000405R	F	34	1909	1.64	57.7	21.4	NW	393.0	27.0	22.7	40.9
P000437R	F	44	1907	1.61	61.9	23.8	NW	430.0	25.0	26.2	42.8
P000622R	M	42	1897	1.73	65.1	21.7	NW	467.0	26.8	26.8	46.4
P00062RR	M	38	1906	1.78	69.2	21.9	NW	482.0	30.2	28.3	48.1
P001482R	F	35	1905	1.69	61.0	21.3	NW	429.0	24.9	31.0	42.4
P01080RR	F	42	1908	1.58	57.5	22.9	NW	419.0	24.4	22.9	40.8
UT01-00D	M	41	1959	1.83	72.7	21.7	NW	489.0	33.3	29.6	46.6
UT02-06D	M	47	1959	1.73	68.2	22.9	NW	450.0	31.7	30.0	45.0
UT03-90D	M	43	1947	1.83	134.0	40.1	OB	447.0	32.6	31.2	45.5
UT04-06D	F	58	1948	1.60	86.4	33.7	OB	409.0	24.3	24.2	37.7
UT04-10D	M	35	1975	1.75	72.7	23.7	NW	469.0	30.0	26.6	48.2
UT05-83D	M	48	1935	1.84	102.3	30.2	OB	480.0	29.8	34.3	50.4
UT06-06D	M	43	1963	1.85	69.1	20.1	NW	465.0	30.2	26.8	45.7
UT07-00D	M	38	1962	1.63	55.5	21.0	NW	440.0	27.1	24.0	41.0
UT07-08D	M	46	1962	1.83	68.2	20.4	NW	472.0	32.4	26.6	49.6
UT08-06D	M	50	1956	1.85	106.8	31.1	OB	510.0	36.0	29.3	51.5
UT08-09D	F	49	1960	1.60	90.9	35.5	OB	440.0	30.2	26.5	40.9
UT08-98D	M	36	1962	1.72	68.6	23.3	NW	452.0	29.1	24.5	44.9
UT09-00D	F	43	1957	1.70	66.1	23.0	NW	451.0	30.3	25.1	43.8
UT100-06D	F	57	1949	1.68	104.5	37.0	OB	449.0	30.5	28.2	43.4
UT10-03D	M	49	1954	1.86	112.5	32.7	OB	480.0	32.3	27.9	48.2
UT10-07D	F	50	1957	1.55	84.1	35.0	OB	418.0	26.1	27.2	41.1
UT101-06	F	60	1946	1.70	97.7	33.8	OB	436.0	29.2	31.2	40.7
UT107-06D	F	54	1952	1.63	54.5	20.6	NW	425.0	27.8	25.2	39.2
UT107-07D	M	46	1961	1.68	105.5	37.5	OB	413.0	29.9	25.9	45.5
UT107-08D	F	52	1956	1.63	53.6	20.3	NW	421.0	27.8	24.8	42.0
UT109-07D	F	48	1959	1.80	75.0	23.1	NW	475.0	29.2	29.6	47.1

Table B.1. Data Continued

CATKEY	APL	LCML	APM	MCML	BCB	FEB	APN	MLN	LAPB	LMLB	MAPB	MMLB
P0001598	62.3	28.0	60.9	25.8	77.3	83.0	33.5	20.7	40.7	24.8	42.0	24.0
P0001599	57.4	22.9	55.8	23.3	65.8	72.0	30.6	19.9	33.1	18.9	32.3	22.0
P0001608	63.5	23.8	61.2	21.8	69.2	78.0	34.6	23.1	35.7	21.6	40.2	23.5
P0001612	58.3	24.2	58.3	23.4	65.9	74.0	31.9	20.2	38.0	22.7	42.9	23.4
P0001614	59.0	24.3	60.1	20.5	64.7	75.0	29.8	18.5	33.9	20.6	39.2	20.7
P0001617	60.3	23.7	56.9	20.2	66.5	73.0	27.5	18.9	35.4	21.5	42.1	22.4
P0001618	66.5	27.1	60.7	24.9	75.2	82.0	35.6	25.8	39.1	24.7	47.9	24.8
P000161R	59.7	25.3	58.6	24.7	68.9	78.0	32.2	23.5	38.2	22.2	44.4	25.3
P000289R	59.3	23.8	58.4	22.3	64.7	74.0	27.5	19.0	36.0	20.3	43.7	22.5
P000301R	67.9	30.2	65.0	28.4	78.4	82.0	33.8	24.5	42.5	26.1	49.3	25.3
P000306R	62.8	24.7	61.6	25.8	70.4	75.0	30.7	21.1	36.1	23.4	40.9	25.1
P000405R	60.4	21.9	56.5	22.2	63.5	72.0	30.1	18.7	33.9	21.3	42.3	21.9
P000437R	58.6	26.0	54.3	21.8	67.9	75.0	32.9	21.3	35.4	23.1	40.8	23.6
P000622R	63.8	28.5	63.4	29.5	77.6	85.0	31.2	21.6	40.7	25.9	43.3	27.0
P00062RR	67.2	26.8	66.5	28.0	80.7	86.0	39.2	27.5	39.6	27.7	48.5	28.6
P001482R	59.0	25.3	58.8	26.3	67.8	74.0	32.0	24.8	36.3	21.3	42.5	24.9
P01080RR	58.0	24.4	58.3	23.0	62.5	72.0	27.5	21.2	31.8	18.9	41.8	22.4
UT01-00D	64.2	27.3	67.2	27.7	78.5	84.0	37.1	24.8	41.2	25.9	48.9	26.6
UT02-06D	63.2	28.7	64.2	28.9	73.2	80.0	38.6	24.4	35.3	22.8	45.7	28.0
UT03-90D	69.5	29.3	66.7	29.7	79.8	82.0	41.1	25.5	42.7	24.4	50.6	27.9
UT04-06D	55.8	21.3	54.2	22.4	65.2	75.0	30.4	20.8	29.4	18.7	39.4	21.5
UT04-10D	66.7	26.6	66.3	25.3	76.2	84.0	32.6	22.5	37.5	22.6	44.5	23.5
UT05-83D	67.5	28.4	67.6	29.7	84.0	89.0	39.5	24.7	41.4	24.3	52.0	28.8
UT06-06D	68.3	27.1	65.0	23.3	75.3	86.0	35.1	22.2	40.6	25.1	48.2	23.6
UT07-00D	55.1	23.8	56.7	22.5	72.8	78.0	30.5	20.6	38.6	23.7	42.2	22.6
UT07-08D	71.1	30.4	67.7	28.4	76.8	86.0	38.2	24.3	42.0	24.6	48.6	27.5
UT08-06D	69.8	33.5	69.0	26.5	82.7	90.0	38.3	29.1	42.4	27.3	50.0	25.9
UT08-09D	58.0	24.4	56.6	25.6	67.6	72.0	31.6	20.0	34.4	19.6	41.9	21.6
UT08-98D	66.4	28.9	64.4	26.0	75.0	83.0	35.2	23.2	40.7	23.3	48.0	24.3
UT09-00D	59.7	25.6	60.8	25.8	67.7	74.0	33.1	23.0	39.2	21.1	44.5	23.2
UT100-06D	63.5	26.2	61.0	27.8	68.5	79.0	35.7	26.1	36.8	20.3	41.7	24.5
UT10-03D	69.7	29.9	68.4	28.3	80.1	88.0	36.9	24.1	44.1	27.6	48.8	25.4
UT10-07D	55.6	24.0	55.5	23.7	65.1	74.0	31.4	20.7	34.6	19.7	40.6	22.3
UT101-06	62.3	23.8	60.8	24.6	70.5	79.0	33.8	23.6	36.6	21.0	42.8	22.2
UT107-06D	56.6	24.2	55.7	26.3	64.5	71.0	31.9	19.6	34.2	20.1	38.8	21.9
UT107-07D	65.2	27.9	61.1	26.2	79.6	84.0	34.6	23.1	39.3	24.0	44.8	22.5
UT107-08D	62.5	25.5	59.8	26.1	67.0	76.0	35.2	21.4	36.2	20.7	41.4	23.3
UT109-07D	66.4	26.4	66.1	27.6	72.4	79.0	34.2	22.5	38.3	22.3	46.5	25.4

Table B.1. Data Continued

CATKEY	ITD	PLET	PMET	BPE	TML	FLCS	FMCS	FDS	TLCS	TMCS	FMS	TNS
P0001598	9.5	24.5	19.7	76.0	396.0	2.23	2.36	0.81	1.64	1.75	1.01	1.62
P0001599	6.6	19.3	15.1	67.0	341.0	2.51	2.39	0.87	1.75	1.47	1.11	1.54
P0001608	10.9	21.4	14.3	73.0	353.0	2.67	2.81	0.92	1.65	1.71	1.16	1.50
P0001612	8.8	19.6	15.2	69.0	349.0	2.41	2.49	0.88	1.67	1.83	1.27	1.58
P0001614	6.3	21.5	16.7	66.0	369.0	2.43	2.93	0.91	1.65	1.89	1.08	1.61
P0001617	9.3	17.8	17.2	67.0	332.0	2.54	2.82	0.91	1.65	1.88	1.02	1.46
P0001618	8.6	22.6	20.3	79.0	393.0	2.45	2.44	0.88	1.58	1.93	1.23	1.38
P000161R	6.5	19.5	17.1	70.0	343.0	2.36	2.37	0.87	1.72	1.75	0.96	1.37
P000289R	8.4	18.6	13.9	65.0	343.0	2.49	2.62	0.92	1.77	1.94	1.06	1.45
P000301R	7.3	23.7	19.8	78.0	403.0	2.25	2.29	0.87	1.63	1.95	1.03	1.38
P000306R	8.4	21.5	16.4	71.0	352.0	2.54	2.39	0.89	1.54	1.63	1.12	1.45
P000405R	8.3	21.9	18.0	66.0	310.0	2.76	2.55	0.95	1.59	1.93	1.19	1.61
P000437R	5.7	20.7	15.3	71.0	358.0	2.25	2.49	0.86	1.53	1.73	0.95	1.54
P000622R	8.2	23.9	18.7	79.0	365.0	2.24	2.15	0.82	1.57	1.60	1.00	1.44
P00062RR	12.5	23.1	19.1	80.0	386.0	2.51	2.38	0.83	1.43	1.70	1.07	1.43
P001482R	7.6	22.8	16.5	67.0	341.0	2.33	2.24	0.87	1.70	1.71	0.80	1.29
P01080RR	7.5	16.3	14.7	64.0	346.0	2.38	2.53	0.93	1.68	1.87	1.07	1.30
UT01-00D	10.0	26.8	18.4	79.0	424.0	2.35	2.43	0.82	1.59	1.84	1.13	1.50
UT02-06D	6.7	21.8	18.3	75.0	372.0	2.20	2.22	0.86	1.55	1.63	1.06	1.58
UT03-90D	6.8	24.0	17.7	80.0	390.0	2.37	2.25	0.87	1.75	1.81	1.04	1.61
UT04-06D	10.7	19.2	14.5	68.0	354.0	2.62	2.42	0.86	1.57	1.83	1.00	1.46
UT04-10D	9.6	23.6	20.9	78.0	385.0	2.51	2.62	0.88	1.66	1.89	1.13	1.45
UT05-83D	8.3	25.4	21.8	84.0	406.0	2.38	2.28	0.80	1.70	1.81	0.87	1.60
UT06-06D	9.7	23.8	20.2	79.0	379.0	2.52	2.79	0.91	1.62	2.04	1.13	1.58
UT07-00D	8.8	17.6	14.8	73.0	358.0	2.32	2.52	0.76	1.63	1.87	1.13	1.48
UT07-08D	7.3	23.4	17.7	81.0	403.0	2.34	2.38	0.93	1.71	1.77	1.22	1.57
UT08-06D	6.5	20.8	19.2	83.0	429.0	2.08	2.60	0.84	1.55	1.93	1.23	1.32
UT08-09D	4.7	20.2	14.4	68.0	350.0	2.38	2.21	0.86	1.76	1.94	1.14	1.58
UT08-98D	8.0	24.1	16.2	76.0	372.0	2.30	2.48	0.89	1.75	1.98	1.19	1.52
UT09-00D	4.8	20.8	15.8	70.0	373.0	2.33	2.36	0.88	1.86	1.92	1.21	1.44
UT100-06D	8.1	22.1	16.8	73.0	361.0	2.42	2.19	0.93	1.81	1.70	1.08	1.37
UT10-03D	7.6	23.3	20.1	80.0	400.0	2.33	2.42	0.87	1.60	1.92	1.16	1.53
UT10-07D	6.3	20.5	12.6	68.0	343.0	2.32	2.34	0.85	1.76	1.82	0.96	1.52
UT101-06	8.4	20.8	16.1	73.0	358.0	2.62	2.47	0.88	1.74	1.93	0.94	1.43
UT107-06D	6.4	16.8	14.6	67.0	346.0	2.34	2.12	0.88	1.70	1.77	1.10	1.63
UT107-07D	8.8	18.1	18.2	78.0	342.0	2.34	2.33	0.82	1.64	1.99	1.15	1.50
UT107-08D	8.3	21.3	18.4	73.0	349.0	2.45	2.29	0.93	1.75	1.78	1.12	1.64
UT109-07D	6.9	23.0	18.7	75.0	404.0	2.52	2.39	0.92	1.72	1.83	0.99	1.52

Table B.1: Data Continued

CATKEY	Sex	Age	YOB	Stature	Weight	BMI	Category	FML	APS	MLS	VHD
UT11-04D	F	54	1950	1.66	54.5	19.8	NW	388.0	25.2	24.3	40.2
UT11-06D	F	60	1946	1.60	54.5	21.3	NW	428.0	28.0	24.1	39.6
UT111-07D	F	50	1957	1.64	55.5	20.6	NW	493.0	27.7	23.9	44.4
UT114-07D	M	44	1963	1.78	113.6	35.9	OB	463.0	33.4	30.6	48.5
UT115-07D	F	57	1950	1.72	153.2	51.8	OB	469.0	28.2	27.9	43.2
UT116-07D	M	53	1954	1.75	106.8	34.8	OB	440.0	28.4	29.8	45.9
UT12-02D	F	49	1953	1.78	181.8	57.4	OB	454.0	30.0	29.7	43.0
UT12-04D	F	60	1944	1.68	56.8	20.1	NW	453.0	26.3	24.3	41.3
UT13-88D	M	31	1957	1.82	77.7	23.6	NW	487.0	33.4	28.6	51.7
UT13-91D	M	34	1957	1.85	79.2	23.0	NW	505.0	28.5	26.0	48.2
UT14-03D	M	50	1953	1.65	95.5	35.3	OB	455.0	32.9	25.6	44.8
UT14-90D	M	37	1953	1.75	69.6	22.7	NW	500.0	33.4	27.1	45.1
UT14-91D	M	53	1938	1.73	63.2	21.2	NW	460.0	32.5	23.2	46.9
UT14-93D	M	32	1961	1.75	129.1	42.0	OB	469.0	30.0	28.9	49.0
UT16-89D	M	35	1954	1.78	62.4	19.7	NW	457.0	28.9	25.4	46.2
UT16-91D	M	46	1945	1.65	91.4	33.5	OB	425.0	28.7	27.5	43.5
UT17-01D	M	51	1950	1.95	167.7	44.1	OB	531.0	34.8	35.7	49.9
UT17-05D	F	58	1947	1.51	105.5	46.2	OB	415.0	28.0	29.2	42.0
UT18-03D	F	47	1956	1.54	46.8	19.7	NW	410.0	26.5	23.1	41.7
UT20-03D	F	44	1959	1.55	46.8	19.6	NW	427.0	29.9	23.8	39.7
UT21-06D	M	46	1960	1.70	90.9	31.4	OB	453.0	32.0	27.6	43.8
UT22-01D	M	47	1954	1.83	144.5	43.2	OB	497.0	34.4	29.9	49.1
UT25-05D	F	51	1954	1.60	138.2	54.0	OB	423.0	25.6	30.0	41.9
UT25-06D	F	44	1962	1.67	52.3	18.7	NW	466.0	27.7	29.0	46.6
UT26-03D	M	49	1954	1.73	60.7	20.3	NW	480.0	29.8	27.0	49.7
UT27-03D	M	46	1957	1.88	137.7	39.0	OB	430.0	30.1	29.3	46.6
UT27-05	F	59	1946	1.54	88.0	37.2	OB	399.0	22.8	23.6	43.3
UT27-07D	F	45	1962	1.70	54.5	18.8	NW	439.0	27.5	23.8	43.2
UT28-03D	M	54	1949	1.75	72.7	23.7	NW	470.0	30.0	27.3	46.4
UT28-05D	M	53	1952	1.74	72.7	24.2	NW	472.0	30.9	28.0	49.9
UT29-00D	M	39	1961	1.83	65.9	19.7	NW	494.0	28.6	29.0	46.0
UT29-03D	F	59	1944	1.55	49.1	20.4	NW	433.0	26.7	24.7	42.6
UT33-08D	F	29	1979	1.64	90.9	33.8	OB	447.0	28.3	25.6	42.6
UT34-05D	M	44	1961	1.73	113.6	38.1	OB	468.0	34.5	28.5	48.4
UT34-10D	F	52	1958	1.65	118.2	43.4	OB	438.0	30.0	26.5	42.4
UT35-02D	F	55	1947	1.74	63.2	20.9	NW	471.0	28.9	26.8	45.1
UT35-07D	F	46	1961	1.66	63.2	22.8	NW	445.0	27.2	24.5	42.3
UT36-05D	M	41	1964	1.73	65.7	22.0	NW	489.0	31.0	26.9	46.9

Table B.1: Data Continued

CATKEY	APL	LCML	APM	MCML	BCB	FEB	APN	MLN	LAPB	LMLB	MAPB	MMLB
UT11-04D	59.3	22.0	58.2	23.5	65.8	73.0	29.8	18.8	32.5	18.4	40.1	22.6
UT11-06D	59.8	23.6	58.8	25.2	66.5	71.0	31.8	23.0	31.3	20.1	42.0	22.5
UT111-07D	65.4	27.6	63.3	25.7	71.6	77.0	30.0	20.2	40.2	21.5	42.4	22.7
UT114-07D	67.3	28.1	68.3	29.0	77.8	89.0	41.8	27.7	39.9	23.5	48.1	27.8
UT115-07D	62.8	25.9	62.0	29.0	69.6	78.0	36.4	23.7	36.0	20.7	47.7	24.0
UT116-07D	64.0	28.2	61.9	29.6	75.9	84.0	33.3	22.7	42.1	23.2	47.5	24.8
UT12-02D	63.1	26.6	61.8	24.0	73.7	81.0	35.3	26.6	36.5	23.0	46.2	23.7
UT12-04D	59.9	24.4	57.0	22.9	67.2	74.0	29.7	21.2	33.9	19.8	38.3	22.0
UT13-88D	68.9	28.6	68.4	27.3	82.7	96.0	40.3	27.0	46.8	26.7	54.0	25.9
UT13-91D	68.4	28.6	65.2	27.9	76.5	88.0	35.8	22.9	42.2	24.6	47.0	25.1
UT14-03D	62.3	26.9	60.8	23.7	74.3	80.0	35.6	21.9	38.5	23.5	43.9	23.2
UT14-90D	65.6	27.6	62.8	27.8	77.3	84.0	35.2	23.4	42.5	22.9	46.8	25.8
UT14-91D	68.1	28.0	66.8	25.5	78.3	85.0	33.9	22.7	41.0	25.6	49.1	24.7
UT14-93D	66.5	30.9	62.9	31.4	79.8	85.0	37.5	28.4	38.9	25.4	45.8	27.3
UT16-89D	66.5	29.6	63.4	28.4	74.2	85.0	33.3	23.4	40.7	24.2	47.2	24.8
UT16-91D	61.8	28.7	64.2	27.2	73.9	80.0	34.4	23.1	38.3	23.6	44.5	24.6
UT17-01D	69.4	31.1	74.0	31.0	82.1	89.0	43.0	30.2	44.1	25.3	49.7	30.7
UT17-05D	59.6	24.0	59.3	25.8	68.5	78.0	35.3	23.1	38.9	19.1	43.2	24.8
UT18-03D	57.0	23.4	56.5	23.5	69.4	75.0	27.3	19.7	34.6	19.4	41.8	23.5
UT20-03D	61.6	21.9	56.5	23.5	63.2	73.0	31.2	22.9	36.5	19.6	42.1	23.0
UT21-06D	60.2	25.8	59.9	27.4	75.6	79.0	38.6	23.9	40.5	26.1	45.2	23.7
UT22-01D	74.5	31.3	72.2	31.1	80.6	90.0	36.4	26.4	44.4	25.9	49.5	27.8
UT25-05D	60.2	25.1	60.9	25.1	68.6	73.0	35.2	21.8	34.2	20.6	42.7	22.2
UT25-06D	61.7	24.8	63.0	25.2	69.9	77.0	34.7	21.7	38.6	18.8	42.4	23.2
UT26-03D	65.4	27.0	63.5	28.7	74.1	82.0	41.0	23.9	41.7	23.0	47.1	25.2
UT27-03D	67.5	30.6	69.6	28.9	73.8	86.0	35.3	21.0	39.2	25.1	49.9	26.8
UT27-05	56.2	21.8	54.8	21.0	65.6	74.0	25.8	19.5	36.4	20.6	39.7	20.0
UT27-07D	63.6	24.9	61.5	23.4	67.9	79.0	30.8	21.9	35.2	21.4	42.5	22.8
UT28-03D	67.0	29.7	67.2	25.7	78.1	85.0	35.5	23.9	37.8	23.1	47.7	24.1
UT28-05D	66.6	30.0	67.5	28.7	82.7	86.0	35.6	27.3	44.1	22.0	48.9	26.1
UT29-00D	61.6	28.0	62.2	27.9	73.8	80.0	33.6	21.3	37.5	22.4	48.8	26.1
UT29-03D	62.9	23.2	60.2	25.3	66.5	78.0	30.4	21.0	37.2	19.1	44.7	23.2
UT33-08D	61.5	25.5	58.2	27.5	65.6	74.0	30.8	23.0	39.0	22.1	42.3	24.5
UT34-05D	68.1	29.7	66.8	28.1	77.5	85.0	40.4	25.2	39.0	21.7	44.4	26.9
UT34-10D	60.1	23.7	58.8	24.1	67.0	76.0	31.0	22.9	36.1	20.6	42.5	22.9
UT35-02D	64.6	25.3	62.9	27.6	70.4	78.0	33.0	20.9	36.7	21.6	43.7	25.0
UT35-07D	59.7	22.8	57.6	22.9	64.2	75.0	30.4	23.2	36.2	18.7	41.2	20.9
UT36-05D	67.5	32.0	69.6	28.5	80.0	89.0	39.5	25.0	40.6	23.6	49.7	29.1

Table B.1: Data Continued

CATKEY	ITD	PLET	PMET	BPE	TML	FLCS	FMCS	FDS	TLCS	TMCS	FMS	TNS
UT11-04D	7.3	22.1	18.3	69.0	332.0	2.70	2.48	0.90	1.77	1.77	1.04	1.59
UT11-06D	7.6	17.7	13.2	66.0	344.0	2.53	2.33	0.90	1.56	1.87	1.16	1.38
UT111-07D	6.8	22.5	18.1	71.0	395.0	2.37	2.46	0.91	1.87	1.87	1.16	1.49
UT114-07D	8.1	25.0	19.0	80.0	392.0	2.40	2.36	0.87	1.70	1.73	1.09	1.51
UT115-07D	5.6	22.0	15.3	72.0	406.0	2.42	2.14	0.90	1.74	1.99	1.01	1.54
UT116-07D	9.7	22.0	18.4	77.0	365.0	2.27	2.09	0.84	1.81	1.92	0.95	1.47
UT12-02D	6.6	21.9	15.0	75.0	378.0	2.37	2.58	0.86	1.59	1.95	1.01	1.33
UT12-04D	6.8	19.6	14.1	67.0	367.0	2.45	2.49	0.89	1.71	1.74	1.08	1.40
UT13-88D	10.9	24.2	22.4	87.0	423.0	2.41	2.51	0.83	1.75	2.08	1.17	1.49
UT13-91D	7.9	25.1	19.4	82.0	435.0	2.39	2.34	0.89	1.72	1.87	1.10	1.56
UT14-03D	7.3	24.3	18.0	75.0	380.0	2.32	2.57	0.84	1.64	1.89	1.29	1.63
UT14-90D	6.9	22.2	18.5	81.0	493.0	2.38	2.26	0.85	1.86	1.81	1.23	1.50
UT14-91D	9.5	22.9	20.3	81.0	374.0	2.43	2.62	0.87	1.60	1.99	1.40	1.49
UT14-93D	7.4	23.2	20.7	79.0	384.0	2.15	2.00	0.83	1.53	1.68	1.04	1.32
UT16-89D	7.9	22.8	19.3	81.0	383.0	2.25	2.23	0.90	1.68	1.90	1.14	1.42
UT16-91D	7.9	17.6	14.7	74.0	336.0	2.15	2.36	0.84	1.62	1.81	1.04	1.49
UT17-01D	7.9	24.5	23.2	86.0	467.0	2.23	2.39	0.85	1.74	1.62	0.97	1.42
UT17-05D	6.6	20.8	15.9	71.0	356.0	2.48	2.30	0.87	2.04	1.74	0.96	1.53
UT18-03D	7.4	17.4	15.3	70.0	335.0	2.44	2.40	0.82	1.78	1.78	1.15	1.39
UT20-03D	7.3	19.6	19.0	66.0	364.0	2.81	2.40	0.97	1.86	1.83	1.26	1.36
UT21-06D	5.4	22.6	15.3	75.0	370.0	2.33	2.19	0.80	1.55	1.91	1.16	1.62
UT22-01D	6.4	24.5	22.0	81.0	412.0	2.38	2.32	0.92	1.71	1.78	1.15	1.38
UT25-05D	7.1	23.4	15.8	71.0	346.0	2.40	2.43	0.88	1.66	1.92	0.85	1.61
UT25-06D	8.8	20.2	19.4	74.0	388.0	2.49	2.50	0.88	2.05	1.83	0.96	1.60
UT26-03D	5.9	23.7	20.6	75.0	392.0	2.42	2.21	0.88	1.81	1.87	1.10	1.72
UT27-03D	4.2	24.8	18.1	79.0	367.0	2.21	2.41	0.91	1.56	1.86	1.03	1.68
UT27-05	5.6	21.9	14.8	69.0	334.0	2.58	2.61	0.86	1.77	1.99	0.97	1.32
UT27-07D	7.9	21.6	16.5	73.0	350.0	2.55	2.63	0.94	1.64	1.86	1.16	1.41
UT28-03D	9.5	21.5	18.0	78.0	393.0	2.26	2.61	0.86	1.64	1.98	1.10	1.49
UT28-05D	11.0	24.8	18.7	82.0	395.0	2.22	2.35	0.81	2.00	1.87	1.10	1.30
UT29-00D	6.9	23.1	18.2	75.0	406.0	2.20	2.23	0.83	1.67	1.87	0.99	1.58
UT29-03D	9.3	23.3	16.7	73.0	352.0	2.71	2.38	0.95	1.95	1.93	1.08	1.45
UT33-08D	5.2	20.3	16.9	68.0	365.0	2.41	2.12	0.94	1.76	1.73	1.11	1.34
UT34-05D	8.9	20.4	18.3	81.0	392.0	2.29	2.38	0.88	1.80	1.65	1.21	1.60
UT34-10D	5.0	22.2	18.3	69.0	353.0	2.54	2.44	0.90	1.75	1.86	1.13	1.35
UT35-02D	6.3	21.0	16.3	75.0	380.0	2.55	2.28	0.92	1.70	1.75	1.08	1.58
UT35-07D	8.8	19.9	17.7	68.0	372.0	2.62	2.52	0.93	1.94	1.97	1.11	1.31
UT36-05D	6.6	26.0	17.2	83.0	389.0	2.11	2.44	0.84	1.72	1.71	1.15	1.58

Table B.1: Data Continued

CATKEY	Sex	Age	YOB	Stature	Weight	BMI	Category	FML	APS	MLS	VHD
UT37-02D	F	52	1950	1.63	83.2	31.5	OB	440.0	27.5	24.7	42.4
UT39-01D	F	36	1965	1.58	90.9	36.4	OB	455.0	26.9	26.1	41.9
UT42-03D	M	40	1963	1.67	95.0	34.3	OB	457.0	30.8	28.7	48.1
UT42-05D	M	42	1963	1.88	79.5	22.5	NW	515.0	29.2	28.6	47.0
UT43-10D	F	41	1969	1.57	106.8	43.1	OB	408.0	26.7	26.7	40.1
UT44-04D	M	39	1965	1.83	136.4	40.7	OB	470.0	31.6	31.7	48.6
UT45-04D	M	54	1950	1.78	181.8	57.5	OB	480.0	38.8	32.3	52.3
UT47-08D	F	58	1950	1.66	63.6	23.2	NW	441.0	28.5	27.8	44.9
UT49-06D	M	44	1962	1.70	100.0	34.6	OB	499.0	26.3	32.2	45.5
UT49-08D	M	50	1958	1.74	66.8	22.1	NW	488.0	33.7	29.8	47.5
UT49-09D	F	42	1967	1.65	113.6	41.7	OB	426.0	27.5	24.8	39.4
UT50-07D	M	38	1969	1.65	86.4	31.9	OB	447.0	27.9	27.4	48.5
UT51-07D	F	44	1963	1.63	90.9	34.4	OB	435.0	29.8	27.1	43.6
UT53-03D	F	60	1943	1.70	68.2	23.6	NW	439.0	28.9	25.4	40.6
UT53-06D	F	54	1952	1.57	55.7	22.5	NW	409.0	27.8	23.2	42.4
UT54-05D	F	54	1951	1.65	84.1	30.8	OB	440.0	25.7	24.9	40.6
UT54-09D	M	30	1979	1.80	70.5	21.7	NW	481.0	30.3	26.3	47.2
UT57-09D	F	34	1975	1.70	113.6	39.2	OB	447.0	33.7	27.0	44.4
UT58-05D	M	53	1952	1.72	113.9	38.7	OB	457.0	31.9	30.0	49.5
UT61-04D	M	50	1954	1.61	102.3	39.5	OB	438.0	33.1	29.4	46.9
UT61-05D	F	55	1950	1.66	86.4	31.3	OB	445.0	27.8	25.3	41.8
UT62-09D	F	52	1957	1.68	100.0	35.6	OB	449.0	31.4	24.5	42.3
UT63-06D	M	43	1963	1.73	59.1	19.8	NW	456.0	29.9	26.3	44.1
UT65-06D	M	31	1975	1.87	77.3	22.1	NW	512.0	31.0	25.9	47.5
UT68-06D	F	54	1952	1.65	54.5	20.0	NW	447.0	26.2	24.1	45.0
UT69-06D	F	45	1961	1.65	63.6	23.4	NW	441.0	24.6	24.2	44.3
UT72-08D	F	55	1953	1.63	118.2	44.5	OB	431.0	28.6	30.2	43.2
UT73-08	F	60	1948	1.70	136.4	47.1	OB	465.0	28.6	26.8	41.3
UT74-06D	F	42	1964	1.68	100.0	35.6	OB	436.0	27.4	26.7	42.7
UT74-08D	M	47	1961	1.93	84.1	22.6	NW	523.0	32.9	28.5	47.9
UT78-05D	M	53	1952	1.73	58.2	19.5	NW	471.0	29.4	25.7	46.8
UT79-05D	F	59	1946	1.68	63.6	22.6	NW	456.0	25.1	23.0	38.9
UT80-06D	M	55	1951	1.87	154.5	44.2	OB	475.0	32.9	28.9	46.1
UT81-05D	M	45	1960	1.75	76.4	24.9	NW	486.0	31.1	27.3	49.5
UT82-08D	M	26	1982	1.83	77.3	23.1	NW	467.0	30.3	26.9	45.9
UT82-09D	M	44	1965	1.78	113.6	35.9	OB	468.0	35.7	32.5	48.0
UT83-05D	M	54	1951	1.73	68.2	22.9	NW	446.0	25.4	25.5	44.0

Table B.1: Data Continued

CATKEY	APL	LCML	APM	MCML	BCB	FEB	APN	MLN	LAPB	LMLB	MAPB	MMLB
UT37-02D	62.7	24.5	61.5	22.8	66.5	77.0	31.6	24.2	34.2	19.6	40.0	21.9
UT39-01D	61.6	24.7	60.1	24.5	69.9	78.0	31.1	23.6	35.8	20.3	45.0	22.8
UT42-03D	65.9	26.3	64.5	26.1	73.1	84.0	36.9	22.1	39.3	24.2	47.7	25.6
UT42-05D	67.1	29.6	63.0	28.5	75.3	83.0	34.6	25.3	39.9	23.0	47.1	27.7
UT43-10D	55.4	23.5	54.4	24.0	65.5	73.0	29.7	18.3	35.8	19.1	38.6	23.5
UT44-04D	71.2	30.4	65.1	30.9	75.7	87.0	38.3	23.3	39.6	25.6	53.1	28.1
UT45-04D	71.3	33.7	69.3	33.7	84.4	91.0	42.8	27.8	45.4	25.3	51.9	32.1
UT47-08D	62.4	26.6	59.3	25.2	72.4	80.0	32.3	23.5	37.7	20.7	41.0	22.9
UT49-06D	64.0	25.8	64.3	25.8	72.1	81.0	33.8	20.5	34.2	21.0	42.6	25.3
UT49-08D	68.5	30.0	64.8	27.1	77.4	85.0	35.3	23.6	38.9	23.5	46.6	27.3
UT49-09D	59.3	24.3	57.4	23.1	64.7	71.0	32.6	19.5	39.2	20.4	41.2	20.0
UT50-07D	65.6	27.4	64.2	30.2	81.7	85.0	35.1	24.5	39.2	23.4	47.2	28.4
UT51-07D	59.3	26.5	61.5	25.3	71.5	77.0	30.8	20.5	34.5	19.2	40.3	24.1
UT53-03D	56.9	21.5	58.1	20.8	66.0	74.0	30.4	20.6	35.9	20.7	42.3	21.0
UT53-06D	61.6	25.5	58.2	23.9	67.8	76.0	28.3	23.3	36.7	23.0	42.9	24.1
UT54-05D	64.7	26.6	60.0	24.5	65.4	74.0	30.8	19.4	33.6	20.3	37.7	22.6
UT54-09D	64.2	25.6	63.9	28.3	74.5	82.0	37.0	22.7	40.2	23.4	47.8	26.8
UT57-09D	61.8	26.0	64.0	28.7	69.1	80.0	39.4	25.1	39.7	22.0	44.8	26.0
UT58-05D	64.8	29.7	65.2	27.6	79.9	89.0	38.2	24.3	41.8	24.9	49.3	27.8
UT61-04D	63.5	25.9	63.7	29.1	77.3	84.0	36.4	28.1	37.9	25.2	46.9	27.0
UT61-05D	59.5	24.4	57.4	23.5	65.9	73.0	27.9	19.6	35.6	20.3	42.5	20.3
UT62-09D	63.3	23.6	64.0	28.2	74.4	81.0	36.1	25.4	38.5	17.3	45.6	21.4
UT63-06D	61.1	25.7	59.6	24.2	72.1	79.0	33.5	21.6	32.8	21.4	43.4	24.8
UT65-06D	73.3	29.9	70.5	29.7	78.7	90.0	34.9	22.4	41.5	25.3	45.6	26.6
UT68-06D	62.6	25.7	61.5	23.7	69.6	74.0	27.5	21.7	39.1	23.1	44.8	21.8
UT69-06D	58.3	23.3	56.8	27.0	67.3	74.0	31.1	19.6	34.1	17.5	42.7	24.1
UT72-08D	60.4	26.1	59.2	23.1	70.4	78.0	33.0	20.7	35.5	21.3	43.1	22.4
UT73-08	60.1	23.8	57.0	24.8	66.4	75.0	34.1	20.3	37.6	20.6	39.7	22.3
UT74-06D	62.9	22.8	62.8	23.5	68.9	81.0	33.8	21.6	33.0	18.5	44.7	24.0
UT74-08D	67.5	30.6	65.6	29.5	78.9	84.0	44.1	23.3	43.1	25.6	51.2	29.7
UT78-05D	64.2	27.7	64.8	26.5	76.9	84.0	34.0	23.2	40.4	21.6	45.7	24.6
UT79-05D	58.3	21.8	56.9	24.9	63.9	70.0	31.7	21.4	33.4	19.9	41.3	22.6
UT80-06D	69.1	28.2	64.2	27.6	74.1	85.0	38.5	23.9	36.6	23.0	49.6	25.2
UT81-05D	68.2	25.6	65.2	27.2	78.8	87.0	33.3	24.3	38.4	24.2	40.3	26.2
UT82-08D	65.2	26.8	64.7	26.6	78.9	85.0	39.5	23.9	41.3	24.4	48.3	26.5
UT82-09D	70.8	29.7	67.6	30.8	83.6	91.0	39.7	23.9	41.4	28.3	47.5	29.2
UT83-05D	61.3	28.5	60.7	25.5	74.6	81.0	31.1	21.1	36.0	24.4	46.4	23.8

Table B.1 Data Continued

CATKEY	ITD	PLET	PMET	BPE	TML	FLCS	FMCS	FDS	TLCS	TMCS	FMS	TNS
UT37-02D	6.0	22.7	17.2	69.0	357.0	2.56	2.70	0.94	1.74	1.83	1.11	1.31
UT39-01D	9.5	21.6	17.2	72.0	370.0	2.49	2.45	0.88	1.76	1.97	1.03	1.32
UT42-03D	8.6	21.9	19.5	79.0	374.0	2.51	2.47	0.90	1.62	1.86	1.07	1.67
UT42-05D	7.5	25.5	20.0	77.0	433.0	2.27	2.21	0.89	1.73	1.70	1.02	1.37
UT43-10D	8.4	20.9	13.6	69.0	341.0	2.36	2.27	0.85	1.87	1.64	1.00	1.62
UT44-04D	6.5	23.7	19.9	81.0	398.0	2.34	2.11	0.94	1.55	1.89	1.00	1.64
UT45-04D	5.6	22.8	19.7	85.0	408.0	2.12	2.06	0.84	1.79	1.62	1.20	1.54
UT47-08D	8.7	24.2	16.9	74.0	356.0	2.35	2.35	0.86	1.82	1.79	1.03	1.37
UT49-06D	8.1	19.6	20.3	76.0	416.0	2.48	2.49	0.89	1.63	1.68	0.82	1.65
UT49-08D	9.2	22.3	21.2	80.0	400.0	2.28	2.39	0.89	1.66	1.71	1.13	1.50
UT49-09D	4.7	19.4	16.1	67.0	350.0	2.44	2.48	0.92	1.92	2.06	1.11	1.67
UT50-07D	10.2	22.6	21.7	82.0	368.0	2.39	2.13	0.80	1.68	1.66	1.02	1.43
UT51-07D	9.2	17.3	16.2	74.0	347.0	2.24	2.43	0.83	1.80	1.67	1.10	1.50
UT53-03D	9.1	19.4	15.9	68.0	369.0	2.65	2.79	0.86	1.73	2.01	1.14	1.48
UT53-06D	6.4	18.5	16.1	71.0	335.0	2.42	2.44	0.91	1.60	1.78	1.20	1.21
UT54-05D	9.5	22.6	17.8	69.0	355.0	2.43	2.45	0.99	1.66	1.67	1.03	1.59
UT54-09D	8.6	24.5	17.5	79.0	400.0	2.51	2.26	0.86	1.72	1.78	1.15	1.63
UT57-09D	7.8	22.6	16.3	77.0	382.0	2.38	2.23	0.89	1.80	1.72	1.25	1.57
UT58-05D	8.8	22.8	20.7	82.0	381.0	2.18	2.36	0.81	1.68	1.77	1.06	1.57
UT61-04D	10.5	20.0	16.6	78.0	370.0	2.45	2.19	0.82	1.50	1.74	1.13	1.30
UT61-05D	7.5	22.4	18.2	69.0	354.0	2.44	2.44	0.90	1.75	2.09	1.10	1.42
UT62-09D	12.9	21.3	16.5	74.0	371.0	2.68	2.27	0.85	2.23	2.13	1.28	1.42
UT63-06D	8.3	20.8	19.8	73.0	384.0	2.38	2.46	0.85	1.53	1.75	1.14	1.55
UT65-06D	11.1	27.5	18.8	83.0	428.0	2.45	2.37	0.93	1.64	1.71	1.20	1.56
UT68-06D	8.4	21.2	15.4	70.0	355.0	2.44	2.59	0.90	1.69	2.06	1.09	1.27
UT69-06D	6.0	20.1	14.6	62.0	354.0	2.50	2.10	0.87	1.95	1.77	1.02	1.59
UT72-08D	6.2	22.1	16.6	73.0	364.0	2.31	2.56	0.86	1.67	1.92	0.95	1.59
UT73-08	6.2	21.6	16.2	70.0	379.0	2.53	2.30	0.91	1.83	1.78	1.07	1.68
UT74-06D	8.0	19.4	15.9	71.0	355.0	2.76	2.67	0.91	1.78	1.86	1.03	1.56
UT74-08D	5.7	24.1	17.3	81.0	435.0	2.21	2.22	0.86	1.68	1.72	1.15	1.89
UT78-05D	10.7	20.7	19.5	79.0	369.0	2.32	2.45	0.83	1.87	1.86	1.14	1.47
UT79-05D	5.7	21.1	13.6	65.0	368.0	2.67	2.29	0.91	1.68	1.83	1.09	1.48
UT80-06D	6.8	24.8	16.6	79.0	401.0	2.45	2.33	0.93	1.59	1.97	1.14	1.61
UT81-05D	10.5	26.7	15.9	80.0	400.0	2.66	2.40	0.87	1.59	1.54	1.14	1.37
UT82-08D	11.5	21.0	17.4	80.0	397.0	2.43	2.43	0.83	1.69	1.82	1.13	1.65
UT82-09D	10.1	22.3	15.7	85.0	390.0	2.38	2.19	0.85	1.46	1.63	1.10	1.66
UT83-05D	8.0	22.0	17.7	75.0	365.0	2.15	2.38	0.82	1.48	1.95	1.00	1.47

Table B.1: Data Continued

CATKEY	Sex	Age	YOB	Stature	Weight	BMI	Category	FML	APS	MLS	VHD
UT83-07D	M	50	1957	1.75	65.9	21.5	NW	471.0	32.3	27.4	48.4
UT85-05D	F	46	1959	1.47	68.2	31.4	OB	396.0	25.2	23.8	39.4
UT85-08D	F	47	1961	1.76	116.8	37.9	OB	462.0	26.4	31.5	44.3
UT88-07D	M	54	1953	1.70	125.0	43.2	OB	427.0	29.2	28.3	46.9
UT89-06D	F	50	1956	1.60	86.8	33.9	OB	421.0	26.6	24.8	39.9
UT90-05D	M	52	1953	1.96	143.2	37.4	OB	523.0	32.8	31.0	51.0
UT90-06D	M	49	1957	1.74	72.7	24.0	NW	468.0	30.8	28.6	48.0
UT92-05D	F	47	1958	1.83	72.3	21.6	NW	478.0	28.7	24.9	42.9
UT93-08D	M	46	1962	1.80	108.2	33.4	OB	495.0	36.5	28.6	49.4
UT95-08D	M	50	1958	1.74	99.5	32.9	OB	475.0	29.8	28.4	43.0
UT99-07D	M	54	1953	1.68	86.8	30.9	OB	430.0	26.4	27.1	45.7
UT99-09D	M	55	1954	1.73	152.3	51.0	OB	428.0	31.4	29.4	45.8

Table B.1 Data Continued

CATKEY	APL	LCML	APM	MCML	BCB	FEB	APN	MLN	LAPB	LMLB	MAPB	MMLB
UT83-07D	66.5	31.2	67.0	29.1	78.9	85.0	37.4	26.2	40.7	24.5	49.5	27.5
UT85-05D	57.4	21.1	53.2	22.8	65.3	71.0	28.9	19.5	33.9	19.7	37.4	21.1
UT85-08D	61.8	25.4	62.1	27.4	68.5	80.0	33.9	23.8	37.7	22.1	42.8	24.1
UT88-07D	61.8	28.8	58.8	25.9	76.9	83.0	34.5	24.0	40.4	23.7	45.9	24.3
UT89-06D	56.5	23.9	53.1	25.0	68.1	72.0	27.1	18.1	34.2	19.0	41.1	21.5
UT90-05D	77.5	32.6	74.6	29.8	84.1	99.0	38.0	24.7	47.5	26.8	52.1	27.8
UT90-06D	65.6	27.6	63.3	25.7	74.7	85.0	38.3	25.5	39.6	21.8	46.4	27.9
UT92-05D	63.7	23.6	62.6	24.6	68.1	77.0	34.7	20.9	35.2	18.2	44.0	23.8
UT93-08D	66.0	29.5	65.0	31.5	77.7	83.0	38.0	28.0	44.5	27.5	44.5	30.4
UT95-08D	63.1	26.2	63.3	25.7	73.5	81.0	36.0	22.4	37.3	20.3	45.8	25.5
UT99-07D	62.3	26.6	58.6	23.7	76.3	86.0	31.6	22.8	39.7	26.0	41.9	23.4
UT99-09D	65.4	29.3	64.9	29.6	77.7	86.0	39.9	24.9	37.4	23.6	45.7	27.3

Table B.1: Data Continued

CATKEY	ITD	PLET	PMET	BPE	TML	FLCS	FMCS	FDS	TLCS	TMCS	FMS	TNS
UT83-07D	6.3	25.6	16.7	79.0	380.0	2.13	2.30	0.84	1.66	1.80	1.18	1.43
UT85-05D	8.5	14.9	13.3	65.0	318.0	2.72	2.33	0.88	1.72	1.77	1.06	1.48
UT85-08D	6.4	21.7	17.4	74.0	375.0	2.43	2.27	0.90	1.71	1.78	0.84	1.42
UT88-07D	10.6	21.7	19.0	79.0	361.0	2.15	2.27	0.80	1.70	1.89	1.03	1.44
UT89-06D	6.2	18.8	14.9	67.0	347.0	2.36	2.12	0.83	1.80	1.91	1.07	1.50
UT90-05D	9.0	28.6	20.9	89.0	454.0	2.38	2.50	0.92	1.77	1.87	1.06	1.54
UT90-06D	7.4	24.9	18.2	80.0	380.0	2.38	2.46	0.88	1.82	1.66	1.08	1.50
UT92-05D	9.6	20.2	17.8	72.0	410.0	2.70	2.54	0.94	1.93	1.85	1.15	1.66
UT93-08D	5.8	22.2	20.6	80.0	408.0	2.24	2.06	0.85	1.62	1.46	1.28	1.36
UT95-08D	7.7	19.9	16.8	76.0	385.0	2.41	2.46	0.86	1.84	1.80	1.05	1.61
UT99-07D	7.8	17.6	16.3	79.0	352.0	2.34	2.47	0.82	1.53	1.79	0.97	1.39
UT99-09D	8.7	20.8	17.6	81.0	353.0	2.23	2.19	0.84	1.58	1.67	1.07	1.60

APPENDIX C

Table C.1. Descriptive Statistics for Females

Variable	N	Mean	SD	Minimum	Maximum
AGE	75	47.71	9.45	29	60
YOB	75	1941	22.17	1870	1979
STAT	75	1.6381	0.0663	1.47	1.83
WGHT	75	76.2827	27.05833	46.80	181.80
BMI	75	28.3813	9.4536	18.70	57.40
FML	75	436.1733	22.2373	388.00	493.00
APS	75	27.2467	2.1593	20.80	31.50
MLS	75	25.5240	2.2488	20.80	31.50
VHD	75	42.0333	1.9762	37.70	47.10
APL	75	60.4093	2.7617	55.40	66.40
LCML	75	24.3053	1.5042	21.10	27.60
APM	75	59.0707	2.9124	53.10	66.10
MCML	75	24.4147	1.9040	20.20	29.00
BCB	75	67.5613	2.6202	62.50	74.40
FEB	75	75.2400	2.9171	70.00	81.00
APN	75	31.5907	2.6525	25.80	39.40
MLN	75	21.5640	1.9863	18.10	26.60
LAPB	75	35.6400	2.1058	29.40	40.20
LMLB	75	20.6547	1.5017	17.30	24.00
MAPB	75	41.9893	2.4233	32.30	47.40
MMLB	75	22.9173	1.2757	20.00	26.00
ITD	75	7.7027	1.6941	4.70	12.9
PLET	75	20.5387	1.9852	14.90	24.50
PMET	75	16.0827	1.5389	12.60	19.40
BPE	75	69.6400	3.1263	62.00	77.00
TML	75	356.1200	20.4066	310.00	410.00
FLCS	75	2.4909	.01344	2.22	2.81
FMCS	75	2.4297	0.1765	2.10	2.93
FDS	75	0.8955	0.0345	0.82	0.99
TLCS	75	1.7316	0.1331	1.51	2.23
TMCS	75	1.8355	0.1157	1.47	2.13
FMS	75	1.0729	0.0981	0.80	1.28
TNS	75	1.4709	0.1173	1.21	1.68

Tables C.2. Descriptive Statistics for Males

Variable	N	Mean	SD	Minimum	Maximum
AGE	87	43.85	6.95	26	55
YOB	87	1940	30.98	1876	1982
STAT	87	1.7543	0.0803	1.53	1.96
WGHT	87	87.1356	28.9657	53.00	181.80
BMI	87	28.2115	8.5887	19.50	57.50
FML	87	465.4253	28.5501	382.00	531.00
APS	87	30.7495	2.7187	25.10	38.80
MLS	87	28.3391	2.2823	23.20	35.70
VHD	87	47.2862	2.3604	41.00	52.40
APL	87	65.8379	4.0246	51.30	77.50
LCML	87	28.4701	2.2477	22.50	33.70
APM	87	64.6609	3.9139	50.10	74.60
MCML	87	28.0299	2.5712	22.10	39.30
BCB	87	77.3322	3.4301	65.40	84.40
FEB	87	84.3793	3.9627	70.00	99.00
APN	87	36.4713	3.0239	29.60	44.10
MLN	87	24.3218	2.2334	20.00	30.20
LAPB	87	40.2069	3.2470	32.80	50.10
LMLB	87	24.4908	1.8916	20.30	29.10
MAPB	87	47.2437	3.0516	38.70	55.30
MMLB	87	26.4908	1.9655	22.50	32.10
ITD	87	8.2735	1.7326	4.20	12.90
PLET	87	22.8989	2.4246	16.90	29.70
PMET	87	18.6943	1.8911	13.50	23.30
BPE	87	78.9540	3.5336	66.00	89.00
TML	87	385.2874	30.2582	313.00	493.00
FLCS	87	2.31920	0.1311	2.01	2.66
FMCS	87	2.3190	0.1779	1.73	2.79
APLBCB	87	0.8515	0.0384	0.76	0.94
TLCS	87	1.6448	0.1111	1.38	2.00
TMCS	87	1.7885	0.1246	1.46	2.80
FMS	87	1.0891	0.0972	0.82	1.40
TNS	87	1.5057	0.1227	1.17	1.89

Table C.3. Sexual Dimorphism

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.54309539	98.76	<.0001
WGHT	1	4744.19299300	6.01	0.0153
BMI	1	1.16182512	0.01	0.9048
FML	1	34464.76057000	51.68	<.0001
APS	1	494.18086210	80.63	<.0001
MLS	1	319.18841920	62.12	<.0001
VHD	1	1111.37186000	231.49	<.0001
APL	1	1186.97294000	97.03	<.0001
LCML	1	698.63440240	185.71	<.0001
APM	1	1258.71790100	103.54	<.0001
MCML	1	526.42266160	100.65	<.0001
BCB	1	3845.30015000	404.80	<.0001
FEB	1	3364.28168600	271.84	<.0001
APN	1	959.42608850	117.45	<.0001
MLN	1	306.33974360	67.99	<.0001
LAPB	1	840.05524900	108.84	<.0001
LMLB	1	592.72593410	199.82	<.0001
MAPB	1	1111.99451000	144.02	<.0001
MMLB	1	514.33501310	181.80	<.0001
ITD	1	13.12744904	4.46	0.0362
PLET	1	224.36607540	45.03	<.0001
PMET	1	274.70985130	91.04	<.0001
BPE	1	3494.13847600	311.09	<.0001
TML	1	34265.70218000	50.04	<.0001
FLCS	1	1.18794943	67.52	<.0001
FMCS	1	0.49418856	15.73	0.0001
FDS	1	0.07460904	55.58	<.0001
TLCS	1	0.30326959	20.44	<.0001
TMCS	1	0.08882571	6.11	0.0145
FMS	1	0.01050161	1.10	0.2955
TNS	1	0.04881667	3.37	0.0681

Table C.4. Secular Trend for Year of Birth (Sexes Pooled)

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.04603856	8.98	0.0032
WGHT	1	17865.38936000	26.18	<.0001
BMI	1	1686.44357400	23.65	<.0001
FML	1	6778.82101600	10.89	0.0012
APS	1	103.34283350	18.61	<.0001
MLS	1	12.94161813	2.55	0.1121
VHD	1	1.78440936	0.37	0.5437
APL	1	56.47614212	4.71	0.0314
LCML	1	4.78902556	1.27	0.2615
APM	1	40.81632904	3.39	0.0676
MCML	1	7.33261395	1.45	0.2297
BCB	1	29.42868556	3.12	0.0791
FEB	1	96.43378098	8.12	0.0050
APN	1	59.98235838	7.60	0.0065
MLN	1	0.75346923	0.17	0.6842
LAPB	1	24.68190605	3.22	0.0745
LMLB	1	20.39376580	7.11	0.0085
MAPB	1	9.73259158	1.26	0.2643
MMLB	1	2.29924771	0.81	0.3694
ITD	1	2.33618143	0.81	0.3684
PLET	1	12.54377632	2.53	0.1137
PMET	1	0.64055716	0.21	0.6475
BPE	1	121.32383960	11.46	0.0009
TML	1	13652.71714000	23.37	<.0001
FLCS	1	0.00339605	0.19	0.6610
FMCS	1	0.00536948	0.18	0.6736
FDS	1	0.00161325	1.21	0.2730
TLCS	1	0.33915967	26.34	<.0001
TMCS	1	0.06084159	4.25	0.0409
FMS	1	0.05757464	6.25	0.0134
TNS	1	0.07398359	5.25	0.0232

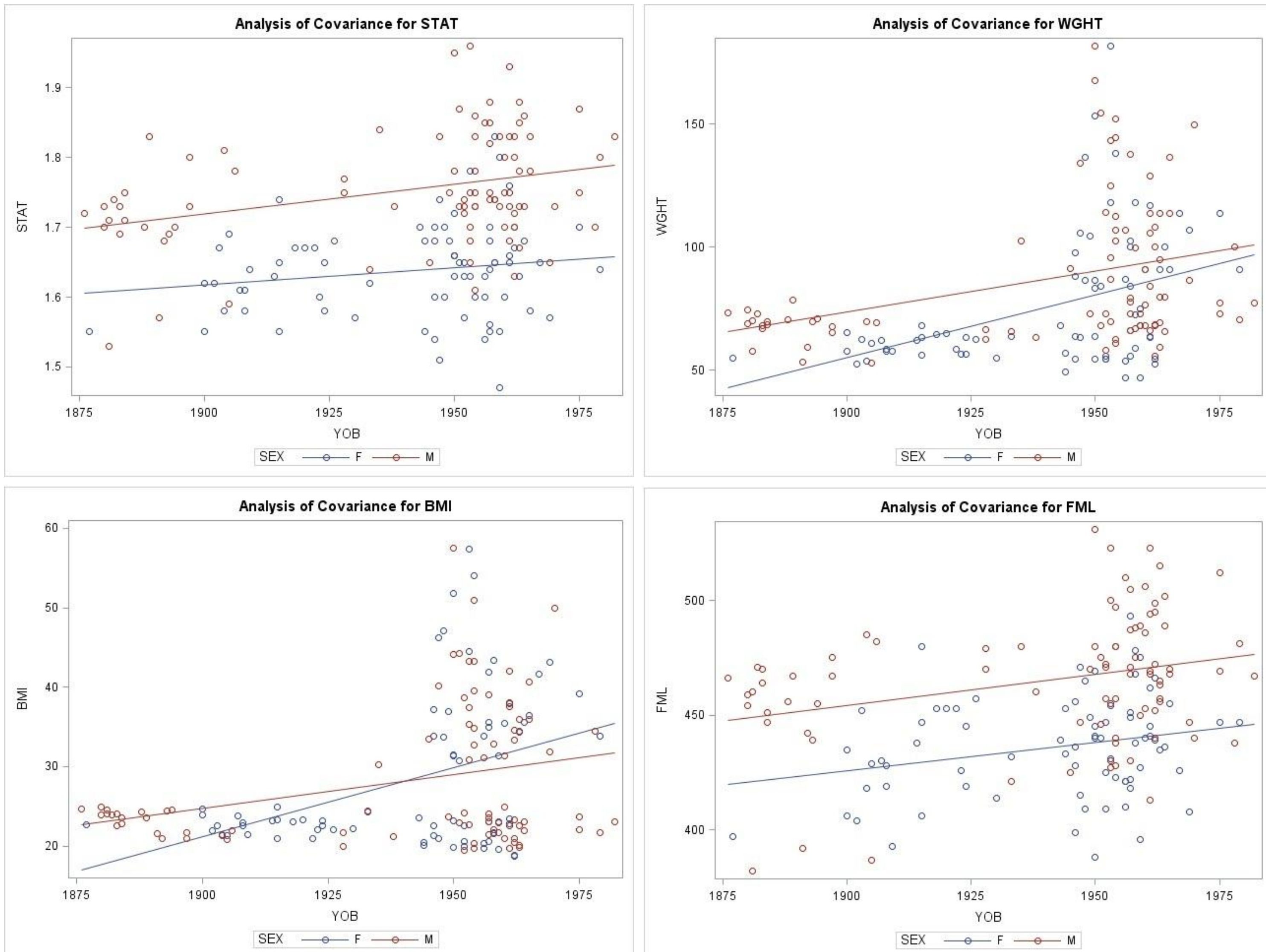


Figure C.1. Year of Birth Secular Trends

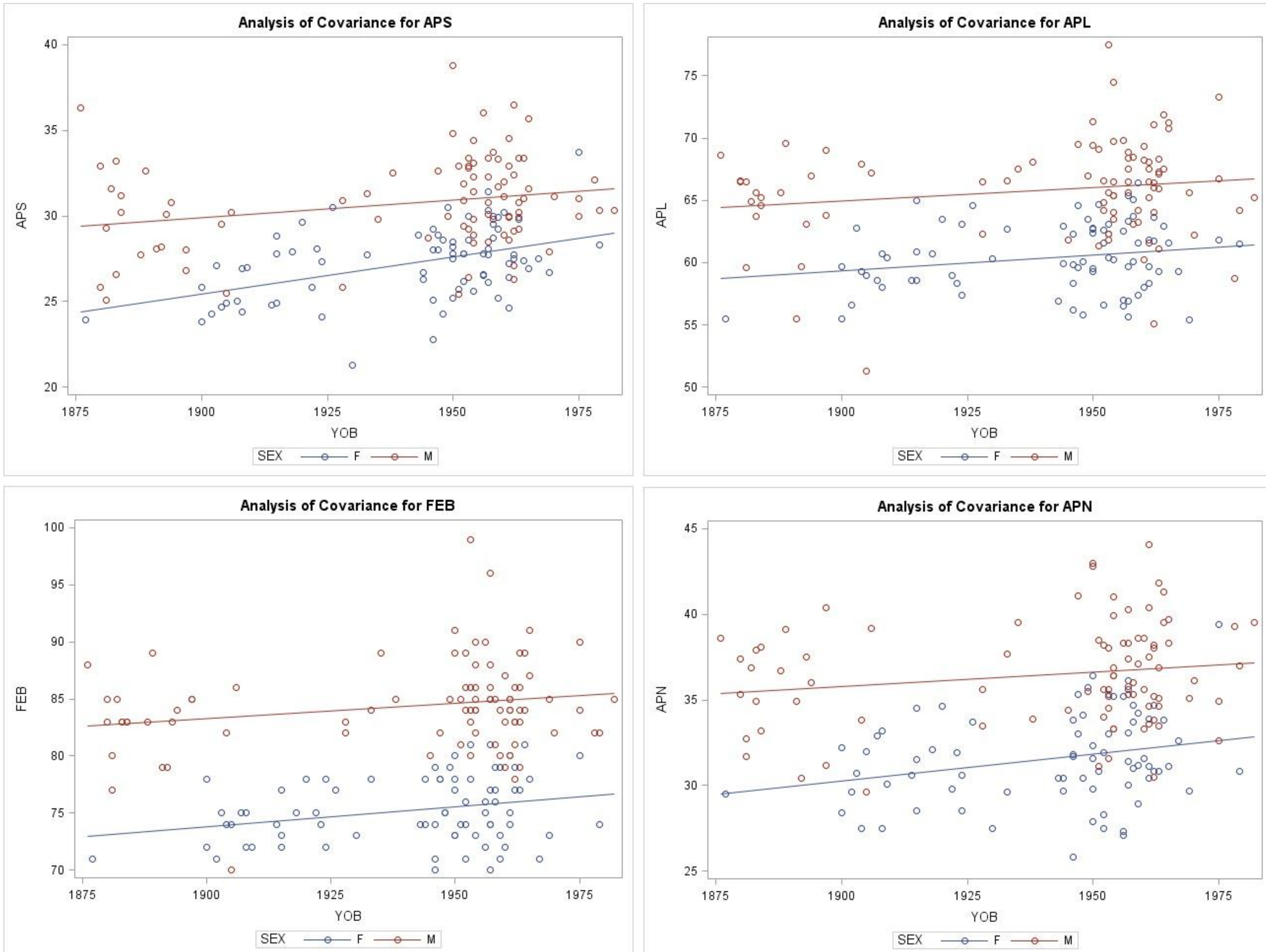


Figure C.1. Continued. Year of Birth Secular Trends

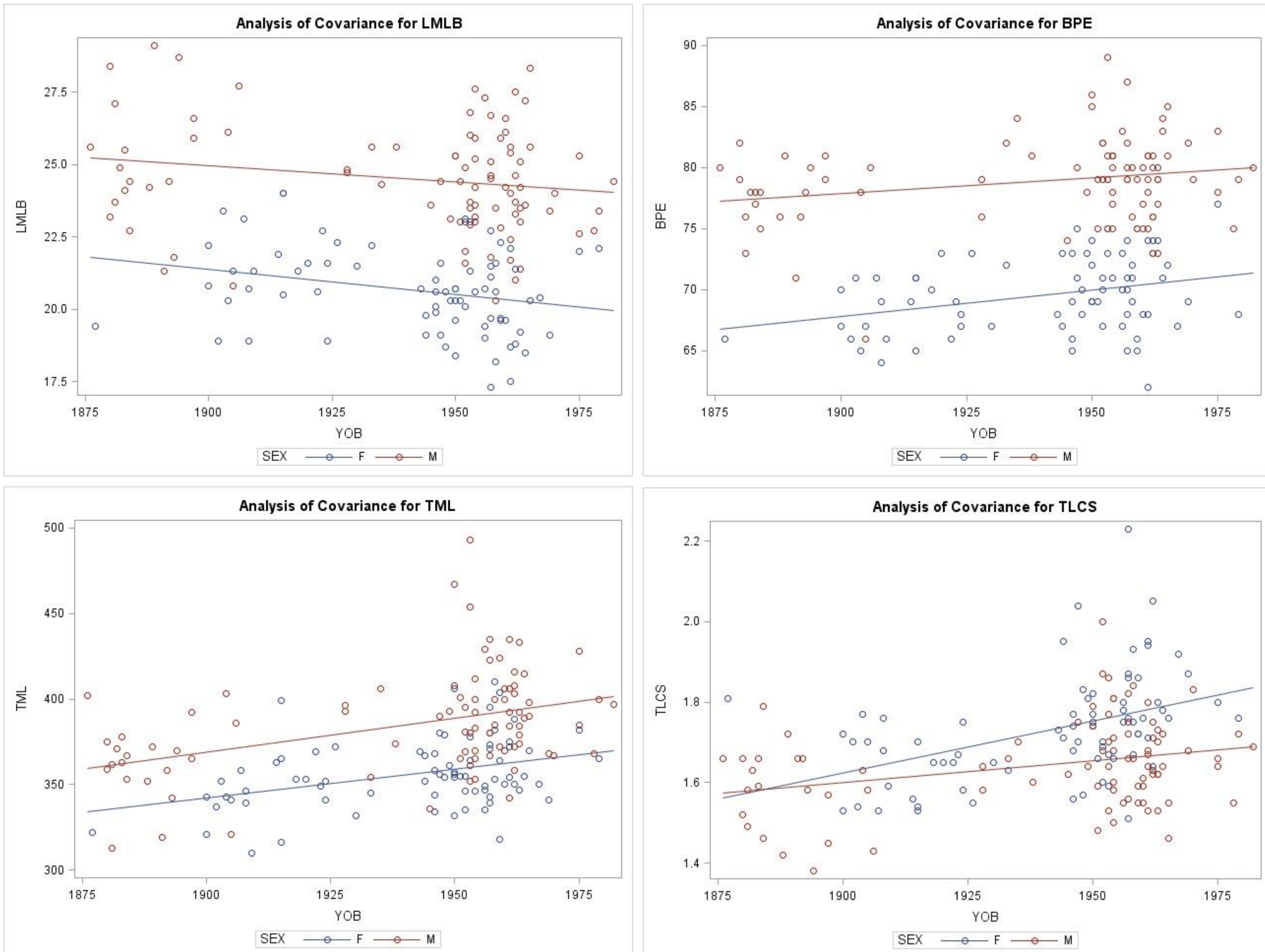


Figure C.1., Continued. Year of Birth Secular Trends

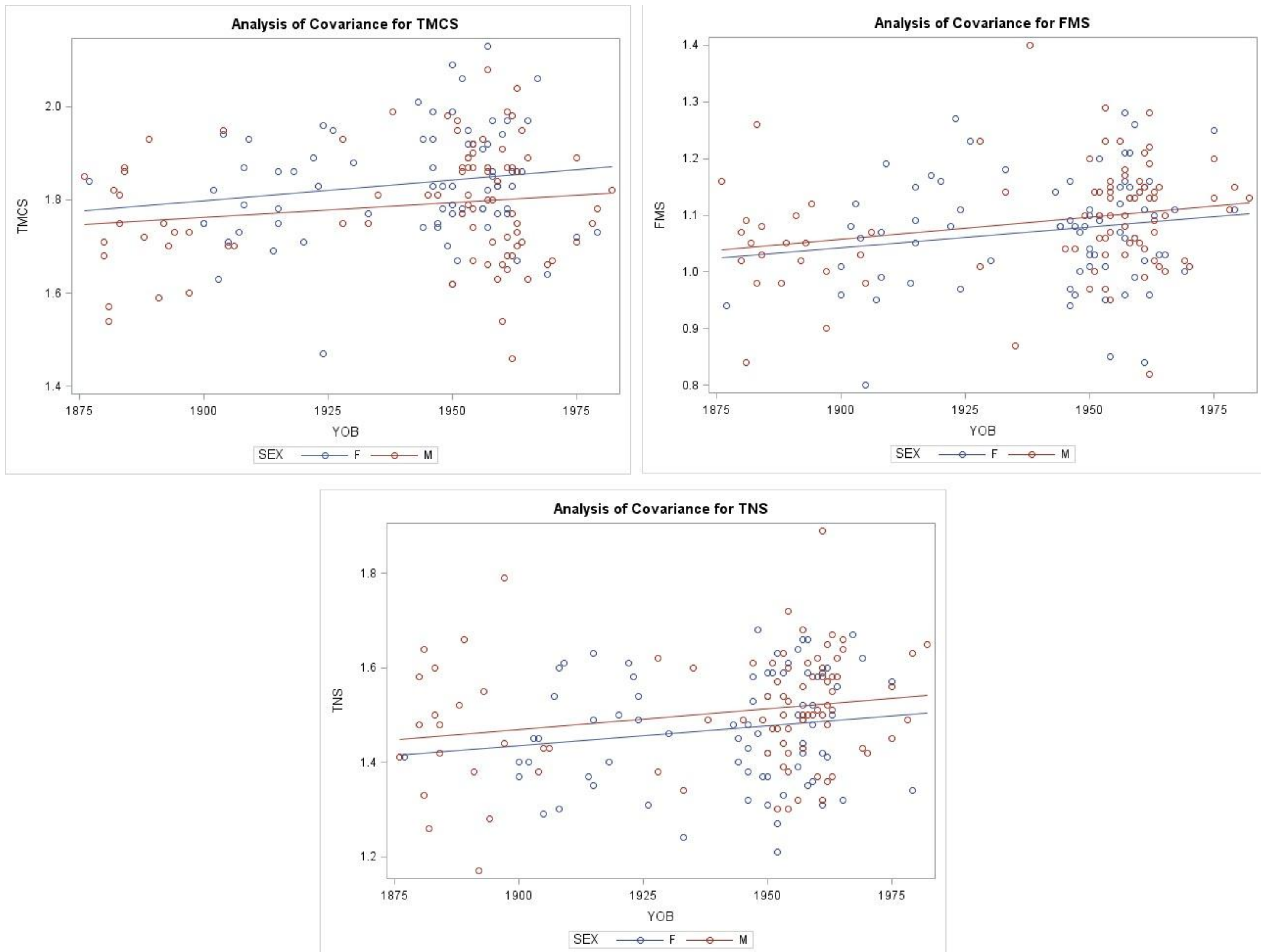


Figure C.1., Continued. Year of Birth Secular Trends

Table C.5. Interaction Between Year of Birth and Sex

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.00339137	0.66	0.4173
WGHT	1	821.69507000	1.20	0.2742
BMI	1	201.21821500	2.82	0.0950
FML	1	15.49453700	0.02	0.8749
APS	1	13.42633540	2.42	0.1219
MLS	1	16.52803073	3.26	0.0729
VHD	1	6.60489545	1.37	0.2435
APL	1	0.20140986	0.02	0.8970
LCML	1	3.40161869	0.90	0.3437
APM	1	2.83892137	0.24	0.6280
MCML	1	39.80206337	7.89	0.0056
BCB	1	10.19455206	1.08	0.2999
FEB	1	1.48839904	0.13	0.7238
APN	1	5.02581683	0.64	0.4260
MLN	1	3.97321627	0.88	0.3508
LAPB	1	6.17100427	0.81	0.3707
LMLB	1	0.86797400	0.30	0.5831
MAPB	1	3.09951184	0.40	0.5282
MMLB	1	0.49565674	0.17	0.6766
ITD	1	16.87057646	5.88	0.0165
PLET	1	0.08113700	0.02	0.8984
PMET	1	0.03355250	0.01	0.9166
BPE	1	7.35776430	0.69	0.4058
TML	1	95.96708000	0.16	0.6858
FLCS	1	0.02012345	1.14	0.2865
FMCS	1	0.24628581	8.17	0.0048
FDS	1	0.00092365	0.69	0.4065
TLCS	1	0.05701858	4.43	0.0369
TMCS	1	0.00177731	0.12	0.7251
FMS	1	0.00009856	0.01	0.9177
TNS	1	0.00003994	0.00	0.9576

Table C.6. Secular Trend for Year of Birth in Females

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.00880	2.03	0.1586
WGHT	1	9491.23720	15.50	0.0002
BMI	1	1099.58962	14.56	0.0003
FML	1	2213.83362	4.70	0.0334
APS	1	68.89458	18.21	<.0001
MLS	1	21.15100	4.37	0.0400
VHD	1	5.49499	1.41	0.2381
APL	1	22.84488	3.08	0.0835
LCML	1	5.85790	2.65	0.1081
APM	1	23.47932	2.84	0.0964
MCML	1	29.28496	8.95	0.0038
BCB	1	26.75019	4.06	0.0477
FEB	1	43.90223	5.47	0.0221
APN	1	35.92391	5.41	0.0228
MLN	1	2.94900	0.74	0.3909
LAPB	1	20.00398	4.74	0.0327
LMLB	1	10.68939	5.00	0.0285
MAPB	1	8.57882	1.47	0.2292
MMLB	1	0.23767	0.14	0.7051
ITD	1	11.44089	4.16	0.0451
PLET	1	5.27425	1.34	0.2500
PMET	1	0.34843	0.15	0.7041
BPE	1	67.87483	7.56	0.0075
TML	1	4127.66656	11.29	0.0012
FLCS	1	0.00252	0.14	0.7116
FMCS	1	0.11684	3.90	0.0521
FDS	1	0.00003	0.03	0.8665
TLCS	1	0.24288	16.59	0.0001
TMCS	1	0.03005	2.28	0.1351
FMS	1	0.01906	2.01	0.1609
TNS	1	0.02542	1.87	0.1759

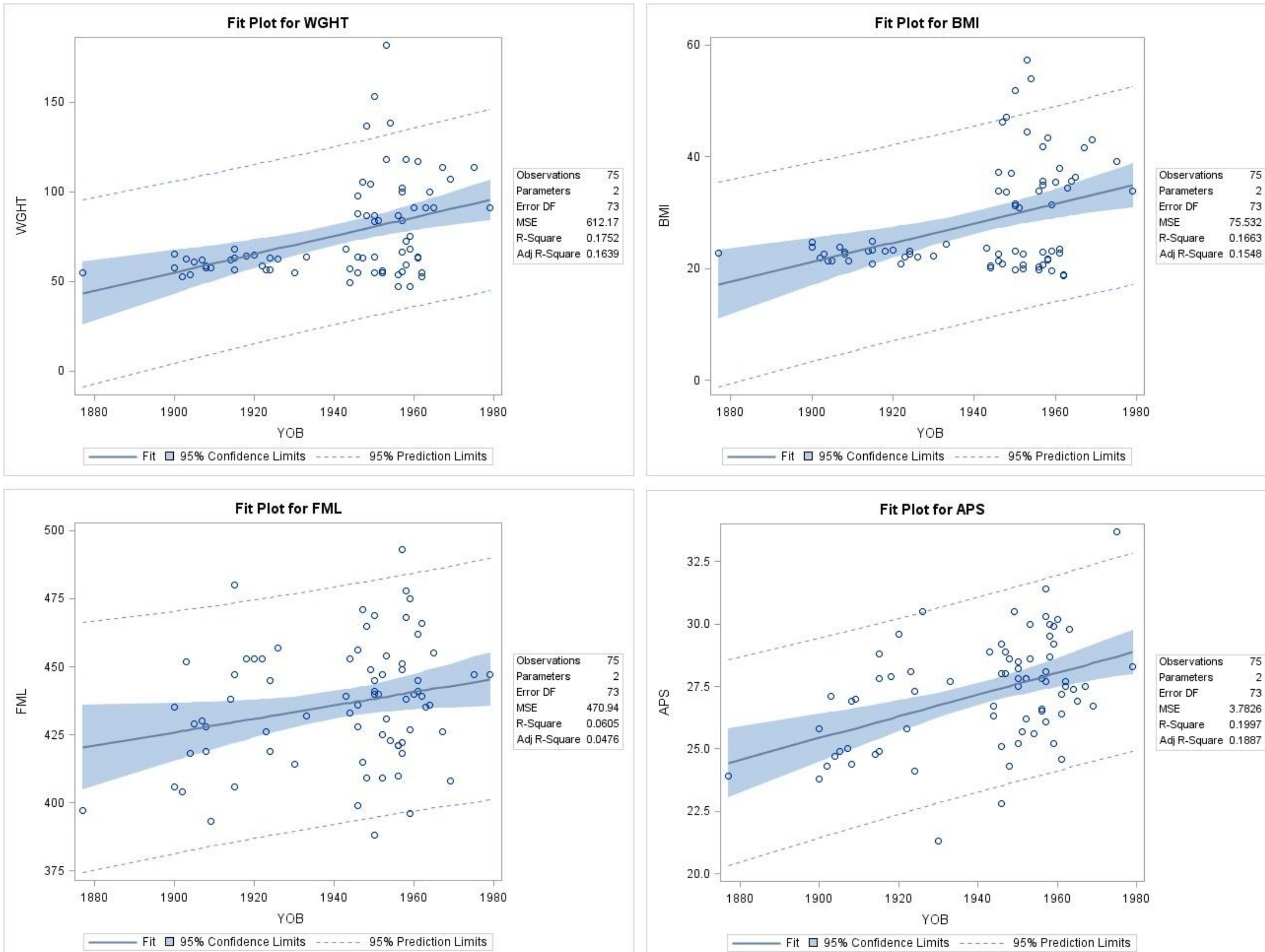


Figure C.2. Year of Birth Secular Trends in Females

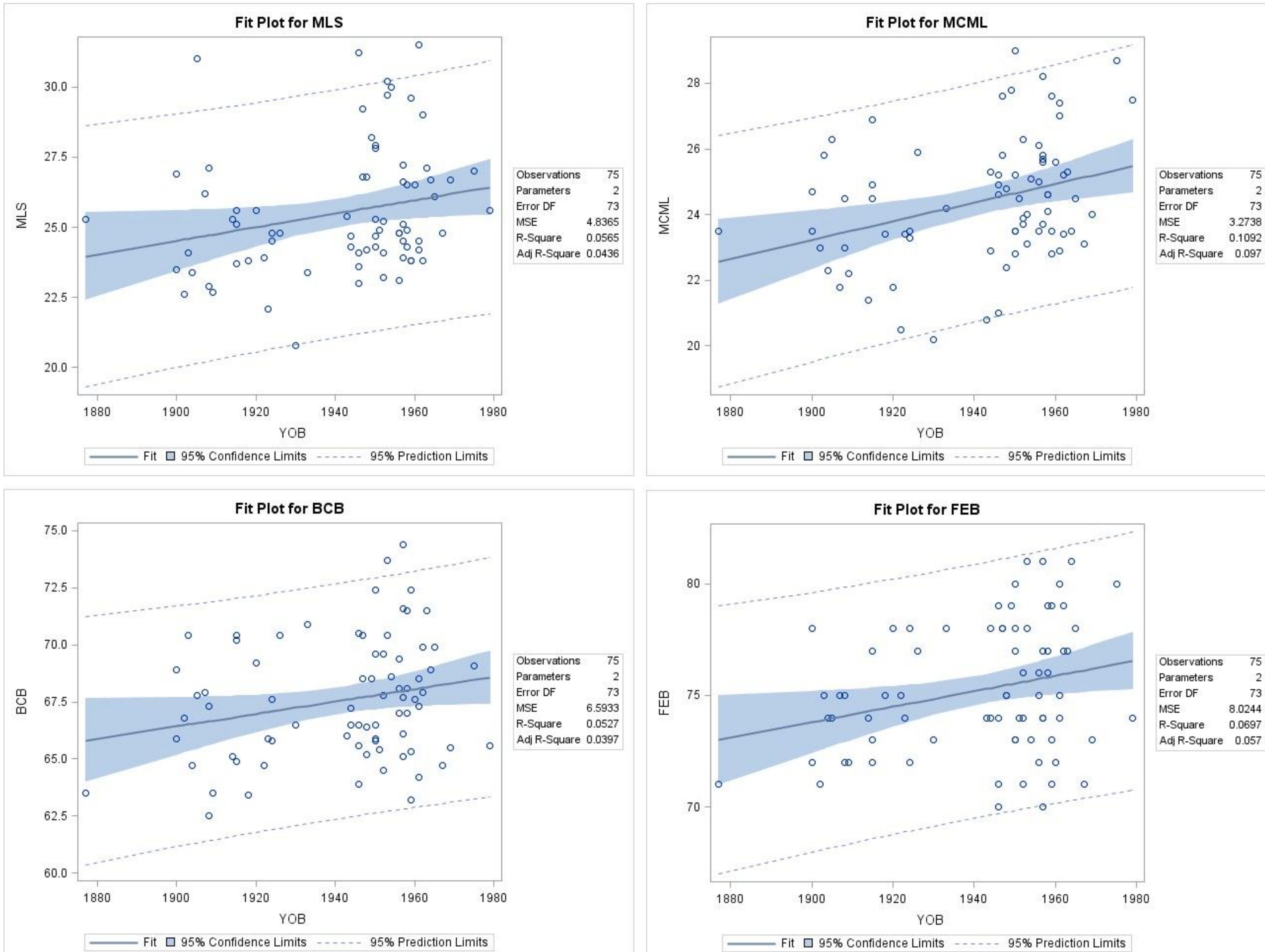


Figure C.2. Year of Birth Secular Trends in Females

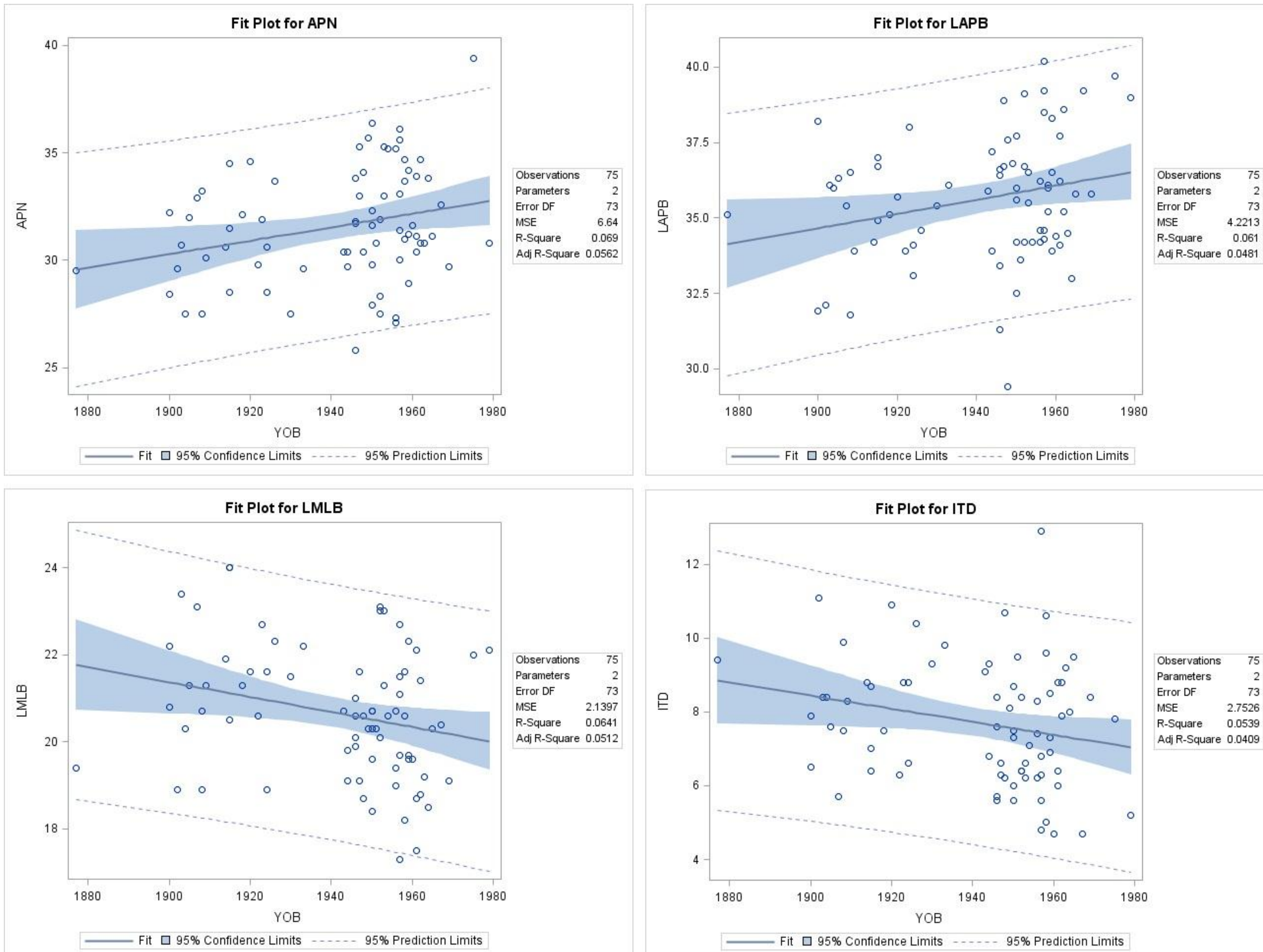
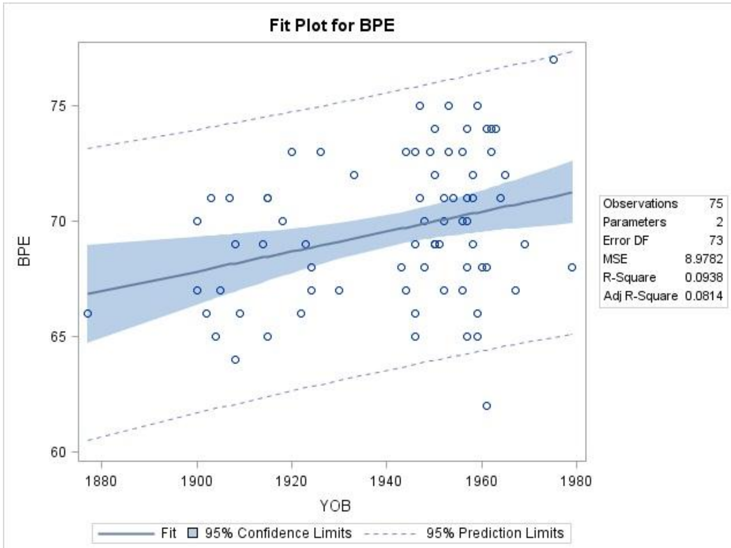
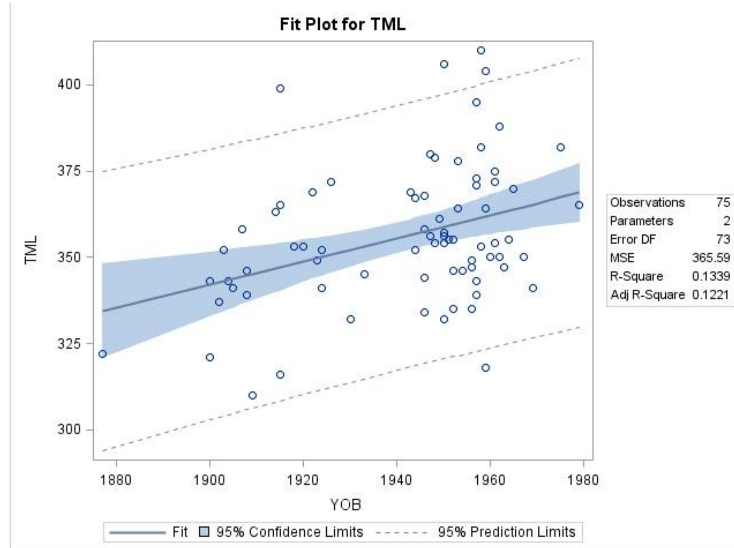


Figure C.2. Year of Birth Secular Trends in Females





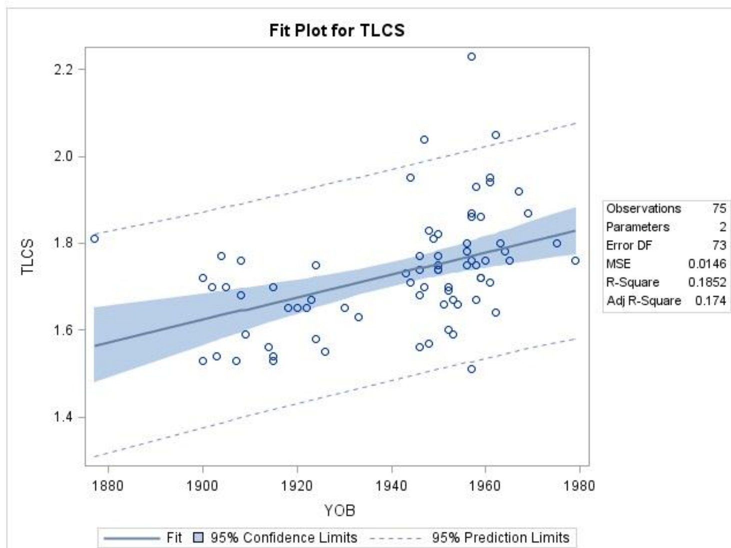


Figure C.2. Year of Birth Secular Trends in Females

Table C.7. Secular Trend for Year of Birth in Males

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.06081	10.47	0.0017
WGHT	1	9008.47902	12.13	0.0008
BMI	1	590.47418	8.72	0.0041
FML	1	6081.66584	8.07	0.0056
APS	1	34.54145	4.88	0.0298
MLS	1	0.17899	0.03	0.8542
VHD	1	1.24469	0.22	0.6392
APL	1	40.80232	2.56	0.1130
LCML	1	0.09672	0.02	0.8909
APM	1	18.08056	1.18	0.2799
MCML	1	10.59625	1.61	0.2074
BCB	1	4.07066	0.34	0.5595
FEB	1	60.43770	3.98	0.0492
APN	1	24.74583	2.76	0.1002
MLN	1	1.03470	0.21	0.6515
LAPB	1	5.04180	0.48	0.4924
LMLB	1	10.49811	3.00	0.0868
MAPB	1	1.50956	0.16	0.6897
MMLB	1	4.02855	1.04	0.3099
ITD	1	5.43477	1.83	0.1800
PLET	1	8.66774	1.48	0.2267
PMET	1	0.31126	0.09	0.7699
BPE	1	56.32345	4.71	0.0329
TML	1	13105.00000	16.97	<.0001
FLCS	1	0.03273	1.92	0.1690
FMCS	1	0.14621	4.82	0.0308
FDS	1	0.00407	2.82	0.0965
TLCS	1	0.09647	8.49	0.0046
TMCS	1	0.03417	2.23	0.1389
FMS	1	0.05102	5.69	0.0192
TNS	1	0.06330	4.37	0.0396

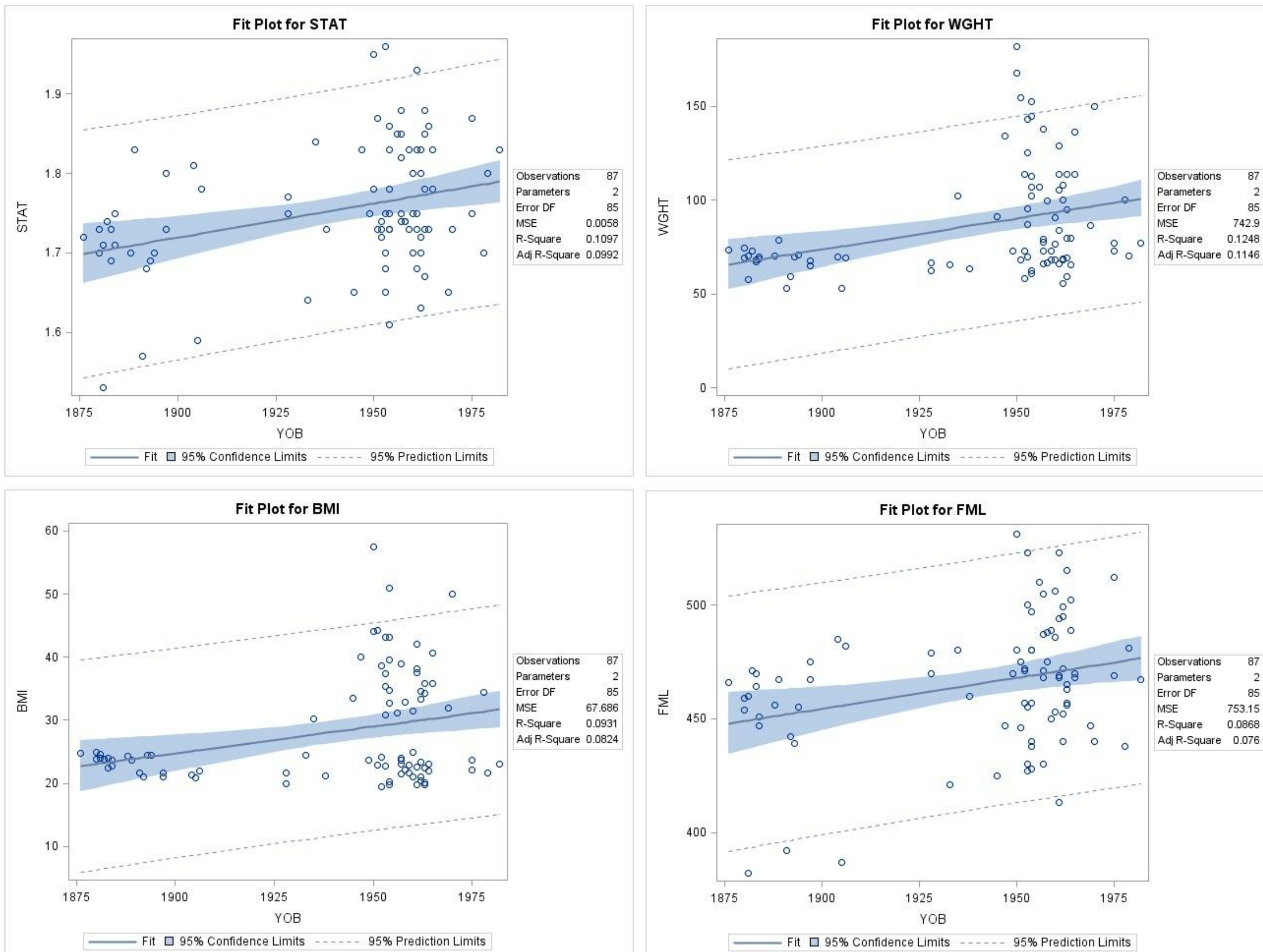


Figure C.3. Year of Birth Secular Trends in Males

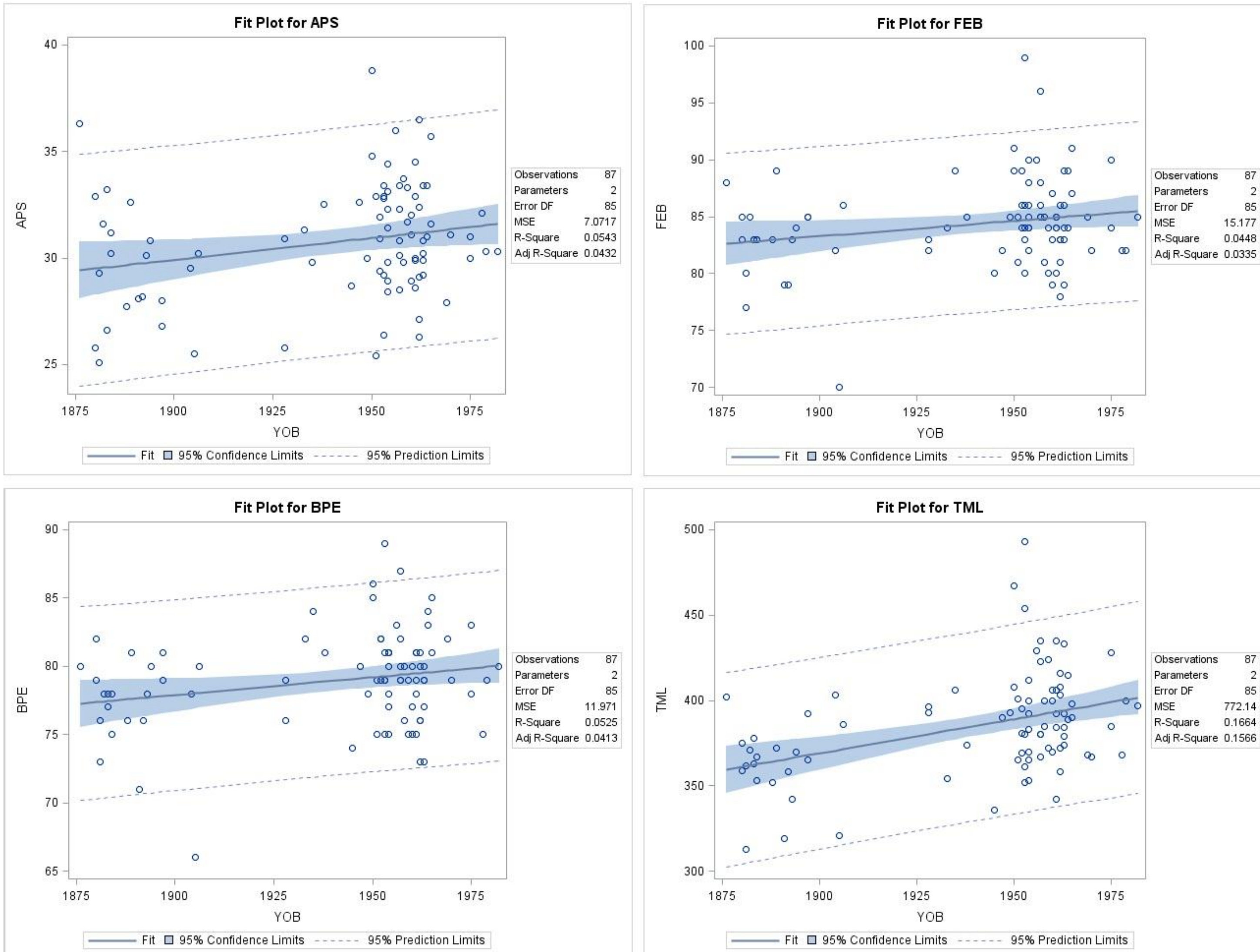


Figure C.3. Year of Birth Secular Trends in Males

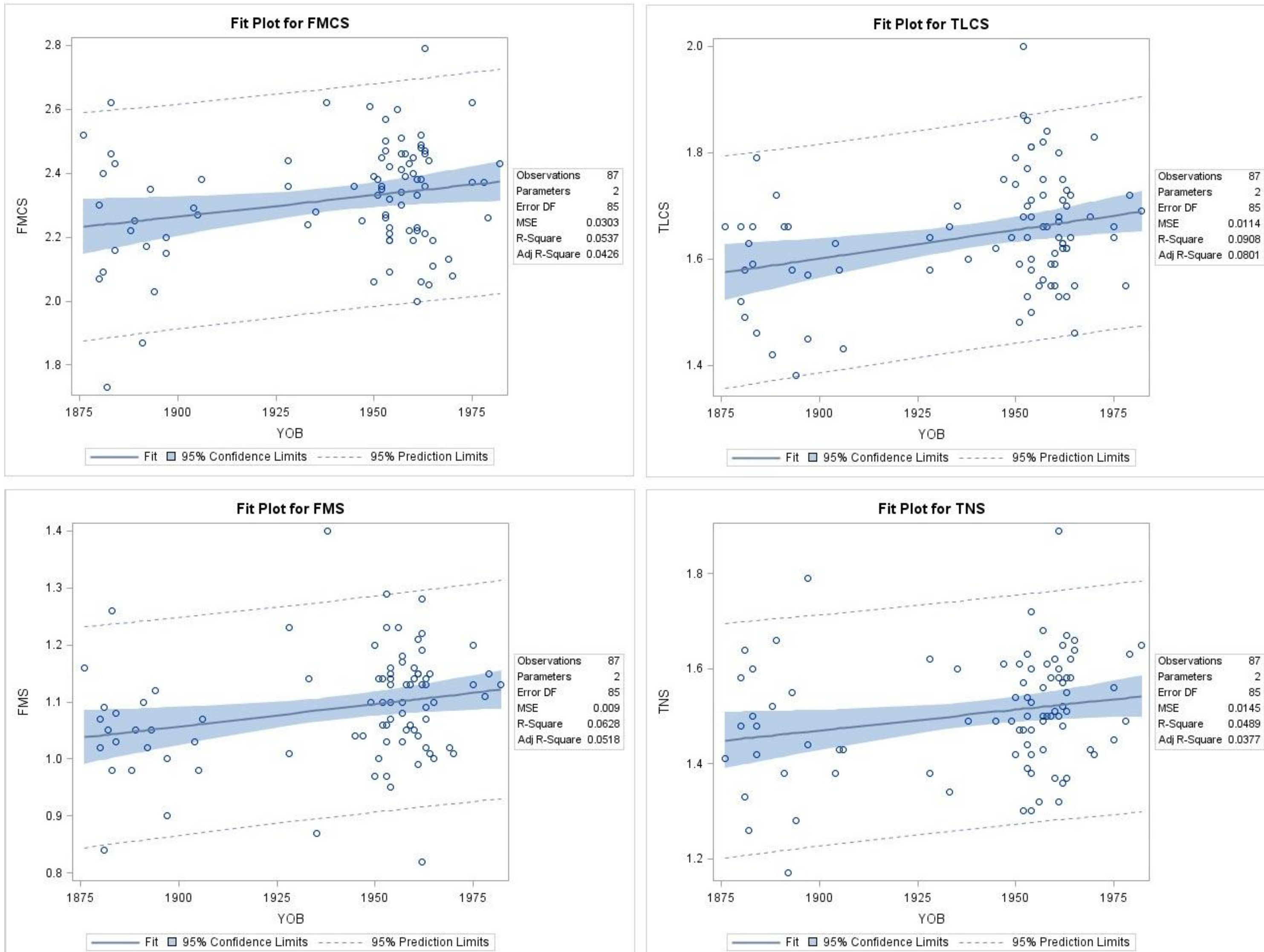


Figure C.3. Year of Birth Secular Trends in Males

Table C.8. Differences Between Normal Weight and Obese Females

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.00188392	0.43	0.5143
WGHT	1	36176.82323000	148.58	<.0001
BMI	1	5111.44465400	250.48	<.0001
FML	1	159.41753400	0.33	0.5680
APS	1	16.46179663	3.74	0.0572
MLS	1	76.72378756	18.57	<.0001
VHD	1	5.17632365	1.34	0.2502
APL	1	6.97579696	0.94	0.3349
LCML	1	0.65469238	0.30	0.5854
APM	1	4.08527782	0.49	0.4876
MCML	1	10.38302669	2.91	0.0924
BCB	1	4.49577346	0.66	0.4175
FEB	1	14.11784455	1.70	0.1962
APN	1	32.46265948	4.83	0.0312
MLN	1	4.50676893	1.13	0.2912
LAPB	1	0.86299983	0.19	0.6642
LMLB	1	6.22062280	2.82	0.0977
MAPB	1	0.01390129	0.00	0.9618
MMLB	1	2.01096231	1.22	0.2724
ITD	1	9.02374056	3.24	0.0760
PLET	1	2.86982751	0.74	0.3927
PMET	1	1.81393361	0.75	0.3880
BPE	1	20.09669297	2.10	0.1519
TML	1	32.35202300	0.08	0.7799
FLCS	1	0.03561176	2.00	0.1619
FMCS	1	0.16220870	5.48	0.0220
FDS	1	0.00407179	3.51	0.0651
TLCS	1	0.06272434	3.63	0.0606
TMCS	1	0.01729436	1.28	0.2618
FMS	1	0.04077425	4.49	0.0375
TNS	1	0.01328203	0.95	0.3319

Table C.9. Differences Between Normal Weight and Obese Males

Variable	DF	Mean Square	F-value	P-value
STAT	1	0.00145429	0.24	0.6225
WGHT	1	42405.05070000	165.66	<.0001
BMI	1	4454.56917000	274.85	<.0001
FML	1	2484.88915000	3.32	0.0720
APS	1	37.33673925	5.47	0.0217
MLS	1	102.72974200	25.05	<.0001
VHD	1	2.61040002	0.46	0.4982
APL	1	6.32610177	0.39	0.5334
LCML	1	5.18434978	1.01	0.3166
APM	1	13.98273404	0.91	0.3437
MCML	1	30.45284090	4.97	0.0284
BCB	1	25.61510429	2.19	0.1428
FEB	1	48.13318890	3.19	0.0779
APN	1	40.67921318	4.66	0.0337
MLN	1	16.03078927	3.26	0.0744
LAPB	1	1.35570701	0.13	0.7227
LMLB	1	3.44354877	0.98	0.3258
MAPB	1	2.68898955	0.28	0.5959
MMLB	1	11.88810040	3.22	0.0762
ITD	1	5.51610471	1.87	0.1755
PLET	1	22.32153545	3.91	0.0511
PMET	1	0.58653067	0.16	0.6895
BPE	1	22.67333774	1.88	0.1741
TML	1	1125.73565000	1.45	0.2316
FLCS	1	0.00904935	0.52	0.4714
FMCS	1	0.10234618	3.56	0.0625
FDS	1	0.00063631	0.43	0.5123
TLCS	1	0.00662245	0.58	0.4502
TMCS	1	0.02524075	1.71	0.1951
FMS	1	0.03047897	3.47	0.0658
TNS	1	0.00100919	0.07	0.7966

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