2004-08-12

Variance In Percent Body Fat Between And Within Families As Measured By Dual-energy X-ray Absorptiometry

Laurel Anne Kelsey
Brigham Young University - Provo

VARIANCE IN PERCENT BODY FAT BETWEEN AND WITHIN FAMILIES AS MEASURED BY DUAL-ENERGY X-RAY ABSORPTIOMETRY

by

Laurel Anne Robinson Kelsey

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Exercise Sciences

Brigham Young University

December 2004

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Laurel Anne Robinson Kelsey

This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

Date	Pat R. Vehrs, Chair
Date	Philip E. Allsen
Date	Ron L. Hager

BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Laurel A. Kelsey in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

Date

Pat R. Vehrs
Chair, Graduate Committee

Accepted for the Department

Ruel Barker, Chair
Department of Exercise Sciences

Accepted for the College

Sara Lee Gibb
Dean, College of Health and Human Performance

ABSTRACT

VARIANCE IN PERCENT BODY FAT BETWEEN AND WITHIN FAMILIES AS MEASURED BY DUAL-ENERGY X-RAY ABSORPTIOMETRY

Laurel Anne Robinson Kelsey

Department of Exercise Sciences

Master of Science

Objective: To determine the variance in percent body fat between and within families as measured by dual-energy x-ray absorptiometry (DXA). Methods: Percent body fat (%BF) assessed in 95 females, 120 males (included 54 sets of biological siblings) using DXA. Physical activity questionnaire used to assess current physical activity habits in each participant. Results: Variance in %BF between and within families is similar. Amount of television viewing and levels of physical activity can affect %BF. Discussion: A model such as the one derived in this study can be a useful tool in intervention programs implemented to decrease obesity. Key words: television viewing, physical activity, obesity interventions

ACKNOWLEDGMENTS

I would like to thank my husband and family for their continuous love, support, and encouragement they have given me. In addition, I want to thank my advisor and mentor, Dr. Pat Vehrs, for the endless hours he has spent over the last year helping me to broaden my knowledge and perspective of the world. I am especially grateful for all the time he has dedicated to helping me to finish this thesis in a very timely manner.

Table of Contents

List of Tables

Lists of Figures

VARIANCE IN PERCENT BODY FAT BETWEEN AND WITHIN FAMILIES

AS MEASURED BY DUAL-ENERGY X-RAY ABSORPTIOMETRY

by

Laurel Anne Robinson Kelsey, MS

Pat R. Vehrs, PhD

Philip E. Allsen, EdD

Ron L. Hager, PhD

Gilbert W. Fellingham, PhD

Department of Exercise Sciences

Brigham Young University

ABSTRACT

Objective: To determine the variance in percent body fat between and within families and to determine the impact of television viewing and physical activity (PA) on percent body fat (%BF). Methods: %BF was assessed in 95 females and 120 males (included 54 sets of biological siblings) using DXA. A PA questionnaire was used to assess current PA habits in each participant. Results: Variance in %BF between (18.1%) and within (22.6%) families was similar. Amount of television viewing and PA were significant predictors of %BF. If television viewing was > 2 hrs/day, PA had little effect on decreasing %BF. Discussion: Results from this study justify the continual implementation of obesity interventions for children and adolescents. Key words: television viewing, physical activity, obesity interventions, adolescents, body composition

INTRODUCTION

In the United States there is a trend toward increasing physical inactivity, television viewing, use of electronic devices, and consumption of convenience foods which are high in fat and sugars.[1-4] The culmination of these trends may be contributing factors to the increased prevalence of obesity throughout the United States. Body mass index (BMI) is often used as an indicator of obesity. BMI is calculated as weight in kilograms divided by height in meters squared. Adults are classified as overweight or obese when their BMI is $\geq$ 25 and $\geq$ 30, respectively. Children and adolescents are classified as overweight or at risk for being overweight when their BMI is greater than the 95th or 85th percentile, respectively, as determined by the Centers for Disease Control (CDC) BMI-for-age growth charts.[5-7]

According to the 1999 – 2000 National Health and Nutrition Examination Survey (NHANES) data released in 2002, 64% of adults 20 years of age and older and 15% of children and adolescents 6 – 19 years of age are overweight. This is a 10% increase for children and adolescents and a 16% increase for adults classified as overweight since the NHANES II survey conducted between 1976 – 1980.[5] Of the 64% of adults who are overweight, 31% (about 59 million people) are classified as obese.[5-7] There are genetic and environmental (behavioral) factors that contribute to body composition of an individual.

Studies demonstrate that genetics accounts for about 60 – 70% of body fat and BMI within twin pairs.[8,9] In addition, there appears to be more heterogeneity in percent body fat between pairs of twins than within pairs of twins when levels of physical activity are controlled for within and between pairs of twins.[10,11] It has also been shown that within a family there is a positive correlation in percent body fat between parents and children and between siblings.[12,13] In addition, it has been reported that 62% of percent body fat trends within families is determined by genetics and familial environment.[14] In spite of a significant genetic component to body composition, lifestyle factors also significantly contribute to body composition. For example, recent studies have reported that television viewing time and participation in physical activity appear to have a significant impact on body composition.[15-19]

Most studies estimated percent body fat using bioelectrical impedance or skinfolds measurements, or used BMI as an indicator of obesity. Few studies have used dual-energy x-ray absorptiometry (DXA) for assessing body composition. It would be beneficial to estimate body composition of adolescents using a reference method such as the DXA.

Knowledge of factors that contribute to differences in body composition between individuals and between families could lead to a greater understanding of current trends in body composition and appropriate interventions. The variance between and within families has not yet been reported. Therefore, the purpose of this study was to determine if the variance in percent body fat as measured by DXA between families is similar to the variance within families. In addition, a secondary purpose was to determine the contribution of physical activity and television viewing to the variance in body composition.

METHODS

Participants

Two hundred and fifteen Caucasian participants (120 male, 95 female) between the ages of 12 – 17 years participated in this study. The 215 participants were from 168 families, 54 of which had more than one biological sibling participating in the study. This study was reviewed and approved by the Institutional Review Board for the Use of Human Subjects (IRB). All participants and their parent(s) gave informed consent. Participants were assured confidentiality of all test results. All participants voluntarily participated in the study. After participating in the study, each participant received coupons for local movie theaters, water parks, community recreation centers, and rock climbing gyms.

Procedures

Participants were instructed to wear athletic shorts and a T-shirt to the appointment and avoid eating a meal or participating in strenuous physical activity or exercise 3 – 4 hours prior to the appointment. Appointments for girls were made at a time when they were not menstruating.

Weight and height of each participant were measured using a standard calibrated scale (Detecto 439 Beam Medical Scale; Webb City, MO) to the nearest one-half pound and one-half inch, respectively. Percent body fat of each participant was estimated at least once using DXA (Hologic QDR4500 Elite "Acclaim Series"; Hologic Inc., Bedford, MA). To establish reliability, 90 participants were asked to return for another appointment to assess body composition a second time within one week of the original appointment. DXA scans were performed by one of two Utah

State certified radiologists. Scans were stored for later analysis. All scans were analyzed by a single Utah State certified radiologist. Scan images were segmented and analyzed for body composition. In addition to the DXA scan, each participant was also asked to complete a brief physical activity questionnaire about their recent and current participation in school-based physical education, physical activity levels, and television viewing habits (Figure 1). The questionnaire was answered during the first appointment only. The physical activity questionnaire has not been previously validated.

Statistical analyses

The Statistical Analysis Software (SAS) package was used to analyze the data collected during this study. Data from all 215 participants were used in the analysis. The 54 sets of siblings were identified in the database for analytical purposes. “No” and “Yes” responses to questions 1 – 7 of the questionnaire were coded as 0 and 1, respectively. The five possible responses to the multiple-choice questions (Questions 8 and 9) were coded as 0, 1, 2, 3, and 4, respectively. Responses to questions 1 – 7 were summed to form an overall independent physical activity variable ranging in values from 0 to 7. Following the recommendation of the American Academy of Pediatrics that children and adolescents watch less than 2 hours of television per day,[20] participant responses to Question 8 were grouped into one of two categories, watching less than 2 hours of television per day (coded as 0) or more than 2 hours of television per day (coded as 1). A mixed analysis of variance (Proc Mixed) was used to evaluate the variance in percent body fat between and within families. This procedure appropriately accounts for the covariance structure of the data. Age, gender and the responses to the questionnaire were considered fixed effects. Age, gender and the responses to the questionnaire were used to develop a model to explain differences in percent body fat between and within families. For the purpose of the analysis, 12 was subtracted from each participant's age so the resulting model would appropriately have a Y-intercept at age 12 rather than age 0. The family-wise alpha level was maintained at $p < 0.05$.

RESULTS

Physical characteristics of the 215 participants are shown in Table 1 and 2. Body mass index (BMI) ranged from 14.37 to 32.25 kg/m^2 and body fat values ranged from 7.30 to 45.30 percent of body weight. Television viewing ranged from less than 2 hours per day to more than 8 hours per day. One hundred and five participants self-reported watching less than 2 hours of television per day and 110 participants self-reported watching more than 2 hours of television per day (Question 8). One hundred and five, 83, 10, 7, and 1 participant(s) self-reported participating in less than 2 hours/day, 2.1 – 4 hours/day, 4.1 – 6 hours/day, 6.1 – 8 hours/day and more than 8 hours/day of physical activity (Question 9), respectively. When the responses of questions 1 though 7 were summed, the values ranged from 0 to 7.

According to the NHANES definitions[5-7],16 females and 12 males were considered at risk of being overweight and 3 females and 9 males were considered overweight. The average BMI values for each age group were all below the 85^{th} percentile of the BMI growth charts. [5-7]

The results of the Proc Mixed analysis indicated that the variance in body fat between (18.1%) and within (22.6%) families after accounting for fixed effects were similar. Residual variance, or the variance between percent body fat values estimated on the first and second day was 0.1657 percent body fat, indicating an extremely high reliability between the 2 DXA measurements. The mean difference between the two measurements was 0.76 percent body fat. Gender, age by gender, age^2 by gender, and activity level (sum of Questions 1-7) by amount of TV viewing (Question 8) were all significant variables in a quadratic model to predict percent body fat. Responses to Question 9 did not significantly contribute to the model. The best-fit model resulted in the following gender specific quadratic equations:

- ***Females watching < 2 hours of television per day***

$\%BF = 23.4592 + 2.0716(age) – 0.2628(age^2) – 0.7741(activity\ level)$

- ***Females watching > 2 hours of television per day***

$\%BF = 23.4592 + 2.0716(age) – 0.2628(age^2) + 0.04982(activity\ level)$

- ***Males watching < 2 hours of television per day***

$BF = 24.5308 – 3.8033(age) + 0.4019(age^2) – 0.7741(activity\ level)$

- ***Males watching > 2 hours of television per day***

$\%BF = 24.5308 – 3.8033(age) + 0.4019(age^2) + 0.04982(activity\ level)$

where: Age = age minus 12, where age is in years and months

(For example 12 years and 9 months = 0.75)

Activity Level = Sum responses to Questions 1 – 7

The gender difference in the intercept (1.07 percent body fat) was not significant ($p = 0.6673$). The linear effect of age and the quadratic effect of age were both significantly different between males and females. The summed responses of questions 1- 7 were significantly different between those who watched less than 2 hours and those who watched more than 2 hours of television per day. If male or female participants watched < 2 hours/day of television, increasing levels of physical activity reduced body composition by 0.77% body fat for each increment of physical activity (summed responses to Questions 1 – 7). If male or female participants watched > 2 hours/day of television, level of physical activity did not reduce percent body fat (see Figures 2 – 5).

DISCUSSION

Over the last twenty years, the prevalence of obesity worldwide has reached epidemic proportions. This drastic increase in obesity is a concern because obesity is a major risk factor for many diseases and clinically relevant conditions such as hypertension, type II diabetes, stroke, cardiovascular and pulmonary diseases, metabolic syndrome and certain types of cancers (breast, colon, prostrate, endometroium, kidney, and gallbladder). Weight gain is a result of a persistent positive caloric imbalance in which caloric intake exceeds caloric expenditure. The most common causes of a positive caloric imbalance are either consumption of excess calories or physical inactivity, or both. The factors that contribute to obesity can be grouped into environmental, lifestyle, and genetic factors. These factors have been considered in controlled experimental studies using twins.[8-11]

The results of this study show a general trend toward increasing body fat over the age span in females and decreasing body fat in males (Figures 2 – 5). Recent NHANES data indicated that 12.8% and 12.4% of 12 – 19 year-old males and females, respectively, were classified as overweight.[7] These values are higher than the data from this study which indicate that 7.8% and 3.2% of males and females, respectively, were classified as overweight. Recent NHANES data also indicated that 30.5% and 25.4% of 12 – 19 year-old males and females, respectively, were classified as overweight or at risk.[7] These values are also higher than the data from this study which indicate that 18.3% and 20.0% of males and females, respectively, were classified as overweight or at risk. The discrepancy between the NHANES data and the data collected in this study is most likely due to the differences in sample size and heterogeneity. The cause of increasing prevalence of being overweight or at risk of overweight is difficult to determine. Evidence from national surveys suggests that poor eating habits, decreasing levels of physical activity, and decreasing participation in physical education are contributing factors.[5-7] It was not possible to detect any significant trends in physical activity or television viewing between genders and across the age span based on participant responses to the questionnaire used in this study.

The results of this study revealed that the variance in percent body fat between and within families was similar. We have not found any published studies that have reported variance in percent body fat between and within families. Variance between and within monozygotic twins has been reported. A study by Bouchard et al. reported that, “changes in body mass, body fat and body energy content were characterized by more heterogeneity between twins pairs than within pairs."[10] Other studies have reported that genetics accounted for 60 – 70% of BMI and percent body fat within sets of twins.[8-11] Rice et al. reported that 62% of percent body fat trends within families is determined by genetics and familial environment.[14] In addition, Rameriz found that, "there was a significant resemblance for the level of fatness within families. Correlations between all siblings were significant for percent body fat, sum of 4 site skinfolds, and subcutaneous adipose tissue thickness as measured by a B-mode ultrasound scanner at 7 sites."[13]

A model such as the one reported in this study describes the influence of physical activity and television viewing on the body composition of adolescents. In addition to age and gender, the amount of television viewing, and school/extracurricular physical activity were significant independent predictors of body composition. Various studies have shown a decline in physical activity levels, concomitant with an increase in television viewing and the use of electronic devices.[1 – 4] The findings of this study suggests the importance of school-based physical activity, participation in physical education, school and community sports, and extracurricular activities such as marching band and dance.

Perhaps the most significant finding of this study is the influence of television viewing time and physical activity on the body composition in adolescents. Almost 50% of the participants in this study reported watching more than 2 hours of television per day (49.5% female, 46.7% male). If adolescents viewed less than 2 hours of television per day, increasing levels of physical activity appeared to contribute to a decrease in percent body fat. Based on the model reported in this study, for each additional level of physical activity (sum of Questions 1-7) there is a decrease of 0.77 percent body fat in females and males. However, if adolescents viewed more than 2 hours of television per day, physical activity did not appear to effect percent body fat.

A number of authors have previously conducted studies that support the findings of the present study. Epstein et al. conducted a randomized study to investigate the effects of reinforcing increased exercise, decreased sedentary time (i.e. television viewing or reading comic books), or a combination of both on weight.[15] Epstein el al. reported that following a 4-month intervention period, the “decrease sedentary time” group had the greatest decrease in body weight compared to the other two exercise groups.[15] Gortmaker et al. conducted a 4-year longitudinal study to evaluate the relationship between hours of television viewing and BMI in 10 – 15 year-olds.[16] Gortmaker et al. reported that, “the odds of being overweight were 4.6 times more for youth watching more than 5 hours of television per day compared with those watching from 0 to 2 hours.”[16] Dietz et al. reported a causal relationship between the amount of television viewing and obesity.[17] It was also reported that the prevalence of obesity “increases 2% for every additional hour of television viewed per day”[17] in children between the ages of 12 – 17 years. These studies all suggest that the amount of time spent in sedentary behaviors is strongly related to percent body fat.

Public health officials and educators need all the resources possible to combat the increasing prevalence and incidence of obesity. Intervention studies have been conducted to study the effects of reducing television viewing as a means of preventing obesity. In 1999, Robinson conducted a 7-month intervention in 3rd and 4th graders which integrated lessons on television viewing choices and challenges to reduce viewing time into the daily curriculum.[18] Even though students in the intervention and control groups gained weight due to normal growth, Robinson reported a significant ($p < 0.002$) decrease in the BMI of the intervention group compared to the control group.[18] Gortmaker et al. conducted a 2-year school intervention which included sessions that focused on decreasing television viewing and consumption of high-fat foods and increasing fruit/vegetable intake and physical activity.[19] Gortmaker et al. reported a decrease in obesity was found in females, but not in males.[19] These studies suggest that school-based interventions may be an effective approach to combat the rise in child obesity. With these types of interventions, a model such as the one derived in the present study could be a useful tool to cost effectively assess obesity levels based on age, television viewing time, and school-based physical activity.

Conclusion

In conclusion, the variance in percent body fat does not appear to be significantly different between or within families. However, adolescents, parents and educators should be aware of the potential impact of television viewing time and physical activity on percent body fat. The findings of this study justify intervention program to decrease television viewing time and to increase school and extracurricular physical activity. Childhood and adolescent obesity intervention programs will continue to be important because obesity is so strongly related to many diseases and clinical conditions.

REFERENCES

1. DuRant RH, Baranowski T, Johnson M, et al. The relationship among television watching, physical activity, and body composition of young children. *Pediatrics*. 1994;94:449-455.
2. Jeffrey RW, French SA. Epidemic obesity in the United States: are fast foods and television viewing contributing? *Am J Public Health*. 1998;88:277-280.
3. Robinson TN, Hammer LD, Killen JD, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics*. 1993;91:273-280.
4. Tucker LA. Television viewing and physical fitness in adults. *Res Q Exerc Sport*. 1990;61:315-320.
5. The Center for Disease Control. Obesity still on the rise, new data show. Available at: http://www.cdc.gov/nchs/pressroom/02news/obesityonrise.htm. Accessed May 27, 2004.
6. Flegal KM, Carroll MD, Ogden CL, et al. Prevalence and trends in obesity among US adults, 1999-2000. *JAMA*. 2002;288:1723-1727.
7. Ogden CL. Flegal KM, Carroll MD, et al. Prevalence and trends in overweight among US children and adolescents, 1999 – 2000. *JAMA*. 2002;288:1728-1732.
8. Stunkard AJ, Harris JR, Pedersen NL, et al. The body-mass index of twins who have been reared apart. *New England Journal of Medicine*. 1990;322:1483-1487.

9. Samaras K, Spector TD, Nguyen TV, et al. Independent genetic factors determine the amount and distribution of fat in women after the menopause. *J Clin Endocrinol* Metab. 1997;82:781-785.

10. Bouchard C, Tremblay A. Genetic influence on the response of body fat and fat distribution to positive and negative energy balances in human identical twins. *J Nutr*. 1997;127:943S-947S.

11. Samaras K, Kelly PJ, Chiano MN, et al. Genetic and environmental influence on total-body and central abdominal fat: the effect of physical activity in female twins. *Ann Intern Med*. 1999;130:873-882.

12. Ramirez ME. Familial aggregation of subcutaneous fat deposits and the peripheral fat distribution pattern. *Int J Obes Relat Metab Disord*. 1993;17:63-68.

13. Ramirez ME. Subcutaneous fat distribution in adolescents. *Hum Biol*. 1993;65:771-782.

14. Rice T, Daw EW, Gangon J, et al. Familial resemblance for body composition measures: the Heritage family study. *Obes Res*. 1997;5:557-562.

15. Epstein LH, Valosk AM, Vara LS, et al. Effects of decreasing sedentary behavior and increasing activity on weight change in obese children. *Health Psychology*. 1995;14:109-115.

16. Gortmaker SL, Must A, Sobol AM, et al. Television viewing as a cause of increasing obesity among children in the United States, 1986 – 1990. *Arch Pediatr Adolesc Med*. 1996;150:356-362.

17. Dietz WH, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics*. 1985;75:807-812.

18. Robinson TN. Reducing children's television viewing to prevent obesity. *JAMA*. 1999;282:1561-1567.

19. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth. *Arch Pediatr Adolesc Med*. 1999;153:409-418.

20. American Academy of Pediatrics. Children, adolescents, and television (RE0043). *Pediatrics*. 2001;107:423-426.

Table 1

Descriptive Characteristics of Female Participants

Age	12	13	14	15	16	17	Combined
N	15	19	14	25	12	10	95
Height (cm)	152.82 ± 8.3	160.35 ± 7.0	160.07 ± 6.7	163.02 ± 7.3	166.00 ± 6.3	164.66 ± 7.0	160.99 ± 8.1
Weight (kg)	42.89 ± 7.0	51.43 ±10.2	56.13 ± 9.2	57.80 ± 8.0	57.19 ± 6.1	61.63 ± 8.2	54.25 ± 9.9
BMI (kg/m^2)	18.30 ± 2.0	19.84 ± 2.7	21.86 ± 3.1	21.81 ± 3.1	20.79 ± 2.2	22.73 ± 2.8	20.84 ± 3.0
Body fat (%)	23.71 ± 5.1	24.95 ± 5.5	27.94 ± 6.3	25.72 ± 7.4	25.29 ± 4.6	27.54 ± 4.4	25.72 ± 6.0
Q8	0.73 ± 0.7	0.63 ± 0.7	0.57 ± 0.7	0.36 ± 0.5	0.50 ± 0.5	1.30 ± 1.3	0.62 ± 0.8
Q9	0.47 ± 0.6	0.58 ± 0.7	0.43 ± 0.7	0.80 ± 0.8	0.58 ± 0.7	0.70 ± 1.0	0.72 ± 0.5
Sum Q1-7	2.93 ± 1.6	2.79 ± 1.8	1.86 ± 1.5	3.24 ± 1.6	2.92 ± 1.6	2.40 ± 1.4	2.77 ± 1.6

Table 2

Descriptive Characteristics of Male Participants

Age	12	13	14	15	16	17	Combined
N	24	18	25	25	12	16	120
Height (cm)	155.92 ± 6.0	161.78 ± 9.4	167.28 ± 6.9	172.42 ± 7.6	171.87 ± 8.5	175.86 ± 6.0	166.86 ±10.0
Weight (kg)	47.72 ±11.6	51.01 ±11.4	53.15 ± 7.0	61.88 ±12.4	66.08 ± 8.7	69.04 ± 8.5	57.00 ±12.7
BMI (kg/m^2)	19.52 ± 3.9	19.51 ± 4.3	18.96 ± 2.1	20.73 ± 3.4	22.54 ± 3.4	22.42 ± 3.5	20.34 ± 3.6
Body Fat (%)	22.21 ± 9.4	18.28 ± 8.9	14.08 ± 4.7	16.32 ± 6.9	14.62 ± 5.7	14.01 ± 4.6	16.85 ± 7.6
Q8	0.92 ± 1.0	0.83 ± 1.1	0.60 ± 1.0	0.68 ± 0.9	0.58 ± 0.9	0.63 ± 0.9	0.95 ± 1.0
Q9	0.33 ± 0.7	0.83 ± 0.9	0.88 ± 0.8	0.84 ± 0.9	0.92 ± 1.2	0.69 ± 0.9	0.73 ± 0.9
Sum Q1-7	2.37 ± 1.7	2.94 ± 1.21	3.04 ± 1.5	3.24 ± 1.6	2.25 ± 1.6	3.06 ± 1.9	2.86 ± 1.6

Figure Captions

Figure 1. Physical Activity Questionnaire.

Figure 2. Percent body fat of adolescent females who watch < 2 hours of television per day. Blank circles represent watching less than 2 hours of television per day and no participation in physical activity. Darkened circles represent watching less than 2 hours of television per day and participating in physical activity (based on sum of questions 1 – 7 equaling 7).

Figure 3. Percent body fat of adolescent males who watch < 2 hours of television per day. Blank diamonds represent watching less than 2 hours of television per day and no participation in physical activity. Darkened diamonds represent watching less than 2 hours of television per day and participating in physical activity (based on sum of questions 1 – 7 equaling 7).

Figure 4. Percent body fat of adolescent females who watch > 2 hours of television per day. Blank circles represent watching more than 2 hours of television per day and no participation in physical activity. Darkened circles represent watching more than 2 hours of television per day and participating in physical activity (based on sum of questions 1 – 7 equaling 7).

Figure 5. Percent body fat of adolescent males who watch > 2 hours of television per day. Blank diamonds represent watching more than 2 hours of television per day and no participation in physical activity. Darkened diamonds represent watching more than 2 hours of television per day and participating in physical activity (based on sum of questions 1 – 7 equaling 7).

Figure 1.

Please respond to the following by checking one of the answer boxes for each question.

Question		
1. Are you <u>currently</u> participating in any organized school sport such as basketball, football, wrestling, dance, baseball?	Yes	No
2. Are you <u>currently</u> participating in any organized sports, sports camps, or activity programs in the community?	Yes	No
3. Have you participated in any organized school or community sports in the last 6 months?	Yes	No
4. Are you <u>currently</u> participating in marching band?	Yes	No
5. Do you do any strength training with weights, calisthenics, elastic bands or cords, or other devices?	Yes	No
6. Are you enrolled in a PE class this semester at school?	Yes	No
7. Were you enrolled in a PE class last semester at school?	Yes	No
8. During an average week, how many hours per day do you watch TV, play on the computer or play station?	0 - 2 hours 2.1 - 4 hours 4.1 - 6 hours 6.1 - 8 hours more than 8 hours per day	
9. On the average how many hours per day do you walk, jog, run, play sports, dance, bike, use your scooter, work out, or participate in a recreational activity?	0 - 2 hours 2.1 - 4 hours 4.1 - 6 hours 6.1 - 8 hours more than 8 hours per day	

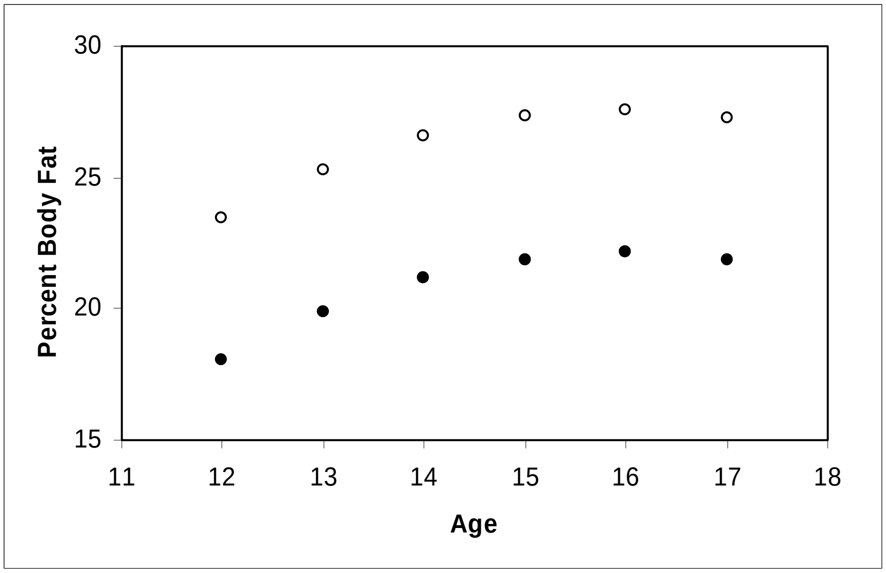

Figure 2.

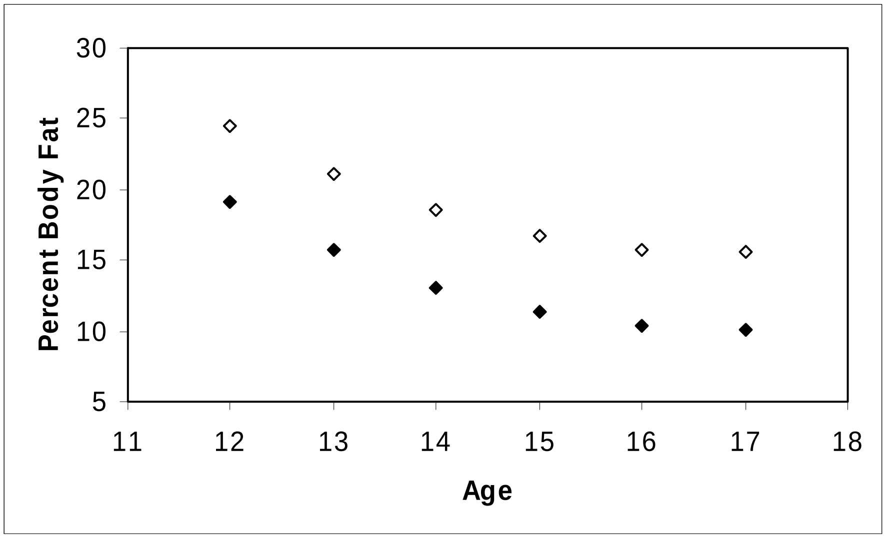

Figure 3.

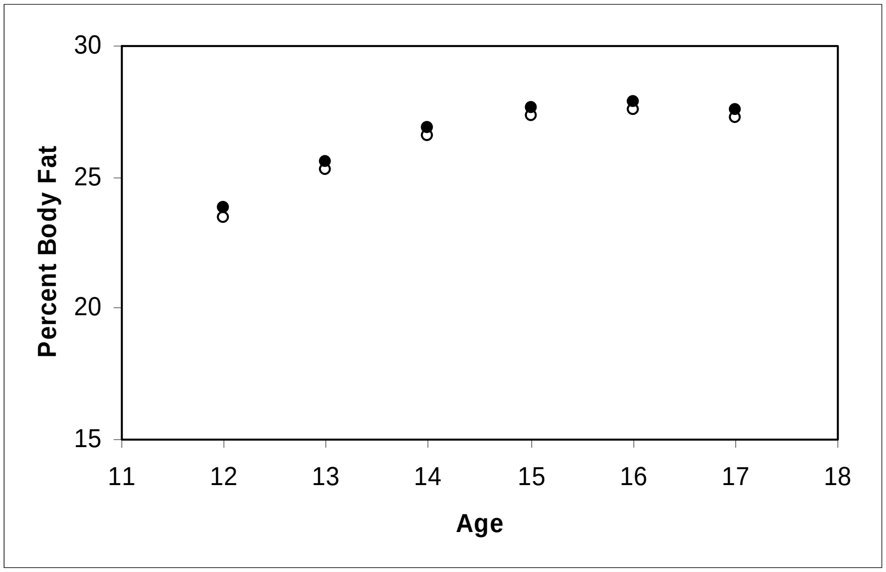

Figure 4.

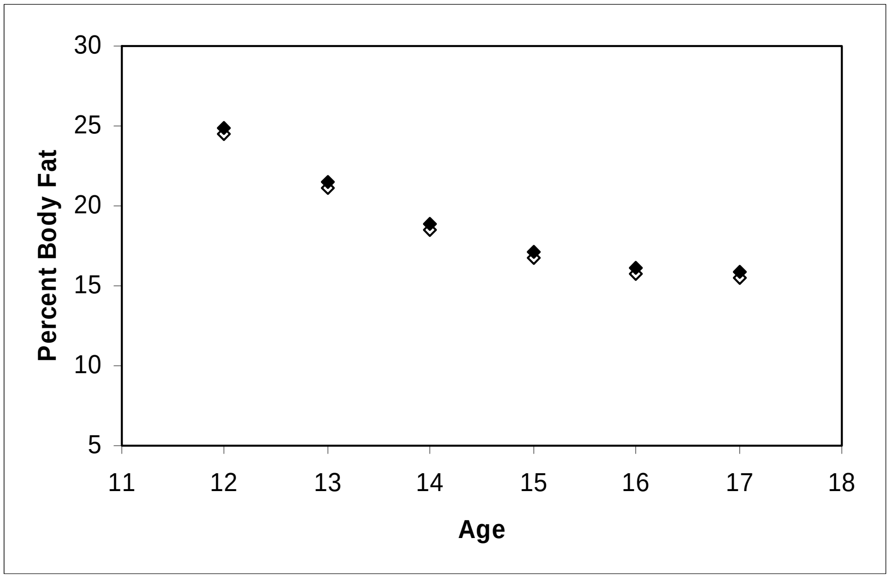

Figure 5.

Appendix A

Prospectus

Chapter 1
Introduction

In the United States there is a trend of increasing physical inactivity, television viewing, use of electronic devices, and consumption of convenience foods which are high in fat and sugars (1 – 4). The culmination of these trends may be contributing factors to the increased prevalence of obesity throughout the United States and the world. Adults are classified as overweight or obese when their body mass index (BMI) is $\geq$ 25 and $\geq$ 30, respectively. Children and adolescents are classified as overweight when their BMI is greater than the 95th percentile as determined by the Centers for Disease Control (CDC) BMI-for-age growth charts (5 – 7).

According to the 1999 – 2000 National Health and Nutrition Examination Survey (NHANES) data released in 2002, 64% of adults 20 years of age and older and 15% of children and adolescents 6 – 19 years of age are overweight. This is a 10% increase for children and adolescents and a 16% increase for adults classified as overweight since the NHANES II survey conducted between 1976 – 1980 (5). Of the 64% of adults who are overweight, 31% (about 59 million people) are classified as obese (5 – 7).

Studies demonstrate that genetics accounts for about 60 – 70% of body fat and BMI within twin pairs (8, 9). The results of studies evaluating differences in physical activity between and within sets of twins helps to confirm the significant role of genetics in the percent body fat of an individual. Studies have shown that genetics has a greater contribution to differences in percent body fat in twins than levels of physical activity (10, 11). However, these studies also demonstrate that the amount of physical activity can change percent body fat within twins. It has also been shown that within a family there is a positive correlation in percent body fat between parents and children and between siblings (12, 13). Most of these studies estimated percent body fat using bioelectrical impedance or skinfolds measurements, or used BMI as an indicator of obesity. Few studies have used dual-energy x-ray absorptiometry (DXA) for assessing body composition.

There is more heterogeneity in percent body fat between pairs of twins than within pairs of twins when levels of physical activity are controlled for within and between pairs of twins (10, 11). Based on these studies, it can be assumed that differences in percent body fat between families are greater than differences in percent body fat within families. However, data supporting this assumption have not been reported. Knowledge of factors that contribute to differences in percent body fat within and between families would be beneficial to help explain obesity trends and provide recommendations to combat the increasing prevalence of overweight and obesity. It would also be beneficial to estimate body composition using a reference method such as the DXA.

Statement of the Problem

The prevalence of obesity in children and adults is increasing. There are genetic and environmental (behavioral) factors that contribute to body composition of an individual. Knowledge of factors that contribute to differences in body composition between individuals and between families could lead to a greater understanding of current trends in body composition. The variance between and within families has not yet been reported. Therefore, the purpose of this study is to determine if the variance in percent body fat as measured by DXA between families is similar to the variance within families. In addition, a secondary purpose is to determine the contribution of physical activity to the variance in body composition.

Hypotheses

Research hypotheses

1. Variance in percent body fat, BMI, bone mineral content, and bone mineral density between families is the same as the variance in percent body fat, BMI, bone mineral content, and bone mineral density between families.
2. Variance in percent body fat, BMI, bone mineral content, and bone mineral density can be attributed to an overall physical activity index.
3. Variance in percent body fat, BMI, bone mineral content, and bone mineral density can be attributed to the amount of time spent viewing television per day.
4. Variance in percent body fat, BMI, bone mineral content, and bone mineral density can be attributed to the amount of time spent in physical activity per day.

Null hypotheses

1. Variance in percent body fat, BMI, bone mineral content, and bone mineral density between families is not the same as the variance in percent body fat, BMI, bone mineral content, and bone mineral density within families.
2. Variance in percent body fat, BMI, bone mineral content, and bone mineral density cannot be attributed to an overall physical activity index.

3. Variance in percent body fat, BMI, bone mineral content, and bone mineral density cannot be attributed to the amount of time spent viewing television per day.
4. Variance in percent body fat, BMI, bone mineral content, and bone mineral density cannot be attributed to the amount of time spent in physical activity per day.

Definition Of Terms

Body composition – a general term used to describe two or more components of the human body such as fat mass and lean body mass.

Body mass index (BMI) – a ratio between weight and height, calculated as weight in kilograms divided by height in meters squared. BMI is used as an indicator of obesity.

Bone mineral content (BMC) – the amount of mineral content in the bone (g).

Bone mineral density (BMD) – bone mineral content divided by the area of the bone (g/cm^2).

Dual-energy x-ray absorptiometry (DXA) – a diagnostic test used to assess body composition based on estimates of fat, lean, and bone mineral masses retrieved from a 2 x-ray energy system.

Exercise – a subset of physical activity that is planned, structured, and repetitive bodily movement done to improve or maintain one or more of the components of physical fitness.

Obesity – in adults, a BMI $\geq$ 30 kg/m^2.

Overweight – in adults, a BMI $\geq$ 25 kg/m^2. Children and adolescents are classified as overweight when their BMI is greater than the 95^{th} percentile as determined by the Centers for Disease Control BMI-for-age growth charts.

Percent body fat – the percentage of total body weight that is fat tissue, most of which is adipose tissue.

Physical activity – any bodily movement produced by skeletal muscle that results in energy expenditure.

Siblings – biological brothers or sisters.

Assumptions

The following assumptions apply to this study:

1. Girls are not menstruating at time of assessing body composition.
2. A heavy meal has not been eaten 3 – 4 hours before the assessment of body composition.
3. Participants responded truthfully on the physical activity questionnaire.
4. All siblings participating in this study are biological siblings.

Delimitations

Participants in this study are junior high school or high school boys or girls between the ages of 12 – 17 years.

Limitations

1. Two technicians administered the DXA scans.
2. Answers to the physical activity questionnaire will be self-reported.

3. Participants in this study came from a relatively homogenous population in Utah Valley recruited primarily from children of faculty and staff at Brigham Young University and therefore may not represent the population as a whole.

Chapter 2

Review of Literature

Obesity

The Center for Disease Control (CDC) defines obesity as "an excessively high amount of body fat or adipose tissue in relation to lean body mass" (14). The most common method of determining the normality of body weight is by calculating body mass index (BMI). BMI is calculated by dividing an individual's weight in kilograms by height in meters squared. According to the National Institutes of Health, an adult with a BMI $\geq$ 25 is considered overweight (5, 15, 16). An adult with a BMI $\geq$ 30 is considered obese (5, 15, 16).

Over the last twenty years, the prevalence of obesity worldwide has reached epidemic proportions. Based on the 1999 – 2000 National Health and Nutrition Examination Survey (NHANES) released in 2002, 64% of all adults in the United States over the age of 20 years are overweight or obese. Of that 64%, over 31% (about 59 million) are classified as obese (5, 6). This represents a 16% increase since the NHANES II Survey completed in 1976 – 1980 (5).

The increasing prevalence in obesity is not limited to adults. The number of overweight and obese children and adolescents is also increasing. Children and adolescents are classified as overweight when their BMIs are greater than the 95th percentile as determined by the 2000 CDC BMI-for-age growth charts (5, 7). According to the NHANES 1999 – 2000 Survey, 15% of children and adolescents between the ages of 6 – 19 are overweight. This is a 10% increase from the NHANES II (1976 – 1980) Survey.

This obesity epidemic is concerning because of its impact on the quality of life of the individual. Obesity in and of itself decreases ones functional capacity by adversely affecting cardiorespiratory fitness (VO_2max ml/kg/min) and imposing limitations on physical movement. Regardless of its cause, obesity is often part of a spiraling cycle of decreased physical activity and increasing body fat. Obesity is also a major risk factor for many diseases and clinically relevant conditions including hypertension, type II diabetes, stroke, cardiovascular and pulmonary diseases, metabolic syndrome, and certain types of cancers (breast, colon, prostrate, endometroium, kidney, and gallbladder).

According to the World Health Organization (WHO), "approximately 85% of people with diabetes are type II, and of these, 90% are obese or overweight. In adjunct, about 64% of type II diabetes in U.S. men and 74% in U.S. women could be avoided if there were no BMIs above 25 kg/m^2" (16, 17). The increased prevalence of overweight and obesity has had a similar impact on the health of children. Type II diabetes, which historically has been characterized as "adult onset," has recently become a childhood disease. Due to decreasing levels of physical activity and increasing levels of body fat in children, an increase in the prevalence of type II diabetes could be expected.

In 2000 the prevalence of type II diabetes in U.S. children and adolescents was less than 1% (7). Of the newly diagnosed cases of diabetes in children and adolescents, reports indicate that 8-46% are type II diabetes (18). The wide variance in incidence of type II diabetes in children and adolescents in the U.S. is due to ethnicity, with the largest incidence occurring in the Pima Indians. The national economic cost of obesity related diseases is astounding, last estimated to be $117 billion in 2003 (19).

There are several contributing factors to the development of obesity. Even though there is a genetic component to obesity, obesity has been described as a lifestyle disease. Ultimately, changes in weight and body fat are due to positive or negative imbalances in caloric intake and caloric expenditure. A persistent positive caloric imbalance will result in weight gain. French et al., after completing a literature review on the environmental influences of eating and physical activity, stated that the obesity epidemic is “largely due to an environment that encourages eating and discourages physical activity” (20). Thus, much of the increase in overweight and obesity can be prevented. Despite increasing public awareness of obesity and the enormous amount of available public information on nutrition and physical activity, there is an actual decline in physical activity levels, concomitant with an increase in television viewing, use of electronic devices, and availability of convenience foods containing more simple sugars and fats (1 – 4).

Obesity and television viewing. There is a dose-response relationship in children between the hours of television viewed per day and being overweight. Gortmaker et al. (21) conducted a four – year longitudinal study to evaluate the relationship between hours of television viewing and BMI in 10 – 15 year olds. Overweight was defined in the study as a BMI greater than the 85th percentile for age and gender based on the first NHANES survey conducted from 1971 – 1973. Gortmaker et al. reported that, “the odds of being overweight were 4.6 times more for youth watching more than 5 hours of television per day compared with those watching for 0 to 2 hours” (21).

In 1999, Robinson studied the effect of reducing television viewing in 3rd and 4th graders as a means of preventing obesity. A 7 – month intervention integrated lessons on television viewing choices and challenges to reduce viewing time into the curriculum. Over the course of the 7 – month intervention period students in the intervention and control groups gained weight due to normal growth. Yet Robinson found that the BMI of the intervention group had significantly decreased ($p < 0.002$) compared to the control group (22). In addition to the studies by Gortmaker et al. (21) and Robinson (22), other studies have shown that percent body fat increases in children as television viewing time increases (23 – 25). In these studies, triceps skinfold measurements, BMI, and bioelectrical impedance (BIA) were used to assess body composition.

Assessment of body composition

Many different methods can be used to assess percent body fat. Each method is unique in the underlying principles upon which it is based, cost, required training, ease of administration, time to complete an assessment, and validity and reliability in various subgroups of the population (26 – 32). Methods that are most often used to assess body composition in the field include foot-to-foot and handheld BIA, anthropometric skinfold measurements, and near-infrared interactance (NIR). Methods that are typically reserved for laboratory use include underwater weighing, air-displacement plethysmography (BodPod), DXA, and total body electrical conductance (TOBEC). Other methods such as isotope dilution, potassium spectroscopy, hydrometry, and densitometry are typically reserved for use in laboratories, clinical settings, or research centers (33, 34).

Numerous studies have evaluated the validity of body composition assessment methods. Even so, results from each method are not interchangeable (35, 36). None of the methods actually measure body fat, but measure some other parameter such as thickness of a skinfold, resistance to a small electrical current, or body volume. The parameter that is actually measured is then used to predict body density or one of the components of body composition (i.e., body water, fat mass or lean mass). An estimate of body density or one of the components allows other components of body composition to be calculated. Each method of assessing body composition is therefore based on a unique set of underlying assumptions about the parameter being measured and one of the components of body composition. Because different methods use different technologies to measure different parameters to predict different components of body composition, it is not uncommon to obtain different results from different methods of assessment on the same body.

Dual-energy x-ray absorptiometry. Historically, underwater weighing has been the criterion measure of body composition (33). Due to the difficulty of the procedures for some individuals, learning curves, and the number of trials required to obtain a valid assessment, other methods of assessing body composition have replaced underwater weighing as criterion methods. DXA has slowly become one of the accepted criterion methods of estimating body composition. There are several advantages to using DXA as a criterion method. Although DXA scans must be performed by certified radiologists and requires a great deal of training, total body body composition scans can be completed in less than 10 minutes with minimal discomfort or inconvenience to the participant. DXA devices are often found in clinical and laboratory settings in which BMC and BMD are also measured. Using two x-ray energies, percent body fat can be estimated based on estimates of fat, lean, and bone mineral mass (37).

Body composition methods are validated by comparing body composition assessments of the method in question to body composition assessments of a method that is accepted as a criterion method. DXA estimates of body composition have been shown to be valid and reliable in adults when compared to bioelectrical impedance, computed tomography, total nitrogen analysis, and total body potassium (37, 38).

Validation of body composition methods in children and adolescents is difficult due to the large variation in stature (height and weight), body composition, growth and maturation between boys and girls across the age span. Nevertheless, DXA has become an acceptable criterion measure of body composition in studies of children and adolescent participants (35, 39 – 41). It has been proposed that DXA be used in clinical applications in pediatric populations 6 – 18 years of age (42). In addition Goran suggests that "DXA is an accurate method of determining body composition in pediatric ages and a useful tool for studying skeletal maturation and growth development (43, 44).

Familial trends in body composition

Weight gain is a result of a persistent positive caloric imbalance in which caloric intake exceeds caloric expenditure. Although caloric balance can be affected by disease processes, the most common causes of a positive caloric imbalance is probably consumption of excess calories or physical inactivity. The contributing role of genetics and lifestyle factors can only be studied within families. Even though one would suspect that biological siblings raised in the same environment would have equal predisposition to a particular body composition, the best way to study the genetic and lifestyle components of body composition is to perform experimental studies in sets of twins within the same family.

Twin studies. The independent influence of genetics and lifestyle on body composition can only be determined by conducting controlled experimental studies with twins raised in the same or different environments. Stunkard et al. conducted a study in 1990 to evaluate differences in BMI in pairs of twins who were raised apart (8). Results suggested that independent of environmental influences, genetics accounted for 70% and 66% of the BMI within pairs of male and female twins, respectively. Approximately 30% of the variance in BMI found between twins was related to environmental factors (8). Samaras et al. found similar findings in 1997 while analyzing the amount and distribution of fat in women after menopause. They concluded that, "genetic factors contribute up to 60% of total population variance in both total and central body fat" (9). Bouchard and Tremblay found that when monozygotic twins participated in a study which involved a negative energy balance, "changes in body mass, body fat and body energy content were characterized by more heterogeneity between twin pairs than within pairs" (10). The results of Bouchard and Tremblay (10) suggest that twins respond similarly to lifestyle interventions and differences in responses are greatest between sets of twins. In addition, Samaras et al. (11) found that monozygotic twins who exercise for the same amount of time at the same intensity each week had less of a difference in body fat mass compared to the twin pairs who exercised for different amounts of time and intensity. Samaras et al. concluded that the twin who participated in more exercise had lower total-body fat mass" (11). Based on these studies, it can be concluded that genetics plays the most significant role in body fat between siblings. However, non-shared environmental factors such as amount of physical activity can also affect body composition.

Parent-child/sibling-sibling. Katzmarzyk et al. found that, based on anthropometric indicators of fatness and fat distribution, the genetic contribution to fatness and fat distribution within a family (parent-sibling or sibling-sibling) was 46 – 60% and 29 – 48%, respectively (45). Differences in fatness and fat distribution between spouses were not significant (45). The effect of environmental factors on body composition such as shared environments or physical activity was not studied. In order to determine the familial resemblance of body composition within a biological family unit, Rice et al. enlisted 20 previously sedentary families (parents and children > 16 years old) into a 20 – week endurance program to determine familial resemblance for body composition (46). Rice et al. reported that 62% of the percent body fat trends found in families was determined by genetics and familial environment (46). They also concluded that "low to moderate levels of physical activity have little effect on familial aggregation" (46).

In contrast to the findings of Katzmarzyk et al. (45), Ramirez found that there was a significant correlation in measures of fatness between spouses (12). Other findings of Ramirez (12) concur with those of Katzmaryzk et al. (45) in that parent-sibling and sibling-sibling correlations were significantly positive. Correlations for overall body fat measurements were the highest between sisters (0.36 – 0.49). Unfortunately, Ramirez's study only examined relationships between parents and children, between sisters and between brothers. It did not examine the correlations between brothers and sisters (12). The results from Ramirez's study suggest that environmental and lifestyle factors such as eating habits do play a role in body composition within a family because there were positive correlations found between spouses as well as between parent-child or siblings.

In another study evaluating the relationship in body composition between all siblings, not exclusively between sisters or brothers, Rameriz found that, "there was a significant resemblance for the level of fatness within families. Correlations between all siblings were significant for percent body fat, sum of 4 site skinfolds, and subcutaneous adipose tissue thickness as measured by a B-mode ultrasound scanner at 7 sites" (13). In addition, Ramirez found that patterns of fat distribution on the trunk region were only significant within a gender, although "there was a significant resemblance among all siblings for fatness at the peripheral sites" (13). This study supports the theory that genetics has a significant role in body composition and fat distribution within families.

Conclusion

Research has demonstrated both genetic and environmental influences on body composition within families. In addition, studies show that trends in body composition or fat distribution within families are similar. To the best of our knowledge, there have been no studies reporting comparisons of body composition between and within families. The purpose of this study is to compare differences in body composition between and within families.

Chapter 3

Methods

Participants

Two hundred and forty participants between the ages of 12 – 17 years will be recruited through flyers sent to all the faculty and staff employed at Brigham Young University. Appointments will be scheduled with the parents of interested participants. Of these 240 participants, there will be 54 sets of biological siblings. After participating in the study, each participant will receive coupons for local movie theaters, water parks, community recreation centers, and rock climbing gyms. This study will be conducted as part of a larger scale study which has already been completed. The primary author of the present study fulfilled a key role in the larger scale study including participant recruitment, organization of data collection, data collection, and data entry.

Methods

Body composition of each participant will be assessed on at least one day. To establish reliability, 98 participants will be asked to return for another appointment to assess body composition a second time within one week of the original appointment. Appointments will be made with the parents of interested participants. Parents will be instructed to have their children wear athletic shorts and a T-shirt to the appointment and avoid eating a meal or participating in strenuous physical activity or exercise 3 – 4 hours prior to the appointment. Appointments for girls will be made at a time when they are not menstruating.

During the appointment, participants and their parent(s) will give informed consent. This study and the informed consent process will be reviewed and approved by the Institutional Review Board (IRB) for the use of human subjects at Brigham Young University. A copy of the assent for participation in research form is included in Appendix A. Participants will be assured confidentiality of all test results. All participants will voluntarily participate in the study. Each participant will also be asked to complete a brief physical activity questionnaire (Appendix B) about their recent and current participation in school-based physical education, physical activity levels, and television viewing habits. This questionnaire has not been validated using the research process.

Weight and height of each participant will be measured using a standard calibrated scale (Detecto 439 Beam Medical Scale; Webb City, MO) to the nearest one-half pound and one-half inch respectively. Percent body fat of each participant will be estimated at least once using DXA (Hologic QDR4500 Elite "Acclaim Series"; Hologic Inc., Bedford, MA). DXA scans will be performed by one of two Utah State certified radiologists. Scans will be stored for later analysis. All scans will be analyzed by a single Utah State certified radiologist. Scan images will be segmented and analyzed for body composition, BMD, and BMC.

Statistical analysis

The Statistical Analysis Software (SAS) statistical packages will be used to analyze the data collected during this study. Data from all 240 participants will be used in the analysis. The 54 sets of siblings will be identified in the database for analytical purposes. A mixed analysis of variance (Proc Mixed) will be used to evaluate the variance component between individuals and between families for percent body fat, BMD, and BMC. The responses to the questionnaire will be coded for statistical analysis. “Yes” and “no” responses will be coded as ones and zeros, respectively. In multiple-choice questions (questions 8 and 9), the five responses will be coded as 0, 1, 2, 3, 4, and 5. The responses to the questionnaire will be grouped into three variables. Responses to questions 1 – 7 will be summed to form an overall independent physical activity variable ranging in values from 0 to 7. Responses to questions 8 and 9 will be used as independent variables. The responses to the questionnaire will be analyzed in a model to explain differences in the variance between individuals and between families. The family-wise alpha level will be maintained at $p < 0.05$.

As a result of analysis, a list of findings will be generated. Based on these findings conclusions and recommendations will be made.

References

1. DuRant RH, Baranowski T, Johnson M, Thompson WO. The relationship among television watching, physical activity, and body composition of young children. *Pediatrics*. 1994;94:449-455.
2. Jeffrey RW, French SA. Epidemic obesity in the United States: are fast foods and television viewing contributing? *Am J Public Health*. 1998;88:277-280.
3. Robinson TN, Hammer LD, Killen JD, Kraemer HC, Wilson DM, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics*. 1993;91:273-280.
4. Tucker LA. Television viewing and physical fitness in adults. *Res Q Exerc Sport*. 1990;61:315-320.
5. The Center for Disease Control. Obesity still on the rise, new data show. Last updated Oct 2002. Available at: http://www.cdc.gov/nchs/pressroom/02news/obesityonrise.htm. Accessed May 27, 2004.
6. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999-2000. *JAMA*. 2002;288:1723-1727.
7. Ogden CL. Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999 – 2000. *JAMA*. 2002;288:1728-1732.
8. Stunkard AJ, Harris JR, Pedersen NL, McClearn GE. The body-mass index of twins who have been reared apart. *N Engl J Med*. 1990;322:1483-1487.

9. Samaras K, Spector TD, Nguyen TV, Baan K, Campbell LV, Kelly PJ. Independent genetic factors determine the amount and distribution of fat in women after the menopause. *J Clin Endocrinol* Metab. 1997;82:781-785.

10. Bouchard C, Tremblay A. Genetic influence on the response of body fat and fat distribution to positive and negative energy balances in human identical twins. *J Nutr*. 1997;127:943S-947S.

11. Samaras K, Kelly PJ, Chiano MN, Spector TD, Campbell LV. Genetic and environmental influence on total-body and central abdominal fat: the effect of physical activity in female twins. *Ann Intern Med*. 1999;130:873-882.

12. Ramirez ME. Familial aggregation of subcutaneous fat deposits and the peripheral fat distribution pattern. *Int J Obes*. 1993;17:63-68.

13. Ramirez ME. Subcutaneous fat distribution in adolescents. *Hum Biol*. 1993;65:771-782.

14. The Center for Disease Control. Overweight and obesity: defining overweight and obesity. Last updated Feb 24, 2004. Available at: http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm#Adolescents. Accessed May 27, 2004.

15. National Institutes of Health. National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. Evidence report. No. 98-4083. Sept 1998. p62.

16. The World Health Organization. Obesity and overweight. Last updated 2004. Available at: www.who.int/dietphysicalactivity/publications/facts/obesity/en/. Accessed May 27, 2004.

17. Visscher TLS, Seidell, JC. The public heath impact of obesity. *Ann Rev Public Health*. 2001;22:355-375.

18. American Diabetes Association. Type II diabetes in children and adolescents. *Diabetes Care*. 2000;23:381-389.

19. U.S. Department of Health and Human Services. National Institutes of Health. Statistics related to overweight and obesity. NIH Publication No. 03-4158. July 2003. Available at: http://www.niddk.nih.gov/health/nutrit/pubs/statobes.htm#econ. Accessed June 8, 2004.

20. French SA, Story M, Jeffery RW. Environmental influences one eating and physical activity. *Annu Rev Public Health*. 2001;22:309-315.

21. Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obeisty among children in the United States, 1986 – 1990. *Arch Pediatr Adolesc Med*. 1996;150:356-362.

22. Robinson TN. Reducing children's television viewing to prevent obesity. *JAMA*. 1999;282:1561-1567.

23. Dietz WH. Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics*. 1985;75:807-812.

24. Gortmaker SL, Peterson K, Wiecha J, Sobol AM, Dixit S, Fox MK, Laird N. Reducing obesity via a school-based interdisciplinary intervention among youth. *Arch Pediatr Adolesc Med*. 1999;153:409-418.

25. Epstein LH, Valosk AM, Vara LS, McCurley J, Wisniewski L, Kalarchian MA, Klein KR, Shrager LR. Effects of decreasing sedentary behavior and increasing activity on weight change in obese children. *Health Psychology*. 1995;14:109-115.

26. Yoshinaga M, Shimago A, Noikura Y, Kinou S, Ohara Y, Miyta K. Body fat percentage in girls increased steadily with age and percentile rank of body mass index. *Pediatr Int*. 2002;44:149-162.

27. Bell NA, McClure PD, Hill RJ, Davies PSW. Assessment of foot-to-foot bioelectrical impedance analysis for the prediction for total body water. *Eur J Clin Nutr*. 1998;52:856-859.

28. Weyers AM, Mazzetti SA, Love DM, Gomez AL, Kraemer WJ, Volek JS. Comparison of methods for assessing body composition changes during weight loss. *Med Sci Sports Exerc*. 2002;34:497-502.

29. Goss F, Robertson R, Williams A, Sward K, Abt K, Ladewig M, Timmer J, Dixon C. A comparison of skinfolds and leg-to-leg bioelectrical impedance for the assessment of body composition in children. *Dynamic Medicine*. 2003;2:5-15.

30. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD, Bemben DA. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol*. 1988;60:709-723.

31. Wells JC, Fuller NJ. Precision of measurement and body size in whole-body air-displacement plethysmography. *Int J Obes Relat Metab Disord*. 2001;25:1161-1167.

32. Housh TJ, Johnson GO, Thorland WG, et al. Validity and Intertester Error of Anthropometric Estimations of Body Density. J Sports Med Phys Fitnes. 1989;l29:149-156.

33. Wagner DR, Heyward VH. Techniques of body composition assessment: a review of laboratory and field methods. *Res Q Exerc Spt*. 1999;70:135-149.

34. Houtkooper LB, Going SB. Body composition: how should it be measured? Does it affect sport performances. *Sport Science Exchange*. 1994;7.

35. Eisenkolbl J, Kartasurya M, Widhalm K. Underestimation of percentage fat mass measured by bioelectrical impedance analysis compared to dual energy x-ray absorptiometry method in obese children. *Eur J Clin Nutr*. 2001;55:423-429.

36. Treuth MS, Butte NF, Wong WW, Ellis KJ. Body composition in prepubertal girls: comparison of six methods. *Int J Obes Relat Metab Disord*. 2001;25:1352-1359.

37. Bolanowski M, Nilsson BE. Assessment of human body composition using dual-energy x-ray absorptiometry and bioelectrical impedance analysis. *Med Sci Monit*. 2001;7:1029-1033.

38. Visser M, Fuerst T, Lang T, Salamone L, Harris TB. Validity of fan-beam dual-energy x-ray absorptiometry for measuring fat-free mass and leg muscle mass. *J Appl Physiol*. 1999;87:1513-1520.

39. Okasora K, Takaya R, Tokuda M, Fujikunaga Y, Oguni T, Tanaka H, Onishi K, Tamai H. Comparison of bioelectrical impedance analysis and dual-energy x-ray absorptiometry for assessment of body composition in children. *Pediatr Int*. 1999;41:121-125.

40. Bray GA, DeLany JP, Harsha DW, Volaufova J, Champagne CM. Body composition of African American and white children: a 2-year follow-up of the BAROC study. *Obes Res*. 2001;9:605-621.

41. Tyrrell VJ, Richards G, Hofman P, Gillies GF, Robinson E, Cutfield WS. Foot-to-foot bioelectrical impedance analysis: a valuable tool for the measurement of body composition in children. *Int J Obes Relat Metab Disord*. 2001;25:273-280.

42. Sopher AB, Thornton JC, Wang J, Peirson RN Jr, Heymsfield SB, Horlick M. Measurement of percentage of body fat in 411 children and adolescents: a comparison of dual-energy x-ray absorptiometry with a four-compartment model. *Pediatrics*. 2004;113:1285-1290.

43. Pietrobelli A, Peroni DG, Faith MS. Pediatric body composition in clinical studies: which methods in which situations? *Acta Diabetol*. 2003;40:S270-S273.

44. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics.* 1998;101:505-518.

45. Katzmarzyk PT, Malina RM, Perusse L, Rice T, Province MA, Rao DC, Bouchard C. Familial resemblance in fatness and fat distribution. *Am J Hum Biol*. 2000;12:395-404.

46. Rice T, Daw EW, Gangon J, Bouchard C, Leon AS, Skinner JS, Wilmore JH, Rao DC. Familial resemblance for body composition measures: the Heritage family study. *Obes Res*. 1997;5:557-562.

Appendix A-1

Assent for Participation in Research

ASSENT FOR PARTICIPATION IN RESEARCH

Title: Validity and Reliability of Body Composition Measurements in Adolescents using Bio-Electrical Impedance.

Principal Investigator: Pat Vehrs, Ph.D.
116 | B Richards Building
801-422-1626

1. Measurements of body composition give information about how much muscle and fat there is on a body. The purpose of this research project is to find out the accuracy of body composition measurements in children and adolescents using machines that are used in many public schools. The predictions of body composition from this machine will be compared to another measurement which is considered to be the most accurate.

2. As a volunteer participant in this research project, you will be asked to do the following:
   a) Not eat or drink (except water) and avoid exercise for four (4) hours prior to participation,
   b) Complete two brief questionnaires, one about conditions that might effect accuracy of body composition measurements, and one about your physical activity and exercise habits,
   c) Have your height and weight measured,
   d) Have your body composition measured using the following methods:

Skinfold thicknesses will be measured on the triceps (back of the arm) and the calf (lower leg) using a skinfold caliper. The measurement will be made while “pinching” the skin and then measuring the thickness of the fold with the caliper. The Kiosk measures body composition while standing on a platform that measures body weight with the hands placed on two sensor pads. The pads measure the resistance to a small electrical current between the two hands. Another machine also measure electrical impedance by standing with bare feet on a scale with two sensor pads. These three measurements take about 1 minute each and will be done twice. Body composition will also be measured using DEXA (dual energy x-ray absorptiometry). During the DEXA measurement participant will lie on a table while a lens above moves back and forth scanning the body. This measurement will take about 6 minutes and will be done only once. In total, all the measurements will take about 30 minutes.

   e) Return on a different day and repeat the measurements (only about 30 people will be asked to repeat measurements on another day).

3. As a benefit from participating in this study, you will be given information about the results of the body composition measurements and how they compare to healthy values if you want to know the results. Any questions or concerns that you have about your results will be explained to you.

You will receive coupons or vouchers (valued at over $20) to get into movie theaters, water parks, or other recreational parks. If you are here with a youth group, the group leaders will also receive $5 to be used for activities for the group. If you are here alone, the Physical Education Department of the school that I attend will receive $5 for equipment for their Physical Education program.

4. The DEXA assessment will have a radiation dose that is many times less than a dental x-ray or a chest x-ray. The bio-electrical impedance machine uses a current of 800

microamps (800/1,000,000 of an amp) which is so small that you will not be able to feel it. There are no other risks that we know of in any of the other body composition measurements.

5. If by chance, an accident or injury were to occur during your participation, the necessary medical facilities or treatment centers will be contacted immediately.

6. All information gathered about you during this study will be confidential. There is always the chance that your information may become known. The researchers will keep your information confidential by only sharing your body composition and weight measurements with you. Data gathered from this research may be published or presented in professional meetings but your identity will remain confidential.

7. Your participation in this research study is entirely voluntary. You may chose not to participate at any time. Any information from measurements already taken will still be given to you. You will receive the coupons or vouchers only if body composition measurements are actually completed. You will be informed of any new information or a changes in the study which might affect your willingness to participate.

8. The investigator may terminate your participation in this study if you are unable to follow instructions, unwilling to have one or more of the measurements done, or if it is difficult to schedule appointments. You may also be asked not to participate or to participate later if you have certain conditions. These conditions include currently menstruating, pregnancy, anemia, bulimia, or anorexia since these conditions effect the accuracy of body composition assessments. Questions about these conditions are asked in the questionnaire that you will be completing before any measurements are taken.

9. You can ask questions about the research any time, and the investigators will answer them to your satisfaction.

   The person responsible for this research study is Pat Vehrs, Ph.D., a faculty member in the Department of Physical Education. Dr. Vehrs can be contacted at 801-422-1626 or in person in 116B Richards Building. This project has been reviewed by the Brigham Young University Institutional Review Board for Research with Human Participants. If I have questions regarding myrights as a research subject, or if I think my rights as a human research subject have been violated or my personal safety is in jeopardy, I can submit my concerns or complaints to Chair of the committee (Dr. Shane Schulthies at 801-422-5490).

_______________________________   _____________
Signature of Participating Youth   Date

I give consent for my child to participate in this research study.

_______________________________   _____________
Signature of Parent or Guardian   Date

_______________________________   _____________
Signature of Witness   Date

Appendix A-2

Physical Activity Questionnaire

Brigham Young University
College of Health and Human Performance
Department of Physical Education
Exercise Physiology Laboratory

Please respond to the following by checking one of the answer boxes for each question.

1. Are you currently participating in any organized school sport such as basketball, football, wrestling, dance, baseball?	Yes	No
2. Are you currently participating in any organized sports, sports camps, or activity programs in the community?	Yes	No
3. Have you participated in any organized school or community sports in the last 6 months?	Yes	No
4. Are you currently participating in marching band?	Yes	No
5. Do you do any strength training with weights, calisthenics, elastic bands or cords, or other devices?	Yes	No
6. Are you enrolled in a PE class this semester at school?	Yes	No
7. Were you enrolled in a PE class last semester at school?	Yes	No
8. During an average week, how many hours per day do you watch TV, play on the computer or play stations?	0 - 2 hours 2.1 - 4 hours 4.1 - 6 hours 6.1 - 8 hours more than 8 hours per day	
9. On the average how many hours per day do you walk, jog, run, play sports, dance, bike, use your scooter, work out, or are participating in a recreational activity?	0 - 2 hours 2.1 - 4 hours 4.1 - 6 hours 6.1 - 8 hours more than 8 hours per day	

Appendix B

Summary of Statistical Results

The SAS System
The Mixed Procedure

Covariance Parameter Estimates

ID (within family)	22.5695
Family (between family)	18.0956
Residual	0.1657

Solution for Fixed Effects

Effect	Q8	Gender	Estimate	Stand. Error	DF	T value	Pr > t
gender		0	23.4592	2.0921	57	11.21	<0.0001
gender		1	24.5208	1.6202	57	15.14	<0.0001
Age*gender		0	20.716	1.5167	57	1.37	0.1774
Age*gender		1	-3.8033	1.1204	57	-3.39	0.0013
Age2*gender		0	-0.2628	0.2533	57	-1.04	0.3039
Age2*gender		1	0.4019	0.1863	57	2.16	0.0352
activity*q8	0		-0.7741	0.2765	57	-2.8	0.0070
activity*q8	1		0.04982	0.3114	57	0.16	0.8735

Estimates

Label	Estimate	Stand. Error	DF	T value	Pr > t
gender	1.0716	2.4797	57	0.43	0.6673
linear-age	-5.8748	1.9055	57	-3.08	0.0032
quad-age	0.6647	0.3194	57	2.08	0.0419
activity*q8	0.824	0.2694	57	3.06	0.0034