ABSTRACT

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The current study was designed to investigate age-related changes in body composition among 27 Caucasian women aged 42-75 years, 12 years subsequent to initial testing. Subjects were recruited from a pool of 68 women who participated in a prior study. Height, weight, BMI, RV, density, % BF, FFW, skinfold measures, and WHR were assessed with density, % BF, and FFW determined by hydrodensitometry. A 1-way REANOVA was used to examine differences among the means. All variables with the exception of WHR displayed significant ($p < .01$) changes over the course of 12 years. Height decreased .5 cm while weight and BMI increased by 10%. Percent body fat increased 4.3% due primarily to increased fat weight. Of note, FFW rose 1.4 kg from baseline measures. It was theorized that the FFW increase was attributable to the increase in total body mass. Cross-sectional comparisons were made between subgroups divided by age and activity level. A 2-way REANOVA was used for analysis. All subgroups showed similar body composition changes to those of the entire group. However, no significant ($p > .05$) interaction was noted between either young and old or trained and untrained women.

**AGING AND BODY COMPOSITION: A 12 YEAR LONGITUDINAL
STUDY OF MIDDLE-AGED AND ELDERLY WOMEN**

**A THESIS PRESENTED TO
THE GRADUATE FACULTY
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CHAPTER I

INTRODUCTION

Background

Aging has rapidly become a prominent and problematic national issue as Americans enjoy progressively longer lifespans due to continued advances in medical science over the last several decades. The sheer volume of people currently categorized as elderly, along with the staggering numbers forecast for the future, have placed issues related to aging squarely in the national spotlight. A week does not pass in which numerous headlines regarding the "greying of America" dot the media landscape.

In response, research regarding aging and its impact on the human body has increased dramatically within the past decade. One such area of investigation is the relationship between aging and changes in body composition. Researchers are currently attempting to document age-related alterations in body composition, along with any potential consequences associated with these changes. Recent findings indicate that changes in body composition may adversely impact health by contributing to chronic diseases such as diabetes mellitus, cardiovascular disease, hypertension, dyslipidemia, stroke, cancer, and osteoarthritis (Despres et al., 1990; Pi-Sunyer, 1993). Additionally, significant changes in body composition are linked to premature death (Folsom et al., 1993).

Alterations in body weight, fat weight (FW), and fat free weight (FFW) are frequently used as significant indicators of change in human body composition. Past research has identified certain general trends in these variables which occur with increasing age. For example, body weight and FW tend to increase with age until reaching a point in advanced old age at which both begin a gradual decline. In contrast, FFW typically peaks in early adulthood and decreases continually thereafter.

Need for the Study

Unfortunately, the rate and extent at which these changes occur with age remains somewhat nebulous. This is in large part due to the cross-sectional nature of many research studies and the lack of longitudinal investigations in this area. This problem is particularly acute in studies relating to women. A strong need exists for longitudinal body composition data on women as they age.

The subjects in a 1984 study (Butts, Brewster, Van Ossbree, & Price, 1985; Butts & Price, 1994) offered a unique opportunity for a longitudinal study focused on aging and body composition changes in women. Sixty-eight women, ranging in age from 30 to 63 years, participated in a study designed to assess changes in body composition and muscular endurance following 12 weeks of strength training. Body composition was analyzed using hydrostatic weighing and skinfold measurements prior to and following the training regime. The body composition measures obtained from both hydrodensitometry and skinfold calipers were comparable to those reported in other research studies for women of similar ages. The present study provides follow-up data on

these women 12 years later to document any age-related changes in body composition over this time frame.

Purpose of the Study

The question addressed by this study was what, if any, changes in body composition occur in women 12 years after participating in a strength training study. A secondary purpose was to determine what, if any, effect continuation of resistance training and age (i.e., younger versus older) had on body composition. Specific variables measured were height, weight, body mass index (BMI), residual lung volume (RV), body density, percent body fat (% BF), FFW, triceps, suprailiac, abdominal, thigh, and summed skinfolds, and waist-to-hip ratio (WHR).

Hypotheses

Directional

Total body mass, BMI, % BF, and skinfold measures were expected to gradually increase with age while body density was forecast to move in direct opposition to changes in % BF. It was theorized that FFW and height would display a gradual, inexorable decline with each passing year. It was anticipated that RV would increase in a linear fashion with age. In regard to fat distribution, it was predicted that abdominal/truncal fat depots would expand with age, while fat storage sites in the extremities either declined or showed little change relative to abdominal increases. No significant change was expected in WHR with age.

Null

1. There will be no significant difference in the body composition of women 12 years after participating in a strength training study.
2. There will be no significant difference in the body composition of women who continued to participate in resistance training versus those who did not.
3. There will be no significant difference in the body composition of the younger women (< 52 years) compared to the older women (> 52 years) 12 years after participating in a strength training program.

Assumptions

1. Hydrodensitometry, based upon the two-compartment model, is a valid and reliable method of measuring body composition in middle-aged and elderly women (Baumgartner, Heymsfield, Lichtman, Wang, & Pierson, 1991; Heymsfield et al., 1989; Martin & Drinkwater, 1991).
2. The density of human body fat is $.900 \text{ g}\cdot\text{cc}^{-1}$ (Fildanza, Keys, & Anderson, 1953).
3. The density of lean body mass in humans is $1.100 \text{ g}\cdot\text{cc}^{-1}$ (Brozek, Grande, Anderson, & Keys, 1963).
4. The density of both FW and FFW is consistent among individuals.
5. Densities of the individual components of FFW (mineral/bone, protein/muscle, and water) are constant within and between individuals. In addition, the proportional contribution of these components to the density of FFW also remains invariable (Martin & Drinkwater, 1991).

6. Subjects adhered to any and all instructions related to testing and completed questionnaires honestly and completely.
7. All equipment was in proper working order, testing was performed in accordance with standard practices/guidelines, and data were recorded accurately.
8. All data arising from the previous study were assumed to be reliable and accurate.
9. Readings obtained from a loadcell weighing system were not significantly different from those of a standard autopsy scale (Fahey & Schroeder, 1978).

Delimitations

1. No random sampling was performed as subjects were volunteers who participated in the original 1984 study.
2. Nutritional habits were not controlled or investigated in the present study.
3. Physical activity patterns were not controlled, although both past and current activity levels were assessed via questionnaire.
4. No measurable data were gathered on menopausal status aside from individual, subjective assessments of pre-, peri-, or postmenopause.
5. In postmenopausal subjects or participants who have had hysterectomies, no measurable controls were implemented in regard to hormone replacement therapy.

Limitations

The sample size in the present study ($n = 27$) was smaller than that in the 1984 study ($n = 68$) due to the length of time which had passed since the initial study. It was

impossible to locate a number of subjects, while others were unwilling or unable to participate in the current follow-up study.

Definition of Terms

Body Composition - the percentage of total body weight comprised of fat and fat-free tissue (American College of Sports Medicine, 1995) as measured by hydrostatic weighing in the Human Performance Laboratory at the University of Wisconsin-La Crosse.

Fat Weight (FW) - the portion of the human body equivalent to all dissolvable lipid tissue.

Fat Free Weight (FFW) - the remainder of body tissue which is not fat and comprised of three primary components; mineral/bone, protein/muscle, and water.

Percent Body Fat (% BF) - the fat weight as a percent of total body weight; calculated using the equation derived by Brozek et al. (1963) as $\% BF = ((4.570/D) - 4.142) * 100$, where D = body density as measured by hydrodensitometry (Brozek et al., 1963).

Hydrostatic Weighing - method of estimating total body density by measuring total body mass on land, body mass while submerged underwater, residual lung volume, density of water, and volume of gastro-intestinal air. Based upon the two-compartment model (body weight = FW + FFW) developed by Behnke, Feen, and Welham (1942) and Brozek et al. (1963).

Residual Volume - the amount of air, expressed in liters, remaining in the lungs following complete, forced exhalation as determined by the oxygen dilution technique described by Wilmore (1969).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Following years of neglect, research related to women and aging has become increasingly abundant in recent years. However, while high profile diseases such as osteoporosis and cardiovascular disease have received intense scrutiny and substantial funding, other women's health issues have garnered far less attention. Recently, investigations exploring the relationship between age and body composition have risen in number due to compelling evidence of a strong association between body composition and chronic, terminal diseases. While several universal trends in age-related body composition changes have been reported, no quantifiable rate or magnitude of change has been established. In addition, the age at which these changes begin remains unclear due to several confounding factors. Certain cross-sectional studies and a scant few longitudinal studies have provided estimates for the rate, magnitude, and onset of change in body composition variables which require substantiation and refinement.

Fat Free Weight

Conventional wisdom dictates that FFW declines inexorably with age due to a continual decrease in muscular, skeletal, and aqueous mass. Cross-sectional comparisons between young adults, both male and female, and their elderly counterparts indicate a decrease in FFW of 15 - 30% by 80 years of age (Going, Williams, & Lohman, 1995).

This can only be considered a rough estimate, however, as the absolute magnitude and rate of change in FFW with age remains unclear due to several complicating factors. The degree to which FFW changes is dramatically influenced by such variables as gender, activity level, genetic factors, and the individual subcomponents of FFW (Going, Williams, Lohman, & Hewitt, 1994). The variation in the FFW subcomponents (muscle, bone, and body water) which tend to fluctuate at differing rates with age makes estimation of total FFW changes all the more difficult. While the majority of published literature supports the notion that FFW declines with age, it should be noted that there is compelling evidence to the contrary.

Forbes (1987) utilized total body potassium counting (TBK) to estimate FFW in both young and old subjects and reported a 30% decrease in male FFW and a 20% drop in female FFW by the age of 80. Similar results were presented in a cross-sectional study by Frontera, Hughes, Lutz, and Evans (1991) which examined FFW values obtained from hydrodensitometry in men and women ($n = 114$) aged 45 to 78. Data from this study indicated an approximate decline in female FFW of 5.0% (2.2 kg) per decade with no significant variation in the rate of change between age groups. Extrapolated over four decades, this decline in FFW is similar to that reported by Forbes (1987).

A cross-sectional comparison of FFW determined by hydrodensitometry in 29 women over 40 years of age and 39 under the age of 40 revealed a significantly lower FFW (1.6 kg, 3.6%) in the older group (Butts et al., 1985; Butts & Price, 1994). The mean age difference between the two groups was exactly 11 years. While consistent with

results from Forbes (1987) and Frontera et al. (1991) in describing a decline in FFW with age, the magnitude of change was slightly less in the study by Butts et al. (1985) and Butts and Price (1994).

An even lower reduction in age-related FFW was reported by Kohrt, Malley, Dalsky, and Holloszy (1992) who conducted a cross-sectional investigation of body composition in 168 women. The subjects were divided into groups based on activity level (sedentary vs. trained) and then further subdivided by age (young vs. old). In both the sedentary and trained groups, mean age differences between the younger and older subgroups was approximately 40 years. Among sedentary individuals, Kohrt et al. reported a 2.7 kg (6.0%) decline in FFW with age which equates to roughly .68 kg (1.5%) per decade. Surprisingly, results from the trained group showed a greater difference in FFW of 3.7 kg (7.8%) between the two age groups. Again, this number can be adjusted to .93 kg (2.0%) per decade. No significant difference in FFW was noted between the sedentary and trained groups of similar age.

A 1991 study by Aloia, McGowan, Vaswani, Ross, and Cohn employed TBK to measure FFW in 964 women. Results from this cross-sectional study revealed no significant loss of FFW prior to menopause but showed a rapid decline in FFW following menopause. Postmenopausal women tended to lose FFW at a rate of .61% a year (6.1% per decade) and an accelerated rate of decline (1.3% per year) was noted within the first 3 years after menopause. Further investigation into the potential postmenopausal loss of FFW was performed by Aloia, Vaswani, Russo, Sheehan, and Flaster (1995). This

longitudinal study examined FFW changes over the course of 3 years in 118 postmenopausal women using dual photon absorptiometry. All the women were within 6 years of menopause. A significant drop in FFW of 2.5 kg (6.2%) per year was observed which is notably higher than any results previously reported. The significance of the studies by Aloia et al. (1991) and Aloia, Vaswani, Russo, et al. (1995) is an indication that FFW does not decline consistently in a linear fashion with age, but instead remains relatively stable prior to menopause.

Two additional studies (Bemben, Massey, Bemben, Boileau, & Misner, 1995; Flynn, Nolph, Baker, Martin, & Krause, 1989) also support the notion that while FFW declines with age, this change is insignificant until later in life. Flynn et al. (1989) performed a longitudinal study spanning 18 years which employed TBK to measure body composition variables in 61 female subjects. The results demonstrated no significant decline in FFW prior to age 60. Following the age of 60 a .55 kg per year (5.5 kg per decade) decline in FFW was observed. While similar to conclusions made by Aloia et al. (1991) and Aloia, Vaswani, Russo, et al. (1995) which supported the existence of an age-dependent breakpoint for a decrease in FFW, the rate and magnitude of decline as well as the age at which FFW change began were significantly different in the study by Flynn et al. (1989).

Bemben et al. (1995) used densitometry to measure FFW in a cross-sectional study of 157 men between the ages of 20 and 79. The significant finding by Bemben et al. was that FFW was maintained in men less than 70 years of age. Over the course of 60

years, total FFW fell 10.6 kg (16.5%) with the bulk of the decline evident only after age 70. Although subjects in this study were men, the results are consistent with the notion that FFW loss begins near a critical age in the latter half of life.

In contrast to the bulk of published literature, two recent longitudinal studies by Murray, Reilly, Choudhry, and Durnin (1996) and Trappe, Costill, Vukovich, Jones, and Melham (1996) report that FFW may not decline with age and, among certain individuals, may actually increase with the passage of time. Murray et al. examined 22 physically active men in their 60's in a longitudinal investigation covering 6.5 years. Skinfold measurements were used to estimate both % BF and FFW. Fat free weight was found to decline slightly (.2 kg) but not significantly over the course of the study.

Perhaps more surprising were results published by Trappe et al. (1996) which demonstrated an actual increase in FFW with age among a subgroup in the study. This 22 year longitudinal inquiry measured $\text{VO}_{2\text{max}}$ and body composition variables in 53 elite male distance runners. As in the study by Murray et al. (1996), % BF and FFW were calculated from skinfold measurements. Fifteen of the 53 men had become sedentary since the initial measurements and while displaying a significant weight gain (15.5 kg) over the course of 22 years, also experienced a significant gain in FFW (5.2 kg). Two subgroups of similar age had remained physically active and showed no significant change in FFW during the study. It should be noted that in the above groups initial testing was done while the men were in their mid 20's while follow-up measurements were taken in the mid 40's. An older, physically active subgroup measured initially in

their mid 40's and 22 years later in their late 60's did, however, experience a significant reduction of 3.2 kg (5.4%) or roughly 1.5 kg per decade. The avoidance of FFW atrophy prior to an advanced age noted by both Murray et al. and Trappe et al. is similar to results offered by Bemben et al. (1995), Flynn et al. (1989), and Aloia et al. (1991). These results are, however, inconsistent with the linear decline in FFW reported by Frontera et al. (1991) and Kohrt et al. (1992).

Emphasis should be placed on the fact that both Murray et al. (1996) and Trappe et al. (1996) used skinfold prediction equations to estimate FFW and % BF. This procedural difference may account for the contrast in results between these two studies and other studies which used more direct methods such as densitometry or TBK.

Components of Fat Free Weight

Muscle Mass

As with FFW, the majority of published research indicates that muscle mass declines with age and that men, on both an absolute and relative basis, lose more muscle than women (Going et al., 1994). Steen (1988) noted that human skeletal muscle mass loses roughly 40% of its maximal weight by age 70. There is, however, a smattering of evidence obtained primarily from studies of muscle cross-sectional area (CSA) which proposes that muscle mass does not change significantly after young adulthood.

A large cross-sectional study of men and women, aged 20 - 90 years, used TBK as a surrogate marker of muscle mass in an analysis of the relationship between age and muscle mass (Folson, Lin, & Phillips, 1974). A significant decline in muscle mass was

noted between women in their early 20's and those in their 80's although the decrease was not significant prior to age 45. Men, on the other hand, showed a larger, consistent decline in muscle mass across all age groups. Frontera et al. (1991) evaluated urinary creatinine excretion in order to estimate muscle mass in 67 men and 74 women between the ages of 45 and 78. A significant decline in muscle mass (3.5 kg, 19.1%) was observed among women over two decades. A slightly higher rate of muscular atrophy was noted in the older subjects when compared to their younger counterparts. The men, who had significantly greater muscle mass compared to the women, showed a smaller (2.7 kg, 9.7%) decrease in mass over the same period.

Recently, a cross-sectional study by Aloia, Vaswani, Ma, and Flaster (1996) used a four-compartment body composition model to examine age-related changes in female protein, water, mineral, and fat. One hundred fifty-five women ranging in age from 24 to 79 years of age were evaluated using prompt gamma neutron activation in conjunction with total body water (TBW) measurement to estimate body protein content. Protein was viewed by the researchers as an adequate marker for muscle mass. A consistent and linear decline in protein of 1.5 kg was seen between the youngest and oldest subjects.

In a rare longitudinal study, Steen (1988) employed TBK and TBW to estimate muscle mass, FW, and body water in 14 females greater than 70 years of age over the course of 11 years. Surprisingly Steen reported no significant change in muscle mass with increased age. In contrast, 9 elderly male subjects of approximately identical age lost 2.0 kg (6.7%) of their muscle mass in 11 years.

Kanehisa, Ikegawa, Tsunoda, and Fukunaga (1994) used B-mode ultrasound to create muscle and fat CSA images in 275 Japanese females between the ages of 6 and 60 years. Age-related comparisons were made of CSA's taken at the forearm, upper arm, leg, and thigh. At all sites, muscle CSA peaked in the 20's before remaining virtually unchanged with increased age. These results are consistent with those reported by Hakkinen and Hakkinen (1991) who observed no significant changes in the CSA of the quadriceps femoris of women ranging in age from 20 to 50 years.

Body Water

The role of body water (H₂O) is crucial in understanding age-related changes in FFW given that water is only found within FFW and comprises roughly 73.2% of the FFW (Keys & Brozek, 1953). The distribution of water between extracellular and intracellular compartments is also important due to the strong link between intracellular water and MM. It is generally accepted that H₂O, as measured by absolute weight, displays an inverse relationship to age (Going et al., 1994). However, the magnitude, rate, and age at which H₂O declines continues to be debated.

Schoeller (1989) stated that H₂O may remain relatively constant in women prior to the age of 70 before declining at a rate of .7 kg per year. In contrast, Alola et al. (1996) reported a consistent linear decline in female H₂O of approximately .08 kg per year between the ages of 24 and 79. An 11 year longitudinal study involving 14 elderly women recorded a net decline in H₂O of 3.5 kg (.3 kg per year) between the ages of 70 and 81 (Steen, 1988).

As a percentage of total body weight, H₂O also displays an inverse relationship with age. While water accounts for roughly 50% of body weight in young women, it falls to around 45% in older women as a result of an increase in body fat (Schoeller, 1989; Watson, Watson, & Batt, 1980). Steen (1988) agreed with this contention but notes that in advanced old age (> 70 years), H₂O as a percent of body weight may actually increase due to a decrease in body fat. Similar results were found in the cross-sectional study by Aloia et al. (1996) which documented a consistent decline in H₂O as a percent of weight between women in their 20's (54.8%) and women in their 60's (45.7%). A slight increase in percent H₂O was noted after the age of 70.

At present, there is conflicting evidence regarding whether the decline in H₂O comes primarily from the extracellular or intracellular compartment. As noted earlier, intracellular water is strongly associated with muscle mass. Going et al. (1994) report that the vast majority of cross-sectional studies link the decline in H₂O to a decrease in intracellular water as muscle mass atrophies with age. In contrast, the longitudinal study by Steen (1988) and a longitudinal animal study by Lesser, Deutsch, and Markofsky (1980) found the decline in H₂O was due to a decrease in extracellular water.

Bone Mass

Several studies have documented the loss of both bone mineral mass and density (BMD) with age in both men and women (Going et al., 1994). Several variables which influence and regulate changes in BMD have been noted. These BMD determinants include genetic factors (race, family history), nutritional factors (calcium intake), lifestyle

factors (smoking, alcohol consumption), hormonal factors (circulating estrogens), and mechanical loading factors (physical activity, body weight). Of these, the most crucial in the determination of BMD in women appears to be serum estrogen concentration. Low estrogen levels have been connected with reduced BMD and the significant decline in estrogen levels following menopause is associated with an acceleration in the rate of BMD loss (Wardlaw, 1996). As with the other subcomponents of FFW, there is considerable debate surrounding the numerical estimates of bone loss with age. Although the rate, magnitude, and age of onset of bone loss varies greatly between compact and trabecular bone and by location within the body, certain general trends have emerged.

The skeletal system as a whole, which is comprised of approximately 80% compact bone, and sites within the skeleton high in compact bone such as the radius tend to display a curvilinear BMD pattern with age. Typically, no significant decline in compact bone BMD is notable in women prior to menopause. Following menopause, a decline in BMD of approximately 1% a year is evident well into the 70's, at which time the rate of decline appears to slow (Aloia, Vaswani, Ellis, Yuen, & Cohn, 1985; Mazess & Cameron, 1974). A recent longitudinal investigation by Aloia, Vaswani, Ross, and Cohn (1990) involving women aged 20 to 80 years also reported a curvilinear trend in skeletal and radial BMD which began near menopause and declined at roughly 1% a year thereafter. On average, postmenopausal women lost 1.2% a year in skeletal BMD and 1.5% a year in radial BMD. The rate of BMD loss in the entire skeleton was significantly higher in the years immediately following menopause as opposed to later years.

Evidence regarding trabecular bone loss indicates a linear relationship with age. Trabecular bone loss, which begins prior to menopause, may accelerate during menopause before slowing after menopause (Going et al., 1994). Cross-sectional data from Mazess et al. (1987) indicate that during a woman's life, BMD falls by approximately 20% in the vertebrae and 25 - 30% in the femoral neck. Similar results were published by Aloia et al. (1990) who found a 19% decline in vertebral BMD and a 26% decrease in femoral neck BMD over the course of 60 years. An examination of annualized spinal BMD loss revealed an average deterioration of 1.3% per year. However, no significant change in the rate of loss was evident between early postmenopausal and later postmenopausal years as had been indicated by other cross-sectional studies. Additionally, while it is now generally accepted that trabecular BMD begins to fall prior to menopause, there is a wide disparity in opinion as to the exact age at which this descent begins.

It has become common practice for postmenopausal women to use hormone replacement therapy (HRT), in part, to forestall the loss in BMD associated with the absence of menses. Research shows that HRT limits bone loss following either a natural menopause or a hysterectomy (Aloia et al., 1990; Wardlaw, 1996). For those postmenopausal women not using HRT, reports indicate that excess body weight due to either increased FFW or FW may play a preventative role in reducing the rate of bone loss. Recent research (Wardlaw, 1996) has shown that during and following menopause, BMD in the total body, spine, hip region, and radius is positively correlated with weight,

BMI, FW, and FFW. It should be reiterated that these associations are only seen in women not using HRT. In women using HRT, excess weight appears to confer no significant benefit in limiting bone loss. These correlations support clinical observations that obese women tend to experience a lower incidence of osteoporotic fractures when compared to their thinner counterparts. It is theorized that the body may respond to the additional stress of excess weight by encouraging osteoblast (bone forming) activity.

The majority of research consistently reports a stronger relationship between FW and BMD than FFW and BMD (Baumgartner, Stauber, Koehler, Romero, & Garry, 1996; Tremollieres, Pouilles, & Ribot, 1993; Wardlaw, 1996). It has been reported that following menopause, FW becomes the primary determinant of endogenous estrogen levels as adipose tissue increases conversion of androgens to estrogen (Edelstein & Barrett-Connor, 1993). There is, however, a small amount of conflicting evidence which supports the theory that FFW, rather than FW, is the key player in postmenopausal BMD retention (Aloia, Vaswani, Ma, & Flaster, 1995).

A longitudinal study by Tremollieres et al. (1993) followed 155 early postmenopausal women for approximately 2.5 years. Subjects were assigned to either a normal weight or an overweight group based upon their BMI. A significant reduction in the annual rate of vertebral bone loss (.54 vs. 1.46%) was seen in the overweight group compared to the normal weight group. Additionally, the overweight women had a significantly higher vertebral BMD at baseline than their thinner counterparts. The

authors concluded that excess adipose tissue was protective against postmenopausal bone loss.

Another longitudinal study conducted by Baumgartner et al. (1996) examined the relationship between FFW, FW, and BMD in 132 elderly women not using HRT. These researchers noted a significant association between FW and BMD at a number of sites but found no correlation between FFW and BMD.

In contrast, Aloia, Vaswani, Ma, and Flaster (1995) reported that FFW was the major determinant of bone mass in a cross-sectional study which measured total body calcium in 164 women aged 24 to 79. The group was examined in its entirety and then divided into pre- and postmenopausal groups for further analysis. While both FFW and FW displayed significant correlations with bone mass, a stepwise multiple regression indicated that FFW accounted for 50 - 55% of the variation in bone mass while FW contributed less than 20%. The trend towards FFW prominence was also observed in both subgroups although a slightly larger contribution by FW was evident in the postmenopausal group.

Body Weight and Body Mass Index

Gross body weight tends to increase with advancing age until reaching a point in advanced old age (> 70 years) when a gradual decline may be seen. The BMI, which adjusts weight relative to height, is another measure which tends to display the same age-related pattern. Evidence of increasing body weight with age comes from both large scale epidemiological cohort studies as well as from a number of smaller studies.

Results from the huge cross-sectional National Health and Nutrition Examination Survey III (NHANES III) show an 18.3% increase in the mean BMI of American women between the ages of 20 and 60 (Kuczmarski, Flegal, Campbell, & Johnson, 1994). A slight decrease in BMI of 4.6% was evident after age 60. The 7 year Baltimore Longitudinal Study of Aging (BLSA) also documented significant increases in both weight and BMI among 408 women ranging in age from 17 to 96 years (Shimokata, Tobin, et al., 1989). Participants were divided into four distinct age classes and categorized as either young (< 40 years), middle-aged (40 - 54 years), old (55 - 69 years), or very old (> 70 years). A significant weight gain (3.8 kg, 6.4%) was evident between the young and old groups while a slight decline (1.9 kg, 3.0%) in weight was observed following the age of 70. Mean BMI showed a consistent increase (2.6 kg/m², 12.1%) from the youngest to the oldest participants. Over the course of a lifetime the increase in BMI reported by Shimokata, Tobin, et al. of 12.1% is consistent with the 12.9% offered by Kuczmarski et al (1994).

Silver, Guillen, Kahl, and Morley (1993) reported on a cross-sectional investigation involving 257 women between the ages of 20 and 96 years. A 1.9 kg/m² (7.8%) increase in BMI was noted between the youngest (< 40 years) and an older group aged 65 - 74 years. Following the age of 75, a significant decline in BMI was recorded. Steen (1988) also reported a significant decline in female body weight in advanced old age. Beginning at the age of 70 and continuing until the age of 81, Steen (1988) noted a decrease in weight of roughly 6 kg (8.7%).

The cross-sectional study by Kohrt et al. (1992), which examined age-related trends in body composition among sedentary and fitness trained women, also reported increases in both body weight and BMI with age. Among the sedentary group, the weight of women in their 60's was 9.5 kg (16.0%) greater than that of women in their 20's. The older group's BMI was also significantly higher (4.1 kg/m², 19.2%) than that of the younger women. The trained group showed dramatically different results. While body weight and BMI remained significantly higher in the older group, the difference between the age groups was much smaller than that recorded by the sedentary subjects. The older group's mean weight was only 1.7 kg (3.0%) higher, and their BMI only 1.2 kg/m² (5.9%) greater than the younger group's values.

A cross-sectional investigation by Frontera et al. (1991) noted that female body weight increased 5.0 kg (8.1%) in middle age and fell 3.3 kg (5.0%) in advanced old age, however, these increases did not reach statistical significance. In studying 157 men aged 20 - 79 years, Bembien et al. (1995) noted a consistent increase in weight which peaked in the mid 50's before declining. From the early 20's to the mid 50's peak, body weight climbed 10.7 kg (14.1%). By the age of 80, weight had fallen 12.0 kg (13.8%) from peak and had returned to early adulthood levels.

The 22 year longitudinal study involving 53 male runners by Trappe et al. (1996) also noted a significant weight gain with age. Three subgroups (untrained, fitness trained, highly trained) were tested in their mid 20's and 22 years later in their late 40's. The untrained men recorded an increase in weight of 15.5 kg (23.6%) while their fitness

trained counterparts gained 7.1 kg (10.1%). The highly trained group showed the smallest increase (3.6 kg, 5.4%) in body weight over the 22 years. An older subgroup first tested in their 40's and at follow-up in their 60's showed a nonsignificant weight gain of 1.3 kg (2.0%). These results are similar to those reported by Kohrt et al. (1992) in supporting the notion that while physical activity may not halt an age-related increase in body weight, it can reduce the magnitude of the weight gain.

Height

A preponderance of evidence suggests that humans get shorter as they age. It is theorized that as vertebral BMD declines with age and body weight increases, the weakened vertebrae are unable to withstand the additional mechanical stress. As a result, the vertebrae and the intervertebral spaces become compacted leading to a reduction in height.

Shimokata, Tobin, et al. (1989) noted a consistent decrease in height (8.6 cm, 5.2%) between younger (< 40 years) and older (> 70 years) female subjects. A large Danish cohort study measured height in 13,386 women between the ages of 40 and 74 (van Leer, van Noord, & Seidell, 1992). After adjusting for secular and cohort effects, the researchers concluded that there existed an age-related decline in stature of approximately 3.0 cm over the course of 35 years. A longitudinal investigation by Flynn et al. (1989) also noted a significant decline in female height (2.8 cm, 1.7%) between the ages of 40 and 60 years of age.

Other researchers have noted a decline in height with age but found that it did not reach statistical significance. Frontera et al. (1991) documented a 4.4 cm (2.7%) decrease in height between middle-aged (45 - 54 years) and elderly (65 - 78 years) women but noted that the difference was nonsignificant. Kohrt et al. (1992) reported a 2 cm difference between their younger (< 30 years) and older (> 55 years) subjects which again was statistically insignificant. Results from the study by Butts et al. (1985) and Butts and Price (1994) show heights of women over 40 markedly lower (2.3 cm, 1.4%) than that recorded by women younger than 40 but again the difference was not statistically significant.

Fat Weight and Percent Body Fat

It is generally accepted that the gradual increase in body weight with age is due to a nearly identical increase in FW. In response to a rise in FW along with either a decline or no change in FFW, % BF also rises with age. As with previously mentioned body composition variables, the magnitude, rate, and age of onset of changes in % BF remains debatable. A wide variety of study designs and testing methods, along with the apparent variability in FFW make it difficult to place solid, incontrovertible numbers on the age-related changes in % BF.

An increase in % BF of 9.0% over the course of approximately 20 years was reported by Flynn et al. (1989) in a longitudinal study which used TBK to estimate FFW and FW. Similar findings were related by Kohrt et al. (1992) who used densitometry to estimate % BF and FFW in 168 women. In a cross-sectional comparison spanning

approximately 4 decades, Kohrt et al. (1992) found a 14.3% greater % BF among an older sedentary group of subjects versus a younger group. Upon further analysis of a fitness trained group, the researchers discovered a smaller difference (8.7%) between the two age groups with the older group again possessing the higher % BF.

Frontera et al. (1991) also employed densitometry in a cross-sectional study of 114 women ranging in age from 45 to 78 years. While % BF was not directly presented in the results, it could be easily calculated from the information provided. Results indicated a significant increase in % BF of 8.3% between the youngest group (45 - 54 years) and the middle-aged group (55 - 64 years). There was no significant change in % BF between the middle-aged group and the oldest group (65 - 78 years). When adjusted for differing age ranges, the change in % BF calculated from Frontera et al. is similar to that reported by Flynn et al. (1989) and Kohrt et al. (1992). However, data from Frontera et al. indicate there may be a plateau in % BF near 65 years of age and that the increase in % BF could well be curvilinear rather than linear.

A cross-sectional comparison by Silver et al. (1993) used bioelectrical impedance to measure % BF in 257 women aged 20 - 96 years. The study design divided the women into five distinct groups based upon age. A significantly higher % BF was seen among women aged 40 - 64 year (31.5%) when compared to a younger group less than 40 years of age (24.9%). An absolute difference of 6.6% existed between the two groups. Consistent with results from Frontera et al. (1991), Silver et al. reported a plateau in % BF which began at age 65 and continued through age 85. After the age of 85, a

significant decline in % BF (6.7%) was noted along with a concomitant decrease in BMI (3.6 kg/m^2 , 14.3%). While also observing a significant decline in body weight with advanced age, Steen (1988) found relatively no change in % BF over 11 years in 14 women in excess of 70 years of age. Rather, Steen attributed the loss of weight in the elderly to a reduction in extracellular water. In comparing women over 40 (mean age = 44.6 years) with women under 40 (mean age = 33.6 years), Butts et al. (1985) and Butts and Price (1994) found the older group to have a significantly higher % BF (2.4%).

A curvilinear trend in FW and % BF was also recorded by Aloia et al. (1996) in their cross-sectional study of 155 women aged 24 - 79 years. Results from this study displayed a consistent increase in FW and % BF until approximately age 60. Following age 60, FW declined while % BF increased slightly but nonsignificantly. A comparison of a younger age group (< 40 years) with a middle-aged group (40 - 60 years) revealed an increase of roughly 6.0% in % BF with age. The elderly group (> 60 years) showed a small 1% increase in % BF from middle-age which was statistically nonsignificant. A 3 year longitudinal study of 118 early postmenopausal women by Aloia, Vaswani, Russo, et al. (1995) demonstrated a significant increase in FW of 2.4 kg per year, however, % BF data were not provided.

As longitudinal studies of body composition in women are rare, two studies involving men will be briefly discussed. Skinfold measurements were used to predict % BF by Trappe et al. (1996) in their longitudinal study of elite male distance runners. Among the three groups who were initially tested in their 20's and retested in their 40's

the untrained males experienced a 12.9% increase in % BF. The fitness trained group rose 7.4%, and the highly trained men showed the smallest gain in % BF at 5.2%. The fit older group tested first in their 40's and again in their 60's recorded a 6.4% increase in % BF. Results were consistent with those reported by Kohrt et al. (1992) which indicated that habitual physical activity may limit the increase in % BF with age.

Murray et al. (1996) also employed skinfold prediction equations to estimate % BF in a 5 year longitudinal study of men in their 60's. Over the course of the study no significant changes in % BF were noted. This finding is consistent with reports by Aloia et al. (1996), Silver et al. (1993), Frontera et al. (1991), and Steen (1988) on women which propose a plateau in % BF around 60 years of age or greater.

Perhaps the simplest and quickest method of estimating % BF in a clinical or field setting is the use of skinfold calipers to measure subcutaneous fat storage at various sites throughout the body. To this end, several large scale investigations have centered on the development of skinfold prediction equations which produce % BF values similar to those obtained from established methods such as hydrodensitometry. While several such equations have been developed, there exist two of note which are designed specifically for women and take age into account.

One of the hallmark prediction equations was developed by Durnin and Womersley (1974) to predict body density based upon age and skinfold readings at the biceps, triceps, subscapular, and suprailiac locations. With each decade following the age of 30 and proceeding to the age of 50, this equation results in lower density values. A

decline in density with age results in an increased % BF as the decrease in density theoretically results from an increase in FW and a potential decline in FFW. The equation of Durnin and Womersley does provide a minuscule increase in density for women over the age of 50.

A second set of prediction equations which are frequently used are those developed by Jackson, Pollock, and Ward (1980). Age is a factor in both the seven site equation (chest, axilla, triceps, subscapular, abdomen, suprailium, and thigh) and the three site equations (triceps, suprailium, thigh, triceps, suprailium, and abdomen). Each of these equations assumes an inverse linear relationship between age and density. Again, as body density declines with age, % BF increases.

Fat Distribution

The pattern of fat distribution which occurs with age has received increased attention in recent years due to mounting evidence that the location of fat storage may have serious health implications. While obesity has been linked to elevated cholesterol levels, hypertension, coronary artery disease, diabetes mellitus, and premature mortality, there are also strong indications that central or abdominal obesity may be equally if not more predictive of future health problems. Researchers have thus focused their efforts on describing age-related trends in fat distribution patterns.

One of the most commonly used measures of central adiposity is the waist-to-hip ratio (WHR). A high WHR is typically considered an indication of increased risk for a poor health outcome. As with most things, there is conflicting evidence on whether

WHR increases with age in women. In a cross-sectional comparison involving 408 women in the Baltimore Longitudinal Study of Aging, Shimokata, Tobin, et al. (1989) noted a significant increase in WHR with age although this increase was not evident prior to age 55. Ironically, conflicting evidence arose from a longitudinal analysis of data from the BLSA. Shimokata, Andres, et al. (1989) conducted a 5 year longitudinal investigation into WHR changes in 177 women aged 22 to 86 years. Results from this study contradicted those reported by Shimokata, Tobin, et al. (1989) in revealing virtually identical changes in both waist and hip circumferences and, therefore, no significant change in WHR with age.

There is also debate regarding the theory that fat storage migrates towards the abdominal/truncal regions and away from the extremities with age. Chien et al. (1975) conducted a 12 year longitudinal study on six women with the mean age increasing from 31 to 43 years. Employing skinfold measures, Chien et al. (1975) found significantly greater increases in thickness at the abdomen (9 mm, 36%) and waist (8 mm, 40%) as opposed to the upper arm (4 mm, 22%) and calf (.5 mm, 3%). Conflicting results were offered by Kanehisa et al. (1994) in a large cross-sectional study of 275 Japanese women aged 6 - 60 years. B-mode ultrasound was used to image fat cross-sectional area (CSA) at the forearm, upper arm, leg, and thigh. The authors noted that after the third decade women tended to show a significant increase in upper arm CSA while exhibiting decreases in the leg and thigh CSA's. No significant change with age was noted in the forearm CSA.

Residual Volume

Residual volume (RV) and the change in RV with age dramatically impact calculations of density, % BF, and FFW derived from densitometry. It is widely accepted that aging leads to a progressive deterioration of lung function which includes a decline in vital capacity (VC) and an increase in RV (Shephard, 1993). Several physiologic factors combine to increase RV with age. Atrophy of the respiratory muscles with age, along with reduced elasticity of the rib cage and lungs makes it increasingly difficult to expel air from the lungs. Additionally, in advanced old age a rounding of the thoracic region of the spine may reduce the volume of the thoracic cavity making it all the more difficult for the lungs to fully expand. Further, the increase in RV is approximately equal to the decrease in VC (Burrows, Lebowitz, Camilli, & Knudson, 1986). There is, however, debate surrounding the magnitude, rate, and age of onset of the increase in RV which is directly attributable to age. Confounding factors which can accelerate the true aging process include cigarette smoking, previous respiratory disease, and exposure to air pollutants (Shephard, 1978). The bulk of lung function studies investigating aging tend to report VC as opposed to RV. Given that changes in VC approximate those seen in RV, VC will serve as a surrogate for RV.

In a 1968 study Anderson, Brown, Hall, and Shephard proposed an annual rate of decrease in VC among women free of respiratory disease of 10.5 ml per year. Shephard (1978) reported a slightly higher rate of loss of roughly 18.3 ml/year for urban American women. A cross-sectional study by Jones, Overton, Hammerlindl, and Sproule (1978) of

41 nonsmoking males indicated a significant increase in RV that accelerated rapidly from middle age onward. Over the course of 55 years, RV increased by .93 L (16.9 ml/year). Schoenberg, Beck, and Bouhuys (1978) also reported a small increase in RV during middle age which accelerated rapidly in advanced old age. A cross-sectional study by Morris, Mosk, and Johnson (1971) found that in successive decades from 25 to 75 years of age the VC of nonsmoking men declined by 19, 33, 17, 68, and 82 ml/year.

Finally, in regard to physical activity, evidence has shown that training has no significant impact on static lung volumes provided that VC was not initially poor prior to training (Niinimaa & Shephard, 1978).

Summary

While several comprehensive, age-related trends in body composition variables have been documented, widely varying estimates regarding the rate, direction, extent, and onset of change with age make specific quantitative conclusions untenable. Increased body weight, FW, and % BF, along with a potential decline in FFW are all associated with aging. Age-related changes in fat distribution remain unclear and debatable. Additional, well-designed longitudinal investigations may help clarify much of the confusion which clouds these particular questions.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The current study investigated changes in body composition among a group of middle-aged and elderly women 12 years after completion of a 12 week resistance training study (Butts et al., 1985; Butts & Price, 1994). The current assessment of age-related changes in body composition comprised one part of a larger, two-pronged study. Additional research was also conducted into the relationship between muscular endurance and aging in the same group of women. Both the body composition and muscular endurance studies were reviewed and approved by the University of Wisconsin-La Crosse (UWL) Institutional Review Board to ensure the protection of human subjects.

Original Study

The initial study by Butts et al. (1985) and Butts and Price (1994) was designed to investigate any changes in body composition and muscular endurance in women over 30 years of age which occurred as a result of 12 weeks of resistance training.

Subject Selection

Ninety-two women between the ages of 30 and 63 years volunteered for the original study in response to an announcement printed in the La Crosse Tribune and radio broadcasts by local stations. Seventy-five of the original 92 volunteers completed all pretest requirements and 68 women finished the 12 week training regimen and all posttest

measurements. An additional group of 27 women served as a control group for body composition measures only. Prior to testing, subjects signed an informed consent form and completed a questionnaire requesting such information as medical history, physical activity patterns, and nutritional habits.

Test Methodology

Body composition testing was conducted in the Human Performance Laboratory (HPL) at UWL. Two RV values were obtained using oxygen dilution in a seated position outside the underwater weighing tank according to Wilmore (1969). If the resulting RV's were not within 150 ml of one another, a third trial was conducted and the average of the three volumes was used in calculating density. Body density was determined by hydrodensitometry. Approximately six to ten trials were performed until three similar readings were obtained (Katch, 1968). The average of these three values were used to calculate density. Body density was converted to % BF using the equation developed by Brozek et al. (1963).

Anthropometric measurements were also obtained using a variety of methods. Body weight and height were obtained from a calibrated scale and a wall mounted stadiometer, respectively. Waist and hip circumferences were measured to the nearest .5 cm using a standard tape measure as described by Behnke and Wilmore (1974). Four skinfold measures at the triceps, suprailiac, abdominal, and thigh sites were taken on the right side of the body in triplicate. Skinfold readings were determined to the nearest .1

mm using Harpenden (John Bull, England) calipers. All body composition tests were repeated subsequent to completion of the 12 week weight training program.

Training Methodology

Following proper orientation and preliminary testing, subjects were required to perform one set of 8 to 12 repetitions on 12 distinct weight machines 3 days a week for a total of 12 weeks (36 sessions). The 12 lifting exercises were done on Nautilus (Nautilus International, Huntersville, NC) equipment and included the hip and back, leg extension, leg curl, upright chest, pull-over, multicurl, multitriceps, abdominal, hip flexion, abductors, rotary torso, and low back machines. Resistance was increased when subjects could complete more than 12 repetitions on a given exercise. The weight lifted and number of repetitions completed were recorded following each session.

Current Study

Subject Selection

Subjects in the present study were recruited from the original 68 women who completed all phases (pretest, training, and posttest) of the previous study. Given the length of time (12 years) since the initial study, substantial investigative legwork was required to locate the original subjects. An extensive review of city and criss-cross directories from several cities in Wisconsin, Minnesota, and Iowa was performed in an effort to obtain current addresses and/or phone numbers of past participants. A search of the UWL campus directory was also conducted as many of the women in the earlier study were UWL faculty or staff members. The names of individuals who could not be located

in this manner were then entered into a computer database search program (PhoneDisc Powerfinder, Spring 1994) in an attempt to garner additional addresses and phone numbers. When all else failed, word of mouth was employed. Several subjects were located in this manner due to personal acquaintances and friendships among women in the study group.

Of the original 68 subjects, 47 were located using the methods described above and 21 could not be contacted. Of these 21, 5 had left the La Crosse area and 16 simply could not be found. In soliciting volunteers, a letter (see Appendix A) detailing the intent and import of the current study was mailed to the 47 potential subjects. Within a week of the mailing, subjects were contacted by phone to assess their interest in the study and to schedule testing dates for those who agreed to participate. Thirty-three of the 47 women initially consented to take part in the follow-up study. Twenty-nine women eventually completed all body composition and muscular endurance tests.

Test Methodology

The testing procedures in the current study were virtually identical to those employed in the original study and all body composition testing was again conducted in the HPL. Upon volunteering for the current study subjects completed a questionnaire detailing information such as age, medical history, exercise and dietary habits, menopausal state, and current health status (see Appendix B). Each subject also reviewed and signed an informed consent form prior to testing (see Appendix C). A thorough

explanation of the testing process was provided to each subject before testing began. Any questions and/or concerns raised by participants were also addressed.

Height to the nearest .25 inch was measured using a calibrated, wall mounted stadiometer. Weight was assessed with the subject dry, in a swimsuit, and free of any watches, jewelry, glasses, etc. A calibrated, balanced beam scale recorded weight to the nearest .25 pound in each subject.

Skinfold measurements to the nearest .1 mm were taken at four sites on the right side of the body using Harpenden calipers. The four specific skinfold sites were measured as follows:

Triceps - a vertical fold on the posterior midline of the upper arm (over the triceps muscle), halfway between the acromion and olecranon processes; the elbow extended and relaxed (Jackson & Pollock, 1985).

Suprailiac - a diagonal fold above the crest of the ilium at the spot where an imaginary line would come down from the anterior axillary line (Jackson & Pollock, 1985).

Abdominal - a vertical fold taken at a lateral distance of approximately 2 cm from the umbilicus (Jackson & Pollock, 1985).

Thigh - a vertical fold on the anterior aspect of the thigh midway between hip and knee joints (Jackson & Pollock, 1985).

Three distinct measurements were taken at each of the four skinfold sites. If two of the three values were identical, that particular value was used. Otherwise, an average of the three readings was recorded as the final value.

Both waist and hip girths were measured to the nearest .5 cm using a calibrated tape measure. The waist measurement was taken at the narrowest part of the torso above the umbilicus and below the xiphoid process while the hips were measured at the maximal circumference of the hip or buttock region (Behnke & Wilmore, 1974).

Residual volume was determined using the oxygen dilution method described by Wilmore (1969). A minimum of two RV measurements were obtained with the subject seated in a chair outside the weighing tank. Exactly 5 L of pure oxygen were used for oxygen rebreathing and alveolar, impurity, equilibrium, and final nitrogen values were recorded for each trial. Residual volume dead space equaled 12 ml while oxygen dead space was 68 ml. The oxygen bag was completely purged and refilled following each trial. If either of the two RV measures differed by more than 150 ml, a third RV trial was performed.

Following RV determination, subjects entered the underwater weighing tank and remained still while the loadcells were calibrated. An initial reading was taken with no weight on the scale. A second measurement was then recorded with exactly 4.0 kg on the scale. It should be noted that a loadcell weighing system was employed in the present study as opposed to the autopsy scale used in the initial study. This procedural difference was assumed to be of no significance since Fahey and Schroeder (1978) have indicated

that an individual's underwater weight determined with a loadcell system is no more or less accurate than that obtained by a skilled technician using a conventional scale.

Upon completion of loadcell calibration, instructions were repeated regarding the weighing procedure. Each subject was required to sit forward such that they were totally submerged beneath the water and expel a maximal volume of air from their lungs. Upon a prearranged cue from the participant, the actual weighing was performed.

Approximately 6 - 10 trials were performed depending upon the subject's comfort and expertise with the procedure (Katch, 1968). An average of the last three weighings were used to determine density. Body density, % BF, and FFW were then calculated using available software. The exact equations used in the determination of density, % BF, and FFW are presented below.

Body Density - $D = M_A / (((M_A - M_w) / D_w) - RV - GI)$ where M_A = dry body weight, M_w = weight in the HYDRO tank, D_w = density of water, RV = residual volume, and GI = air in the gastro-intestinal tract. GI was assumed to be .1 liters.

Percent Body Fat - $\% BF = (4.570 / D) - 4.142 * 100$ (Brozek et al., 1963).

Fat Free Weight - $FFW = M_A - (M_A * \% BF)$.

Statistical Treatment

An independent t-test was performed comparing the women in the current study with those in the original study to determine if there were any significant differences between the original and current groups.

A one-way ANOVA with repeated measures was used to analyze differences among the means on pretest (1985), posttest (1985), and current test (1996) body composition variables. The specific variables assessed were age, height, weight, RV, density, % BF, FFW, triceps, suprailiac, abdominal, thigh, and summed skinfolds, waist-to-hip ratio, and BMI. A Tukey's post-hoc test was used to determine specific mean differences.

The subjects were then subdivided into a 52 year and older group and a below 52 year group and a two-way ANOVA with repeated measures assessed differences between the means of the above variables. Again, a Tukey's post-hoc test was employed to target specific mean differences. Subjects were also divided based upon physical activity habits (weight trained vs. untrained) and analyzed using a two-way ANOVA with repeated measures and a Tukey's post-hoc test. It should be noted for clarity that virtually all of the women (89.0%) followed an aerobic exercise regime and thus, the term untrained is used to describe those women who did not include resistance training in their fitness regimen.

Following testing and statistical analysis a summary of personal and group results, along with a thank you letter, was sent to each participant (see Appendix D).

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

A total of 29 Caucasian females ranging in age from 42 - 75 years participated in the current study. As mentioned earlier, these women were recruited from among a larger group of 68 females who participated in an earlier study on strength training, body composition, and muscular endurance (Butts et al., 1985; Butts & Price, 1994). Two of the 29 women were classified as outliers (i.e., the mean body weight [108.2 kg] and 12 year weight gain [19.2 kg] of these two women were greater than two standard deviations from the respective means of the entire group) and were excluded from statistical analysis.

An independent t-test was performed comparing physical characteristics of the 27 women in the current study with the 39 women in the original study who did not return for follow-up testing. No significant ($p > .05$) differences were observed between the two groups. It was assumed, therefore, that the subjects in the present study were representative of the original group.

A one-way ANOVA with repeated measures was used to evaluate 13 different variables among the subjects ($n = 27$) at three different times over the course of 12 years. The variables examined were height, weight, BMI, RV, density, % BF, FFW, skinfolds (triceps, suprailiac, abdominal, thigh, and sum), and waist-to-hip ratio (WHR). Initial

measurements were taken prior to strength training in 1984 and follow-up values were recorded 12 weeks later following completion of the resistance training study (Butts et al., 1985; Butts & Price, 1994). Testing for the current study occurred approximately 12 years after the initial study.

The same 13 variables were also assessed following division of the initial group into two distinct age-related subgroups. Participants were assigned to either a 52 years and older group (> 52 , $n = 14$) or a less than 52 years of age group (< 52 , $n = 13$) which corresponded to the age group division used in the original study. Among the > 52 group, 13 of the 14 women were postmenopausal and 11 of those 13 reported using hormone replacement therapy (HRT). Six of the 13 women in the < 52 group were premenopausal and were not on HRT. Five of the younger women classified themselves as perimenopausal of which two were using HRT. The remaining two women in the < 52 group were postmenopausal following hysterectomies and both were on HRT. A two-way ANOVA with repeated measures was used to examine differences among the means.

Group subdivision was also conducted based upon recent adherence to a weight training program. The physical characteristics of the women who reported strength training within the last 5 years (Trained, $n = 11$) were compared using a two-way ANOVA with repeated measures against those same characteristics in women who did not strength train (Untrained, $n = 16$).

Group Analysis

Selected body composition variables for the entire group are presented in Table 1.

Table 1. Means and standard deviations of body composition variables among original (n = 68) and current (n = 27) subjects.

Variable	Original Group		Current Group		
	Pre	Post	Pre	Post	Current
Age (Yrs)	39.4 7.7	39.4 7.7	41.7 8.2	41.7 8.2	53.7 8.2
Height (cm)	163.1 5.7	163.1 5.7	161.0 5.8	161.0 5.8	160.4 ^{bc} 5.7
Weight (kg)	63.8 10.9	63.7 10.5	60.2 9.1	59.9 7.9	66.1 ^{bc} 9.7
BMI (kg/m ²)	24.0 3.6	23.9 3.5	23.2 3.0	23.1 2.7	25.7 ^{bc} 3.3
RV (L)	1.41 .32	1.52 ^a .35	1.41 .34	1.50 ^a .38	1.53 ^b .26
Density	1.0294 .0152	1.0346 ^b .0155	1.0318 .0137	1.0380 ^b .0139	1.0218 ^{bc} .0112
% Body Fat	29.8 6.5	27.6 ^b 6.6	28.8 5.9	26.2 ^b 5.9	33.1 ^{bc} 4.9
FFW (kg)	44.3 5.1	45.6 ^b 4.8	42.6 4.9	44.0 ^b 4.3	43.9 ^b 4.8

^a significant (p < .05) difference vs. pretest.

^b significant (p < .01) difference vs. pretest.

^c significant (p < .01) difference vs. posttest.

Height

A significant (p < .01) decrease in height of .5 cm was observed between current readings and previous measurements which is consistent with the widely held opinion

that humans become shorter with age. Although vertebral BMD was not assessed as a variable in this study the decrease in height was assumed to be due to a simultaneous loss of BMD and vertebral compaction as documented in the research literature (see Table 2). The magnitude of height loss reported in the current study is consistently less than that reported by other researchers. In the present study an extremely high percentage (87%) of the postmenopausal women were using HRT which may have limited height loss resulting from a decline in spinal bone mass. Additionally, with a mean age of 53.7 years, these women remain relatively young and may not have reached an age at which marked declines in height are evident.

Table 2. Approximate height loss per decade as reported in literature. *

Researcher(s)	Study design	Height loss/decade (cm)
Current study	Longitudinal	.4
Kohrt et al. (1992)	Cross-sectional	.5
van Leer et al. (1992)	Cross-sectional	.9
Shimokata, Tobin, et al. (1989)	Longitudinal	1.1
Flynn et al. (1989)	Longitudinal	1.3
Butts et al. (1985); Butts & Price (1994)	Cross-sectional	2.1
Frontera et al. (1991)	Cross-sectional	2.3

* Calculated from published results and assuming a linear rate of change.

Body Weight and BMI

As expected, mean body weight and BMI increased significantly ($p < .01$) over the course of 12 years. An increase in weight of 5.9 kg (9.8%) was noted from pretest measures while a 6.2 kg (10.3%) rise was seen from posttest values. Similarly, BMI rose 2.5 kg/m² (10.6%) from pretest and 2.6 kg/m² (11.0%) from posttest. These results are consistent with the bulk of published literature which documents an age-related increase in both body weight and BMI (Frontera et al., 1991; Kohrt et al., 1992; Kuczmarski et al., 1994; Shimokata, Tobin, et al., 1989; Silver et al., 1993). However, the magnitude of gain in the current study is consistently greater than that reported by many researchers.

Shimokata, Tobin, et al. (1989) reported a weight gain of approximately 1.1 kg/decade in women prior to the age of 70, after which a slight decline in body weight was observed. In addition, their BMI also increased by roughly .5 kg/m² per decade. Silver et al. (1993) conducted a cross-sectional study which revealed that female BMI climbed approximately .5 kg/m² per decade before decreasing after age 75. Results from the NHANES III study indicate that the typical woman's BMI increases 1.5 kg/m² per decade prior to the age of 60, followed by a gradual decline (Kuczmarski et al., 1994). Kohrt et al. (1992) reported a per decade increase in weight of 2.4 kg and in BMI of 1.0 kg/m² among sedentary women. A smaller increase in both weight (.4 kg/decade) and BMI (.3 kg/m² per decade) was seen among fitness trained subjects. Reports most consistent with those in the current study come from Frontera et al. (1991), who employed a cross-sectional design and observed a 10 year increase in weight of 5.0 kg

and BMI of 2.4 kg/m² among middle-aged women. However, the changes in weight reported by Frontera et al. (1991) were also noted to be nonsignificant.

Residual Volume (RV)

Analysis of RV values presented puzzling results. A comparison of current and pretest values revealed a significant ($p < .01$) increase in RV (.11 L, 7.8%) which is consistent with a documented rise in RV with age (Shephard, 1993). A significant ($p < .05$) difference between pre- and posttest volumes (.09 L, 6.4%) was unexpected as these two measurements were taken within 12 weeks of one another. As a result, no significant ($p > .05$) difference was observed between current and posttest RV values. Unfortunately, two of the three primary factors which may accelerate the decline in RV with age were not assessed in the current study. Specifically, smoking habits and occupational exposure to air pollutants were not addressed. All subjects did, however, declare themselves free of respiratory disease.

The annual rate of decline in RV among the 27 women averaged 9.2 ml/year which is slightly lower than many published reports. Anderson et al. (1968) reported that vital capacity, which typically declines in near proportion to the rise in RV, fell 10.5 ml/year among women free of respiratory disease. Shephard (1978) estimated a slightly greater rate of vital capacity loss of roughly 18.3 ml/year in urban, American women. A cross-sectional study by Jones et al. (1978) of nonsmoking males reported an average RV increase of 16.9 ml/year but noted that the change in RV was less than 16.9 ml/year

during middle-age and grew larger with advanced age. Schoenberg et al. (1978) also reported smaller increases in RV during middle age which accelerated rapidly in old age.

The smaller increase in RV with age reported here, as opposed to that reported in the literature, may be due to a combination of factors. First, the 12 year period examined began with the women exhibiting a mean age of 41.7 years and ended with an average group age of 53.7 years. The group as a whole could be categorized as middle-aged. If the increase in RV is truly curvilinear and accelerates only in old age as suggested by Jones et al. (1978), Schoenberg et al. (1978), and Morris et al. (1971) then the gain in RV noted in this study should be lower than averages calculated over an entire lifespan.

Secondly, the bulk of lung function studies have been cross-sectional in nature. The elderly subjects in these studies may have introduced a secular effect simply by having lived in a time when the prevalence of smoking, respiratory disease, and industrial pollution was more common than it is today. Increased exposure to any of the above elements would only exacerbate and inflate true age-related changes in RV.

Density and Percent Body Fat (% BF)

As with the original group the subjects participating in the present study had a significant ($p < .01$) increase in density as a result of the 12 weeks of training, as well as a significant ($p < .01$) decrease in % BF and an increase ($p < .01$) in FFW. Their current density, however, decreased significantly ($p < .01$) compared to both their pre- and posttest values. A significant inverse relationship between body density and age was evident.

Since % BF measures are inversely related to density there was a significant ($p < .01$) decrease in % BF between pre- and posttest measurements (-2.6%) due to an increase in FFW of 1.4 kg and a decrease in fat weight (FW) of 1.7 kg.

Aging, on the other hand, was directly related to significant ($p < .01$) increases in % BF. The 4.3% rise in % BF from pretest values was the result of a 4.5 kg increase in FW which was partially offset by a 1.4 kg jump in FFW. The 6.9% increase in % BF from posttest measurements was due solely to a 6.2 kg rise in FW as FFW remained unchanged. Table 3 provides a comparison of % BF changes in the current study with other published results. As seen in Table 3, the age-related increases in % BF in the current study are within a few percentage points of many existing studies of both cross-sectional and longitudinal design.

Fat Free Weight (FFW)

The most surprising result of the current study was the relationship between aging and FFW. In the prior study, strength training resulted in a significant ($p < .01$) increase in FFW, however, it was theorized that FFW would decrease over the 12 year period as % BF and body weight increased. Although a significant ($p < .01$) increase in FFW occurred as a result of the original training there was no significant ($p > .05$) difference in FFW between the posttest values and those in the present test. This finding is in direct contrast to reports by Forbes (1987), Frontera et al. (1991), and Kohrt et al. (1992), which documented a significant, linear decline in female FFW with age. Although the rate and magnitude of FFW decline varied in these studies, the direction of change was consistent.

Table 3. Approximate increases in percent body fat per decade as reported in literature. *

Researcher(s)	Study design	Body fat increase/decade (%)
Current Study	Longitudinal	
vs. Pretest		3.6
vs. Posttest		5.8
Butts et al. (1985)	Cross-sectional	2.2
Butts and Price (1994)		
Kohrt et al. (1992)	Cross-sectional	
Sedentary		3.6
Active		2.2
Aloia et al. (1996)	Cross-sectional	3.0
Silver et al. (1993)	Cross-sectional	3.9
Frontera et al. (1991)	Cross-sectional	4.2
Flynn et al. (1989)	Longitudinal	4.5

* Calculated from published results and assuming a linear rate of change.

It has been suggested that decreases in female FFW may be influenced by hormones. Aloia et al. (1991) concluded that FFW loss did not occur in women prior to menopause which supports the longitudinal study by Flynn et al. (1989) who offered similar results in observing that FFW loss in women was not evident before the age of 60. The mean age of the women in the current study was 53.7 years and while 15 of the 27 were postmenopausal, 13 of those were on HRT which dramatically reduces the loss of bone mass following menopause (Aloia et al., 1990; Wardlaw, 1996).

Evidence of a delay in FFW atrophy prior to advanced age has also been reported in men. Bemben et al. (1995) reported that FFW was maintained in men younger than 70 years of age while a longitudinal study by Murray et al. (1996) found no significant decline in FFW over the course of 6 years among men in their 60's.

Only one study to date has reported an increase in FFW with age. Trappe et al. (1996) found a 5.2 kg increase in FFW in sedentary men over the course of 22 years. When adjusted back to a 12 year period, the increase in FFW is roughly 2.8 kg. A nonsignificant increase in FFW of 1.8 kg over 22 years was noted among a group of fitness trained men. This becomes approximately 1.0 kg when adjusted to a 12 year time frame. The 1.4 kg increase in FFW among women in the current study is slightly greater than that experienced by fitness trained men and less than that of sedentary men studied by Trappe et al. (1996).

It is proposed that the increase in FFW seen in the current study is directly related to an even greater rise in body weight. Mean body weight rose 5.9 kg from pretest measures of which 1.4 kg (23.7%) was FFW and 4.5 kg (76.3%) was FW. As FW increases, it is logical to assume that FFW also increases, albeit to a lesser degree, in order to support the increased load on the body. The effect would be counter to that experienced by dieters who lose both FW and FFW. Trappe et al. (1996) also linked the increased FFW in their sedentary subjects to an increase in gross weight. The sedentary men experienced a total weight gain of 15.5 kg over 22 years, of which 5.2 kg (33.6%) was FFW and 10.3 kg (66.4%) was FW.

Additionally, 87% of the postmenopausal subjects (13 of 15) in the current study reported using HRT and only 3 of the 27 (11%) were classified as sedentary. Both HRT and physical activity have been identified as factors which limit the loss of FFW (Alola et al., 1990; Kohrt et al., 1992; Trappe et al., 1996; Wardlaw, 1996).

Skinfold Measures

Every skinfold measurement increased significantly ($p < .01$) over the course of 12 years (see Table 4) which is consistent with changes observed in % BF. Specifically, sum of skinfold measures exceeded posttest values by approximately 24.5%. Although virtually every skinfold measure declined from pre- to posttest, these changes were not significant ($p > .05$). Additionally, similar increases in skinfold thickness were noted at each site when compared against both pre- and posttest values ($p > .05$).

In regard to changes in fat distribution with age, Chien et al. (1975) reported that greater increases in fat storage were noted in the central regions of the body as opposed to peripheral sites. Kanehisa et al. (1994) provided contradictory evidence in reporting an increase in upper arm fat storage and a decrease in leg and thigh fat deposition with age. Evidence from the present study contradicts that of both Chien et al. (1975) and Kanehisa et al. (1994) in that all skinfold sites (central and peripheral, upper and lower body) increased consistently and significantly in both absolute and relative magnitude over the 12 year period.

Waist-to-Hip Ratio (WHR)

The WHR showed no significant ($p > .05$) change over the 12 years which implies

Table 4. Means and standard deviations of anthropometric variables among original (n = 68) and current (n = 27) subjects.

Variable	Original Group		Pre	Current Group	
	Pre	Post		Post	Current
Triceps (mm)	19.7 6.5	19.0 ^b 6.5	18.8 6.8	17.7 5.4	23.2 ^{bc} 7.2
Suprailiac (mm)	16.8 8.0	16.4 8.2	14.9 6.3	14.3 6.0	19.2 ^{bc} 8.0
Abdominal (mm)	24.7 9.1	23.7 ^b 8.6	23.7 8.8	23.3 8.2	28.1 ^{bc} 7.8
Thigh (mm)	29.0 8.3	28.4 ^a 8.1	28.7 8.2	29.0 7.8	34.5 ^{bc} 6.5
Sum (mm)	90.2 27.9	87.1 ^b 27.2	86.1 26.5	84.3 24.5	105.0 ^{bc} 25.5
WHR	.76 .05	.76 .05	.76 .04	.77 .04	.76 .06

^a significant (p < .05) difference vs. pretest.

^b significant (p < .01) difference vs. pretest.

^c significant (p < .01) difference vs. posttest.

that in women fat gains are spread equally throughout the truncal region with age. In contrast, a cross-sectional comparison by Shimokata, Tobin, et al. (1989) noted a significant increase in female WHR following the age of 55. Results from the current study are more consistent with longitudinal data from Shimokata, Andres, et al. (1989) which revealed virtually identical changes in both waist and hip circumferences and therefore no significant change in WHR with age.

Age Comparison

When the group was arbitrarily divided into younger (< 52) and older (> 52) subgroups the mean age difference between the two was exactly 12.8 years. Selected body composition variables for both younger (< 52) and older (> 52) women are presented in Table 5.

Height

A cross-sectional height comparison between older and younger women revealed the older women to be significantly ($p < .01$) shorter (2.9 cm) than their younger counterparts which is consistent with height differences reported in the prior study by Butts et al. (1985) and Butts and Price (1994). This was to be expected, however, as identical age division criteria were used. Additionally, no interaction effect was noted between the > 52 and < 52 groups implying that women of differing ages do not lose height at a significantly different rate.

This finding contrasts with those reported by several other researchers. Flynn et al. (1989) documented a consistent decline in female height with age which reached significance at roughly 60 years of age. Shimokata, Tobin, et al. (1989) noticed an increased loss in stature with age which accelerated markedly after age 70. A significant height reduction of 2.0 cm over the course of 7 years among men in their 60's was reported by Murray et al. (1996). A cross-sectional study on men aged 20 - 79 by

Table 5. Means and standard deviations of body composition variables of younger (< 52 yrs, n = 13) and older (> 52 yrs, n = 14) subjects.

Variable	Under 52			Over 52		
	Pre	Post	Current	Pre	Post	Current
Age (Yrs)	35.1 2.5	35.1 2.5	47.1 2.5	47.9 6.8	47.9 6.8	59.9 6.8
Height (cm)	162.5 5.9	162.5 5.9	161.9 ^{ab} 5.8	159.6 ^f 5.6	159.6 ^f 5.6	159.0 ^{abf} 5.4
Weight (kg)	59.5 10.8	58.9 8.8	66.5 ^{de} 12.6	60.9 7.5	60.9 7.2	65.7 ^{de} 6.5
BMI (kg/m ²)	22.4 3.1	22.3 2.4	25.3 ^{de} 4.0	23.9 ^c 2.8	23.9 ^c 2.8	26.0 ^{de} 2.6
RV (L)	1.33 .25	1.42 .32	1.47 .18	1.49 ^c .41	1.58 ^f .42	1.58 .31
Density	1.0371 .0136	1.0429 .0127	1.0241 ^{de} .0114	1.0268 ^f .0122	1.0334 ^f .0138	1.0197 ^c .0110
% Body Fat	26.5 5.8	24.1 5.4	32.1 ^{de} 4.9	30.9 ^f 5.3	28.1 ^f 5.9	34.0 ^{de} 4.8
FFW (kg)	43.3 5.4	44.4 5.0	44.7 5.8	41.9 4.4	43.5 3.8	43.2 3.8

^a significant (p < .05) difference vs. pretest.

^b significant (p < .05) difference vs. posttest.

^c significant (p < .05) difference vs. younger.

^d significant (p < .01) difference vs. pretest.

^e significant (p < .01) difference vs. posttest.

^f significant (p < .01) difference vs. younger.

Bemben et al. (1995) also noticed a significant and consistent decrease in height beginning at age 60. In a cross-sectional comparison spanning roughly two decades, Frontera et al. (1991) found a greater height loss in women over 65 when compared to younger women but noted that this decrease did not reach significance.

Again, it should be noted that a large percentage (86.7%) of the postmenopausal women in the current study were on HRT which may have limited BMD loss and thus a decline in height. Or perhaps, with a mean age of 59.9 years, the older women had not yet reached a critical age at which height may decline more rapidly.

Body Weight and BMI

While current BMI in the > 52 group (26.0 kg/m^2) exceeded that of the < 52 women (25.3 kg/m^2), the difference was not significant ($p > .05$). Again, no significant ($p > .05$) interaction was noted among the two groups, indicating that the magnitude and direction of weight and BMI changes were similar in both groups. A decline in body weight and/or BMI was not seen among the older group which may be due to the fact that the group as a whole had not yet reached the age (60 - 75 years) at which such declines have frequently been reported (Bemben et al., 1995; Kuczmarski et al., 1994; Shimokata, Tobin, et al., 1989; Silver et al., 1993; Steen, 1988).

Residual Volume (RV)

No significant ($p > .05$) difference was observed between current RV measures of younger and older women, although significantly larger RV's were seen among the older women at both pretest ($p < .05$) and posttest ($p < .01$) periods. While RV of the younger

women showed a greater 12 year increase (.13 L) than that of the older women (.09 L), there was no significant ($p > .05$) interaction. While several researchers (Jones et al., 1978; Morris et al., 1971; Schoenberg et al., 1978) have reported an accelerated increase in RV in advanced age, this trend was not evident in the present study. Again, the women in the current study may not have reached an age at which such a trend would be evident.

Density and Percent Body Fat (% BF)

While current body density was lower and % BF greater among the > 52 women when compared to the < 52 group, this difference did not reach significance ($p > .05$). This would indicate, based upon cross-sectional comparison, that the older women's % BF may have plateaued as suggested by certain researchers (Aloia et al., 1996; Frontera et al., 1991; Silver et al., 1993; Steen, 1988). However, longitudinal data revealed no interaction ($p > .05$) despite the fact that the older women exhibited a larger gain in % BF (.42% /year) as opposed to the younger women (.26% /year).

The reduced rate of increase in % BF among the > 52 women hints towards a possible slowing in the addition of FW but is inconclusive due to its statistical nonsignificance ($p < .05$). Again, the mean age of the > 52 women (59.9 years) was below the critical age of 60 - 65 years proposed in the studies listed above. Interestingly, the one truly elderly woman in the study who was initially tested at age 63 and remeasured again at age 75 displayed a fairly low increase in % BF (1.9%) over the course of 12 years.

Fat Free Weight (FFW)

A cross-sectional comparison of FFW revealed no significant ($p > .05$) difference between younger and older women at any time and the longitudinal analysis revealed no significant ($p > .05$) change in FFW between either group with age. Again, no interaction ($p > .05$) was observed which indicates that changes in FFW were similar among the two groups.

Skinfold Measures

Selected anthropometric variables for both younger and older subjects are presented in Table 6. With the exception of the thigh, current skinfold measures were not significantly ($p > .05$) different between younger and older women which is consistent with the % BF results. Further, no interaction ($p > .05$) was discovered between the two groups. As with % BF, age-related changes in skinfold values do not appear to vary based upon age.

Waist-to-Hip Ratio (WHR)

No significant ($p > .05$) changes in WHR were noted with age or between age groups. This finding is consistent with that of Shimokata, Andres, et al. (1989) who also reported no significant changes in female WHR with age.

Activity Comparison

Based upon their responses to questions regarding their involvement in weight training over the past 5 years, the body composition variables of those who actively trained ($n = 11$) were compared to those who did not weight train ($n = 16$) (see Table 7).

Table 6. Means and standard deviations of anthropometric variables of younger (< 52 yrs, n = 13) and older (> 52 yrs, n = 14) subjects.

Variable	Under 52			Over 52		
	Pre	Post	Current	Pre	Post	Current
Triceps (mm)	16.7 5.6	16.2 5.0	23.0 ^{de} 8.2	20.8 7.3	19.1 5.6	23.3 ^e 6.5
Suprailiac (mm)	14.5 6.6	14.3 5.9	16.9 7.9	15.2 6.2	14.3 6.2	21.4 ^{de} 7.8
Abdominal (mm)	20.1 8.7	19.8 7.5	27.5 ^{de} 7.9	27.0 ^f 7.7	26.6 ^f 7.7	28.6 8.0
Thigh (mm)	26.1 8.8	26.4 8.7	32.1 ^{de} 8.1	31.1 ^f 6.9	31.5 ^f 6.2	36.8 ^{def} 3.5
Sum (mm)	77.4 27.1	76.6 24.7	99.5 ^{de} 30.1	94.1 ^f 24.2	91.5 ^e 22.8	110.2 ^{de} 20.0
WHR	.74 .03	.75 .04	.74 .05	.77 .05	.78 .05	.78 .07

^a significant (p < .05) difference vs. pretest.

^b significant (p < .05) difference vs. posttest.

^c significant (p < .05) difference vs. younger.

^d significant (p < .01) difference vs. pretest.

^e significant (p < .01) difference vs. posttest.

^f significant (p < .01) difference vs. younger.

Table 7. Means and standard deviations of body composition variables of weight trained (n = 11) and untrained (n = 16) subjects.

Variable	Trained			Untrained		
	Pre	Post	Current	Pre	Post	Current
Age (Yrs)	39.5 6.0	39.5 6.0	51.5 6.0	43.2 9.2	43.2 9.2	55.2 9.2
Height (cm)	162.8 6.9	162.8 6.9	162.2 ^{de} 6.7	159.7 ^f 4.7	159.7 ^f 4.7	159.2 ^{abf} 4.7
Weight (kg)	64.5 10.6	64.0 9.5	70.3 ^{de} 11.3	57.2 ^f 6.7	57.1 ^f 5.3	63.2 ^{def} 7.5
BMI (kg/m ²)	24.3 3.6	24.2 3.4	26.8 ^{de} 3.8	22.4 ^c 2.3	22.4 ^c 1.9	24.9 ^{def} 2.8
RV (L)	1.35 .32	1.49 ^a .38	1.53 ^d .29	1.46 .36	1.51 .39	1.52 .24
Density	1.0289 .0165	1.0354 .0179	1.0196 ^{de} .0110	1.0337 .0115	1.0397 .0107	1.0233 ^{de} .0114
% Body Fat	30.1 7.1	27.3 7.6	34.1 ^{de} 4.8	27.9 4.9	25.4 4.5	32.4 ^{de} 5.0
FFW (kg)	44.7 5.7	46.1 5.3	46.1 6.0	41.1 ^f 3.7	42.5 ^f 2.9	42.4 ^f 3.3

^a significant (p < .05) difference vs. pretest.

^b significant (p < .05) difference vs. posttest.

^c significant (p < .05) difference vs. trained.

^d significant (p < .01) difference vs. pretest.

^e significant (p < .01) difference vs. posttest.

^f significant (p < .01) difference vs. trained.

Height

As shown in Table 7, the untrained group was significantly ($p < .01$) shorter than the trained group which is probably due to random chance and not an age-related effect, as the mean ages of the two groups were similar.

Body Weight and BMI

Surprisingly, the trained women exhibited a significantly ($p < .01$) higher weight and BMI when compared to their untrained counterparts. This trend towards significantly greater weight among the lifters was also evident at pre- and posttest measurements. Of the 7.1 kg differential, 3.7 kg was attributable to greater FFW while 3.4 kg was excess FW. Essentially, the additional weight carried by the trained women was evenly divided between fat and lean mass. The percent by which the trained women's BMI exceeded that of the untrained women was slightly smaller than the percent weight differential due to their significantly ($p < .01$) greater height.

Interestingly, there was no significant ($p > .05$) interaction between the two groups with age. Over 12 years, both the lifters and nonlifters gained roughly 6 kg in body weight and increased their BMI by 2.5 kg/m². It appears that adherence to a weight training program confers no protective effect against an age-related increase in both weight and BMI.

Residual Volume (RV)

As expected, there was no significant ($p > .05$) difference in RV between trained and untrained women at either of the three testing periods. No aging effect was expected

due to the similarity in age between the two groups. In addition, research has shown that training will not substantially impact resting lung volumes in healthy individuals (Niinimaa & Shephard, 1978). This theory is further bolstered by the lack of interaction ($p > .05$) between the two groups.

Density and Percent Body Fat (% BF)

Body density was consistently lower and % BF higher among trained women as compared to untrained females, however, this difference was not statistically significant ($p > .05$). Furthermore, both groups displayed a significant ($p < .01$) decrease in density and increase in % BF with age which was consistent with findings for the entire group. However, no significant ($p > .05$) interaction was noted between the two groups as they both displayed % BF increases of 4.0 - 4.5% from pretest baselines. It would appear that weight training does not limit the age-dependent decrease in density and increase in % BF.

Fat Free Weight (FFW)

As expected, current measurements indicated that trained women displayed significantly ($p < .01$) greater FFW than their untrained peers. However, results also showed that the lifters had a significantly ($p < .01$) higher FFW at both pre- and posttest periods, thus no interaction ($p > .05$) was seen between the two groups. This implies that resistance training had no impact on FFW changes with age. Perhaps the 12 year weight gain that is theorized to have also increased FFW masked any impact which may have arisen from weight training. In addition, while both groups gained approximately 1.3 kg

of FFW between initial and follow-up measurements, the increase was nonsignificant. This gain is virtually identical to that recorded by the entire group which makes it probable that sample size was a limiting factor in arriving at significance.

Skinfold Measures

Selected anthropometric variables for both trained and untrained subjects are presented in Table 8. Consistent with % BF findings, skinfold measures were greater among trained subjects as compared to untrained individuals, but the difference did not reach significance ($p > .05$). Similar to the trend seen in % BF, both groups exhibited a significant ($p < .01$) increase in skinfold thickness with age. Although the untrained women displayed a larger increase in summed skinfold thickness (20.3 mm) than the trained women (17.0 mm), no significant ($p > .05$) interaction was evident. Again, weight training appeared to confer no significant benefit in halting the age-related increase in skinfold thickness.

Waist-to-Hip Ratio (WHR)

Consistent with results from the entire group, WHR showed no significant ($p > .05$) change with age between either group. Neither was there a significant ($p > .05$) difference between the trained and untrained groups. As such, no interaction ($p > .05$) was evident.

Table 8. Means and standard deviations of anthropometric variables of weight trained (n = 11) and untrained (n = 16) subjects.

Variable	Trained			Untrained		
	Pre	Post	Current	Pre	Post	Current
Triceps (mm)	19.5 6.6	18.7 6.5	25.0 ^{de} 6.9	18.3 7.0	17.0 4.7	21.9 ^{ae} 7.4
Supraillac (mm)	16.3 6.9	16.1 7.1	20.0 7.9	13.9 5.8	13.1 5.0	18.7 ^b 8.4
Abdominal (mm)	26.5 9.1	25.2 8.6	29.0 8.9	21.7 8.3	22.0 8.0	27.5 ^a 7.3
Thigh (mm)	30.7 8.3	30.5 7.8	36.1 ^{de} 5.4	27.3 8.0	28.0 7.9	33.5 ^{de} 7.1
Sum (mm)	93.0 28.8	90.4 27.7	110.0 ^{de} 22.9	81.3 24.6	80.2 22.0	101.6 ^{de} 27.2
WHR	.76 .03	.77 .04	.77 .05	.75 .05	.77 .05	.76 .07

^a significant (p < .05) difference vs. pretest.

^b significant (p < .05) difference vs. posttest.

^c significant (p < .05) difference vs. younger.

^d significant (p < .01) difference vs. pretest.

^e significant (p < .01) difference vs. posttest.

^f significant (p < .01) difference vs. younger.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

The current study provides solid evidence that aging has a significant detrimental impact on female body composition. Significant ($p < .01$) increases in body weight, BMI, RV, % BF, FFW, and skinfold measurements were observed over the course of this 12 year longitudinal study. Significant ($p < .01$) decreases were evident in both height and body density while no significant change ($p > .05$) was seen in the waist-to-hip ratio with age. Subgroup analysis of changes in body composition between younger and older women revealed no significant ($p > .05$) interaction between groups. In addition, no significant ($p > .05$) interaction was observed between weight trained and untrained females. It would appear that neither age nor resistance training significantly affect body composition changes due to aging. It should be noted, however, that small sample sizes among both subgroups may have limited statistical power.

An understanding of the aging process and its impact on body composition is critical given the link between body composition and chronic or terminal disease. Body composition changes are strongly associated with diabetes mellitus, cardiovascular disease, hypertension, hypercholesterolemia, stroke, cancer, osteoporosis, and premature death (Despres et al., 1990; Folsom et al., 1993; Pl-Sunyer, 1993).

The loss of height with age documented in this study may be indicative of a loss in spinal BMD. While the majority of postmenopausal women in the current study were using HRT, spinal bone loss has been shown to begin prior to menopause (Going et al., 1994) and additionally, HRT only delays rather than prevents the inexorable decline in bone mass.

Increased body weight, BMI, and % BF have all been linked to deteriorating health and premature mortality. Folsom et al. (1993) reported that as BMI increased in women so did the risk of death from chronic disease. Current American College of Sports Medicine (1995) guidelines state that health risks increase above a BMI of 25 kg/m². The mean BMI of the 27 women in the current study increased from 23.2 kg/m² in 1984 to 25.7 kg/m² in 1996. As a group, these women have become borderline health risks as defined by the BMI.

Of interest was the lack of significant ($p > .05$) change in the WHR with age. Recently, researchers have observed that central adiposity, as measured by an increase in WHR, is potentially more dangerous than evenly distributed weight (Folsom et al., 1993). A WHR above .86 is considered indicative of future health problems (American College of Sports Medicine, 1995). With a mean WHR of .76, the women in this study are well below the threshold established by the American College of Sports Medicine. It appears that women, as opposed to men, may deposit fat equally between the upper and lower body with age.

Without a doubt, the most surprising result of the current study was a significant ($p < .01$) increase in FFW from initial 1984 baseline levels. It was theorized that FFW would decline with age as the bulk of published research literature has suggested. It is proposed that FFW increased in response to an even greater increase in body weight. With additional fat deposition a small percentage of FFW may have been added in order to support the increased stress on the body.

Implications

Evidence from both the present study and several other investigations strongly supports the theory that aging has a detrimental impact on the body composition of women. This is particularly worrisome in light of the strong links between poor body composition and terminal diseases. Women would be well advised to adopt lifestyle habits which have been shown to lower body fat and maintain or increase fat free weight. Unfortunately, following a balanced, lowfat diet and adhering to a moderate exercise regime will not halt the aging process. However, such habits may well limit to some degree the age-related changes in body composition and reduce the risk of chronic disease or premature death.

Recommendations For Future Study

Longitudinal investigations into age-related changes in female body composition are rare. It is recommended that additional studies be performed as questions regarding the magnitude, rate, direction, and commencement of body composition changes have not been resolved. The women in the current study should continue to be followed in order to gain additional longitudinal data. In addition, further research should focus on the role

which such factors as diet, exercise, smoking, and HRT play in limiting the detrimental impact of age on body composition.

REFERENCES

- Aloia, J., McGowan, D., Vaswani A., Ross, P., & Cohn, S. (1991). The relationship of menopause to skeletal and muscle mass. American Journal of Clinical Nutrition, 53, 1378-1383.
- Aloia, J., Vaswani, A., Ellis, K., Yuen, K., & Cohn, S. (1985). A model for involutional bone loss. Journal of Laboratory Clinical Medicine, 106, 630-637.
- Aloia, J., Vaswani, A., Ma, R., & Flaster, E. (1995). To what extent is bone mass determined by fat-free or fat mass? American Journal of Clinical Nutrition, 61, 1110-1114.
- Aloia, J., Vaswani, A., Ma, R., & Flaster, E. (1996). Aging in women - the four compartment model of body composition. Metabolism: Clinical and Experimental, 45, 43-48.
- Aloia, J., Vaswani, A., Ross, P., & Cohn, S. (1990). Aging bone loss from the femur, spine, radius, and total skeleton. Metabolism, 39, 1144-1150.
- Aloia, J., Vaswani, A., Russo, L., Sheehan, M., & Flaster, E. (1995). The influence of menopause and hormonal replacement therapy on body cell mass and body fat mass. American Journal of Obstetrics and Gynecology, 172, 896-900.
- American College of Sports Medicine. (1995). ACSM's guidelines for exercise testing and prescription. (5th ed.). Baltimore, MD: Williams & Wilkins.
- Anderson, T., Brown, J., Hall, J., & Shephard, R. (1968). The limitations of linear regressions for the prediction of vital capacity and forced expiratory volume. Respiration, 25, 140-158.
- Baumgartner, R., Heymsfield, S., Lichtman, S., Wang, J., & Pierson Jr., R. (1991). Body composition in elderly people: Effect of criterion estimates on predictive equations. American Journal of Clinical Nutrition, 53, 1345-1353.
- Baumgartner, R., Stauber, P., Koehler, K., Romero, L., & Garry, P. (1996). Associations of fat and muscle masses with bone mineral in elderly men and women. American Journal of Clinical Nutrition, 63, 365-372.

Behnke, A., Feen, B., & Welham, W. (1942). The specific gravity of healthy men. The Journal of the American Medical Association, 118, 495-498.

Behnke, A., & Wilmore, J. (1974). Evaluation and regulation of body build and composition. Englewood Cliffs, NJ: Prentice Hall.

Bemben, M., Massey, B., Bemben, D., Boileau, R., & Misner, J. (1995). Age-related patterns in body composition for men aged 20-79 yr. Medicine and Science in Sports and Exercise, 27, 264-269.

Brozek, J., Grande, F., Anderson, J., & Keys, A. (1963). Densitometric analysis of body composition: Revision of some quantitative assumptions. Annals of the New York Academy of Sciences, 100, 113-140.

Burrows, B., Lebowitz, M., Camilli, A., & Knudson, R. (1986). Longitudinal changes in forced expiratory volume in one second in adults. American Review of Respiratory Disease, 133, 974-980.

Butts, N., Brewster, E., Van Ossbree, P., & Price, S. (1985). Effects of a 12-week weight training program on the body composition of women over and under forty years of age [Abstract]. Medicine and Science in Sports and Exercise, 17, 267.

Butts, N., & Price, S. (1994). Effects of a 12-week weight training program on the body composition of women over 30 years of age. Journal of Strength and Conditioning Research, 8, 265-269.

Chien, S., Peng, M., Chen, K., Huang, T., Chang, C., & Fang, H. (1975). Longitudinal studies on adipose tissue and its distribution in human subjects. Journal of Applied Physiology, 39, 825-830.

Despres, J., Moorjani, S., Lupien, P., Tremblay, A., Nadeau, A., & Bouchard, C. (1990). Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. Arteriosclerosis, 10, 497-511.

Durnin, J., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition, 32, 77-97.

Edelstein, S., & Barrett-Connor, E. (1993). Relation between body size and bone mineral density in elderly men and women. American Journal of Epidemiology, 138, 160-169.

Fahey, T., & Schroeder, R. (1978). A load-cell system for hydrostatic weighing. The Research Quarterly, 49, 85-87.

Fidanza, F., Keys, A., & Anderson, J. (1953). Density of body fat in man and other mammals. Journal of Applied Physiology, 6, 252-256.

Flynn, M., Nolph, G., Baker, S., Martin, W., & Krause, G. (1989). Total body potassium in aging humans: A longitudinal study. American Journal of Clinical Nutrition, 50, 713-717.

Folsom, A., Kaye, S., Sellers, T., Hong, C., Cerhan, J., Potter, J., & Prineas, R. (1993). Body fat distribution and 5-year risk of death in older women. The Journal of the American Medical Association, 269, 483-487.

Forbes, G. (1987). Human body composition: Growth, aging, nutrition, and activity. New York, NY: Springer-Verlag.

Frontera, W., Hughes, V., Lutz, K., & Evans, W. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. Journal of Applied Physiology, 71, 644-650.

Going, S., Williams, D., & Lohman, T. (1995). In J. Holloszy (Ed.), Exercise and Sport Sciences Reviews (pp. 411-458).

Going, S., Williams, D., Lohman, T., & Hewitt, M. (1994). Aging, body composition, and physical activity: A review. Journal of Aging and Physical Activity, 2, 38-66.

Hakkinen, K., & Hakkinen, A. (1991). Muscle cross-sectional area, force production and relaxation characteristics in women at different ages. European Journal of Applied Physiology and Occupational Physiology, 62, 410-414.

Heymsfield, S., Wang, J., Lichtman, S., Kamen, Y., Kehayias, J., & Pierson Jr., R. (1989). Body composition in elderly subjects: A critical appraisal of clinical methodology. American Journal of Clinical Nutrition, 50, 1167-1175.

Jackson, A., & Pollock, M. (1985). Practical assessment of body composition. The Physician and Sportsmedicine, 13 (5), 76-80; 82-90.

Jackson, A., Pollock, M., & Ward, A. (1980). Generalized equations for predicting body density of women. Medicine and Science in Sports and Exercise, 12, 175-182.

Jones, R., Overton, T., Hammerlindl, D., & Sproule, B. (1978). Effects of age on regional residual volume. Journal of Applied Physiology, 44, 195-199.

Kanehisa, H., Ikegawa, S., Tsunoda, N., & Fukunaga, T. (1994). Cross-sectional areas of fat and muscle in limbs during growth and middle age. International Journal of Sports Medicine, 15, 420-425.

Katch, F. (1968). Apparent body density and variability during underwater weighing. The Research Quarterly, 39, 993-999.

Keys, A., & Brozek, J. (1953). Body fat in adult man. Physiological Reviews, 33, 245-325.

Kohrt, W., Malley, M., Dalsky, G., & Holloszy, J. (1992). Body composition of healthy sedentary and trained, young and older men and women. Medicine and Science in Sports and Exercise, 24, 832-837.

Kuczmarski, R., Flegal, K., Campbell, S., & Johnson, C. (1994). Increasing prevalence of overweight among U.S. adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. The Journal of the American Medical Association, 272, 205-211.

Lesser, G., Deutsch, S., & Markofsky, J. (1980). Fat-free mass, total body water, and intracellular water in the aged rat. American Journal of Physiology, 238, R82-90.

Martin, A., & Drinkwater, D. (1991). Variability in the measures of body fat. Assumptions or technique. Sports Medicine, 11, 277-288.

Mazess, R., Barden, H., Ettinger, M., Johnston, C., Dawson-Hughes, B., Baran, D., Powell, M., & Notelovitz, M. (1987). Spine and femur density using dual-photon absorptiometry in U. S. white women. Bone and Mineral, 2, 211-219.

Mazess, R., & Cameron, J. (1974). Bone mineral content in normal U. S. whites. In R. Mazess (Ed.), International conference on bone mineral measurement (pp. 228-237). Washington, DC: U. S. Government Printing Office.

Morris, J., Mosk, A., & Johnson, L. (1971). Spirometric standards for healthy nonsmoking adults. American Review of Respiratory Disease, 103, 57-67.

Murray, L., Reilly, J., Choudhry, M., & Durnin, J. (1996). A longitudinal study of changes in body composition and basal metabolism in physically active elderly men. European Journal of Applied Physiology and Occupational Physiology, 72, 215-218.

- Niinimaa, V., & Shephard, R. (1978). Training and oxygen conductance in the elderly. I. The respiratory system. Journal of Gerontology, 33, 354-361.
- Pierson, R., Lin, D., & Phillips, R. (1974). Total body potassium in health: Effects of age, sex, height, and fat. American Journal of Physiology, 226, 206-212.
- Pi-Sunyer, F. (1993). Medical hazards of obesity. Annals of Internal Medicine, 119, 655-660.
- Schoeller, D. (1989). Changes in total body water with age. American Journal of Clinical Nutrition, 50 (Suppl.), 1176-1181.
- Schoenberg, J., Beck, G., & Bouhuys, A. (1978). Growth and decay of pulmonary function in healthy blacks and whites. Respiration Physiology, 33, 367-393.
- Shephard, R. (1978). Human physiological work capacity. London, England: Cambridge University Press.
- Shephard, R. (1993). Aging, respiratory function, and exercise. Journal of Aging and Physical Activity, 1, 59-83.
- Shimokata, H., Andres, R., Coon, P., Elahi, D., Muller, D., & Tobin, J. (1989). Studies in the distribution of body fat: II. Effects of change in weight. International Journal of Obesity, 13, 455-464.
- Shimokata, H., Tobin, J., Muller, D., Elahi, D., Coon, P., & Andres, R. (1989). Studies in the distribution of body fat: I. Effects of age, sex, and obesity. Journal of Gerontology, 44, M66-73.
- Silver, A., Guillen, C., Kahl, M., & Morley, J. (1993). Effect of aging on body fat. Journal of the American Geriatrics Society, 41, 211-213.
- Steen, B. (1988). Body composition and aging. Nutrition Reviews, 46, 45-51.
- Trappe, S., Costill, D., Vukovich, M., Jones, J., & Melham, T. (1996). Aging among elite distance runners: A 22-yr longitudinal study. Journal of Applied Physiology, 80, 285-290.
- Tremollieres, F., Pouilles, J., & Ribot, C. (1993). Vertebral postmenopausal bone loss is reduced in overweight women: A longitudinal study in 155 early postmenopausal women. Journal of Clinical Endocrinology and Metabolism, 77, 683-686.

van Leer, E., van Noord, P., & Seidell, J. (1992). Components of adult height loss. Secular trend and effects of aging in women in the DOM project. Annals of Epidemiology, 2, 611-615.

Wardlaw, G. (1996). Putting body weight and osteoporosis into perspective. American Journal of Clinical Nutrition, (Suppl.), 433-436.

Watson, P., Watson, I., & Batt, R. (1980). Total body water volumes for adult males and females estimated from simple anthropometric measurements. American Journal of Clinical Nutrition, 33, 27-39.

Wilmore, J. (1969). A simplified method for determination of residual lung volumes. Journal of Applied Physiology, 27, 96-100.

APPENDIX A
INTRODUCTORY LETTER

UNIVERSITY OF WISCONSIN-LA CROSSE

73

HUMAN PERFORMANCE LABORATORY

Nancy Kay Butts, Director

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February 15, 1996

Dear _____

Do you remember what you were doing 12 years ago this month? Believe it or not it has been that long since you participated in a strength training study at the University of Wisconsin - LaCrosse. If you remember as part of that study we measured your muscle strength and evaluated your body composition before and after 12 weeks of strength training. Although this study was one of the first to be conducted on women over thirty, additional research has demonstrated that weight training programs are beneficial to women of all ages.

We would like to invite you, a member of the original group, to participate in a unique follow-up study to determine the impact the past 12 years has had on your body composition and strength (i.e., how strong are you now? how has your body composition changed, etc.)? Unlike the original study we are not asking that you participate in a training program but we would simply like to repeat the same tests you completed for that study (i.e., measure your strength on the same exercises and determine your body composition through the underwater weighing procedure). Upon completing these tests we would provide you with copies of your original data as well as your current results for your personal comparison.

Unfortunately we have not been able to locate all the women so your participation is extremely important. Within the week you will be contacted by Bryce Williams, Mary Jo Soine or myself to further explain this project and answer any questions you might have. I greatly appreciated your time and effort in the past and would enjoy the opportunity to work with you again.

Sincerely,

Nancy Kay Butts, PhD

TIGHTLY BOUND

La Crosse, Wisconsin 54601
An Affirmative Action/Equal Opportunity Employer

APPENDIX B
QUESTIONNAIRE

NAME: _____ Date of Birth: ____/____/____

Address: _____ Telephone: _____ - _____

Height: ____ ft ____ inches Weight: ____ pounds Age: _____

Physical Activity Readiness Questionnaire (PAR - Q).

- YES NO 1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?
- YES NO 2. Do you feel pain in your chest when you do physical activity?
- YES NO 3. In the past month, have you had chest pain when you were not doing physical activity?
- YES NO 4. Do you lose your balance because of dizziness or do you ever lose consciousness?
- YES NO 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
- YES NO 6. Is your doctor currently prescribing drugs for your blood pressure or heart condition?
- YES NO 7. Do you know of any other reason why you should not do physical activity?

Explain:

Reference: PAR - Q American Medical Association: Guide to the Evaluation of Permanent Impairment, AMA, Chicago, 1990
(Modified Version - ACSM, 1995, p. 14)

Since your participation in the original study has a physician told you that you had any of the following?
(please check and give year of onset, if applicable.)

	NO	YES	Year of Onset
1. Coronary heart disease:			
a. Angina pectoris	_____	_____	_____
b. Myocardial infarction	_____	_____	_____
2. Heart arrhythmia	_____	_____	_____
3. Stroke	_____	_____	_____
4. High blood pressure	_____	_____	_____
5. Diabetes mellitus	_____	_____	_____
6. Chronic bronchitis/asthma	_____	_____	_____
7. Chronic back pain	_____	_____	_____
(diagnosis: _____)			
8. Arthritis	_____	_____	_____
(type: _____)			
9. Osteoporosis	_____	_____	_____
(related fractures: _____)			
10. Anxiety Disorder	_____	_____	_____
11. Depression	_____	_____	_____
12. Cancer	_____	_____	_____
(site: _____)			
13. Other major disease	_____	_____	_____
(specify: _____)			

1. What is your current menopausal status? Pre Peri Post
2. If you remember, what was your menopausal status during the original study? Pre Peri Post
3. Are you currently using hormone replacement therapy (HRT)? YES NO
 If YES, how long have you been on HRT? _____
4. Have you used hormone replacement therapy (HRT) in the past? YES NO
 If YES, approximately when were you on HRT? _____
5. Have you been on any weight loss programs since participating in the training study? YES NO
 If YES, when? _____
 how long? _____
 how much weight did you lose? _____
 how much, if any, did you regain? _____
6. Did you continue weightlifting immediately following completion of the training study? YES NO
 If YES, how long? _____
7. Have you participated in any weightlifting program in the past twelve years? YES NO
 If YES, when? _____ How long? _____ Where? _____
8. Are you currently involved in a weightlifting program? YES NO
 If YES, when? _____ How long? _____ Where? _____
9. Compared to other women your age, how **HEALTHY** do you consider yourself?
 a. very unhealthy b. unhealthy c. average d. healthy e. very healthy
10. How would you compare your **HEALTH** today to that 12 years ago **PRIOR** to participating in the original study?
 a. more unhealthy b. unhealthy c. average d. healthy e. more healthy
11. How would you compare your **HEALTH** today to that 12 years ago **AFTER** participating in the original study?
 a. more unhealthy b. unhealthy c. average d. healthy e. more healthy
12. Compared to other women your age how **PHYSICALLY FIT** do you consider yourself now?
 a. very unfit b. unfit c. average d. fit e. very fit

13. Relative to other women how would you classify your **PHYSICAL FITNESS** level 12 years ago **PRIOR** to participating in the original study?

- a. very unfit b. unfit c. average d. fit e. very fit

14. Relative to other women how would you classify your **PHYSICAL FITNESS** level 12 years ago **AFTER** participating in the original study?

- a. very unfit b. unfit c. average d. fit e. very fit

15. How would you compare your current **PHYSICAL ACTIVITY** level to that 12 years ago **PRIOR** to participating in the original study?

- a. considerably less b. less c. same d. more e. considerably more

16. How would you compare your current **PHYSICAL ACTIVITY** level to that 12 years ago **AFTER** participating in the original study?

- a. considerably less b. less c. same d. more e. considerably more

17. How many city blocks or equivalent do you walk **DAILY**? _____ (12 blocks = 1 mile)

18. What is your usual walking pace? (please check one)

- a. ____ casual, strolling (less than 2 mph) b. ____ average (2-3 mph)
c. ____ fairly brisk (3-4 mph) d. ____ brisk, striding (> 4 mph)

19. How many flights of stairs do you climb **DAILY**? _____ (1 flight = 10 steps)

20. What are your current exercise habits?

<u>Activity</u>	<u>Minutes/session</u>	<u>Days/week</u>
Walking	_____	_____
Running/Jogging	_____	_____
Aerobics	_____	_____
Swimming	_____	_____
Cycling	_____	_____
Other (describe)	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

21. When you are exercising in your usual fashion, how would you rate your level of exertion?

0 1 2 3 4 5 6 7 8 9 10

No Exertion Very Weak Weak Moderate Somewhat Strong Strong Very Strong Maximal

APPENDIX C
INFORMED CONSENT FORM

INFORMED CONSENT

A Longitudinal Study on Aging, Body Composition, and Muscular Endurance Changes in Women

Principle Investigators: N.K. Butts PhD, Bryce Williams & Mary Jo Soine

I, _____, being of sound mind and _____ years of age, do hereby voluntarily consent to participate in a follow-up study to determine changes in my body composition and muscular strength 12 years after participating in a 12-week weight training program. I will be asked to complete a health/activity questionnaire to determine my current and past health/physical activity patterns. In addition, I will have my body composition and muscle endurance measured using the same testing procedures I completed in the original project.

Body Composition - Hydrostatic weighing involves having my percent body fat determined through the underwater weighing technique. This procedure involves having my residual lung volume determined while breathing into a spirometer. I also will be required to have my weight determined while I am completely submerged underwater. When working in a water environment there is a risk of infection, accident and possible drowning. However, there has never been a serious accident or report of infection as a result of the hydrostatic weighing procedures in the HPL.

Muscle Endurance - My muscle endurance will be tested utilizing similar Nautilus weight lifting machines that were used during the original study. The actual testing to be conducted at the LaCrosse Family YMCA will consist of performing the maximum number of repetitions to volitional fatigue on the following machines: pullover (latissimus dorsi), upright chest (pectorals), multi-triceps, multi-curl (biceps), abdominal, hip and back (low back and gluteals), leg extension (quadriceps), and leg curl (hamstrings). The weight or resistance for these tests will be the same weight you used during the original tests. Although these are the same tests you completed 12 years ago you will be asked to participate in one or more practice sessions to become comfortable with the machines as well as review the proper lifting techniques.

Risks of participating in this part of the study include the possibility of muscle strain and/or muscle soreness as a result of the practice and testing session. These risks will be minimized by supervision and instruction in the proper lifting techniques and adequate rest periods between sessions. It should be noted, however, that some muscle soreness would be a normal occurrence.

The actual testing will be conducted by Mary Jo Soine and Bryce Williams, graduate students in the Adult Fitness/Cardiac Rehabilitation Masters Program who are certified in CPR. These students will be under the supervision of N.K. Butts, PhD. Muscle testing will take place at the YMCA and the body composition will be conducted in the HPL at UWL.

Upon completing the above tests I will be provided with information regarding changes in my muscular fitness and body composition from the initial study to compare to that obtained from this study. All individual data collected during this study will be kept confidential and only group data will be used in any written report.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with respect to my heart, that would preclude my participation in the exercise tests as described above. I have read the foregoing and I understand what is expected from me. Any questions which may have occurred to me have been answered to my complete satisfaction. I, therefore, voluntarily consent to be tested. Furthermore I know I may withdraw from these tests at any time.

Signed: _____ Date: _____

Witness: _____ Date: _____

APPENDIX D

SUMMARY OF RESULTS AND THANK YOU LETTER

UNIVERSITY OF WISCONSIN-LA CROSSE⁸¹

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Thank you for participating in our follow-up study on the changes in body composition and muscular endurance 12 years after completing the initial weight training study. Of the sixty-seven women who completed all aspects of the initial study in 1984, we were able to contact only 47 and 29 agreed to be retested. Unfortunately we were unable to locate the remaining 27.

Although we have yet to complete all the statistical analysis we thought you would be interested in knowing how your values compare to the group's. The average body composition measures are presented in Table 1 along with your specific values. As you can see the average body weight increased approximately 15.4 lbs or approximately 10%. Unfortunately there was a minimal increase in lean body weight but a substantial increase in percent body fat. The increase in total skinfolds corresponded to the increase in body fat.

The muscular endurance values are presented in Table 2 and are more encouraging. The majority were able to complete more repetitions this time than during the initial (pre) test but, as expected, less than immediately after the training (post-test). There were minimal decreases in the hip & back, leg extension, leg curls, pullovers, bicep and tricep curls exercises. In contrast, both the chest press and abdominal curls were dramatically reduced over the 12 years.

Again we would like to express our appreciation to each of you for taking the time out of your busy schedules to be tested. If you have any questions regarding your results etc. please feel free to contact me at 785-8177 or e-mail (BUTTS@mail.uwlax.edu).

Sincerely,

Nancy Kay Butts

Mary Jo Solne

Bryce Williams

ENCLOSURE

NAME: _____

Table 1. Your body composition values compared to the group's average

<u>Variable</u>	<u>Pre-Training</u>	<u>Post-Training</u>	<u>Follow-up</u>	<u>Follow-up Range</u>
Age (years)	41.0 _____	41.1 _____	53.1 _____	42 - 75
Weight (lbs)	136.8 _____	136.2 _____	151.8 _____	110 - 259
Percent Fat (%)	29.5 _____	27.0 _____	34.0 _____	23.1 - 47.5
Lean Body Weight (lbs)	95.3 _____	98.3 _____	98.8 _____	80.7 - 138.8
Sum of Skinfolds	89.6 _____	88.1 _____	110.2 _____	51.4 - 160.0

NAME: _____

Table 2. Average values for muscular endurance (maximum number of repetitions performed)

<u>Variable</u>	<u>Pre-Training</u>	<u>Post-Training</u>	<u>Follow-up</u>	<u>Follow-up Range</u>
Hip & Kneecap (gluteus)	9.79	23.79	21.93	5 - 67
Leg Extension (quadriceps)	9.31	16.27	13.31	5 - 23
Leg curls (hamstrings)	8.90	13.38	13.24	0 - 36
Chest Press (pectorals)	9.10	21.88	16.96	0 - 60
Pullovers (Latissimus dorsi)	9.28	18.00	15.21	0 - 27
Abdominal Curl	9.21	23.69	14.31	3 - 40
Bicep Curl	8.97	17.76	16.72	7 - 42
Tricep Curl	8.59	17.93	14.07	0 - 31