DOES THE BONE MINERAL CONTENT OF
OLIGOMENORRHEIC WOMEN HAVE AN EFFECT
ON BODY COMPOSITION ESTIMATIONS?

by

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A THESIS

IN

SPORTS HEALTH

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCE

Approved

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ACKNOWLEDGEMENTS

I wish to express appreciation to those who have supported me and encouraged me. Particularly, I would like to acknowledge my debt to following persons.

I would like to give a special word of thanks to Dr. Jacalyn McComb, my thesis committee chair as well as my advisor. I really appreciate her support and encouragement. I enjoyed working with her. I was honored to have her as my advisor. I also would like to express my thanks to Dr. Williams and Dr. Norman for serving my thesis committee. Their helpful suggestions and supports made this project perfect.

I am grateful to Texas Tech University for awarding me a Summer Thesis Research Award. The money was used to cover expenses associated with the gathering of the data. I would like to say thanks to Dimensions for Women's Health. UMC. They helped me to have a DEXA scan for all participants.

Last but not least, I would like to thank my parents, Sang-hyo Lee and Soon-ja Lee who have supported me to make my degree a reality. And I thank all my sisters, Sung-hee, Sung-eun, and Sung-shin. Even though all my family lives in Korea, they always love me and support me. I miss all of them. Especially, I want to thank my little sister, Soo-won, who lives with me in the States.

In addition, I thank my best friends who have encouraged me a lot. I would like to say thanks to Dr. Ju-rip Lee who was my advisor in Korea, and he encouraged me to study in the States. I could have never made my degree without all of you.

TABLES OF CONTENTS

ACKNOWLEDGEMENTS	ii
ABSTRACT	vi
LIST OF TABLES	viii
CHAPTER	
I. INTRODUCTION	1
Statement of Problem	3
Hypothesis	4
Operational Definitions	5
Delimitations	6
Risk Factors	6
Significance of the Study	7
II. REVIEW OF LITERATURE	8
Oligomenorrhea	8
Bone Density	12
Two-Component Model and Multi-Component Model	16
Bone Mineral Density Assessment	19
III. METHODOLOGY	22
Selection of the Participants	22
Instrumentation	22
Procedure	24

IV.	STATISTICS AND RESULTS	29
	Statistical Analysis and Results	29
V.	DISCUSSION AND CONCLUSIONS	37
	Discussion	37
	Conclusions	42
	Suggestions for Further Research	43
	BIBLIOGRAPHY	44
	APPENDICES	
A.	SCRIPT TO BE USED TO RECRUIT VOLUNTEERS FOR THIS STUDY	50
B.	CONSENT FORM	52
C.	WOMEN'S HEALTH HISTORY QUESTIONNAIRE	55
D.	BODY COMPOSITION DATA COLLECTING SHEET	60
E.	PULMONARY DATA COLLECTING SHEET	62
F.	SKINFOLD DATA COLLECTING SHEET	64
G.	WATER DENSITY FOR VARIOUS WATER TEMPERATURES	66
H.	WATER VAPOR PRESSURES OF SATURATED AIR AT VARIOUS TEMPERATURES	68
I.	REPEATED ONE-WAY ANALYSIS OF VARIANCE	70
J.	PAIRED SAMPLE T-TEST	72
K.	RELATIONSHIP OF Db WITH BMD, BMC, 2-COMPONENT, AND 3-COMPONENT MODELS	74
L.	REPEATED MEASUREMENTS WITH 6 LEVELS	76

ABSTRACT

The purpose of this study was to determine if the bone mineral content (BMC) of oligomenorrheic women is altered to an extent that differences would be obtained in the body composition estimations between 2- and 3-component models. The two-component models used to answer this research question were: (a) 7-site skinfolds (SKF) to determine body density (Db) and Siri's equation to determine body composition; and (b) hydrostatic weighing to determine Db and Siri's equation to determine body composition. The three-component models included: (a) hydrostatic weighing to determine Db, BMC as measured by the dual energy x-ray absorptiometry (DEXA), and Lohman's 3-component mineral density equation to determine body composition; and (b) the DEXA Lunar DPX IQ 5006 scan. Two-hundred and eighty-nine participants completed the Women's Health Questionnaire for screening prior to inclusion in the study. Study participants included 10 oligomenorrheic females (age = 20.70 ± 2.67 yr, height = 162.05 ± 5.38 cm, weight = 57.36 ± 9.36 kg). Descriptive statistics and a repeated one-way analysis of variance (ANOVA) were conducted to test for significant differences between four different methods of body composition assessment. There was a significant difference among the models ($F(3, 27) = 26.89, p < .05$). Follow-up paired t-tests between Lohman's 3-component mineral density model and Siri's 2-component model revealed a significant difference in body composition results, $t(9) = 8.647, p < .05$. This would lead one to conclude that the mineral density of this population has an effect on body composition estimations. However, there was also a significant difference between the

2-component models and between the 3-component models. Based on the results of this study, it seems that the method and equation chosen has the greatest impact on body composition estimations rather than the number of components included in the model.

LIST OF TABLES

4.1 Group Descriptive Statistics of Participants	30
4.2 Individual Descriptive Statistics of Participants	31
4.3 Physical Characteristics of Participants	32
4.4 Activities of Participants	33
4.5 Participants' Health History	34
G.1 Water Density for Various Water Temperatures	67
H.1 Water Vapor Pressures of Saturated Air at Various Temperatures	69
I.1 Repeated One-Way Analysis of Variance	71
J.1 Paired Sample T-Test	73
K.1 Relationship of Db with BMD, BMC, 2-Component, and 3-Component Models	75
L.1 Repeated Measurements with 6 Levels	77
M. Paired Sample T-Test with 6 Levels	79

CHAPTER I

INTRODUCTION

Today, more than ever, young athletic females are at a risk for the development of one or more of a triad of medical disorders that include disordered eating, amenorrhea, and osteoporosis. This triad occurs not only in elite athletes but also in physically active women participating in a wide range of physical activities. Numerous studies have linked disordered eating and intense exercise to menstrual cycle disturbances, particularly in women who participate in endurance type sports or in sports where body fat (BF) is maintained at a low level (Drinkwater, Bruemner, & Chesnut, 1990). Women who participate in endurance type sports and who have irregular menstrual cycles also have decreased BF (Calabrese et al., 1983; Carlberg, Buckman, Peake, & Riedesel, 1983). Research has shown that the BF of oligo/amenorrheic women is less (16.9%) than that of eumenorrheic women (20-29%). Female college athletes and women who train intensively are at risk for the development of menstrual disorders and loss of bone mineral density (BMD) (Drinkwater et al., 1984; Frisch et al., 1981). When normal reproductive hormonal mechanisms are disturbed, bone metabolism may be altered (Linnell, Stager, Blue, Oyster, & Robertshaw, 1984; Snow-Harter & Marcus, 1991). Bone remodeling responds to mechanical stress, hormonal alterations, and nutritional status. When estrogen levels are low, bone resorption increases, and bone formation and density decrease resulting in osteoporosis.

Field regression equations have been developed for the general population to estimate body composition based on the 2-component model of body composition

assessment. The 2-component model of body composition divides the body into a fat component and fat-free body (FFB) component. The FFB component consists of all residual chemicals and tissues including water, muscle (protein), and bone (mineral).

Additionally, tables can be found in fitness centers, lab manuals, and athletic settings that estimate body composition based on skinfold thickness. These tables have also been developed from the 2-component model and generally use Siri's equation to estimate body composition (Jackson, Pollock, & Ward, 1980). As previously stated, the 2-component model for body composition assessment is commonly used for the general population. However, for this model to be valid, certain assumptions must be met.

1. The density of fat is 0.901 g/cc.
2. The density of FFB component is 1.100 g/cc.
3. The densities of fat and the FFB components (water, protein, mineral) are the same for all individuals.
4. The densities of various tissues comprising the FFB are constant within an individual, and their proportional contribution to the lean component remains constant.
5. The individual being measured differs from the reference body only in the amount of fat; the FFB component of the reference body is assumed to be 73.8% water, 19.4% protein, and 6.8% mineral.

This may not be an appropriate assumption for women who have altered menstrual cycles and decreased bone density. Research has shown that women who are oligomenorrheic have decreased bone density (Baker & Demers, 1988; Barrow & Saha,

1988; Buchanan, Bitzer, Waldman, & Ford, 1987; Cann, Martin, Genant, & Jaffe, 1984; Drinkwater et al., 1990). Howat, Carbo, Mills, and Wozniak (1989) found that oligo/amenorrheic women's mean bone density was 1.17 ± 0.03 mg/cm² (regular 1.37 ± 0.04 mg/cm²). Cann et al. (1984) also found that spinal bone mass is decreased approximately 22% to 29% from normal values in amenorrheic women.

Significantly decreased bone density in a female athlete would cause an overestimation of BF when using the 2-component model (Lohman, 1992). This overestimation of BF may increase the anxiety of young athletic females who are already pre-occupied with the idea of thinness and thus contribute further to the cycle of amenorrhea, disordered eating, and osteoporosis. At the other end of the spectrum, the risks associated with decreased body composition may not be evident to coaches and health care providers because of an overestimation of BF. Therefore, it may be necessary to use a multi-component model, which measures the variable in question for a specific population. The 3-component model accounts for densities of tissues within a population that may differ from the reference person, such as BMC. If women who are oligomenorrheic have significantly decreased bone density, this variable needs to be accounted for when assessing body composition.

Statement of Problem

The purpose of this research project is to determine if the BMC of oligomenorrheic women significantly alters body composition estimations. More specifically, will there be a difference in body composition estimations when using 2-component models, which do

not account for variation from the reference person in BMC, and the 3-component models which account for variations in BMC for that particular population? The 2-component models used to address this research question will be Siri's equation using either 7-site skinfolds (SKF) or hydrostatic weighing (HW) to estimate Db. Lohman's bone mineral density equation using HW to measure Db and the Lunar DEXA Scan to measure BMC will be one of the 3-component models used. The Lunar DEXA Scan using BMC as the third variable to determine body composition will be the other 3-component model used. DEXA analyzes both BMC and the soft tissue surrounding the bone and measures the amount of fat and fat-free tissue.

The purpose of using more than 1 equation for the 2-component model and the 3-component model is to provide additional reliability and validity to the findings.

Hypothesis

There are null hypothesis and research hypothesis in this study.

1. Null Hypothesis:

The bone mineral content of oligomenorrheic active women will not have an effect on body composition estimations for this particular population. Specifically, there will be no difference between 2-component models and 3-component models when bone mineral content is accounted for in the model.

2. Research Hypothesis:

The bone mineral content of oligomenorrheic active women will have an effect on body composition estimations for this particular population. Specifically, there

will be a difference between the 2-component models and 3-component models when bone mineral content is accounted for in the model.

Operational Definitions

Universally accepted definitions of various menstrual patterns are lacking. The definitions used in this study are consistent with those used in studies of large populations of women. For the purpose of clarification, the following definitions of terms are given.

Eumenorrheic For the purpose of this study the terms eumenorrheic, regular, and cyclic will be used interchangeably to refer to women whose menstrual cycles occur consistently at intervals from 25 to 38 days (Loucks & Horvath, 1985).

Oligomenorrheic For the purpose of this study the terms oligomenorrheic and irregular will be used interchangeably to refer to women whose menstrual cycles occur inconsistently at intervals from 39 to 90 days (Loucks et al., 1985).

Amenorrheic The terms Amenorrheic and acyclic will be used interchangeably to refer to women whose menstrual cycles occur at intervals greater than 90 days (Loucks et al., 1985). Amenorrhea can be defined as either primary (absence of menarche by age 16) or secondary (absence of menstrual function for 6 consecutive times after normal menarche has occurred).

Active women Women who exercise regularly at least 4 days per week for 45 minutes (Drinkwater et al., 1990).

Delimitations

This study makes the following delimitations.

1. Participation is limited to women who live in Lubbock or the surrounding area.
2. Participation is limited to women who meet the following criteria for inclusion in the study.
 - a. Participants must be oligomenorrheic as determined from a menstrual history questionnaire.
 - b. Participants must not be pregnant as determined from a urine test.
 - c. Participants must not have used oral contraceptives for the past 6 months as determined from the menstrual history questionnaire.
 - d. Participants must not have medical problems affecting bone mineral metabolism as determined from the menstrual history questionnaire.
 - e. Participants must be nonsmokers.
 - f. Participants must exercise at least 45 minutes a day 4 times a week.

Risk Factors

This study has following risk factors.

1. Completion of the Health Questionnaire may cause some women to recognize potential existing health problems, which may create some stress.
2. Hydrostatic weighing may increase the anxiety in a participant because of holding one's breath underwater.
3. The DEXA scan may pose a physical risk to participants who are pregnant.

Significance of the Study

Information from this study may establish the need for body composition prediction equations for oligomenorrheic women using the 3-component model. If the bone density levels of these women are significantly altered to impact body composition assessments, this new information will provide the foundation for future study in this area. Accurate regression equations will enable health care professionals to more accurately determine body composition values of active women with menstrual disorders and therefore develop more appropriate treatment options. This study will also benefit the participants involved by providing information about their current BMD and BF levels at no cost to the subject.

CHAPTER II

REVIEW OF LITERATURE

Research findings concerning decreased BMD for oligomenorrheic women will be highlighted initially in this review as well as the terminology used to differentiate menstrual dysfunctions. Secondly, bone density and factors contributing to bone density will be discussed. Lastly, body composition equation models and bone mineral density assessment will be discussed.

Oligomenorrhea

Variation in the definition of menstrual dysfunction exists between what is considered normal or eumenorrheic and what is considered abnormal or oligomenorrheic and amenorrheic. The definitions of menstrual dysfunction are somewhat difficult to compare among research findings. In the research literature, eumenorrhea is normal menstrual function and has been defined as follows: (a) menses with intervals of 23 to 33 days, with a duration of 3 to 7 days (Scott, Disaia, Hammond, & Spellacy, 1984); (b) 10 to 13 menses a year (Barrow et al., 1988; Drinkwater et al., 1990); (c) regular menses at least every 35 days (Lutter & Cushman, 1982); and (d) menstrual cycles between 23 to 35 days in length with menstrual flow from 4 to 6 days (Carlberg et al., 1983).

Oligomenorrhea has been defined as irregular menstrual cycles according to the following criteria: (a) missing 1 to 4 cycles a year (Barrow et al., 1988; Dale, Gerlach, & Wilhite, 1979); (b) irregular menses every 36 days or longer (Lutter et al., 1982; Nattiv,

Agostini, Drinkwater, & Yeager, 1994); (c) cycles with intervals of 35 to 90 days (Bachmann & Kemmann, 1982; Loucks et al., 1985); and (d) menses at intervals greater than 40 days and usually irregular (Scott et al., 1984); and (e) no menstrual periods during the previous 3 months or 4 or fewer periods per year (Calberg et al., 1983).

Amenorrhea has been defined as: (a) menses every 3 months (Barrow et al., 1988; Bachmann et al., 1982; Dale et al., 1979; Singh, 1981); (b) no more than 1 menstruation in the preceding 12 months (Drinkwater et al., 1984); (c) the absence of menses in the preceding year (Lutter et al., 1982); (d) absence of menses for greater than 90 days (Calabrese et al., 1983); and (e) a six-month interval between cycles and irregular cycles differing in length by 9 or more days (Frisch et al., 1981).

Menstrual Dysfunction - Multifunctional Factors

A variety of associated factors has been proposed to cause of menstrual dysfunction and some combination of these associated factors synergistically affects the reproductive system (Loucks et al., 1985). Linnell et al. (1984) stated that causes of changes in menstrual frequency are decreased hypothalamic activity, early pubertal athletic training, low body fatness, and elevated prolactin and endogenous endorphin levels. Other researches have stated that menstrual dysfunction is associated with significant weight loss, decreased BF-to-lean mass ratio, stress, age of sports participants, intensity of athletic training, and the sudden initiation of high volume aerobic training (Baker et al., 1988; Barrow et al., 1988; Cavanaugh, Kanochoff, & Bartels, 1989; Loucks, 1990; Singh, 1981). According to Bachmann et al. (1982) and Barrow et al. (1988), pregnancy history, use of oral contraceptives, the incidence of weight gain, history of

perceived emotional turmoil, excessive mental and physical work loads, and sports activity could be factors that affect menstrual cycles. It has been suggested that menstrual irregularities in athletes are related to low body weight and low BF due to the significant weight loss and energetic sports activity (Carlberg et al., 1983; Speroff & Redwine, 1980).

Hormonal Status

The normal hormone changes throughout the menstrual cycle are depicted in Figure 2.1.

Figure 2.1 Patterns of Hormone Secretion Across the Normal Menstrual Cycle

An LH surge occurs at the time of ovulation and marks the division between the follicular phase (Days 1-14) and the luteal phase (Days 15-28). LH pulse pattern also changes across the menstrual cycle; pulse frequency decreases from the follicular phase (~65- to 80-min intervals) to the luteal phase (~185- to 200-

min intervals), whereas pulse amplitude increases from the follicular phase ($\sim 5\text{mIU/mL}$) to the luteal phase ($\sim 12\text{mIU/mL}$) (Harbor, 1999).

Estradiol concentration is decreased in response to exercise (Adami et al., 1998; Bullen et al., 1985; Loucks et al., 1985). Menstrual dysfunction results from lowered estrogen levels in athletic women, which can lead to a decrease in bone mass (Clarkson & Haymes, 1995). Low estradiol concentrations are suggestive of a lack of ovarian follicular development. Nelson et al. (1986) stated that the average estradiol concentration in the amenorrheic women is only one-third of the level found in the eumenorrheic women during the early follicular phase. Also, Drinkwater et al. (1984) found that estradiol levels are significantly lower in the amenorrheic women. Therefore, estradiol levels are of essential importance in evaluating menstrual dysfunction.

In menstrual dysfunction, the pattern of estrogen and progesterone shows no phasic elevations indicating anovulation with no follicular or luteal development. This ovarian suppression is due to reduced frequency and regularity in the pulsatile secretion of luteinizing hormone (Loucks et al., 1985). Delayed menses and loss of luteinizing hormone surge occurs more frequently in the weight loss women (Bachmann et al., 1982; Bullen et al., 1985; Harbor, 1999). The high incidence of anovulation and luteal disorders also occurs in this group (Bullen et al., 1985).

Circulating estrogens have an effect on the maintenance of bone composition by affecting the bone remodeling process via direct and indirect mechanisms. Bone mineral loss has been reported in young women with low estrogen concentrations. This suggests a major role for estrogens in the prevention of accelerated bone loss (Lloyd et al., 1986;

Loucks et al., 1985; Bemben & Fetters. 2000). Cann et al. (1984) concluded that the combination of decreased estrone and estradiol production in some women may lead to amenorrhea and loss of estrogen's bone protection effect. Extreme weight-bearing exercise partially overcomes the effects of estrogen deprivation (Marcus et al., 1985).

Bone Density

Bone is continuously undergoing the coupled processes of resorption and formation. These processes are important for maintenance of bone mass. Bone hypertrophy occurs when stress is applied in excess of normal levels. Osteoblastic activity exceeds osteoclastic resorption, which leads to a net gain in bone. Snow-Harter and Marcus (1991) suggested that stress-related osteonal fatigue damage stimulates the remodeling process. Bone formation is encouraged by weight bearing activity and hormonal influences such as estrogen, androgen, growth hormone, and thyroid hormones. Excluding articulator cartilage and growth plate, normal growing bones can adapt their architecture to persistent underloading and repeated overloading by different biologic mechanisms (Frost, 1990; Nelson et al., 1986).

Net loss occurs when resorption is greater than formation. A negative balance between bone resorption and formation is the basis of many bone diseases (Bemben, 1999; Rodan, 1992).

Bone Density and Menstrual Dysfunction

Bone is gained during adolescence, reaches a plateau level during the third decade of life, and remains stable until approximately age 50, after which progressive, gradual loss is observed. The prevalence of osteoporosis increases with age and the initial loss of bone at age 50 is temporarily more rapid in women because of menopause (Kaplan, 1985). Bone density may be influenced by variables such as current menstrual status, menstrual history, body mass, functional loading, and calcium balance.

Body weight is a significant predictor for bone density. There are three possible explanations for this relationship: (a) body weight is representative of body size, and larger women have a greater bone mass; (b) the skeleton responds to the greater mechanical stress by increasing mass; and (c) there is the increased conversion of androgens to estrogens in the adipose tissue of the heavier women (Drinkwater et al., 1990).

Linnell et al. (1984) found that there is a relationship between ovarian function and bone density in amenorrheic athletes. Previous studies of oligomenorrheic and eumenorrheic athletes examined BMD at the lumbar vertebrae and the shaft of radius (Drinkwater et al., 1990). Researchers found decreased BMD at the lumbar and radius sites. Explanations for the decrease in bone density in this population are: (a) training errors (Barrow et al., 1988); (b) the hypoestrogenic status affects trabecular, not cortical, bone (Drinkwater et al., 1990); and (c) the active life-style of the amenorrheic women attenuates bone loss at the appendicular sites (Drinkwater et al., 1990). Cann et al. (1984) also found that amenorrhea is associated with decreased spinal bone mass. Women with

oligomenorrhea and amenorrhea are at risk for losing bone mass. The combination of excessive thinness and amenorrhea may affect female athletes by reducing bone mass (Drinkwater et al., 1990). Menstrual dysfunction and decreased bone density have been found to be related (Buchanan et al., 1987). Oligomenorrheic women athletes have a lower BMD compared to normal women, particularly the lumbar spine (Drinkwater et al., 1984; Salamon et al., 1998). Menstrual dysfunction is accompanied by a decrease in bone density in women (Barrow et al., 1988). Decreased bone density is more serious for women with a low body weight (Adami et al., 1998; Drinkwater et al., 1990; Parazzini et al., 1996). Amenorrheic athletes have decreased bone density and a high risk of stress fractures (Baker et al., 1988; Barrow et al., 1988).

Physical Activity and Bone Metabolism

The skeleton is constantly subjected to external ground reaction forces and forces generated by muscle contraction. These forces lead to alterations in bone shape and to a large degree, determine its strength. All forces imposed on bone produce strain of some magnitude. Loading creates stress within a bone, which may stimulate either external or internal remodeling, or both, and can lead to a change in shape and in dimension. When the strain is greater, the probability of damage and failure is higher (Frost, 1990).

The goal of bone development is to provide a structure or framework for the body that allows efficient locomotion with an appropriate level of bone mass to resist fracture (Dalsky, 1990). Regular weight bearing or bone stressing exercise is essential for maintaining bone mass. When the stress is applied to bone, the tissue responds by

increasing in mass, density, and structural properties (Bemben, 1999; Drinkwater et al., 1984).

Bone mass is maintained at appropriate levels to afford structural competence for functional loading. Mechanical loading of the skeleton during weight-bearing exercise causes a strain or deformation of the bone. A negative response is seen with lack of physical activity or a lack of mechanical loading and is associated with resorption, resulting in a net loss in bone mass. The positive influence of exercise on bone can be attenuated by environmental conditions including the hormone and nutritional status of an individual. The positive adaptations of bone to physical activity can be reduced if the environmental conditions for bone promote greater resorption than formation (Dalsky, 1990).

Kaplan (1985) states that mechanical loading through physical exercise is a positive influence on BMD. Physical exercise contributes to a greater than normal bone mass. A lack of physical activity has a negative influence on BMD. An absence of mechanical loading contributes to the net loss of bone mass. This has been demonstrated in studies of prolonged immobilized weakness, and bed rest. The rates of bone loss are primarily a result of an increase in resorption unmatched by formation. Internal forces are created by muscle contraction; external forces are imposed by the gravitational field (static) and by weight bearing (dynamic).

According to Frost (1990), if accumulated strain remains constant, bone will persist in an equilibrium state. If strain decreases, bone is lost until a new equilibrium is reached. An optimal level of strain is necessary to maintain bone mass, and the bone

mass is well correlated with functional loading. Increasing the number of load cycles results in no additional increase in bone mass. Applied to exercise training, this theory predicts that exercise such as weight training, in which load is increased, will be more effective in improving bone mass.

Weight-bearing exercise and estrogen levels are considered to be major factors affecting bone density in women. However, exercise does not seem to increase BMD in women with menstrual dysfunction, although weight-bearing exercise has been reported to increase bone density. Menstrual dysfunction may lower bone density, in spite of physical activity (Howat et al., 1989). The amount of physical activity reported by amenorrheic women does not protect them from a loss of vertebral bone mass. This suggests that the value of exercise does not maintain skeletal integrity in this group of women (Drinkwater et al., 1984). Exercise, especially jogging and distance running, increases the rate of oligomenorrhea from about 5% to 20% of women who exercise regularly and vigorously (Bachmann et al., 1982; Barrow et al., 1988; Lloyd et al., 1986). Recent studies state a positive correlation between intensive exercise and menstrual dysfunction.

Two-Component and Multi-Component Models

This review addresses the assumptions of the 2-component and 3-component models used in estimating body composition values and also decreased BMD.

Two-Component Models

The 2-component model of body composition divides the body into a fat component and a FFB component. The FFB component consists of all residual chemicals and tissues including water, muscle (protein), and bone (mineral). The 2-component model of body composition makes the assumption that the individual being measured differs from the reference body only in the amount of fat; the free-fat component of the reference body is assumed to be 73.8% water, 19.4% protein, and 6.8% mineral. This may not be an appropriate assumption for women who have altered menstrual cycles and decreased bone density. Research has shown that women who are oligomenorrheic have decreased bone density (Baker et al., 1988; Barrow et al., 1988; Buchanan et al., 1987; Cann et al., 1984; Drinkwater et al., 1990).

Generally, the 2-component model equations provide accurate estimates of % BF as long as the basic assumptions of the model are met, and have served as the foundation upon which the HW method is based. However, there are no guarantees that the FFB composition of an individual within a certain population subgroup will exactly match the values assumed for the reference body. FFB density varies with age, gender, ethnicity, level of body fatness, and physical activity level, and depends mainly on the relative proportion of water and mineral comprising the FFB component (Lohman, 1984). The 2-component model is commonly used for general population. This indirect method measuring body composition separates the body into a fat component and a FFB component (Clark, Kuta, & Sullivan, 1992).

However, limitations of the 2-component model are the variations in the fat-free compositional differences among populations (Lohman, 1984). Using assumed proportions of water, mineral, and protein and their respective densities: equations were derived to convert the individual's Db from HW with the 2-component model into relative body fat proportions (%BF). The most commonly used equation is Siri's (1961) equation, $\%BF = (4.95/Db - 4.50) \times 100$. The FFB component is obtained as $FFB = \text{body weight} - (\% \text{ fat}/100)$. However, the validity of such equations relies on the assumption that for each population studied the fat-free body composition is similar (Lohman, 1984).

Multi-Component Models

Researchers have applied multi-component models of body composition based on measured total body water and bone mineral values. This approach can avoid systematic errors in estimating BF by replacing the reference man with population-specific bodies that take into account the age, gender, and ethnicity of the individual. The multi-component model predicts body fatness utilizing the variables Db, body water content, and mineral content of the body. This model analyzes variations in the FFB component from hydration and BMC. The use of the multi-component model enables the researcher to evaluate assumptions in the FFB component such as altered BMD or body water content. This model can be used to assess body composition more accurately and be applied to several populations (Clark et al., 1993; Lohman, 1984). A multi-component model can adjust the proportions and densities of each of the subcomponents of the FFB

component, and yield more appropriate population-specific equations to convert the Db to % BF (Bunt et al., 1989). Lohman's equation has been developed for specific populations that may have altered bone density. Lohman's equation is as follows: % fat = $[6.386/(Db) + 3.961/m \text{ (mineral as a fraction of body weight)} - 6.090] \times 100$ (Bunt et al., 1989; Lohman, 1984). Therefore, new equations will be developed for various populations, which will enable more accurate estimations of fat content from Db.

Bone Mineral Density Assessment

Technical developments have resulted in reliable methods for the quantitative assessment of the skeleton. Accurate, noninvasive measurement of bone mass emerged with the development of photon absorptiometry and computed tomography (CT). The method has high reproducibility and has been used to estimate bone mineral changes (Lohman, 1984).

Computed Tomography

Computed Tomography (CT) frequently has been used to determine trabecular bone density of the lumbar spine. CT measures trabecular bone only, avoiding areas of aortic calcification. Trans-iliac bone biopsy is an invasive technique that provides a core sample of largely trabecular bone bordered by internal and external cortices. Recent applications of this technique also permit assessment of the degree to which trabecular elements are connected to each other, and the magnitude of spaces between adjacent

connectivity of trabecular bone (Clarkson et al., 1995; Hassager & Christiansen, 1994; Lukaski, 1987).

Single Photon Absorptiometry

Single photon absorptiometry (SPA) is based on the attenuation of a collimated photon beam by bone. The measurements are accurate, precise and suited to regions of the body in which variations in soft tissue composition. (Hassager et al., 1994; Snow-Harter et al., 1991). This can be used and accepted for investigation of local and regional bone measurement, usually the radius and the ulna. Local BMC can be measured with either the axial or appendicular skeleton (Lukasiki, 1987). Thus, it is not desirable to use SPA for measuring total body BMC.

Dual Photon Absorptiometry

Isotopes that emit photons permit application of the photon absorptiometry principle to the central skeleton, most often the lumbar spine and proximal end of the femur. Current dual photon absorptiometry (DPA) machines employ gadolinium-153 (Davee, Rosen, & Alder, 1990). DPA has been used for measuring regional BMD particularly spine and femur. The advantages of using DPA are precise method of quantifying total body and regional skeletal and soft tissue components of body, low radiation dose, and total body determination of bone mineral and lean body mass by direct analysis (Lukaski, 1987; Mazess, Barden, Bisek, & Hanson, 1990; Verlooy, Dequeker, Gensens, Nijs, & Gons, 1991).

Dual Energy X-Ray Absorptiometry

Dual energy x-ray absorptiometry (DEXA) has been developed from DPA. DEXA is now commonly used for estimating body composition (Jebb, Goldberg, & Elia, 1993). The relationship between bone mineral and total body mineral is important, and accurate estimates of total body mineral estimates are provided by DEXA. DEXA uses a dual energy x-ray beam and its radiation exposure is much lower (<5mRem) than that from SPA (15mRem) and CT (100-1000mRem). For total body scans, the medium scan mode ensures up to a 100kg body mass and a ratio less than 0.7214 of weight/stature (Wellens, Roche, Guo, Chumlea, & Siervogel, 1993). The DEXA method permits a more precise measurement of body composition than DPA with much faster determinations (Bemben, 1999; Davee et al., 1990; Mazess et al., 1990).

DEXA has been considered an accurate and precise technique for measuring total and regional body composition (Wellens et al., 1993). DEXA can measure any area of interest in the body. DEXA can be used to estimate BMD and may be also useful to estimate soft tissue composition (Clarkson et al., 1995; Hansen et al., 1993; Hassager et al., 1994). DEXA analyzes both BMC and the soft tissue surrounding the bone and measures the amount of fat and fat-free tissue (Clark et al., 1993).

CHAPTER III

METHODOLOGY

Selection of the Participants

Participants were recruited from recreational fitness centers and athletic settings at Texas Tech University (TTU) and the surrounding Lubbock area (see Appendix A). To be eligible for this study, participants must meet the following criteria: (a) participants must be oligomenorrhea (women whose menstrual cycles occur inconsistently at intervals from 39-90 days) for at least 6 months; (b) participants must not have a history of oral contraceptive, hormone or steroid use for at least 6 months or cumulative use of over 6 months (Lloyd et al., 1987); (c) they must not be pregnant or have had a history of hysterectomy, endocrine diseases, or have medical problems affecting bone mineral metabolism; (d) participants must be nonsmokers; and (e) participants must exercise at least 4 times a week for 45 minutes a day.

Instrumentation

Human Subjects Consent Form: Prior to the collection of any data, participants were asked to complete the consent form (see Appendix B).

Women's Health History Questionnaire

Participants were asked to complete a women's health history questionnaire in order to screen for criteria for inclusion in the study (see Appendix C).

Bone Mineral Content and Bone Density

Total body DEXA scan was performed to measure BMD. Selected participants went to the University Medical Center (UMC) to have a bone scan using the Lunar DPX IQ #5006 DEXA scan. The bone scan was conducted at Dimensions Center for Women's Health, UMC, 602 Indiana Avenue; Lubbock, TX 79415: (806) 743-4377.

Seven-Site Skinfolds

Seven-site skinfolds testing was used to assess the accuracy of the HW measurements. There is a possibility when performing underwater measurements that the individual may not expire to residual volume prior to total immersion. This would increase their estimation of BF depending on the amount of air remaining in the lungs. The standard error for SKF is estimated to be $\sim 5\%$ BF; depending on the prediction equation and the sample of subjects, some reported errors have ranged from 3 to 9% BF (Lukaski, 1987). Skinfold measurements were taken using a Lange caliper. Skinfold measurements were taken at seven sites: chest, axillary, triceps, subscapular, abdomen, suprailiac, and thigh (Lohman, 1981, 1982). Lohman (1992) stated that the various sources of error in SKF % fat could include skinfold measurement technique, skinfold location, caliper, and compressibility of skinfold. Therefore, percent error in skinfold is usually higher than HW.

Hydrostatic Weighing

Instrumentation for HW includes a tank (128 cm in diameter and 402 cm in circumference), water maintained at 36°C to 39°C, a scale, a chair, and a weighted belt. A Metler Analytical Scale was used to measure the density of water in order to validate reference norms for the water in this region.

Residual Lung Volume

Residual lung volume (RV) was determined from the closed circuit oxygen dilution method (Wilmore, 1980). Equipment needed for this procedure include: a three-way breathing valve with a mouthpiece, a small (5L) meteorological balloon or a rebreathing bag, O₂ and CO₂ analyzers, a tank containing 100% oxygen, and a nose clip.

Procedure

Before initiating any contact with potential participants, the study was reviewed by the Texas Tech University Review Board for Human Subjects. Study objectives and procedures were relayed to possible study participants through an informed consent (see Appendix B).

Two-hundred and eighty-nine participants completed the Women's Health History Questionnaire (see Appendix C) to screen for menstrual disorders and study eligibility. This questionnaire was administered on-site at recreational or athletic facilities.

Prior to inclusion in the study, participants who answered yes to the question on the women's health history questionnaire, "Is there a possibility you could be pregnant?".

were asked to go to the Storks Nest, 2602 Ave. Q; Lubbock, TX 79405; (806) 762-6730. Testing consisted of providing a urine sample. There was no charge for these services. Fourteen participants met the criteria for inclusion in the study. Ten of these participants agreed to participate in the study. Body composition assessments included the following methods: (a) 7-site skinfolds measurements and Jackson's formula $[Db(g/cc)_b = 1.0970 - 0.00046971(\sum 7SKF) + 0.00000056(\sum 7SKF)^2 - 0.00012828(age)]$ to determine Db using Siri's equation to estimate body composition $[\% Fat = (4.95/ Db - 4.50) \times 100]$; (b) HW to determine Db and Siri's equation to estimate body composition $[\% Fat = (4.95/ Db - 4.50) \times 100]$; (c) HW to determine Db:

$$[Db = \frac{\text{BODY WEIGHT}_{\text{air}}}{\frac{(\text{Body Wt}_{\text{air}} - \text{Net Wt}_{\text{water}})}{\text{Density of water}} - \text{Total Residual Volume}}], \text{ the DEXA Lunar Scan to}$$

determine BMC, and Lohman's bone mineral density equation $[\% Fat = (6.386/Db + 3.961m - 6.090) \times 100]$ to estimate body composition; and (d) the DEXA Lunar Scan to estimate BMD and soft tissue composition.

Skinfolds assessment was obtained using standardized procedures (ACSM, 2000). The procedures are as follows: (a) all measurements were made on the right side of the body; (b) the caliper was placed 1 cm away from the thumb and finger, perpendicular to the skinfold, and half way between the crest and the base of the fold; (c) the pinch was maintained before and while reading the caliper; (d) measurements were taken twice and retested if measurements were not within 1 to 2 mm; (e) measurements sites were rotated or time was allowed for skin to regain normal texture and thickness; and (f) the 2 closest values were averaged for a final skinfold thickness. Standardized description of skinfold

sites are as follows: (a) abdominal (vertical fold); (b) triceps (vertical fold); (c) biceps (vertical fold); (d) chest (diagonal fold); (e) calf (vertical fold); (f) axillary (vertical fold); (g) subscapula (diagonal fold); (h) suprailiac (diagonal fold); and (j) thigh (vertical fold) (Jackson et al., 1980). The formula for % BF using skinfolds can be found in Appendix D.

Standardized procedures for HW are as follows (ACSM, 2000): (a) the participant was asked to urinate prior to testing; (b) the participant wore a bathing suit; (c) the RV and dry weight were taken before hydrostatic weighing; (d) the participant sat on a chair attached to a scale suspended over a tank of water; (e) during the actual weighing procedure, the participant exhaled to RV, held their breath and sat very still while submerged on the chair; (f) the midpoint of the range of fluctuation was recorded; and (g) the highest obtained weight was used if observed more than twice, if this criteria was not met, the second highest obtained weight was used if observed more than once. if neither the first nor the second criteria were met, the third highest weight was used if observed more than once. The procedure required multiple attempts for submersion, stabilization on scale, and determination of underwater weight (Jackson et al., 1980). The formula for Db from HW can be found in Appendix D.

The procedure for the measurement of RV was as follows: (a) the rebreathing bag was flushed at least three times with 100% oxygen, then refilled with 3-5 liters of oxygen; (b) the bag was filled to approximately 80% of the total volume of the bag; (c) the participant was seated comfortably with a nose clip and mouthpiece in place; (d) the participant completed 3-5 normal breathing cycles, then exhaled to residual volume; (e) when the participant indicated attainment of RV, the stopcock was turned to the

rebreathing bag so the participant was connected to the rebreathing bag; (f) the participant took 5-7 deep breaths at a rate of 2 sec per breath, then exhaled to residual volume at the end of the last breath; (g) when the participant reached RV, the valve was switched so the participant was back to breathing room air; and (h) the O₂ and CO₂ concentrations of the rebreathing bag were measured, and RV was calculated according to Wilmore (1980). The equation used for the RV calculation from O₂ dilution technique was: $RV = (VO_2 \times b) \div 79.8 - b$, where VO₂ was the volume of oxygen in the rebreathing bag at the beginning of the measurement and b was the percentage of nitrogen in the rebreathing bag after the measurement; calculated as 100% - %O₂ - %CO₂ (Wilmore, 1969; Wilmore, Vodak, Parr, Girandola, & Billing, 1980). For a more detailed explanation of the procedures and formulas used see Appendix E.

The participant's BMD was measured by the total body dual energy x-ray absorptiometry (DEXA) scan. Procedure for the DEXA was as follows: (a) the participant went to the radiology lab for a DEXA scan; (b) the participant donned a gown and remained very still on a scanning table for a total body DEXA scan; (c) during the scan, the participant was exposed to approximately 3.0 mrem of radiation (less than the amount of radiation received during a chest x-ray and equivalent to being in the sun for several hours).

Body composition estimations were also determined from the DEXA Scan. The DEXA Scan has been found to be a valid method for body composition estimation (Lohman, 1984).

Statistical Procedure

A Repeated One-Way Analysis of Variance (ANOVA) was used to determine if there was a significant difference in BF composition using 4 different methods of body composition assessment: (a) 7 site-skinfolds formula $[Db (g/cc)_b = 1.0970 -$

$0.00046971(\sum 7SKF) + 0.00000056(\sum 7SKF)^2 - 0.00012828(age)]$ (Jackson et al., 1980)

using Siri's Equation $[\%BF = (4.95/Db - 4.50) \times 100]$; (b) HW to determine Db $[Db =$

$$\frac{BODY\ WEIGHT_{air}}{(Body\ Wt_{air} - Net\ Wt_{water})} - \frac{Density\ of\ water}{Total\ Residual\ Volume}]$$
 and Siri's Equation to determine

body composition $[\%BF = (4.95/Db - 4.50) \times 100]$; (c) HW to determine Db, the Lunar

DPX IQ #5006 DEXA scan to determine BMC and Lohman's bone mineral density

equation to determine $[\% Fat = (6.386/Db + 3.961m - 6.090) \times 100]$ and (d) Lunar DPX

IQ #5006 DEXA scan to measure BMC and soft tissue composition.

CHAPTER IV

STATISTICS AND RESULTS

Statistical Analysis

Two hundred eighty-nine completed questionnaires were received from Texas Tech University students. Fourteen participants met the criteria for inclusion in the study. From this pool of participants, ten participants agreed to participate in this study.

Descriptive statistics for the participants are listed in Tables 4.1 to 4.5. A repeated one-way analysis of variance (ANOVA) was conducted to test for significant differences between four different methods of body composition assessment: (a) 7 site-skinfolds formula $[Db (g/cc) = 1.0970 - 0.00046971(\sum 7SKF) + 0.00000056(\sum 7SKF)^2 - 0.00012828(age)]$ (Jackson et al., 1980) using Siri's Equation $[\%BF = (4.95/Db - 4.50) \times 100]$; (b) HW using the 2-component model and Siri's Equation $[\%BF = (4.95/Db - 4.50) \times 100]$; (c) HW using the 3-component model and Lohman's bone mineral density equation $[\% Fat = (6.386/Db + 3.961m - 6.090) \times 100]$; and (d) Lunar DPX IQ #5006 DEXA scan to measure BMC and soft tissue composition.

Statistical significance was accepted at the $p < .05$ level. The SPSS (statistical package for social science) was used for descriptive analysis and all other statistical analyses. Tables 4.1 to 4.5 detail the descriptive statistics of the study participants.

Table 4.1 Group Descriptive Statistics of Participants

Variable	Mean	SD	Range
Age (year)	20.70	2.6687	18-27
Height (cm)	162.05	5.3755	149.68-167.64
Weight (kg)	57.36	9.3592	46.94-80.83
7-site skinfolds (mm)			
Chest	6.15	2.0956	2.5-9.0
Midaxillary	7.85	2.5172	5-12
Triceps	11.40	1.9972	8-14
Subscapula	9.15	2.7188	6-15.5
Abdomen	9.7750	1.9876	7-13
Suprailliac	9.75	3.2167	6-15
Thigh	13.60	1.7920	12-17
7-site sum	67.6750	12.5022	53-92.5
Db (g/ml)	1.047	0.000101	1.03-1.06
SKF % Fat	16.113	2.7786	12.61-21.42
HW % Fat (Siri)	23.63	3.7505	19.68-30.58
HW % Fat (Lohman)	17.132	5.6672	9.6-25.74
DEXA BMC (kg)	2.3448	0.3168	1.82-3.01
BMC/LBM (%)	6.0120	0.6255	5.20-7.30
BMC/TBW (%)	4.1080	0.2997	3.65-4.52
BMD (g/cm ²)	1.1268	0.000648	1.02-1.28
DEXA %Fat (%)	26.82	8.1697	16.6-45.1
SKFFATLO	14.2940	2.8546	10.7 – 19.76
HWLOH2	21.1910	4.9201	15.18 – 29.17
HMWT (months)	8.3750	3.9619	3-12
HMPD (pounds)	6.4000	6.7856	0-20
MENSPYR (times)	5.2500	2.9368	1-9
Estimated RV (ml)	1367.00	86.1588	1190.00 – 1140.00
Measured RV (ml)	1377.50	275.2749	902.00 – 1620.00

Note: Db (g.ml⁻¹) = body density estimated from hydrostatic weighing
SKF %Fat = % fat from 7-site skinfold
HW %Fat (Siri) = % fat estimated from hydrostatic weighing with Siri's equation
HW %fat (Lohman) = % fat estimated from hydrostatic weighing with Lohman's bone mineral equation
BMC = bone mineral content from dual energy X-ray absorptiometry (DEXA)
BMD = bone mineral density from DEXA
BMC/LBM = the ratio of BMC to lean body mass
BMC/BW = the ratio of BMC to body weight
DEXA %Fat = % fat estimated from DEXA
SKFFATLO = % fat from 7-site skinfold with Lohman's 2-component equation
HWLOH2 = % fat estimated from hydrostatic weighing with Lohman's 2-component equation
HMWT = duration of current body weight (months)
HMPD = recent weight changes (pounds)
MENSPYR = menstrual period in a year (times)

Individual group descriptive statistics of participants can be found in Tables 4.1 and 4.2. Group responses to the Women's Health History Questionnaire can be found in Tables 4.3 to 4.5.

Table 4.2 Individual Descriptive Statistics of Participants

Subject	1	2	3	4	5	6	7	8	9	10
Age (year)	20	20	21	23	18	19	18	21	20	27
Height (cm)	167.6 4	167.6 4	157.4 8	149.6 8	162.5 6	165.1	162.5 6	160.0 2	165.1	162.7
Weight (kg)	80.83	58.96	49.89	46.94	57.6	54.43	52.84	62.36	53.52	56.24
Db (g/cm ²)	1.03	1.06	1.04	1.05	1.04	1.04	1.05	1.04	1.06	1.06
Est.RV (ml)	1440	1440	1320	1190	1440	1440	1320	1320	1320	1440
Mea. RV (ml)	1580	1600	1550	1200	1590	1555	1056	1122	902	1620
BMC (kg)	3.009	2.493	1.819	2.12	2.487	2.227	2.202	2.39	2.182	2.519
BMC/LBM	7.3	5.5	5.37	6.28	6.48	6.26	5.6	6.08	5.2	6.05
BMC/BW	3.72	4.22	3.65	4.52	4.32	4.09	4.17	3.83	4.08	4.48
BMD (g/cm ²)	1.277	1.137	1.024	1.108	1.149	1.12	1.102	1.147	1.075	1.129
SKF sum (mm)	92.5	69.5	70	54	73	72	56	78.25	53	58.5
SKF %fat (Siri)	21.42	16.98	16.98	12.61	16.98	16.98	12.61	16.98	12.61	16.98
SKF% Fat (Lohman)	19.76	15.18	15.18	10.70	15.18	15.18	10.70	15.18	10.70	15.18
HW% fat (Siri)	30.58	19.68	25.96	21.42	25.96	25.96	21.42	25.96	19.68	19.68
HW% fat (Lohman3)	25.74	10.19	19.47	17.07	22.13	21.24	15.69	20.21	9.60	9.98
DEXA %fat	45.1	18.2	25.9	21.2	30.4	30.3	24.1	31.3	16.6	25.1

Table 4.3 Physical Characteristics of Participants (see Appendix C: Women's Health History Questionnaire)

Questions	Answers	N	Percentage of Response
Are you an athletic?	Group 1 = No	9	90
	Group 2 = Yes	1	10
	Total	10	100
Do you participate in intramural sports?	Group 1 = No	9	90
	Group 2 = Yes	1	10
	Total	10	100
Do you belong to a sports club?	Group 1 = No	10	100
	Total	10	100
Have you had an injury?	Group 1 = Yes	4	40
	Group 2 = No	6	60
	Total	10	100
How's your health?	Group 1 = Fair	3	30
	Group 2 = Good	7	70
	Total	10	100
Do you have thyroid problems?	Group 1 = No	10	100
	Total	10	100
Do you have ovary problems?	Group 1 = No	10	100
	Total	10	100
Do you have endocrine problems?	Group 1 = No	10	100
	Total	10	100
Do you use contraceptives?	Group 1 = No	10	100
	Total	10	100
Do you use steroids?	Group 1 = No	10	100
	Total	10	100
Are you pregnant?	Group 1 = No	10	100
	Total	10	100
Is there a possibility you could be pregnant?	Group 1 = No	10	100
	Total	10	100
Are you a smoker?	Group 1 = No	10	100
	Total	10	100
Have you ever had a pregnancy test?	Group 1 = No	9	90
	Group 2 = Yes	1	10
	Total	10	100
How would you classify your menstrual cycle?	Group 1 = Irregular	10	100
	Total	10	100
Do you have a problem with uterus?	Group 1 = No	10	100
	Total	10	100
Why do you think you are irregular?	Group 1 = No bleeding every month	9	90
	Group 2 = Short duration	1	10
	Total	10	100
Menstrual bleeding every month?	Group 1 = No	10	100
	Total	10	100
Do you have same duration every period?	Group 1 = No	9	90
	Group 2 = Yes	1	10
	Total	10	100

Table 4.4 Activities of Participants

Level 1	Frequency	Percent	Valid Percent	Cumulative Percent
Aerobics	5	50.0	50.0	50.0
Basketball	1	10.0	10.0	60.0
Wt lifting	1	10.0	10.0	70.0
Walking	1	10.0	10.0	80.0
Racquetball	1	10.0	10.0	90.0
Tennis	1	10.0	10.0	100.0
Total	10	100.0	100.0	

Level 2	Frequency	Percent	Valid Percent	Cumulative Percent
Cycling	3	30.0	30.0	30.0
Jogging	1	10.0	10.0	40.0
Wt lifting	1	10.0	10.0	50.0
Tennis	1	10.0	10.0	60.0
None	4	40.0	40.0	100.0
Total	10	100.0	100.0	

Level 3	Frequency	Percent	Valid Percent	Cumulative Percent
Running	1	10.0	10.0	10.0
Wt lifting	1	10.0	10.0	20.0
Walking	1	10.0	10.0	30.0
None	7	70.0	70.0	100.0
Total	10	100.0	100.0	

Level 4	Frequency	Percent	Valid Percent	Cumulative Percent
Swimming	1	10.0	10.0	10.0
None	9	90.0	90.0	100.0
Total	10	100.0	100.0	

Level 5	Frequency	Percent	Valid Percent	Cumulative Percent
Wt lifting	1	10.0	10.0	10.0
None	9	90.0	90.0	100.0
Total	10	100.0	100.0	

Note: The number of activities each participant engaged in was a level, ranging from 1 to 5. Participants who only participated in 1 activity are listed in level 1, included who participated in five activities are listed in level 5.

Table 4.5 Participants' Health History

Type of Injury	Frequency	Percent	Valid Percent	Cumulative Percent
Tendon and ligament	2	20.0	20.0	20.0
Spinal meniscus	1	10.0	10.0	30.0
Muscle	1	10.0	10.0	40.0
None	6	60.0	60.0	100.0
Total	10	100.0	100.0	

Eating Disorders	Frequency	Percent	Valid Percent	Cumulative Percent
Anorexia Nervosa	2	20.0	20.0	20.0
Bulimia Nervosa	0	0	0	0
None	8	80.0	80.0	100.0
Total	10	100.0	100.0	

		ACTTIME	ACTHOUR	ACTSCHE
N	Valid	10	10	10
	Missing	0	0	0
Mean $\pm$ SD		7.10 $\pm$ 5.3635	7.50 $\pm$ 9.0952	14.70 $\pm$ 22.6816

Note: ACTTIME = activity times in a week (times)
 ACTHOUR = activity hours in a week (hours)
 ACTSCHE = duration of activity schedules (months)

A repeated one-way ANOVA was conducted to test for significant differences among four different methods of body composition analysis. Results are listed in Appendix I. There was a significant difference among the four methods incorporating both 2-component and 3-component models, $F(3, 27) = 26.89$, $p < .05$.

Follow up tests among the four different body composition methods included paired sample t-test between all the possible combinations (see Appendix J). Paired t-tests demonstrated a significant difference between the following measurement techniques: (a) skinfold % fat using Siri's equation and hydrostatic weighing % fat using Siri's equation (SKFFATSI – HWFATSI), $t(9) = -9.115$, $p < .05$; (b) skinfold % fat using Siri's equation and DEXA % fat (SKFFATSI – DEXAFAT), $t(9) = -5.464$, $p < .05$, (c)

hydrostatic weighing % fat using Siri's equation and hydrostatic weighing % fat using Lohman's bone mineral density equation (HWFATSI – HWFATLOH3). $t(9) = 8.647$, $p < .05$; and (d) hydrostatic weighing % fat using Lohman's bone mineral density equation and DEXA % fat (HWFATLOH3 – DEXAFAT), $t(9) = -6.839$, $p < .05$.

In an effort to further understand the data, correlation coefficients were run between Db, BMD, BMC, and the 2- and 3-component models (see Appendix K). Additionally, Lohman's equation for BF composition (Lohman, 1981) [% fat = $(5.09/Db - 4.65) \times 100$] was used to calculate the percentage of BF from skinfold measurements using Db in the equation as calculated from Jackson's equation (Jackson et al., 1980) and also using Db from HW utilizing the 2- component model as with Siri's equation. This increased the number of levels from four to six in the repeated measurement analysis (see Appendix L and M). There was a significant difference among levels, $F(5, 45) = 29.16$, $p < .05$. Only significant comparisons between the two additional levels (Lohman's 2-component equation for SKF and HW) will be discussed, since the previous four level comparisons are the same: (a) skinfold % fat using Siri's equation and skinfold % fat using Lohman's 2-component equation (SKFFATSI – SKFFATLO), $t(9) = 75.465$, $p < .05$; (b) hydrostatic weighing % fat using Siri's equation and hydrostatic weighing % fat using Lohman's bone mineral density equation (HWFATSI – HWFATLOH3). $t(9) = 8.647$, $p < .05$; (c) hydrostatic weighing % fat using Siri's equation and hydrostatic weighing % fat using Lohman's 2-component equation (HWFATSI – HWLOH2). $t(9) = 5.417$, $p < .05$; (d) hydrostatic weighing % fat using Lohman's bone mineral density equation and hydrostatic weighing % fat using Lohman's 2-component equation

(HWFATLOH3 – HWLOH2), $t(9) = -11.370$, $p < .05$; (e) DEXA % fat and skinfold % fat using Lohman's 2-component equation (DEXAFAT – SKFFATLO), $t(9) = 3.903$, $p < .05$; and (f) skinfold % fat using Lohman's 2-component equation and hydrostatic weighing % fat using Lohman's 2-component equation (SKFFATLO – HWLOH2), $t(9) = -5.558$, $p < .05$.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Discussion

General Introduction

The women's skinfold thickness and corresponding % BF using Siri's equation in this group of participants was significantly lower than that of normal women. According to Jackson et al. (1980), the sum of SKF for normal women was 110.40 ± 34.10 (mm) and SKF % fat was 21.80 ± 6.40 using Siri's equation. According to Lohman (1981), the SKF % fat for the reference woman was 26.90% using Siri's equation. Baker et al. (1988) found that oligomenorrheic women % fat was $15.61 \pm 1.21\%$ using SKF with Siri's equation. In this group of participants, the sum of SKF was 67.68 ± 12.50 (mm) and SKF % fat was 16.11 ± 2.78 using Siri's equation.

Other studies found that percent BF using the 2-component model using HW with Brozek's equation for oligo/amenorrheic female athletes was $17.40 \pm 1.10\%$ and for eumenorrheic athletes' was $24.70 \pm 1.59\%$ (Howat et al., 1989). In this study, the 2-component model using HW was 23.63 ± 3.75 .

Since there was a high correlation ($r = .703$) between measured RV and estimated RV in this study ($p < .05$), one would not expect that Db would be affected by estimating RV. There does not seem to be a difference in Db between normal values and the values of the participants in the study. Db was 1.04 ± 0.01 (g/cm²) in this study. Reference Db

values for females have been estimated to be $1.05 \pm 0.01(\text{g}/\text{cm}^2)$ (Jackson et al., 1984) and $1.04 \pm 0.01 (\text{g}/\text{cm}^2)$ (Linnell et al., 1984).

Normal content of BMD has been reported as $1.37 \pm 0.04 \text{ mg}/\text{cm}^2$ (Howat et al., 1989). Howat et al. (1989) found that oligo/amenorrheic women's mean bone density was $1.17 \pm 0.03 \text{ mg}/\text{cm}^2$. Cann et al. (1984) also found that spinal bone mass was decreased in all amenorrheic women 22% to 29% from normal values. BMD was $1.13 \pm 0.000648 (\text{g}/\text{cm}^2)$ in this study.

Total BMC of the participants in this study was below that expected for this age group (age 18-27). In the present study, total BMC was $2.34 \pm 0.31 (\text{kg})$. According to Hansen et al. (1993), normal values for total BMC has been reported as $2.56 \pm 0.46 (\text{kg})$ for women age 28 to 39 yrs. However, few researchers have used total BMC in their study but rather BMC has been estimated based on the content of regional sites (radius, hip and lumbar vertebrae).

The ratio of BMC/LBM for the reference person is $6.8 \pm 0.9\%$. In the present study, BMC/LBM was $6.01 \pm 0.63\%$. Furthermore, the ratio of BMC to total body weight (BW) was even lower, $4.11 \pm 2.99\%$. Linnell et al. (1984) found that the BMC/BW (estimated from the radius) for the five leanest amenorrheic runners in their study was $7.40 \pm 3.60\%$ and for the five fattest runners was $17.10 \pm 3.70\%$.

Specific Findings

The purpose of this research project was to determine if the BMC of oligomenorrheic women significantly alters body composition estimations. More specifically, the question was will there be a different body composition estimation when BMC is included in the model for this specific population. Because of the inconsistency in findings within and between the 2-component models and the 3-component models in this study, it seems that body composition estimations depend more on the method or equation chosen for that population rather than the number of components included in the model. In the present study, the 2-component equation resulted in body composition estimations ranging from $16.11 \pm 2.78\%$ to $23.63 \pm 3.75\%$. Three-component models yielded results ranging from $17.13 \pm 5.67\%$ to $26.82 \pm 8.17\%$. Since there was not an agreement between the 3-component models which include BMC nor the 2-component models which do not include BMC, but surprisingly, agreement between the 2 and 3 component models, the question must be raised, “Which body composition estimation method is most accurate and how reliable are the different body composition measurements?”

To answer this question, one must look at the standard error of estimates of the methods. DEXA has been shown to have a standard error of $\sim 2\%$, considerably less than traditional methods (Wellens et al., 1993). The advantage of using DEXA to study body composition is that a direct determination of BMC, BMD, and % BF of the entire body can be obtained. Clark et al. (1993) reported that the difference in % fat between the methods was dependent upon the percentage of bone and suggests an inadequate

correlation for variation in bone mass in the HW technique may explain 50-66% of the difference in % fat between DEXA and HW.

Even though DEXA has been considered to be an exact measurement for body composition, the results in this study from DEXA are questionable. In this study, the mean DEXA % fat was 26.82 ± 8.17 %. Four participants' DEXA % fat were over 30% and one participant had a body composition estimation of 45%. The large difference in individual data between DEXA and the other 3 methods, and the fact that obesity is considered to be a BF content above 30% for young women aged 17 to 27 yrs, suggests that we should interpret the results from DEXA with caution. A Body Mass Index (BMI) is used to assess weight relative to height and is calculated by body weight (kg)/height (m^2). A BMI value > 30 is considered to constitute obesity (ACSM, 2000). None of the participants in this study had a BMI of 30 or greater. However, we still do not know for sure whether these results are valid given the past research findings which states the validity and accuracy of DEXA measurements (Clark et al., 1993).

Measurements of human body composition by indirect techniques such as HW and SKF have larger errors than direct methods (Going et al., 1990). The standard error for SKF is estimated to be $\sim 5\%$ BF; depending on the prediction equation and the sample of subjects, some reported errors have ranged from 3 to 9% BF (Lukaski, 1987). HW may have a 2% - 4% error, depending on the population (Lohman, 1982). According to Katch (1980), when HW is used to measure Db, the variance is $\pm 3.8\%$. This error may come from the variance in FFB component. HW may also have inconsistencies because of the participant's movement in water, and variation in equipment and methodologies all

contribute to errors in HW. When evaluating estimations of % BF using the 2-component model, it should be recognized that part of the error may be associated with BMC and its influence on % BF.

The difference between of % BF was 6.4% when using Db from HW and comparing Siri's 2-component and Lohman's 3-component equations in this study. To be within the 95% confidence interval for a given population, Lohman (1992) stated that if the estimation of mineral (BMC/lean body mass) was $6.80 \pm 0.90\%$ (5.9 - 7.7%) in a given population, one could expect that the results obtained from Siri's 2-component equation and from Lohman's 3-component equation would be similar. In this study, BMC as a fraction of lean body mass (LBM) was $6.01 \pm 0.62\%$ (5.2 - 7.3%). This range was below that required for the 95% confidence interval. It is understandable that different results would be obtained based on this reference. The 2-component model (fat and fat free body component) assumes that the composition and density of the FFB component are constant among individuals. According to the results of a study by Going et al. (1990), this assumption may not be valid for all groups and significant errors in estimating body composition could result if the assumptions are not valid.

Even though there are errors in estimations when using HW, HW has served as the gold standard to determine the validity of body composition methods (Lukaski et al., 1987). According to the results of this study, there was a high correlation between HWFATSI and HWFATLOH3 ($r = .954$). HWFATSI and DEXAFAT were also highly correlated ($r = .912$). The high correlation between DEXA and HW suggests that DEXA

may be a viable method for predicting %BF. Therefore, it seems that both HW and DEXA are accurate measurements for estimating %BF.

Conclusions

In most clinical situations, measurements of body composition are limited to only one method (Katch, 1980). The method chosen depends on the validity and reliability of the method as well as the practicality of using that method (Hassager et al., 1994). The purpose of this study was to determine if this specific population would have different body composition assessment results when BMC was used in the equation. Because of the inconsistency in the findings among the estimations using either the 2-component or 3-component model, we cannot answer that question. There was no difference in the 2-component model when using Jackson's 7-site skinfold formula to estimate Db and Siri's equation and Lohman's 3-component model. Additionally there was a significant difference between the 3-component models in percentage of BF when comparing the DEXA results and Lohman's bone mineral density equation. Based on the results of this study, it seems that the method and equation chosen has the greatest impact on body composition estimations rather than the number of components included in the model.

A number of factors should be considered when selecting one or more methods for assessing body composition for a specific population. Some factors to consider are time, money, ethnicity, and gender (Wellens et al., 1993). Perhaps more than one method should be used to compare the results obtained for that population. Lohman (1984) stated that research has been marked by an emphasis in using only one method to estimate body

composition, and this has led to inaccurate body composition estimations. The difficult question becomes which method is the most valid. We cannot answer that question based on the conflicting results obtain within and between 2- and 3-component models.

Suggestions for Further Research

The suggestions which follow may be helpful to continue the research begun in the present study.

1. Inconsistencies between DEXA and hydrostatic weighing in the prediction of % fat should be identified in future research.
2. Comparison of the 2- and the 3-component models for the purpose of understanding the contribution of an added variable in the equation should be limited to only one method.
3. Future research should utilize a control group to see if the differences found between the 2-component and 3-component models is the same for both eumenorrheic and oligomenorrheic women.

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APPENDIX A

SCRIPT TO BE USED TO RECRUIT VOLUNTEERS FOR THIS STUDY

Script To Be Used To Recruit Volunteers For This Study

Hello, my name is Namju Lee. I am a graduate student in the Department of Health, Physical Education and Recreation (HPER). Dr. Jacalyn McComb and I are conducting a study for which we are seeking volunteers. We need 12 volunteers in this study. The purpose of this research project is twofold: (a) first we must determine if women with abnormal menstrual cycles have decreased bone mineral content; (b) secondly, we want to see if this has an effect on body composition estimations. Decreased bone mineral content in women with abnormal menstrual cycles could cause mistakes in estimating body fat.

After signing the consent form, you will go through two stages of screening in order to qualify for participation in the study. The first stage is for you to complete a Women's Health Questionnaire. In order to be a participant in the study you must be (a) female; (b) 18-25 years of age; (c) exercising at least 45 minutes a day for 4 times a week; (d) have irregular menstrual cycles for at least 6 months; (e) not have a history of oral contraceptive and hormone use; (f) not be pregnant, and (g) a nonsmoker. In stage 2, you will be asked to have a pregnancy test if you are unsure about the possibility of pregnancy. If there is a possibility that you might be pregnant, you will be asked to go to the Storks Nest, 2602 Ave. Q: Lubbock, TX 79405; (806) 762-6730. The Storks Nest is open Monday through Friday from 8:30 - 5:30, it is closed from 12:00-1:00 for lunch. Testing consists of a urine sample. It is a community service program operated by University Medical Center. There is no charge for their services.

Provided that you meet the criteria for inclusion in the study, your body fat will be assessed by two methods: 1) the 7-site skinfolds measurement and 2) hydrostatic weighing. You will schedule an appointment with the investigator to measure your body composition. Body composition will be assessed at the Men's Gym at Texas Tech University, Room 117. Total body DEXA scan will be performed to measure the mineral in your bone. The bone scan will be conducted at Dimensions Center for Women's Health, UMC, 602 Indiana Avenue; Lubbock, TX 79415; (806) 743-4377. Your participation in the study will cost you your time and energy. We anticipate the time cost to be 3 hours, given the time required for body component assessment and bone mineral measurements. Completion of the Women's Health Questionnaire may be stressful for some women if they recognize potential existing health problems, which require treatment. Hydrostatic weighing may cause some discomfort to participants who are afraid of water.

The benefits to you from your participation in the study are the following. This study will benefit the participants involved by providing information about their bone mineral content and body fat levels at no cost to the participant. The cost of bone mineral density assessment using DEXA ranges from \$180.00 to \$235.00. The cost of hydrostatic weighing is \$50.00. This study will benefit other individuals by providing information that can be used to more accurately determine the body fat levels of active women with menstrual disorders. This study will also benefit the participants involved by providing information about their current bone mineral content and body fat levels at no cost to the participant. This information has a market value of \$285.00. Thank you for your attention. I will now respond to your questions, and accept volunteers for the study.

APPENDIX B
CONSENT FORM

Consent Form

I hereby give my consent for my participation in the project entitled: Does the Mineral Bone Content of Oligomenorrheic Active Women Have an Affect on Body Composition Estimations?

I understand that the investigators responsible for this project are Dr. Jaclyn McComb. (806) 742-3371, and Namju Lee (806) 780-3114.

Explanation of the Purpose and Procedures

The investigators have explained to me that the purpose of this study is to measure the bone mineral content of active women who have abnormal menstrual cycles and to see if the amount of their bone mineral content has an affect on body composition estimations. Decreased bone mineral content in women could cause mistakes in estimating body fat.

The investigators or their authorized representatives have explained the procedures as follows: My participation will involve a total of approximately 3-4 hours. This will consist of answering a Women's Health Questionnaire. If there is a possibility that I may be pregnant, I will be asked to go the Storks Nest, 2206 Ave. Q to have a urine sample taken. Following the screening procedures, I will have body composition and bone mineral assessed. The actual testing time following screening is as follows: (a) a 7-site skin fold assessment (approximately 30 min); (b) hydrostatic weighing (approximately 30 min); and (c) total body DEXA scan (approximately 30 min).

The body composition procedure involves assessment of subcutaneous fat at seven sites using a skinfold caliper. You will be asked to wear a bathing suit. Hydrostatic weighing will be performed after the skinfold measurement. While still in the bathing suit, you will be asked to sit on a seat attached to a scale that is suspended over a tank of water. During the actual weighing procedure, you will be asked to exhale as much air as possible, hold the breath and sit very still while submerged on the seat. You may voluntarily rise out of the water as necessary to breathe and/or maximize your comfort with the procedure. This procedure may require multiple attempts for submersion, stabilization of the scale, and determination of underwater weight.

You will be asked to go to the radiology lab for a DEXA scan. You will be asked to don a gown and to lie very still on a scanning table for a total body DEXA scan. During the scan, you will be exposed to approximately 10% of the radiation that you receive during a chest x-ray or an x-ray of a broken bone. This is equivalent to being in the sun for several hours.

Benefits

The benefits to you from your participation in the study are the following. This study will benefit the participants involved by providing information about their bone mineral content and body fat levels at no cost to the participant. The cost of bone mineral density assessment using DEXA ranges from \$180.00 to \$235.00. The cost of hydrostatic weighing is \$50.00. This study will benefit other individuals by providing information that can be used to more accurately determine the body fat levels of active women with menstrual disorders. This study will also benefit the participants involved by providing

information about their current bone mineral content and body fat levels at no cost to the participant. This information has a market value of \$285.00.

Precautionary Measures

I have been informed that if I experience any abnormal symptoms or discomfort while undergoing any of the testing, I should inform the trained personnel administering the test, and they will stop the test immediately.

I give my consent for the release of the information from the lab reports to the investigator. It has further been explained to me that only the investigators will have access to the records and/or data collected for this study, and that all data associated with this study will remain strictly confidential. This information will be used for statistical purposes in order to understand the role of mineral content in estimating body fat levels

Dr. Jacalyn McComb has agreed to answer any inquiries I may have regarding the procedures. I may also contact the Texas Tech University Institutional Review Board for the Protection of Human Subjects by writing them in care of the Office of Research Services, Texas Tech University, Lubbock, Texas, 79409, or by calling 742-3884.

If this research project causes any physical injury to participants in this project, treatment will be supplied in accordance with the participant's insurance. There is not necessarily any treatment available at Texas Tech University, nor do necessarily the University or its personnel applicable to cover any such injury carry any insurance. Financial compensation for any such injury must be provided through the participant's own insurance program. Further information about these matters may be obtained from Dr. Robert M. Sweazy, Vice Provost for Research, (806) 742-3884, Room 203, Holden Hall, Texas Tech University, Lubbock, Texas, 79409-1035.

I understand that I may not derive therapeutic treatment from participation in this study. I understand that I may discontinue this study at any time I choose without penalty.

Signature of Participant_____

Date_____

Signature of Project Director or her Authorized Representative:

Date_____

Signature of Witness to Oral Presentation:

Date_____

APPENDIX C
WOMEN'S HEALTH QUESTIONNAIRE

Women's Health Questionnaire

We are conducting a study that will benefit women who may have decreased bone mineral content and are interested in obtaining accurate body composition estimations. Your body fat will be assessed by two methods: skinfold equations and hydrostatic weighing. You will also have bone mineral assessments taken. This information will be given to you following the testing. If you are interested in participating in this study, please take a few minutes to complete the questionnaire, and we will tell you if you are eligible to participate in this project. Thank you.

Name: _____ phone # : _____ e-mail: _____

ID# _____ (Last 4 digits of social security number)

Age: _____

Birth date: _____

Height: _____ Weight: _____

How many years have you been at your present weight? _____

Have you lost _____ or gained _____ weight recently?

If you have lost or gained weight recently, how many pounds? _____

Ethnic background: (Check one)

Caucasian, non-Hispanic	_____	Hispanic	_____
American Indian	_____	Black, non- Hispanic	_____
Asian	_____	Other/specify	_____

If you are an intercollegiate athlete, please check the sport/activity, in which you currently participate, if you are not presently an intercollegiate athlete, please skip to the next question (Check one):

Basketball	_____	Golf	_____	Soccer	_____
Tennis	_____	Track	_____	Volleyball	_____
Softball	_____	Other, please specify	_____		

If you play intramural sports, please check the sport/activity in which you currently participate, if you do not presently participate in intramural sports, please skip to the next question (Check one):

Basketball	_____	Golf	_____	Soccer	_____
Tennis	_____	Track	_____	Volleyball	_____
Softball	_____	Other, please specify	_____		

If you belong to a club sport/activity, please check the sport/activity in which you currently participate, if you do not presently participate in club sports/activities, please skip to the next question (Check one):

Dance	_____	Theater	_____	Soccer	_____
Volleyball	_____	Running	_____	Golf	_____
Water-skiing	_____	Cycling	_____	Other, please specify	_____

Please check the type and amount of exercise you usually engage in each week. Be as specific as possible, for example, weight training 1.5 hours per week; jogging 4 mph for

1 hour two times a week or aerobics 30 minutes two time a week. or walking 3 mph 4 hours each week.

Activity	#times per week	hours per week	miles per week (if applicable)
Aerobics	_____	_____	_____
Basketball	_____	_____	_____
Calisthenics	_____	_____	_____
Cycling	_____	_____	_____
Dance			
Ballet	_____	_____	_____
Jazz	_____	_____	_____
Tap dance	_____	_____	_____
Modern	_____	_____	_____
Golf	_____	_____	_____
Handball	_____	_____	_____
Jogging	_____	_____	_____
Racquetball	_____	_____	_____
Running	_____	_____	_____
Soccer	_____	_____	_____
Softball	_____	_____	_____
Swimming	_____	_____	_____
Water-skiing	_____	_____	_____
Track			
(Specify type of event)			
Volleyball	_____	_____	_____
Weight-lifting	_____	_____	_____
Other (list)	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

How many years (or months) have you been involved in the above activity schedule?
_____years _____months
List any injuries you have had or presently have that are related to your participation in these activities.

How is your health? Good _____ Fair _____ Poor _____

Please explain: _____

Has a health care professional ever told you that you have problems with your thyroid glands? Yes _____ No _____

Has a health care professional ever told you that you had problems with your ovaries?
Yes _____ No _____

Has a health care professional ever told you that you had problems with your uterus?
Yes _____ No _____

Has a health care professional ever told you that you had problems with your endocrine system? Yes _____ No _____

Are you now using or have you ever used birth control pills or other hormones (these are used to prevent pregnancy or regulate menstrual periods)?
Yes _____ No _____

If you have used birth control pills or other hormones, for what reason did you use these? Regulate menstrual periods _____

Prevent pregnancy _____

Other reason. Please explain _____

If you have used birth control pills or other hormones, how long has it been since you used them? _____

Within the past year, have you taken steroids for any reason (these are occasionally used to reduce inflammation/swelling, etc. during illness or injury)?

Yes _____ No _____

If you have taken steroids, how long has it been since you took them?

Are you pregnant? Yes _____ No _____

Is there a possibility you could be pregnant? Yes _____ No _____

Have you recently had a pregnancy test? Yes _____ No _____

If you answered yes, when was the test? Date _____

Do you currently smoke? Yes _____ No _____

Would you classify your menstrual cycle as regular? _____

Or irregular? _____

Please explain why? _____

Approximately how many menstrual periods do you have in a year? _____

Do you experience menstrual bleeding every month? _____

Do you have a menstrual period every month that is about the same number of days

apart from month to month? Yes _____ No _____

What was the first day of your last menstrual period? (If you are currently on your menstrual period, please list the first day of your current period). _____

How many days long was your last menstrual period? _____

How many days ago was your last menstrual period? _____

What is the average duration (length in number of days) from the beginning of one menstrual cycle to the beginning of your next menstrual cycle? _____

How old were you when you first began menses? _____

Have you ever had or presently have anorexia nervosa or bulimia that you are aware of?

How did you become aware of this? _____

APPENDIX D

BODY COMPOSITION DATA COLLECTING SHEET

Body Composition Data Collecting Sheet

1. Body Weight in air _____ gms
2. Total weight in water _____ gms
3. Tare weight _____ gms
4. Net weight (2-3) _____ gms
5. Temperature of water _____ °C
6. Density of the water _____
7. Estimated Residual Volume _____ ml
8. Measured Residual Volume _____ ml
9. Total Bone Density _____ g/cm²
10. % Fat (Siri) _____
11. % Fat (Lohman's Mineral-Density Equation) _____

$$Db = \frac{\text{BODY WEIGHT}_{\text{air}}}{\frac{(\text{Body Wt}_{\text{air}} - \text{Net Wt}_{\text{water}})}{\text{Density of water}} - \text{Total Residual Volume}}$$

Db = _____

Siri's Equation (universally accepted)

% Fat = $4.95/Db - 4.50 \times 100$

% Fat = _____

Lohman's Mineral-Density Equation (where m = total bone mineral content)

% Fat = $(6.386/Db + 3.961m - 6.090) \times 100$

% Fat = _____

DEXA Scan Body Fat Computation

% Fat = _____

Results from 7 -site skinfolds

% Fat = _____ (see Appendix F)

APPENDIX E

PULMONARY FUNCTION DATA COLLECTING SHEET

Pulmonary Function Data Collecting Sheet

Residual Volume Calculation

Nitrogen in a Bag at equilibration

	100%	-	% O ₂	-	% CO ₂	=	% Nitrogen
Trial 1:	100%	-	_____	-	_____	=	_____
Trial 2:	100%	-	_____	-	_____	=	_____
Trial 3:	100%	-	_____	-	_____	=	_____

Residual Volume

	Bag Volume (L)	×	%N ₂	÷	(79.8 - %N ₂)	=	RV	(L, ATPS)
Trial 1:	_____	×	_____	÷	(79.8 - _____)	=	_____	(L, ATPS)
	_____	÷	_____			=	_____	(L, ATPS)
Trial 2:	_____	×	_____	÷	(79.8 - _____)	=	_____	(L, ATPS)
	_____	÷	_____			=	_____	(L, ATPS)
Trial 3:	_____	×	_____	÷	(79.8 - _____)	=	_____	(L, ATPS)
	_____	÷	_____			=	_____	(L, ATPS)

Bag Volume calculation:	_____ mm	×	20.73	=	_____	(L, ATPS)
	_____ mm	×	20.73	=	_____	(L, ATPS)
	_____ mm	×	20.73	=	_____	(L, ATPS)

BTPS Correlation Factor (BTPS_{CF})

$$310 \div (\text{Room Temp} + 273) \times [P_B - (P_{H_2O})_{RT}] \div [P_B - (P_{H_2O})_{BT}] = \text{BTPS}_{CF}$$

$$310 \div (_____ + 273) \times [_____ - _____] \div [_____ - _____]$$

$$_____ \times _____ \div _____ = _____$$

Measured Residual Volume

$$\frac{V_{BTPS}}{V_{ATPS}} = \frac{V_{BTPS}}{V_{ATPS}} \times \text{BTPS}_{CF}$$

APPENDIX F

SKINFOLD DATA COLLECTING SHEET

Skinfold Data Collecting Sheet

7-site formula for women

Chest			
	(	+	) ÷ 2 =
Midaxillary			
	(	+	) ÷ 2 =
Triceps			
	(	+	) ÷ 2 =
Subscapular			
	(	+	) ÷ 2 =
Abdomen			
	(	+	) ÷ 2 =
Suprailliac			
	(	+	) ÷ 2 =
Thigh			
	(	+	) ÷ 2 =

Body density Formula for Women:

$$Db(g/cc)_b = 1.0970 - 0.00046971(\sum 7SKF) + 0.00000056(\sum 7SKF)^2 - 0.00012828(age)$$

Db=___

Siri's Equation (universally accepted)

$$\% Fat = 4.95 / Db - 4.50 \times 100$$

% Fat = _____

APPENDIX G

WATER DENSITY FOR VARIOUS WATER TEMPERATURES

Table G.1 Water Density (Dw) for Various Water Temperatures

Water Temperature (°C)	Water Density (g/cc)
4	1.00000
10	0.99973
15	0.99913
20	0.99823
25	0.99707
26	0.99681
27	0.99654
28	0.99626
29	0.99595
30	0.99567
31	0.99537
32	0.99505
33	0.99473
34	0.99440
35	0.99406
36	0.99371
37	0.99336
38	0.99299
39	0.99262
40	0.99224

Fox, E. L., Bowers, R. W. & Foss, M. L. (1989). The physiological basis of physical education and athletics. (4th ed.). Iowa: Wm. C. Brown Publishers.

APPENDIX H

WATER VAPOR PRESSURES OF SATURATED AIR AT VARIOUS TEMPERATURES

Table H.1 Water Vapor Pressures of Saturated Air at Various Temperatures

Temperature (°C)	Water Vapor Pressure (mmHg)
18	15.6
19	16.55
20	17.5
21	18.65
22	19.8
23	21.1
24	22.4
25	23.8
26	25.2
27	26.75
28	28.3
29	30.05
30	31.8
37	47.1

APPENDIX I
REPEATED ONE-WAY ANALYSIS OF VARIANCE

Table I.1
Repeated One-Way Analysis of Variance

Within-Subjects Factors		Dependent Variable
BODYFAT		
1		SKFFATSI
2		HWFATSI
3		HWFATLOH3
4		DEXAFAT

Note: SKFFATSI = % fat from 7-site skinfolds using Siri's equation
HWFATSI = % fat from HW with Siri's equation
HWFATLOH3 = % fat from with Lohman's bone mineral equation
DEXAFAT = % fat from DEXA

Descriptive Statistics

	Mean	Std. Deviation	N
SKFFATSI	16.1130	2.7786	10
HWFATSI	23.6300	3.7505	10
HWFATLOH3	17.1320	5.6672	10
DEXAFAT	26.8200	8.1697	10

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
BODYFAT	Sphericity Assumed	796.102	3	265.367	26.889	.000	.749
	Greenhouse-Geisser	796.102	1.718	463.286	26.889	.000	.749
	Huynh-Feldt	796.102	2.085	381.783	26.889	.000	.749
	Lower-bound	796.102	1.000	796.102	26.889	.001	.749
Error (BODYFAT)	Sphericity Assumed	266.458	27	9.869			
	Greenhouse-Geisser	266.458	15.465	17.229			
	Huynh-Feldt	266.458	18.767	14.198			
	Lower-bound	266.458	9.000	29.606			

APPENDIX J
PAIRED SAMPLE T-TEST

Table J.1
Paired Sample T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SKFFATSI	16.1130	10	2.7786	.8787
	HWFATSI	23.6300	10	3.7505	1.1860
Pair 2	SKFFATSI	16.1130	10	2.7786	.8787
	HWFATLOH3	17.1320	10	5.6672	1.7921
Pair 3	SKFFATSI	16.1130	10	2.7786	.8787
	DEXAFAT	26.8200	10	8.1697	2.5835
Pair 4	HWFATSI	23.6300	10	3.7505	1.1860
	HWFATLOH3	17.1320	10	5.6672	1.7921
Pair 5	HWFATSI	23.6300	10	3.7505	1.1860
	DEXAFAT	26.8200	10	8.1697	2.5835
Pair 6	HWFATLOH3	17.1320	10	5.6672	1.7921
	DEXAFAT	26.8200	10	8.1697	2.5835

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	SKFFATSI & HWFATSI	10	.719	.019
Pair 2	SKFFATSI & HWFATLOH3	10	.548	.101
Pair 3	SKFFATSI & DEXAFAT	10	.794	.006
Pair 4	HWFATSI & HWFATLOH3	10	.954	.000
Pair 5	HWFATSI & DEXAFAT	10	.912	.000
Pair 6	HWFATLOH3 & DEXAFAT	10	.851	.002

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	SKFFATSI – HWFATSI	-7.5170	2.6079	.8247	-9.115	9	.000
Pair 2	SKFFATSI – HWFATLOH3	-1.0190	4.7507	1.5023	.678	9	.515
Pair 3	SKFFAT – DEXAFAT	-10.7070	6.1972	1.9597	-5.464	9	.000
Pair 4	HWFATSI – HWFATLOH3	6.4980	2.3764	.7515	8.647	9	.000
Pair 5	HWFATSI – DEXAFAT	-3.1900	4.9936	1.5791	-2.020	9	.074
Pair 6	HWFATLOH3 – DEXAFAT	-9.6880	4.4796	1.4166	-6.839	9	.000

APPENDIX K

RELATIONSHIP OF BODY DENSITY WITH BMD, BMC, 2-COMPONENT AND 3-COMPONENT MODELS

Table K.1
Relationship of Db with Bone Mineral Density, Bone Mineral Content, 2-Component,
and 3-Component Models (N=10)

		Db	BMD	BMC	SKF FATSI	HWFAT SI	HWFAT LOH3	DEXA FAT
Db	Pearson Correlation	1.000	-.441	-.236	-.598	-.981**	-.988**	-.870**
	Sig. (2-tailed)	.	.202	.512	.068	.000	.000	.001
BMD	Pearson Correlation	-.441	1.000	.956**	.668 *	.521	.465	.755*
	Sig. (2-tailed)	.202	.	.000	.035	.123	.176	.012
BMC	Pearson Correlation	-.236	.956**	1.000	.665*	.349	.249	.630
	Sig. (2-tailed)	.512	.000	.	.036	.323	.488	.051
SKFFAT SI	Pearson Correlation	-.598	.668*	.665 *	1.000	.719*	.548	.794**
	Sig. (2-tailed)	.068	.035	.036	.	.019	.101	.006
HWFATSI	Pearson Correlation	-.981**	.521	.349	.719*	1.000	.954	.912**
	Sig. (2-tailed)	.000	.123	.323	.019	.	.000	.000
HWFAT LOH3	Pearson Correlation	-.988**	.465	.249	.548	.954**	1.000	.851
	Sig. (2-tailed)	.000	.176	.488	.101	.000	.	.002
DEXA FAT	Pearson Correlation	-.870**	.755 *	.630	.794**	.912**	.851 **	1.000
	Sig. (2-tailed)	.001	.012	.051	.006	.000	.002	.

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

* Correlation is significant at the 0.05 level (2-tailed).

Note: Db = body density

BMD = bone mineral density

BMC = bone mineral content

SKFFATSI = 7-site skinfolds %fat

HWFATSI = underwater weight %fat with Siri's equation

HWFATLOH3 = underwater weight %fat with Lohman's bone mineral equation

DEXAFAT = %fat from DEXA

APPENDIX L

REPEATED MEASUREMENTS WITH 6 LEVELS

Table L.1
Repeated Measurements with 6 Levels

Within-Subjects Factors
Measure: MEASURE_1

LEVELS	Dependent Variable
1	SKFFATSI
2	HWFATSI
3	HWFATLOH3
4	DEXAFAT
5	SKFFATLO
6	HWLOH2

Note: SKFFATSI = % fat from 7-site skinfolds using Siri's equation (2-Component Model)
HWFATSI = % fat from HW using Siri's equation (2-Component Model)
HWFATLOH3 = % fat from HW using Lohman's equation (3-Component Model)
DEXAFAT = % fat from DEXA (3-Component Model)
SKFFATLO = % fat from 7-site skinfolds using Lohman's equation (2-Component Model)
HWLOH2 = % fat from HW using Lohman's equation (2-Component Model)

Descriptive Statistics

	Mean	Std. Deviation	N
SKFFAT	16.1130	2.7786	10
HWFATSI	23.6300	3.7505	10
HWFATLOH	17.1320	5.6672	10
DEXAFAT	26.8200	8.1697	10
SKFFATLO	14.2940	2.8546	10
HWLOH2	21.1910	4.9201	10

Tests of Within-Subjects Effects
Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
LEVELS	Sphericity Assumed	1168.883	5	233.777	29.161 .000
	Greenhouse-Geisser	1168.883	1.765	662.381	29.161 .000
	Huynh-Feldt	1168.883	2.163	540.514	29.161 .000
	Lower-bound	1168.883	1.000	1168.883	29.161 .000
Error (LEVELS)	Sphericity Assumed	360.754	45	8.017	
	Greenhouse-Geisser	360.754	15.882	22.715	
	Huynh-Feldt	360.754	19.463	18.535	
	Lower-bound	360.754	9.000	40.084	

APPENDIX M

PAIRED SAMPLE T-TEST WITH 6 LEVELS

Table M.1
Paired Sample T-Test with 6 Levels

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	SKFFATSI	16.1130	10	2.7786	.8787
	HWFATSI	23.6300	10	3.7505	1.1860
Pair 2	SKFFATSI	16.1130	10	2.7786	.8787
	HWFATLOH3	17.1320	10	5.6672	1.7921
Pair 3	SKFFATSI	16.1130	10	2.7786	.8787
	DEXAFAT	26.8200	10	8.1697	2.5835
Pair 4	SKFFATSI	16.1130	10	2.7786	.8787
	SKFFATLO	14.2940	10	2.8546	.9027
Pair 5	SKFFATSI	16.1130	10	2.7786	.8787
	HWLOH2	21.1910	10	4.9201	1.5559
Pair 6	HWFATSI	23.6300	10	3.7505	1.1860
	HWFATLOH3	17.1320	10	5.6672	1.7921
Pair 7	HWFATSI	23.6300	10	3.7505	1.1860
	DEXAFAT	26.8200	10	8.1697	2.5835
Pair 8	HWFATSI	23.6300	10	3.7505	1.1860
	SKFFATLO	14.2940	10	2.8546	.9027
Pair 9	HWFATSI	23.6300	10	3.7505	1.1860
	HWLOH2	21.1910	10	4.9201	1.5559
Pair 10	HWFATLOH3	17.1320	10	5.6672	1.7921
	DEXAFAT	26.8200	10	8.1697	2.5835
Pair 11	HWFATLOH3	17.1320	10	5.6672	1.7921
	SKFFATLO	14.2940	10	2.8546	.9027
Pair 12	HWFATLOH3	17.1320	10	5.6672	1.7921
	HWLOH2	21.1910	10	4.9201	1.5559
Pair 13	DEXAFAT	26.8200	10	8.1697	2.5835
	SKFFATLO	14.2940	10	2.8546	.9027
Pair 14	DEXAFAT	26.8200	10	8.1697	2.5835
	HWLOH2	21.1910	10	4.9201	1.5559
Pair 15	SKFFATLO	14.2940	10	2.8546	.9027
	HWLOH2	21.1910	10	4.9201	1.5559

Note: SKFFATSI = % fat from 7-site skinfolds using Siri's equation (2-Component Model)
 HWFATSI = % fat from HW using Siri's equation (2-Component Model)
 HWFATLOH = % fat from HW using Lohman's equation (3-Component Model)
 DEXAFAT = % fat from DEXA (3-Component Model)
 SKFFATLO = % fat from 7-site skinfolds using Lohman's equation (2-Component Model)
 HWLOH2 = % fat from HW using Lohman's equation (2-Component Model)

Table M.1. Continued.
Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	SKFFATSI & HWFATSI	10	.719	.019
Pair 2	SKFFATSI & HWFATLOH3	10	.548	.101
Pair 3	SKFFATSI & DEXAFAT	10	.794	.006
Pair 4	SKFFATSI & SKFFATLO	10	1.000	.000
Pair 5	SKFFATSI & HWLOH2	10	.603	.065
Pair 6	HWFATSI & HWFATLOH3	10	.954	.000
Pair 7	HWFATSI & DEXAFAT	10	.912	.000
Pair 8	HWFATSI & SKFFATLO	10	.720	.019
Pair 9	HWFATSI & HWLOH2	10	.982	.000
Pair 10	HWFATLOH3 & DEXAFAT	10	.851	.002
Pair 11	HWFATLOH3 & SKFFATLO	10	.549	.100
Pair 12	HWFATLOH3 & HWLOH2	10	.987	.000
Pair 13	DEXAFAT & SKFFATLO	10	.795	.006
Pair 14	DEXAFAT & HWLOH2	10	.873	.001
Pair 15	SKFFATLO & HWLOH2	10	.604	.065

Note: SKFFATSI = % fat from 7-site skinfolds using Siri's equation (2-Component Model)
HWFATSI = % fat from HW using Siri's equation (2-Component Model)
HWFATLOH3 = % fat from HW using Lohman's equation (3-Component Model)
DEXAFAT = % fat from DEXA (3-Component Model)
SKFFATLO = % fat from 7-site skinfolds using Lohman's equation (2-Component Model)
HWLOH2 = % fat from HW using Lohman's equation (2-Component Model)

Table M.1. Continued.
Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	SKFFATSI – HWFATSI	-7.5170	2.6079	.8247	-9.115	9	.000
Pair 2	SKFFATSI – HWFATLOH3	-1.0190	4.7507	1.5023	-.678	9	.515
Pair 3	SKFFATSI – DEXAFAT	-10.7070	6.1972	1.9597	-5.464	9	.000
Pair 4	SKFFATSI – SKFFATLO	1.8190	7.622E-02	2.410E-02	75.465	9	.000
Pair 5	SKFFATSI – HWLOH2	-5.0780	3.9292	1.2425	-4.087	9	.003
Pair 6	HWFATSI – HWFATLOH3	6.4980	2.3764	.7515	8.647	9	.000
Pair 7	HWFATSI – DEXAFAT	-3.1900	4.9936	1.5791	-2.020	9	.074
Pair 8	HWFATSI – SKFFATLO	9.3360	2.6093	.8251	11.315	9	.000
Pair 9	HWFATSI – HWLOH2	2.4390	1.4239	.4503	5.417	9	.000
Pair 10	HWFATLOH3 – DEXAFAT	-9.6880	4.4796	1.4166	-6.839	9	.000
Pair 11	HWFATLOH3 – SKFFATLO	2.8380	4.7443	1.5003	1.892	9	.091
Pair 12	HWFATLOH3 – HWLOH2	-4.0590	1.1289	.3570	-11.370	9	.000
Pair 13	DEXAFAT – SKFFATLO	12.5260	6.1490	1.9445	6.442	9	.000
Pair 14	DEXAFAT – HWLOH2	5.6290	4.5610	1.4423	3.903	9	.004
Pair 15	SKFFATLO – HWLOH2	-6.8970	3.9244	1.2410	-5.558	9	.000

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