MUSCLE MASS LOSS IN ACTIVE ADULTS

By:

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Submitted to the Faculty of the University Graduate School
in partial fulfillment of the requirements
for the degree
Master of Science
in the Department of Kinesiology of the School of Health, Physical Education, and Recreation
Indiana University
December 2009

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Joel M. Stager, for his support and guidance throughout my education. His knowledge, advice, and motivation cultivated my curiosity. His encouragement throughout my academic tenure has been invaluable. I am truly grateful to him for allowing my learning style to grow into academic success.

I would like to thank my Indiana family-- Andrew Cornett, Mindy and Barry King, Louisa Raisbeck, Kristy Streefkerk and Brian Wright—whose support, laughter and perspectives were saving graces.

A special thank you to Louisa Raisbeck. Her friendship, data collection support, and collaboration enabled my research, and made the process a pleasure.

Thank you to Sandy Tecklenburg-Lund for her guidance with creatinine assays and expertise during data collection. Her tutelage made possible my reign as "Pee-queen."

I would like to thank Jonathon Stickford for his involvement with data collection and for helping me solve what seemed impossible. His was a voice of reason when things seemed most unreasonable.

Many students studying in the Exercise Physiology program volunteered their time to help with data collection. I am truly grateful for their willingness to wake early for science.

Thank you to Dr. Dave Tanner, Nan Stager, and Dr. Stager for their membership on the research team in California. Their help made the project possible.

Thanks goes to the entire Worlds research team for their willingness to travel on short notice; and their generosity—taking 7 days for the vacation without a vacation. The experience was often challenging—we put the project together in 36 hrs—and would not have been as fulfilling nor successful without their involvement.

I am grateful to Carol Kennedy-Armbruster, whose initial motivation for graduate school, guided me to where I am today; and for countless hours listening, counseling, and leading.

Additional thanks goes to the FINA world Masters Swimming Championship committee and the United States Masters Swimming Endowment Fund for the financial support to make this project possible.

Finally, I would like to thank my family for their continued love and support. This process was not easy for me—and so, likewise, for those who care about me. They were full of support and encouragement. Home was always a reprieve when I needed it.

ABSTRACT

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TITLE: MUSCLE MASS LOSS IN ACTIVE ADULTS

PROBLEM: It is generally concluded that muscle mass declines with increasing age. Most of the research in this area is focused on the general population which is largely sedentary. The purpose of this study was to examine the muscle mass of highly active adults using several independent methods.

METHODS: 167 women aged 50.91 +/- 14.03 yrs and 219 men aged 52.08 +/- 13.45 yrs underwent body composition analysis via 8-lead bioelectric impedance analysis, anthropometric measurements to assess limb circumference, and 24 hour creatinine clearance. Comparative data for the general population (GP) was obtained from the Baltimore Longitudinal Study of Aging, National Health and Nutrition Examination Survey III and The American College of Sports Medicine and Center for Disease Control recommended physical activity guidelines. Highly active subjects were all masters swimmers and a priori categorized as highly active (USMS). To verify this, the USMS were found to participate in 447 min/wk of moderate to vigorous physical activity which was much greater than 150 min/wk reported for the GP.

ANALYSIS: Muscle mass was the primary the dependent variable. Single sample t-tests were used to examine muscle mass differences between groups separated by age and sex. Linear regression analysis was used to describe the trend of muscle mass versus age.

RESULTS: USMS women had more muscle mass than GP in the 30-39, 40-49, 50-59, 60-69, & 70-79 age groups. Y-intercepts were significantly ($p < .05$) different for both sexes between the highly active and general population. No significant differences were found for between men

USMS and GP in 30-39, 40-49, 50-59, & 80 + age groups. Linear regression analysis of the USMS men and women yielded losses of approximately 0.3 lbs per year.

DISCUSSION: Highly active subjects participated in significantly greater amounts of dedicated physical activity per week when compared to values available for the general population (NHANES III). Comparisons of the muscle mass slopes yielded no differences between the GP and the USMS. Muscle mass loss occurs at similar rates in both populations. Importantly, and specifically, in the USMS women, muscle mass is greater any given age. However, this was not true for the USMS men. Intensive activity may combat many problems associated with losses in muscle mass, especially those within older women. Why this is not evident in the men requires additional research.

Table of Contents

ACKNOWLEDGEMENTS ii

ABSTRACT iv

List of Figures viii

List of Tables ix

Chapter

1. INTRODUCTION 1

Problem Statement 1

Purpose 2

Significance of the Study 2

Hypotheses 3

Delimitations 4

Limitations 4

Assumptions 5

Definition of Terms 5

2. REVIEW OF LITERATURE 7

Aging 7

Inactivity: Characteristics associated with the inactive 9

Physical Activity 12

Aging and Hypokinesis 14

Aging and Exercise 15

3. METHODOLOGY 24

Selection of Subjects 24

Research Design 25

Instrumentation..25

Data Analysis 26

Subject Testing...26

4. RESULTS...29

5. DISCUSSION...40

REFERENCES..43

APPENDICES 52

a. Physical Activity Questionnaire and medical history..54

b. Urine Collection Procedures 81

c. Institutional Review Board Documentation..83

d. Data Collection Sheet 87

e. Raw Data..89

VITAE 96

List of Tables

Table 4.1 USMS Men's anthropometric measurements 30

Table 4.2 USMS Women's anthropometric measurements 30

Table 4.3 USMS men's and women's muscle mass analysis for each age group 31

Table 4.4 Muscle mass results of USMS and GP men and women from BIA analysis..........33

Table 4.5 Muscle mass results of USMS and GP men and women from creatinine analysis 33

Table 4.6 Muscle mass results of USMS and GP men and women from corrected girth analysis 33

Table 5.1 National averages of physical activity participation by sex 40

Table 5.2 Body composition differences in untrained and trained men.................................40

List of Figures

Figure 4.1 USMS subject distribution by age groups for men and women 31

Figure 4.2 Activity profiles of USMS and GP...31

Figure 4.3 Men's muscle mass comparisons from BIA 34

Figure 4.4 Women's muscle mass comparisons from BIA 35

Figure 4.5 Regression analysis of men's muscle mass (as measured by BIA) vs age 37

Figure 4.6 Regression analysis of women's muscle mass (as measured by BIA) vs age 38

Chapter 1

INTRODUCTION

Decreases in muscle mass and strength can lead to loss of mobility, independence, and functional capacity in aging individuals. Physical activity is one key element in minimizing the age associated strength loss. As physical activity levels decrease over time, muscle mass is lost leading to a decrease in muscular strength (Roubenoff, 2000; Doherty 2000 & 2003). Roubenoff (2000) states muscular strength decreases at a rate of 1% per year after the age of 30. As much of 50-60% of muscular strength can be lost before it is noticed, this usually occurring in the 6^{th} and 7^{th} decades of life (Roubenoff, 2000). Muscular endurance is also affected by these losses since an individual's aerobic capacity is likewise diminished (Kirkendall and Garrett, 1998). The following chapter includes: (a) Problem Statement, (b) Hypothesis, (c) Significance of the Study, (d) Delimitations, (e) Limitations, (f) Assumptions, and (g) Definition of Terms.

Problem Statement

The focus of the study is to examine the muscle mass of an active aging population. Past research assessing sarcopenia issues has been performed on sedentary populations. This research identifies muscle mass in a chronically physically active aging population. Swim training is mostly interval training comprised of high and low intensities with varying bouts of work and rest (Counsilman & Counsilman, 1994). The sample consists of subjects 20-80 years in age, whom, on average has been engaged in nearly routine swim training for 15+ years.

Purpose

Sarcopenia causes a loss of independence, strength, functionality, and mobility in older adults. Decreases in muscle mass lead to decreases in muscular strength and therefore negatively impact aerobic capacity. Regular lifetime exercise is a means to preventing sarcopenia from occurring. The following study compares a highly active population with the general population. The highly active population exercises minimally from 3-7 days a week, for at least one hour at a time while the general population is known to be much less active, exercising less than four days and fewer than three hours of physical activity per week (NHANES III).

Significance of the Study

Many age-related outcomes have been identified specific to different systems, some, but not all, are associated with disease states. This review seeks to gather information about aging, physical activity, muscle mass, and the decreases in muscle mass associated with aging and low levels of physical activity.

Neuromuscular function declines as a factor of increasing age (Doherty, 2001 & 2003; Nair, 1995; Roubenoff, 2003). It is well documented that skeletal muscle mass decreases and is associated with a concomitant decline in muscular strength (Doherty 2001 & 2003; Nair, 1995; Roubenoff, 2003). Muscle strength declinations occur at rates of about 10-15% per decade after the age of 30 without training. By 60-70 yr, the rates of loss increase per year and persons typically have 50% less strength compared with younger adults (Doherty, 2001). Similarly, decreases in muscle mass occur rapidly. Studies have shown that as much as a 40% decline in muscle cross sectional area can occur from ages 20 to 40 yr or about 1% per year in an adult American population (Doherty, 2001). It has been suggested that structural and functional losses impact mobility, balance and coordination. Muscular strength contributions to structural and functional abilities are integral components for maintaining functional independence (Doherty, 2001).

In addition to the loss in skeletal muscle cross sectional area, aging induces an increase in fat and connective tissue surrounding the muscles. A negative correlation has been found with the amount of physical activity and the amount of non-muscle tissue (Doherty, 2001). Therefore, activity levels can increase or keep muscle quality consistent as aging occurs (Doherty, 2003).

Hypotheses

1. An aging population can be identified that exceeds the minimal daily physical activity recommendations set forth by the American College of Sports Medicine (ACSM) and The Centers for Disease Control (CDC).
2. Active individuals (USMS) have more muscle mass than the general population (GP).
    a. Men USMS have more muscle mass than men GP
    b. Women USMS have more muscle mass than women GP
3. Young USMS men have more muscle mass than old USMS men
4. Young USMS women have more muscle mass than old USMS women

Delimitations

The delimiting factors of the study are as follows:

1. Subjects were men and women registered with United States masters swimming.
    a. Subjects participating in muscle mass measurements were aged 20-89 yrs old.
2. Subjects completed a questionnaire to eliminate those with COPD, heart conditions, or any other medical condition which these tests may be harmful or detrimental to their health.
3. Subjects completed a questionnaire to describe training status, years involved in the sport, the level of competitiveness.

4. Subjects had muscle mass analyzed by a 24 urinary collection measuring for urinary creatinine: this includes a three-day meat free diet.

Limitations

The limitations of the study are as follows:

1. Subjects are North American Caucasians.
2. Subjects are USMS registered swimmers.
3. Masters swimmers represent a relatively high socioeconomic cohort.
4. Masters swimmers represent a highly educated cohort.
5. Subjects were self selected.

Assumptions

1. As per the literature (Heymsfield *et al*. 1983) the ratio of muscle mass to creatinine excreted is 20 kg skeletal muscle mass per 1 gram creatinine excreted. This is true regardless of age, sex, nutrition, and physical activity. Subjects did not have some pathology of disease that caused accelerated rates of creatinine clearance.
2. Subjects followed procedures for 24 hr urinary collection properly.
3. Subjects truthfully answered questionnaires.
4. Subjects were of sufficient hydration status when BIA analysis completed.
5. Subjects abstained from vigorous exercise 12 hr prior to BIA measurement.
6. Subjects abstained from alcoholic beverages 48 hr prior to BIA measurement.
7. Subjects voided completely before the assessment
8. Subjects abstained from eating or drinking within 4 hours of the assessment
9. Subjects did not ingest any diuretic agents, including caffeine, prior to the assessment unless prescribed by a physician.

Definition of Terms

Aging: A chronological increase in age characterized by declines in all organ systems in the body ultimately leading to death (Kirkendall and Garrett, 1998).

Bioelectrical impedance analysis: The conduction of an applied electrical current to index conductor volume (muscle mass) (Lukaski, 1997).

Cross-sectional muscle area: The area of a two dimensional slice of muscle (Trappe, 2001).

Endurance: The capacity of skeletal muscle to engage in continuous activity (Wilmore & Costill, 2004).

General Population: The control populations from the literature used as comparison groups in this study (Gallagher *et al.* 1997; Haskill *et al.,* 2007).

Highly Active: As defined by this study, individuals that perform weekly activity $\geq \overline{x}_{\text{USMS}} + 1$ std dev; $\overline{x}_{\text{USMS}} = 579$ min/wk.

Meat-free diet: Nutrition of daily living that is void of any products of meat (e. g. beef, pork, poultry, fish) (Heymsfield *et al.,* 1983).

Moderate Activity: As given by the seven day activity recall in this study "sports such as golf or doubles tennis, yard work, heavy house cleaning, bicycling on level ground, etc."

Physical Activity: bodily movement that is produced by the contraction of skeletal muscles and that substantially increases the amount of energy expended (USDHHS, 1996).

Resistance Exercise: exercise involving the exertion of force against a load used to develop muscle strength and endurance and/or muscle hypertrophy (Brown, Miller & Easton, 2006).

Sarcopenia: The decline in muscle mass and strength that occurs with aging (Roche, 1994).

Sedentary: Applied to a person who is relatively inactive and has a lifestyle characterized by a lot of sitting (Oxford Sports Medicine Dictionary, 2006).

Segmental: Partitioning the body into separate compartments, rather than as one whole unit (Pietrobelli *et al.,* 2004).

Strength: The ability of skeletal muscle to produce or oppose force (Brooks *et al.,* 2000).

Vigorous Exercise: As given by the seven day activity recall in this study, "jogging or running, swimming, strenuous sports such as singles tennis or racquetball, digging in the garden, chopping wood, brisk walking, etc."

Chapter 2

REVIEW OF LITERATURE

Literature relating to aging and exercise is presented in this chapter. Topics for this chapter include: (a) Aging, (b) Inactivity: Characteristics associated with the inactive, (c) Physical Activity (d) Aging and Hypokinesis, and (e) Aging and Exercise. This review seeks to gather information about aging, physical activity, muscle mass, and the changes in muscle mass associated with aging and physical activity.

Aging

What is aging? Aging can be defined in many ways, from simply 'getting older' to the complex physical and mental deterioration which ultimately lead to death (Hooyer and Rodin, 2008). A few researchers suggest differing views on aging but most agree that losses are deteriorative leading to death. Typically aging is characterized by declines in function in all organ systems of the body (Kirkendall and Garrett, 1998).

Through research, scientists have classified aging into different categories. Rowe and Kahn (1997) describe three main aspects of aging; most importantly the characteristics of *successful* aging: 1) low probability of disease or disability including minimal or absent risk factors for disease, 2) high cognitive and physical functioning capacity, and 3) active engagement in life. Each characteristic is multi-dimensional, having specialized components which allow for an intricate analysis of human behavior(s). Low probability of disease or disability refers not only to the disease itself but the number of risk factors, and the severity of the disease for which the factors are risks (Rowe & Kahn, 1997). Physical and cognitive capacity refers to the potential of the individual to perform daily functions and typical tasks. A reserve functional capacity generally exists above that required to perform these daily functional tasks (Rowe & Kahn, 1997). A lifetime of physical inactivity can reduce or eliminate this reserve. These factors are part of an optimal aging perspective. However, normal or usual aging and successful aging are not one in the same. More frequently they are quite different.

With increasing age, compromises in physiologic capacity are often assumed to be inevitable and unavoidable. However, Waldron *et al.,* (1982) notes that many of these assumed "age-intrinsic" compromises are the result of cultural changes in diet, exercise, and nutrition. Increased consumption of processed foods, decreases in physical activity, and decreased consumption of raw fruits and vegetables have been observed in western society (Waldron *et al.,* 1982). These decreases are not seen in pastoral and traditional agricultural societies (Waldron *et al.,* 1982). This may lead one to assume these deteriorations are preventable rather than inevitable.

Typically increases in cardiovascular risk factors such as blood pressure, body weight, and serum cholesterol levels are deemed inevitable with increasing age. However, research has shown modifications with diet and exercise can help and prevent these increases (Rowe & Kahn, 1997).

Many habitual, cultural, and societal situations impact a person on a highly preventable level (Waldron *et al.*, 1982). Decreases in bone-density, muscle mass, and body composition are preventable and modifiable based on alterations in activity type and patterns (Rowe & Kahn, 1997). Activities of daily living have been replaced by machines or by sedentary behavior. Rather than using the body to climb flights of stairs, machines do the work. The decrease a gradual decrease in activity over time allows the body to lose the adaptations once gained to sustain the stress of activity. Researchers are consistent with findings that most of the age associated increases in risk factors (such as carbohydrate intolerance) are due to self inflicted behaviors of which many are modifiable (Rowe & Kahn, 1997). Decreases in lean body mass, total body mass and increases in body fat are typical with aging; these can all be modified or prevented by physical activity.

Inactivity: Characteristics associated with the inactive

Hypokinesis, hypo meaning deficient or less than normal, and kinesis, meaning movement or motion, is a lack, or insufficient amount of, regular exercise or movement of the body (Webster, 1990). Daily activity and energy expenditure typically decreases with advanced age. As a result of decreased activity, the body no longer has a stimulus to which it must adapt. Rather, the body is lacking a stimulus to balance anabolism and catabolism. Just as the body makes adaptations to increases in physical activity, the opposite is true. Increases in oxidative enzymes from endurance training will revert to pre-training values. Decreases in neuromuscular activity induce changes toward a more glycolytically based energy metabolism (Hollozy & Coyle, 1998).

Similarly, muscle fibers can change from slow to fast with decreases in neuromuscular activity, immobilization, microgravity, or mechanical unloading. These fiber type changes are also accompanied by muscular atrophy from decreased protein synthesis (Pette, 2005). Type II fibers are more involved in this process than type I fibers. However in micro-gravity, type I fibers do not have the constant gravity stimulus; thereby similar changes are apparent in both types of muscle fibers (Pette, 2005). It has been concluded by a number of researchers that immobilization contributes to the increase in the percentage of type II fibers and concomitant decrease in the percentage of type I fibers; this shift tends to make the muscles "faster" (Hortobagyi, 2000).

D'Antona *et al*., (2003) used 3.5 months immobilization of the left leg to study fiber type changes in the elderly. The three groups of comparison were young (30 $\pm$ 2.2 yr) n=7, elderly (72.2 $\pm$ 2.3 yr) n=7 and elderly with immobilization (70 and 75) n = 2. Consistent with previous research, the immobilized limbs showed a shift in myosin heavy chain (MHC) isoforms from type I to type II. Elderly immobilized subjects' muscle fiber type shifted towards a predominantly fast phenotype. Similarly, fiber type distribution also yielded the same response, showing a shift in MHC isoforms from type I to type II (D'Antona *et al.,* 2003). Research is unclear as to the mechanism behind the changes. Typically, aging results in a shift towards a fast phenotype in skeletal muscles due to from disuse. Fiber type composition of the young subjects was significantly different from the elderly and the elderly immobilized (D'Antona *et al.,* 2003). Specifically, young subjects had more type I fibers with significantly more isoform MHC-2a and significantly less of isoform MHC-2x (D'Antona *et al.,* 2003). The level of MHC-2a significantly decreased from young to both elderly groups, with elderly immobilized yielding MHC-2a, the lowest proportion of the muscle (D'Antona *et al.,* 2003). The immobilized group's MHC isoform composition was the highest in MHC-2x and the lowest in MHC-2a and MHC-1 (D'Antona *et al.,* 2003). In addition to phenotype shifts, muscle fiber size decreased (D'Antona *et al.,* 2003).

The shift of muscle fiber distribution from slow to fast is common with disuse, and often demonstrated in aging subjects (D'Antona *et al.,* 2004; Pette, 2005; Trappe, 2001). Conversely, the shift from preferential denervation of fast twitch motor units with aging contributes to a slower phenotype in the muscle (D'Antona *et al.,* 2004; Hortobagyi *et al.,* 2000). Both of these adaptations are highly dependent upon the individuals' activity and health status rather than simply associated with the aging process. Type I fibers are preferential for maintaining posture and withstanding gravity and type II fibers allow for maximum strength and quick response (Pette, 2005). A denervation of the type II fibers would in turn make the muscles “slower” and ultimately weaker. On the contrary, with a decrease in type I fibers the muscles are “faster” albeit faster to fatigue and less likely to endure activities such as standing for long durations. Type I fibers are also smaller; the decreased fatigability of the muscle fibers is a benefit of a predominant slow phenotype. The authors (D’Antona *et al.,* 2004; Deschenes, 2004; Hortobagyi *et al.,* 2000) note that disuse such as immobilization promotes a shift towards a faster phenotype whereas denervation promotes the opposite, a shift towards slower phenotype.

The difference in the two shifts maybe preferential as with immediate immobilization it is essential the organism move. Thus, the requirement for initial movement post-immobilization is in short fast bursts. As the muscle becomes accustomed to movement, adaptations occur allowing the muscle to withstand longer durations of exercise. In the study at hand, D’Antona *et al.,* 2004, the muscles of the immobilized subjects contained neonatal MHC isoforms indicative that muscle fiber regeneration was occurring. Regeneration can innervate new muscle fibers allowing for differentiated motor unit recruitment and firing, thus giving the individual greater control, strength and endurance (D’Antona *et al.,* 2004).

It is evident from research that aging changes the isoform distribution of muscle fibers (D’Antona *et al.,* 2004; Deschenes, 2004; Hortobagyi *et al.*, 2000; Pette, 2005). Similarly, immobilization alters the composition of muscle fibers distribution and muscle isoforms. Research by D’Antona and colleagues shows that with extreme disuse, muscle down regulates type I fibers and isoforms. Type II fiber size decreases with immobilization whereas losses in strength are not equivalent to muscle mass loss. Disuse seems to shift the muscle towards faster isoforms, whereas aging with ambulation shifts to slower muscles (type I muscle fibers and isoforms) (D'Antona *et al.,* 2004; Deschenes, 2004; Hortobagyi *et al.,* 2000; Pette, 2005).

Physical Activity

Stress is the nonspecific response of the body to any demand made upon it (Selye, 1975). Generally, adaptations to training increase the body's ability to handle stress for extended periods of time. In other words, stress requires adaptation. Adaptations allow an individual to handle training for longer durations based upon the frequency, intensity and duration of the training.

Humans started out as a nomadic species spending most of their lives moving, involved in daily physical activity (Haviland, 2008). Physical activity or exercise can be divided into two categories: dynamic (endurance exercise) and resistance (strength exercise) (Brooks, 2000; Bompa, 1999). These two categories are not completely exclusive from one another. However, each has its own specific demands it places on the body. Thus, specific training yields adaptations for each specific stimulus.

Some physiologic adaptations from aerobic training include: decreased resting heart rate, increased stroke volume, increased cardiac output, lower resting blood pressure, increased total blood flow to the body, increased mitochondrial density, increased capillary density, increased aerobic enzyme activity, and increased a-vO_2 difference (Brooks *et al.,* 2000; Hollozy and Coyle, 1984). Metabolic adaptations allow for increased utilization of phosphate-rich energy sources (Pette, 2005). These metabolic adaptations seem to reserve carbohydrate energy sources by utilizing fat oxidation for energy (Brooks *et al.*, 2000; Pette, 2005). Moderate changes in activity induce metabolic changes whereas increases beyond induce fiber type changes (Pette, 2005).

Usually, increases in persistent contractile activity of the skeletal muscle can induce changes of some (type IIa) fast fibers to that of the slow fibers (type I) (Pette, 2005).

In order to examine the adaptations of skeletal muscle to endurance exercise, Hollozy and Coyle (1984) used trained rats. Endurance exercise training induces an increase in the mitochondrial content of skeletal muscle as demonstrated in rats. It was concluded in order for large training effects to take place; training must be progressively increased beyond the capacity of the untrained state (Hollozy and Coyle, 1984). This must occur or the stimulus for adaptation will not be present (Hollozy and Coyle, 1984). Biopsied rat gastrocnemious muscle produced a doubled increase of the mitochondrial capacity to oxidize pyruvate (Hollozy and Coyle, 1984). Similarly, succinate dehydrogenase, NADH dehydrogenase, NADH-cytochrome *c* reductase, and cytochrome oxidase activities per gram of muscle increased twofold in the exercising rats (Hollozy and Coyle, 1984). All of these adaptations combine to increase the oxidative capacity of the muscle.

Studies of rats and some with humans confirm that the increase in mitochondrial capacity is a result of increased mitochondrial size and quantity (Hollozy and Coyle, 1984). Additionally, these studies have shown adaptations to exercise including increased capacity to oxidize fatty acids, ketones, and pyruvate (Hollozy and Coyle, 1984). Overall, endurance training increases mitochondrial function via increasing the levels of the enzymes responsible for aerobic and anaerobic glycolysis. For instance, mitochondrial adaptations of humans whom have been training for years (6-20yr) maintain higher than normal values of mitochondrial enzymes after a 12 week period of inactivity (Hollozy and Coyle, 1984). The subjects underwent a period of inactivity and still showed elevated mitochondrial enzyme levels (Hollozy and Coyle, 1984). Presumably, the enzyme levels remained elevated after a period of inactivity due to years of chronic endurance exercise. These muscular adaptations seem to be mediated by the contractions of the muscles used in the activities; specifically by muscle fiber recruitments during exercise. Increasing stress on the body is not limited to the changes seen with aerobic training; different muscular changes are seen with resistance exercise.

Resistance training can be defined as training to increase strength, power, and muscular endurance. Just as with endurance training, many physiologic changes are inevitable with this type of training. Adaptations to resistance training include synchronization and recruitment of additional motor units, increased rate coding of motor units, muscle hypertrophy, increased number of muscle fiber isoforms. Many of these adaptations are a result of muscles' myoplasticity, specifically altered gene expression, which up-regulates specific muscle isoforms or alters protein synthesis and degradation (Brooks, 2000).

Aging and Hypokinesis

Hypokinesis can cause serious detriments to the body as noted previously, bed rest and immobilization studies are extreme examples of this lack of physical activity. Hypokinesis can be the result of many different factors: disease, injury, or free-will. It is common for physical activity to decrease with age, however it is not certain. Decreases in regular physical activity can lead to decreased strength, mobility, overall health, independence, among other things. Many of the characteristics associated with hypokinesis can be reversed or attenuated with an increase in physical activity. However, with advanced age other confounding variables can make the reversal process complex and possibly unattainable. It is of great importance to curb behaviors which promote hypokinesis thereby preventing the decline of functional capacities.

One specific decline in functional capacity with increased age is that of the neuromuscular system (Doherty, 2001 & 2003; Nair, 1995; Roubenoff, 2003). It is well documented that skeletal muscle mass decreases with increased age and is associated with a concomitant decline in muscular strength (Doherty 2001 & 2003; Nair, 1995; Roubenoff, 2003). Doherty (2001) states that the structural and functional losses impacting mobility, balance, and coordination are integral components of maintaining functional independence. Muscle strength declinations occur at rates of about 10-15% after the age of 30 without training (Doherty, 2001). By 60-70 yr, the rates increase and persons typically have 50% less strength compared with younger adults (Doherty, 2001). Similarly, decreases in muscle mass occur rapidly. Studies have shown that as much as a 40% decline in muscle cross sectional area can occur from ages 20 to 40 yr (Doherty, 2001). In addition to the loss in skeletal muscle cross sectional area, aging induces an increase in fat and connective tissue surrounding the muscles. A negative correlation has been found with the amount of physical activity and the amount of non-muscle tissue (Doherty, 2001). Thus, physical activity can increase or maintain muscle quality as aging occurs (Doherty, 2003).

Aging and Exercise

The word "aging" is commonly interchanged with "senescence" meaning declining ability to respond to stress, increasing homeostatic imbalance, and increased risk of disease. If this alternate definition is used, many of the changes normally associated with aging fall into a category of the body's reduced ability to respond to stress. Physiologically, many changes take place in response to stress and can revert with removal of the stimulus. For instance, cardiac output declines with increased age mainly due to a decreased stroke volume. With endurance exercise, there is an increase in stroke volume, blood volume, and ultimately cardiac output (Brooks *et al.*, 2000).

In order to examine adaptations seen in endurance trained adults, Kasch and Wallace (1976) tested sixteen men (initially aged 32-56 yr) over a ten year period. The subjects trained running or swimming at or above 60% of VO_2 max for all exercise sessions. The average exercise session occurred three times a week lasting 59 minutes each at an intensity of 86% of VO_2 max. No changes were observed in body weight, resting HR, or resting BP. Mean VO_2 max was stable absolute (3.376 and 3.303 L/min) and relative (43.7 and 44.4 ml/kg/min) pre and post, respectively. The authors conclude that with adequate maintenance of training at appropriate work intensities, VO_2 max can be maintained over a 10 year period (Kasch and Wallace, 1976).

Similarly, Heath *et al.,* (1981) sought to compare young and old endurance athletes. The purpose of this study was to obtain insights regarding the effects of aging in individuals who maintain a high level of physical activity. Subjects were 32 men: 16 masters athletes aged 50-72 yr, and 16 young athletes aged 18-27 yr. Masters athletes were active in age-group competition and the young athletes were competing for local colleges and athletic clubs. Each group had one cyclist and 15 middle and/or long distance runners. The subjects were matched with regard to their habitual exercise programs by either: a) miles run or bicycled per week, b) training intensity relative to VO_2 max, or c) best performance times in the same events at approximately the same age. Another group of middle aged men were recruited to be untrained controls containing nine who had greater body fat than the masters athletes, and nine who were of the same body composition as the masters athletes. Subjects underwent VO_2 max, body composition, echocardiography, and blood pressure tests.

Results showed masters athletes to have significantly ($p < .05$) lower % body fat than both the untrained groups. There were no differences between masters and young athletes' % body fat and lean body mass. Untrained subjects had significantly higher lean body weight than the masters athletes; however this is confounded by their significantly higher body mass. Both groups of athletes had significantly lower heart rates at rest and during submaximal exercise than either group of untrained subjects. Blood pressure was significantly higher in the untrained group. There were no differences between lean untrained men and the masters athletes at rest or during exercise. The masters athletes and the untrained middle-aged men had significantly lower maximum heart rates than the young athletes. Similarly, VO_2 max was 15% lower in the masters athletes than in the young athletes. The masters athletes had a significantly higher VO_2 max than either of the untrained groups. Thus, these athletes have a greater capacity for work than do untrained individuals of the same age. However, as demonstrated by athletes and non-athletes alike, there appear to be inherent decreases seen with increased age.

The findings of this study conclude that if physical activity and body composition are kept constant, deterioration due to the aging process results in a decline in VO_2 max of 5% per decade. This is primarily due to a slowing of maximal heart rate. Maximum cardiac output decreases with increasing age; this has been attributed to decreased stroke volume and heart rate. The endurance athletes of this study, both young and old, exhibited common adaptations to endurance exercise. However, the old athletes had a lower VO_2 max, maximum heart rate, a higher systolic blood pressure during submaximal exercise and a slightly larger left ventricular volume than young athletes. Echocardiography did not show that aging or training appeared to have an effect on left ventricular contractile function at rest (Heath *et al.,* 1981). It is evident that with training muscle mass can be maintained and depending on the type of training it can be increased (Heath *et al.,* 1981).

Additionally, Stratton *et al.,* (1994) examined the response of the heart to exercise. The purpose of the study was: (a) to determine whether rigorously screened sedentary healthy older men do have altered ejection fraction and cardiac volume responses to exercise compared with healthy young men (b) to determine whether aging alters cardiac adaptations to endurance training in men. Two groups of men: 11 young men aged 24-32 years, mean age 28 $\pm$ 3 years, and 13 older men aged 60 to 82 years, mean age 68 $\pm$ 6 years, were rigorously checked for occult disease and all of whom were healthy volunteered for the study. Subjects were tested before and after a 6 month training program which was initially based at 50% to 60% of heart rate reserve and increased to 80-85% by the third or fourth month and continued thereon for the continuation of the training. The program consisted of walking, jogging, and bicycling for 45 minutes four or five times a week, while under supervision. Aerobic capacity was measured with a VO_2 max test on the treadmill following the Bruce protocol. VO_2 max increased by 21% in the older men and 17% in young men and peak work rate increased by 24% and 28% in the older men and younger men, respectively.

The main findings of this study are that age-related differences exist in cardiovascular responses to supine exercise. These differences comprise a decline with aging in peak exercise heart rate, ejection fraction, stroke volume, and cardiac index. There is an increase with aging in blood pressure and cardiac dilation with exercise. Additionally, endurance exercise training alters cardiovascular function similarly in old and young men (when comparing a single bout of exercise). Decreases in β-adrenergic responsiveness with aging can account for decreased responsiveness to exercise for the older men. Specifically, reduced ejection fraction, peak ejection rate, and cardiac output values for the older men confirm earlier investigations of age-associated decreased responsiveness to β-adrenergic stimulation with isoproterenol. The decreased responses in the older men are clarified by the change in β-adrenergic response during exercise with age (Stratton *et al.*, 1994). The authors found that the cardiovascular systems of the old and young men responded similarly to the exercise training (Stratton *et al.*, 1994). The authors note that most of the decreases seen with aging are also seen with inactivity (Stratton *et* *al.*, 1994). Furthermore, many decreases with advancing age can be reversed by training (Stratton *et al.*, 1994).

Pollock and colleagues (1987) proposed to determine if the aerobic capacity, performance, and body composition of masters athletes was related to age and maintenance of training over a 10 year period. The hypothesis of the study stated that training maintenance over 10 years would prevent certain physiological variables from changing. Twenty-four (initially aged 50-82 yr) master track athletes were tested two times, each testing period 10 years apart (T_1 and T_2). All athletes were healthy, physically active men (50-82 yr old). Five runners were primarily sprinters (800m or less); 17 were distance runners (1,500m or more). All athletes did some distance training (minimum 2-3 continuous miles) on a regular basis. Subjects were placed into two categories: COMP (actively training for high-level competition and their daily training pace was within 30 s of times recorded during their first test), and POST-COMP (not actively training for high-level competition and their daily training intensity was 90s slower than that at initial testing). The data shows that active subjects have higher VO_2 max values than that of age-matched sedentary subjects. Also, the active subjects have VO_2 max values higher or equal to sedentary subjects as much as 50 years younger. The authors also note that max HR and VO_2 max values for the COMP group remained relatively unchanged suggesting that cardiac output may be maintained through and increase in stroke volume and/or O_2 extraction. Sedentary subjects have shown increases in O_2 extraction with 12 months of endurance training, giving credence to the argument for an increased O_2 extraction with training. However if subjects are already trained, further endurance training may not have an effect on O_2 extraction as with sedentary persons where it may be maintenance rather than an increase in O_2 extraction. Another physiologic variable, body composition was examined in this study. The authors note that body composition (fat-free weight) changes may be related to aging, but more related to the type of training done.

Similarly, Tanaka and colleagues (1997) tested the hypothesis that the rate of decline in VO_2 max with age is greater in physically active than in sedentary women. In this cross-sectional study, 156 women (84 endurance trained and 72 sedentary) subjects had VO_2 max and body composition tested. From this data it was apparent that a gradual decline in VO_2 max with advancing age was greater in the endurance trained women as compared to the sedentary group. The authors noted that the greater rate of decline exhibited in the endurance trained women could be associated with the greater baseline measure. Those that had higher VO_2 max at baseline then had greater room to decline when compared with the sedentary individuals that had much lower VO_2 max values. The authors indicate that although the rate of decline in VO_2 max with age is greater for the endurance trained individuals than for the sedentary, the endurance trained individuals have much higher absolute values indicative of higher physiological functioning and therefore a greater capacity for work. These individuals also have the capacity to work at these increased levels for longer in their lifetime, ultimately preventing premature mortality. A major limitation of this study is that it is cross-sectional rather than longitudinal. Longitudinal data could give more insight to the rate of decline of the endurance-trained over time as well as the changes in physiological capacity with increasing age.

Hawkins *et al.,* (2001) sought to assess the change in VO_{2max} and maximal heart rate in master athletes. The purpose of the study was to determine the longitudinal change in VO_{2max} and HR_{max} in men and women master endurance runners and to compare these changes based upon gender, age, and change in training volume. Eighty-six men and forty-nine women master endurance runners had body composition, VO_2 max, lactate, and lung volume measurements tested in the laboratory. These measurements were compared with subjects training volumes. Data supports the notion that there are no differences in rates of decline in VO_2 max between trained and sedentary individuals. However, it is still unclear if the loss in VO_2 max with age can be reduced by chronic physical activity. There is research to suggest that training can retard the age-related decline in VO_2 max.   It is well accepted that body composition changes can affect relative VO_2 max. Some of the similarity between trained and sedentary individuals can be explained by the reduction in training volume that the master athletes exhibit with increasing age. Other studies show that VO_2 max can be maintained with increasing age with consistent training volumes.

Wiswell *et al.,* (2001) sought to describe the relationship between physiological loss, performance decrement, and age in master athletes. The purpose of this study was use a cross-sectional design to relate performance, training intensity, and frequency to laboratory tests of cardiovascular function, strength, bone status, and body composition. This study tested 146 men and 82 women master athletes, ages 40-86 yr. All subjects were actively training and competing in their respective athletic events at the time of baseline measurements. The majority of the subjects competed in running events (87% men and 91% women) and 40% were considered highly competitive. Subjects had the following tested: body composition via hydrodensitometry, resting EKG, maximal oxygen consumption via continuous, graded exercise test on a motor driven treadmill, blood lactate and glucose for each minute of exercise, at peak and at two and five minutes post exercise, bone mineral density and bone mineral content by DXA, muscle strength by maximal isokinetic knee extension, and blood chemistry.

Results show there are gender differences in the rate of decline of $VO_{2max.}$ Specifically, men lose maximal aerobic power at a rate of 1.2% per year from age 40 to 80 and women at a rate of 0.8% per year after the age of 40. This study also notes that several of the functional and performance variables do not decline in a linear manner. The authors also suggest that there is a more rapid loss in VO_{2max} during the 20's and 30's which is then slowed with advancing age. Additionally, declines in strength do not occur in a linear fashion, rather quadratic representation is best to predict muscle strength. This finding is in agreement with other researchers (Metter *et al.*, 1999). However, most research is not clear as to whether changes occur in a linear or other manner. Most research is conducted using linear regression for prediction of aging, however many researchers have concluded longitudinal studies would give much needed perspective to these analyses. Conversely, longitudinal studies are quite expensive and require numerous resources. Many cross-sectional studies are useful in assessment for potential longitudinal studies.

As noted in the aforementioned research it is apparent that the aging processes in a group of highly active individuals may be different than those of a sedentary group. Specifically, it seems that a lifetime of chronic physical activity may possibly retard the commonly associated age-related decline in aerobic capacity. In addition, a lifetime of physical activity may alter the typical age-related changes in muscle mass, strength and body composition. The proposed study seeks to determine whether or not muscle mass decreases with advanced age in a similar fashion among a highly active group as compared to the general population.

Chapter 3

METHODOLOGY

Sarcopenia is described as a loss in muscle mass associated with aging. A contributing factor is a decrease in activity which can intensify a loss of muscle strength and muscle mass which ultimately decreased ability to perform daily tasks. As muscle mass decreases muscle strength follows accordingly, giving rise to less activity and enhancing the downward spiral towards immobility and a loss of independence. The following chapter outlines the measures needed to assess the muscle mass of Subjects involved in this study: (a) Institutional Review Board Approval (b) Subjects (c) Protocol (d) Methods (e) Statistical Analysis.

Institutional Review Board Approval

Prior to testing, all procedures were submitted and reviewed by the Indiana University Institutional Review Board (IRB). In accordance with Indiana University IRB, written consent was received from all subjects prior to testing.

Subjects

Subjects were men and women involved in a competitive masters swimming program. Subjects were registered members of United States Masters Swimming. Selection criteria required subjects to be healthy and able to complete tests without physical detriment and was confirmed by completion of a medical history form and questionnaire (see Appendix A). Participation was completely voluntary and subjects received results pertaining to their individual results compared to the general population. Subjects were recruited at the FINA World Masters Swimming Championships held at Stanford University in August of 2006 an additional 23 from the Noblesville Area Masters Swim Team in central Indiana. FINA subjects were recruited by word of mouth and by informational fliers posted on the competition site. Noblesville subjects were recruited by informational emails and a researcher's visit to the swim team practice.

Protocol

Subjects at FINA completed testing underneath tents at the Stanford University's swimming facility. Noblesville subjects completed testing at the Noblesville High School Natatorium, where their practices are held. Subjects arrived at the testing site and completed the medical history and physical activity questionnaire (Appendix A). Subjects were lead through the testing stations: 1) height 2) weight 3) skinfolds: biceps, triceps, suprailiac, thigh, and medial calf 4) circumferences: mid-upper arm, waist, hips, thigh, and calf. At conclusion of the testing subjects were given instructions (appendix B) and materials for an at home completion of the 24 hour urine collection.

Methods

Each of the tests used the following procedures:

1) Height (cm): Each subject's height was measured using a portable stadiometer. Height was measured to the nearest 0.1 cm. Subjects stood with body weight evenly distributed on both feet, heals against the stadiometer without wearing shoes. Subjects were asked to remain prostrate with arms at their sides, while their head was at Frankfurt horizontal (Lohman, Roche, & Martorell, 1988).
2) Weight (kg): Each subject was instructed to wear a swim suit or light clothing. Subjects stood on a portable scale (Scale-Tronix, Inc. Carol Stream, IL) and weight was measured to the nearest 0.1 kg.

3) BIA muscle mass (kg): Subjects were instructed to wear a swim suit or minimal clothing. Subjects' height, age, clothing weight, and body type were entered into the analyzer as per instrumentation guidelines. Bioelectrical impedance analysis was completed using Tanita BC-418 bioelectrical impedance analysis system (Tanita, Corp., Tokyo).The system base has two stainless steel foot pad electrodes in a metal platform which is used to determine impedance and body weight. The subject also holds two hand grip electrodes to determine upper body skeletal muscle mass. This system allows for the measurement of impedance without the need for placement of conventional gel electrodes (Pietrobelli *et al.,* 2004). Skeletal muscle mass was measured to the nearest .01 kg.
4) Corrected girth skeletal muscle mass (kg): Subjects wore swim suits or minimal clothing. Skinfold and circumference measures were made three times each, with the average measure used for calculation sites and procedures. Skinfold thickness was measured on the right side of the body to the nearest 0.1 mm using calibrated Harpenden skinfold calipers (Croswell, UK). All circumferences were measured using a flexible standard measuring tape (Haskill, *et al.,* 1988). Skinfold thicknesses were measured following the procedures of Lee *et al.,* 2000. Skinfold measurement of the upper arm was measured in the midline posterior over the triceps muscle at a point midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna. The skinfold thickness of the thigh was measured at the midline of the anterior aspect of the thigh, midway between the inguinal crease and the proximal border of the patella. The skinfold of the calf was measured on the medial aspect of the calf at the point of maximal

circumference. The circumference of the upper arm was measured midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna. The thigh circumference was measured midway between the midpoint of the inguinal crease and the proximal border of the patella. The calf circumference was measured at the maximal circumference. Skinfold thicknesses (*S*) were assumed to be twice the subcutaneous adipose tissue thickness, thereby each limb circumference was corrected following the equation ($Cm = C_{limb} - \pi S$). Each measurement was used to predict skeletal muscle mass from the equation:

$$SM\ (kg) = Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2 + 0.00441 \times CCG^2) + 2.4 \times sex - 0.048 \times age + race + 7.8$$

Where, sex = 1 for male and 0 for female, race = -2.0 for Asian, 1.1 for African American, and 0 for white or Hispanic. CAG=corrected arm girth, CTH=corrected thigh girth, and CCG= corrected calf girth.

5) Creatinine Excretion Muscle mass (kg): Subjects were given written instructions explaining the guidelines for the dietary restrictions and the collection procedures. Urine was collected for the final 24 hours of a 72 hour meat free diet. Subjects were instructed to void their bladders upon rising and record this time as the start time of the collection. All urine was to be collected for the next 24 hours including the next morning's void. Following completion of the collection, subjects recorded total volume of urine collected and sent a 30-50 ml sample to Indiana University for analysis. All micturitions were collected in 400 ml polyethelyne graduated beakers then transferred to 3L opaque storage containers (Fischer Scientific, Boston, MA). Subjects were supplied with either one 50 ml Vulcan test tube with screw cap or two 15 ml Vulcan test tubes with screw caps. Subjects sent the samples in sealed pre-paid mailing tubes to Indiana University for analysis. Samples were frozen in a specimen

freezer (-80°C) and stored until analysis. Urinary Creatinine was analyzed using a colorimetric assay utilizing a 96 well format (PowerWave Microplate Spectrophotometer, BioTek, VT). The samples were analyzed following the procedures for Cayman Chemical Creatinine (Kit #500701, Cayman Chemical, Kalamazoo, MI) assay kit. The

Data Analysis

Three independent measures were tested: age, sex and muscle mass. Independent t-tests determined the differences between the general population and the masters swimmer sample and between age groups of the masters swimmers. ANCOVA analysis was utilized to determine whether or not age, height, or body surface area accounted for more variance thus changing the outcomes of the between groups tests. Outliers were removed from the study if the creatinine values were less or greater than 2 standard deviations from the mean. Also, data points were removed if the creatinine conversion value for muscle mass indicated a value impossible to achieve (e. g. skeletal muscle mass > total body mass (kg)). The bonferroni correction was used for each of the within group tests. In addition to the one sample t-tests used to compare the GP and the USMS muscle mass; multiple planned comparisons were utilized to analyze differences within the USMS population. In order to protect against type I error inflation a Tukey's correction factor for multiple planned comparisons was used (Jaccard *et al.,* 1984). Statistical tests were completed using SPSS version 15.0 for windows.

As a result of using the data from the Baltimore Longitudinal Study of Aging (BLSA), whereas only means and standard deviations were supplied, other methods of comparison were used to analyze the loss of muscle mass with increasing age. In order to compare the trend of muscle mass loss over time, muscle mass estimates from BIA were compared with data from published research (Gallagher *et al.,* 1997). Following methods referenced in Wright *et al.,* (1987) slopes and y-intercepts were compared and differences or lack thereof were noted (figures 4.8 and 4.9).

Subject Testing

Many of the questionnaires were lost in the mail; therefore, subjects were contacted via email to complete an online questionnaire to assess physical activity level.

All questionnaire data from the FINA Subjects was lost, however, some was retrieved by subjects completing the survey online. Not all subjects tested completed all parts of the study; those who chose not to complete the urine collection were not included in creatinine muscle mass comparisons. Subjects were excluded if they failed to complete the urine collection portion of the testing and/or did not complete the collection according the instructions.

Chapter 4

RESULTS

Three hundred thirty-nine (198 men and 141 women) masters swimmers served as subjects for this study. All subjects were members of United States Masters Swimming (USMS). Subject characteristics for the 198 USMS men by age group shown are in Table 4.1 (mean: 52.3 yr $\pm$ 13.15 yr, height 179.8 cm $\pm$ 6.74 cm, body mass 81.3 kg $\pm$ 9.77 kg).

Age Group (yr)	Age (yr)	Height (cm)	Body Mass (kg)
20-29	27.3 ± 1.5	176.9 ± 4.5	72.17 ± 12.0
30-39	35.1 ± 2.6	181.06 ± 7.1	80.30 ± 9.9
40-49	44.6 ± 2.9	181.45 ± 5.7	82.88 ± 9.8
50-59	54.3 ± 3.0	180.73 ± 7.4	84.37 ± 9.0
60-69	64.6 ± 2.7	82.59 ± 6.2	79.61 ± 8.8
70-79	73.1 ± 2.3	173.95 ± 6.1	77.27 ± 9.0
80 +	84.5 ± 4.4	172.80 ± 3.8	70.56 ± 7.0

Table 4.1. USMS Men's anthropometric measurements. All values are expressed as the mean value $\pm$ standard deviation.

Subject characteristics for the 141 USMS women by age group are shown in Table 4.2 (mean: 51.9 $\pm$ 14 yr, height 166.4 $\pm$ 6.66 cm, body mass of 64.8 $\pm$ 10.24 kg). Figure 4.1 shows the age distribution of the USMS subjects.

Age Group (yr)	Age (yr)	Height (cm)	Body Mass (kg)
20-29	25.1 ± 3.1	166.6 ± 10.4	62.0 ± 11.3
30-39	34.4 ± 2.7	168.4 ± 5.7	65.9 ± 10.9
40-49	45.4 ± 2.8	168.8 ± 6.9	66.0 ± 11.5
50-59	53.5 ± 2.8	166.6 ± 6.1	64.6 ± 9.1
60-69	63.6 ± 3.1	162.7 ± 4.4	64.7 ± 9.5
70-79	72.8 ± 2.7	162.0 ± 5.1	64.0 ± 11.2
80 +	83.0 ± 1.9	163.7 ± 6.8	60.7 ± 7.1

Table 4.2. USMS Women's anthropometric measurements. All values are expressed as the mean value $\pm$ standard deviation.

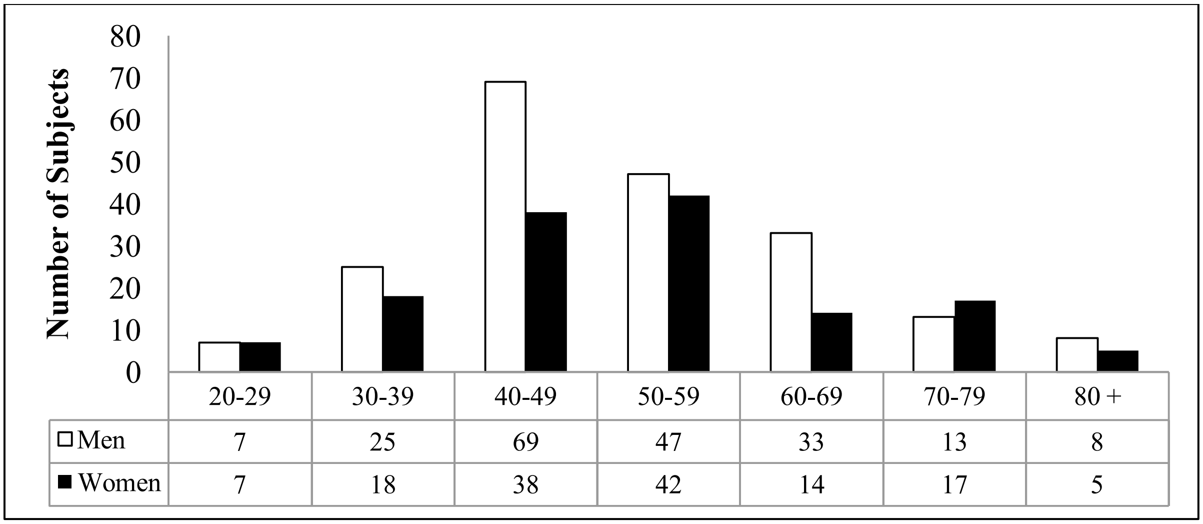


Figure 4.1. USMS subject distribution across age groups for men and women.

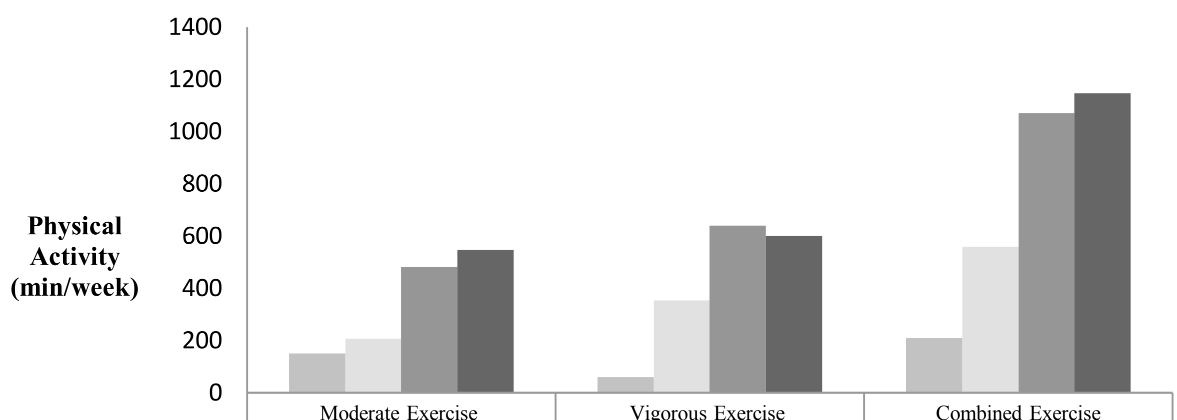
Statistical analyses of activity levels and muscle mass between the USMS and GP were conducted using independent samples t-tests. Muscle mass was measured by three techniques (BIA, Corrected Girth (CG), and Creatinine (CR)) for the USMS subjects. General characteristics for each of the methods are shown in Table 4.3.

Age Range (yr)	Men			Women		
	Mean Muscle Mass (kgs)			Mean Muscle Mass (kgs)		
	Bioelectrical Impedance	Corrected Girth	Creatinine	Bioelectrical Impedance	Corrected Girth	Creatinine
20-29	33.1 ± 4.9	36.1 ± 3.4	26.7*	23.9 ± 3.9	26.1 ± 3.7	26.9 ± 11.2
30-39	35.4 ± 4.0	35.3 ± 3.6	37.5 ± 7.0	24.1 ± 3.1	27.9 ± 3.3	20.7 ± 4.5
40-49	36.2 ± 4.0	36.6 ± 3.8	32.9 ± 11.3	23.4 ± 3.7	26.3 ± 4.4	22.3 ± 5.9
50-59	36.5 ± 3.8	36.6 ± 3.5	32.0 ± 11.9	22.0 ±2.7	24.7 ± 3.0	20.3 ± 14.1
60-69	34.2 ± 3.5	33.0 ± 3.2	27.4 ± 5.6	21.3 ± 2.4	25.5 ± 4.2	18.3 ± 6.7
70-79	31.7 ± 4.0	31.2 ± 3.1	41.2 ± 42.6	19.9 ± 3.0	23.2 ± 3.9	15.5 ± 5.2
80 +	28.8 ± 3.6	27.1 ± 3.6	20.3 ± 4.9	18.9 ± 1.9	21.4 ± 2.0	15*
Total	35.2 ± 4.2	35.1 ± 4.2	32 ± 16.2	22.3 ± 3.4	25.4 ± 4.0	20.4 ± 9.8

Table 4.3 USMS men's and women's muscle mass analysis for each age group, all are presented as mean muscle mass (kg) ± standard deviation, * denotes samples that only had $n = 1$, therefore no standard deviation was possible.

Bivariate correlations to determine the validity of each of the muscle mass methods yielded the following results for CG and CR $r = 0.377$; for BIA and CR $r = 0.403$; for BIA and CG $r = 0.920$, all P-values were significant at < 0.01. ANCOVA analysis showed muscle mass is not different ($p > 0.05$) between groups when body surface area, age, or height is co-varied for all groups.

One hundred seventeen subjects completed the activity survey for which all activity comparisons were made. As such the first hypothesis tested was USMS members were highly active. One hundred thirteen subjects exceeded the minimal recommended amount of physical activity according to ACSM & CDC guidelines, 579 ± 276.9 minutes of activity a week (range 180 to 1340 minutes). Four subjects did not meet the minimal recommendations (3 men, 1 woman, average physical activity ≤ 210 minutes per week). 19 subjects (9 women, 10 men) met the criterion to be defined as highly active. Therefore, USMS members who exceed these recommended values are defined as active as compared to the GP who do not meet these recommended values. Additionally, the HA ($\bar{x}$ = 1146.67 min/wk ± 145.26, $\bar{x}$ = 1071.0 min/wk ± 152.35) engage in high amounts of physical activity for women and men, respectively. The highly active performed significantly ($p < 0.01$) more physical activity than the general population (Figure 4.2).



	Moderate Exercise	Vigorous Exercise	Combined Exercise
General Population	150	60	210
Masters Swimmers	207	352	559
Highly Active Men	480	639	1071
Highly Active Women	547	600	1147

Figure 4.2 Exercise profiles masters swimmers and the general population's recommendations.

The second and third hypotheses were tested together utilizing three different methods of muscle mass analysis: bioelectrical impedance analysis (BIA), creatinine excretion (CR), and anthropometric measurements: corrected girth (CG).

BIA Muscle Mass Analysis Results

BIA Estimated Muscle Mass (kg)								
Age Group	**USMS Men n**	**GP Men n**	**USMS Women n**	**GP Women n**	**USMS Men**	**GP Men**	**USMS Women**	**GP Women**
20-29	3	295	7	100	33.1 ± 4.9	38.9 ± 6.3	23.9 ± 3.9	22.4 ± 5.3
30-39	25	872	18	160	35.4 ± 4.0	37.5 ± 6.3	24.1 ± 3.1	21.3 ± 4.4
40-49	68	1218	37	106	36.2 ± 4.0	35.6 ± 6.3	23.4 ± 3.7	20.9 ± 4.9
50-59	47	1537	41	136	36.5 ± 3.8*	34.0 ± 5.8	22.0 ±2.7	19.5 ± 4.1
60-69	33	1369	14	178	34.2 ± 3.5*	31.5 ± 5.4	21.3 ± 2.4	17.9 ± 4.4
70-79	13	1395	17	168	31.7 ± 4.0*	27.5 ± 5.6	19.9 ± 3.0	16.9 ± 3.7
80 +	8	436	5	39	28.8 ± 3.6‡	24.5 ± 4.8	18.9 ± 1.9	14.6 ± 3.8

Table 4.5 Muscle mass results of USMS and GP men and women from BIA analysis. ‡ denotes ($p < 0.05$), * denotes ($p < 0.01$)

Analysis of the men yielded the following results (Table 4.5, Figure 4.3): the 50-59 yr olds, 60-69 yr olds, 70-79 yr old, and 80 yr and older USMS groups had significantly ($p < 0.05$) more muscle mass than the GP. Additionally, the 20-29, 30-39, and 40-49 yr old and groups were not different from the GP.

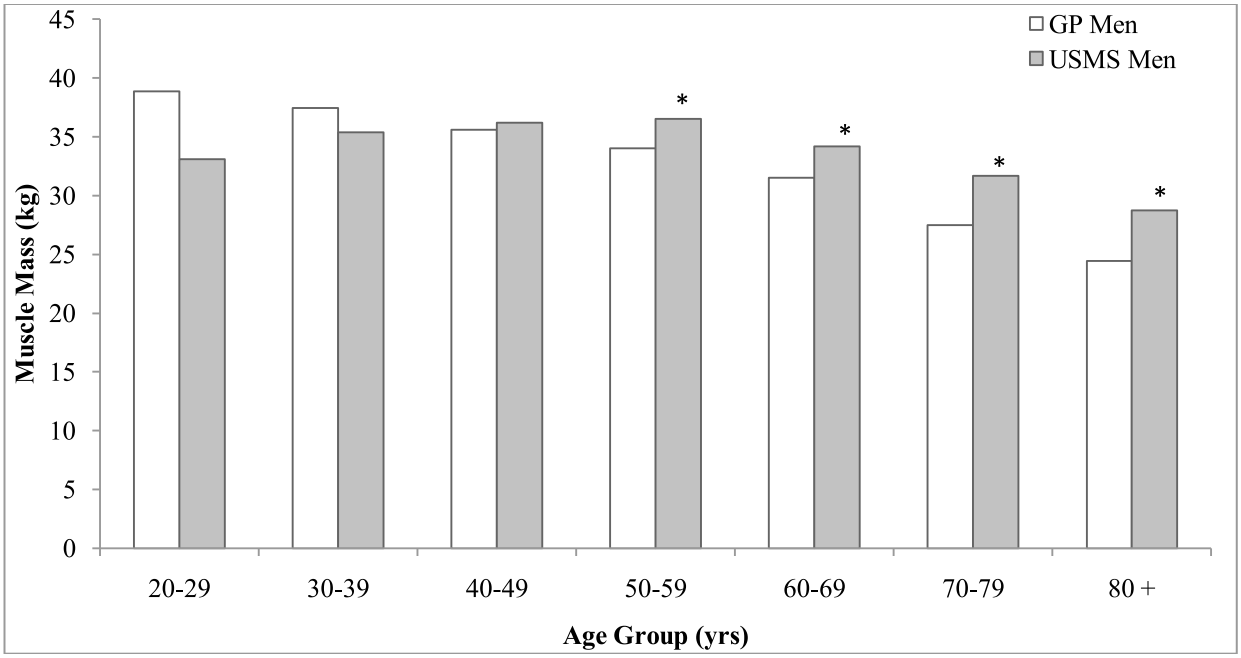


Figure 4.3. Men's muscle mass comparisons from BIA. General population (GP), active (USMS) Muscle mass (kg). * denotes ($p < 0.05$). GP data obtained from BLSA.

BIA muscle mass analysis between age groups of USMS men (Table 4.5) yielded the following differences: 30-39 yr olds, 40-49 yr olds, 50-59 yr olds 60- 69 yr olds have significantly greater muscle mass than the 80 yr and older group; the 40-49 yr olds and 50-59 yr olds have significantly greater muscle mass than the 70-79 yr olds (all significance $p < 0.05$). However, 20-29 yr old group was not different ($p > 0.05$) from any of the groups. Additionally, the 70-79 yr old group was not significantly ($p > 0.05$) different than the 80 yr and older group.

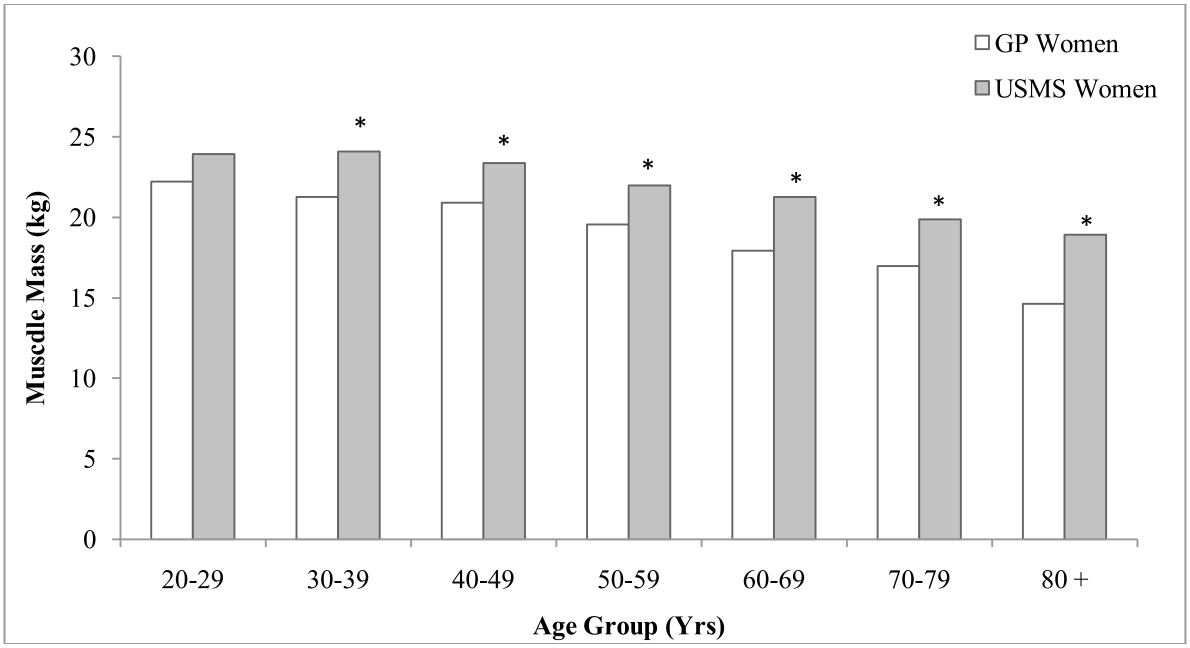


Figure 4.4. Women's muscle mass comparisons from BIA. General population (GP), active (USMS). * denotes significance difference ($p < 0.05$). GP data obtained from Baltimore Longitudinal Study of Aging.

USMS women (Table 4.4) had significantly ($p < 0.05$) greater muscle mass than the GP for all age groups except the 20-29 yr old group. Additionally, between groups comparisons of USMS women, the 30-39 yr old age group have significantly ($p <0.05$) greater muscle mass than the 70-79 yr olds and the 80 and older group; the 40-49 yr olds have significantly ($p <0.05$) greater muscle mass than the 70-79 yr olds and the 80 yr and older groups.

Creatinine Muscle Mass Analysis

Creatinine Estimated Muscle Mass (kg)								
Age Group	**USMS Men n**	**GP Men n**	**USMS Women n**	**GP Women n**	**USMS Men**	**GP Men**	**USMS Women**	**GP Women**
20-29	1+	295	2	100	26.7+	38.9 ± 6.3	26.9 ± 11.2	22.4 ± 5.3
30-39	5	872	8	160	37.5 ± 7.0	37.5 ± 6.3	20.7 ± 4.5	21.3 ± 4.4
40-49	28	1218	22	106	32.9 ± 11.3	35.6 ± 6.3*	22.3 ± 5.9	20.9 ± 4.9
50-59	25	1537	25	136	32.0 ± 11.9	34.0 ± 5.8	20.3 ± 14.1	19.5 ± 4.1
60-69	21	1369	8	178	27.4 ± 5.6	31.5 ± 5.4*	18.3 ± 6.7	17.9 ± 4.4
70-79	8	1395	7	168	41.2 ± 42.6*	27.5 ± 5.6	15.5 ± 5.2	16.9 ± 3.7
80 +	3	436	1+	39	20.3 ± 4.9	24.5 ± 4.8	15	14.6 ± 3.8

Table 4.6 Muscle mass results of men and women from creatinine excretion. + denotes insufficient *n* to complete analyses. * denotes significant difference ($p < 0.05$)

Alternatively, data from creatinine analysis of muscle mass (Table 4.6) indicate of the USMS men the 70-79 yr old group had significantly ($p < 0.05$) higher muscle mass than the general population. Whereas, the USMS men in the 40-49 yr and 60-69 yr old groups had significantly ($p < 0.05$) less muscle mass than the GP. Additionally, the 30-39 yr, 50-59 yr, and 80 & older groups did not show any differences from the GP. The 20-29 yr old age group could not be compared due to an insufficient sample size.

In tests of between group differences, USMS men in the 30-39 (yr) age group were significantly different, from the 50-59 (yr), 60-69 (yr), and 70-79 (yr) age groups. Similarly, USMS men in the 40-49 age group had significantly ($p < 0.05$) more muscle mass than the 50-59 (yr), 60-69(yr), and 70-79(yr) age groups. The 20-29 (yr) age group could not be compared to the other age groups due to an insufficient sample size, n = 1.

USMS women's muscle mass was not different ($p > 0.05$) than the GP across 30-39 (yr), 40-49 (yr), 50-59 (yr), 60-69(yr), 70-79(yr) and 80 (yr) & older age groups. Tests between

USMS groups indicated the 20-29 (yr) and 40-49 (yr) groups have significantly ($p < 0.05$) more muscle mass than 70-79 (yr) age group. The 80 + (yr) age group could not be included in this analysis due to an insufficient sample size (n = 1).

Anthropometric Measurements: Corrected Girth

Corrected Girth Estimated Muscle Mass (kg)								
Age Group	**USMS Men n**	**GP Men n**	**USMS Women n**	**GP Women n**	**USMS Men**	**GP Men**	**USMS Women**	**GP Women**
20-29	3	295	7	100	36.1 ± 3.4	38.9 ± 6.3	26.1 ± 3.7	22.4 ± 5.3
30-39	25	872	18	160	35.3 ± 3.6	37.5 ± 6.3	27.9 ± 3.3	21.3 ± 4.4
40-49	65	1218	34	106	36.6 ± 3.8	35.6 ± 6.3	26.3 ± 4.4	20.9 ± 4.9
50-59	46	1537	39	136	36.6 ± 3.5	34.0 ± 5.8	24.7 ± 3.0	19.5 ± 4.1
60-69	33	1369	13	178	33.0 ± 3.2	31.5 ± 5.4	25.5 ± 4.2	17.9 ± 4.4
70-79	13	1395	17	168	31.2 ± 3.1	27.5 ± 5.6	23.2 ± 3.9	16.9 ± 3.7
80 +	6	436	5	39	27.1 ± 3.6	24.5 ± 4.8	21.4 ± 2.0	14.6 ± 3.8

Table 4.7 Muscle mass results of USMS and GP men and women from corrected girth measurements.
* denotes a significant difference ($p < 0.05$)

Data from corrected girth estimates of muscle mass indicate the USMS men in the 50-59 yr old and 70-79 yr old age groups had significantly ($p <0.05$) more muscle mass than the GP. Additionally, the other age groups (20-29 yr, 30-39 yr, 40-49 yr, 60-69 yr, and 80 yr & older) did not have significantly different ($p > 0.05$) muscle mass than the GP.

Between groups tests yielded the following results: the 20-29 yr olds have significantly ($p <0.05$) more muscle mass than the 80 yr and older group. The 30-39 yr old group has significantly ($p <0.05$) more muscle mass than the 70-79 yr old and 80 yr and older groups. The 40-49 yr old and 50-59 yr old groups have significantly more ($p <0.05$) muscle mass than the 60-69 yr old, 70-79 yr old, and 80 yr and older groups. The 80 yr and older group has significantly less muscle mass than all age groups except the 70-79 yr olds.

The USMS women had significantly ($p < 0.05$) more muscle mass than the GP for each age group. However, the 20-29 yr olds were not different ($p > 0.05$) from the GP. Between groups of the USMS the 20-29 yr old, 40-49 yr old, and 60-69 yr old group were not different from any other age groups. However, the 30-39 yr old age group had significantly ($p < 0.05$) more muscle mass than the 50-59 yr old, 70-79 yr old, and 80 yr and older groups.

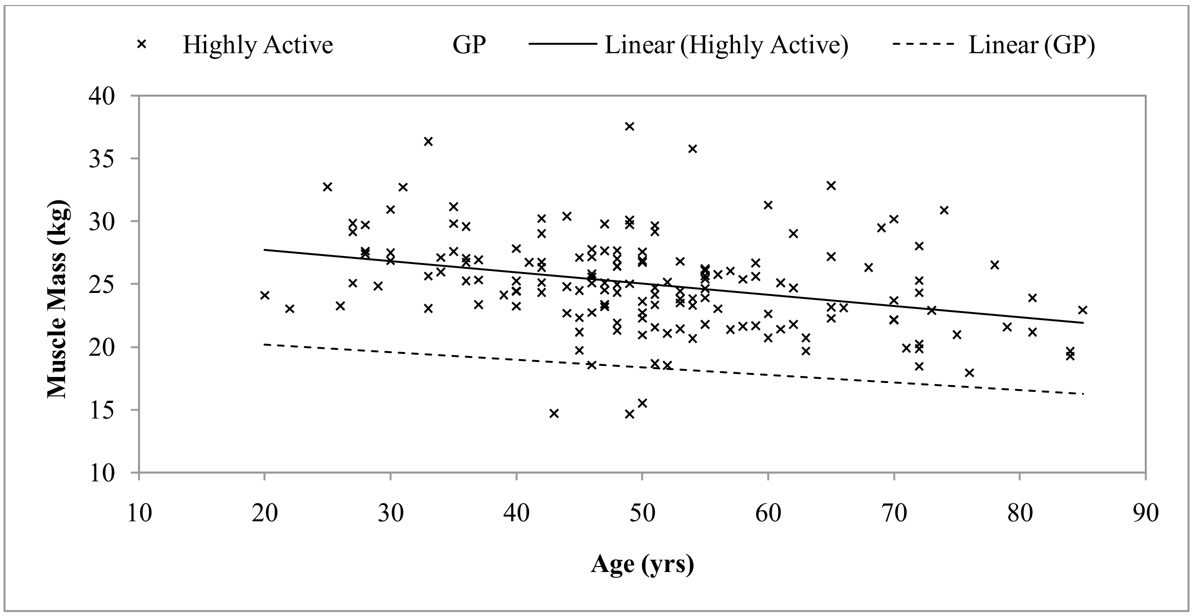


Figure 4.5. Regression analysis of women's muscle mass (as measured by BIA) vs age. HA muscle mass (kg) = -0.094(age) + 28.38 kg, r = 0.325, p< 0.001, GP muscle mass kg = -0.06(age) + 21.37 kg, r = 0.43(Gallagher *et al.* 1997)

Regression analysis of muscle mass across all ages of USMS resulted in the following equations: Muscle Mass (kg) = -0.148(age) + 43.04 kg, r = 0.416, p< 0.001, Muscle Mass (kg) = -0.094(age) + 28.38 kg, r = 0.325, p< 0.001 for men and women, respectively. Gallagher and colleagues (1997) used dual-energy X-ray absorptiometry (DXA) to measure appendicular skeletal muscle mass in 132 Caucasian men and women. From their measurements they determined the following equations for the general population (GP): Muscle Mass (kg) = -

0.10(age) + 32.52 kg, r = 0.52; Muscle Mass (kg) = -0.06(age) + 21.37 kg, r = 0.43 for men and women, respectively.

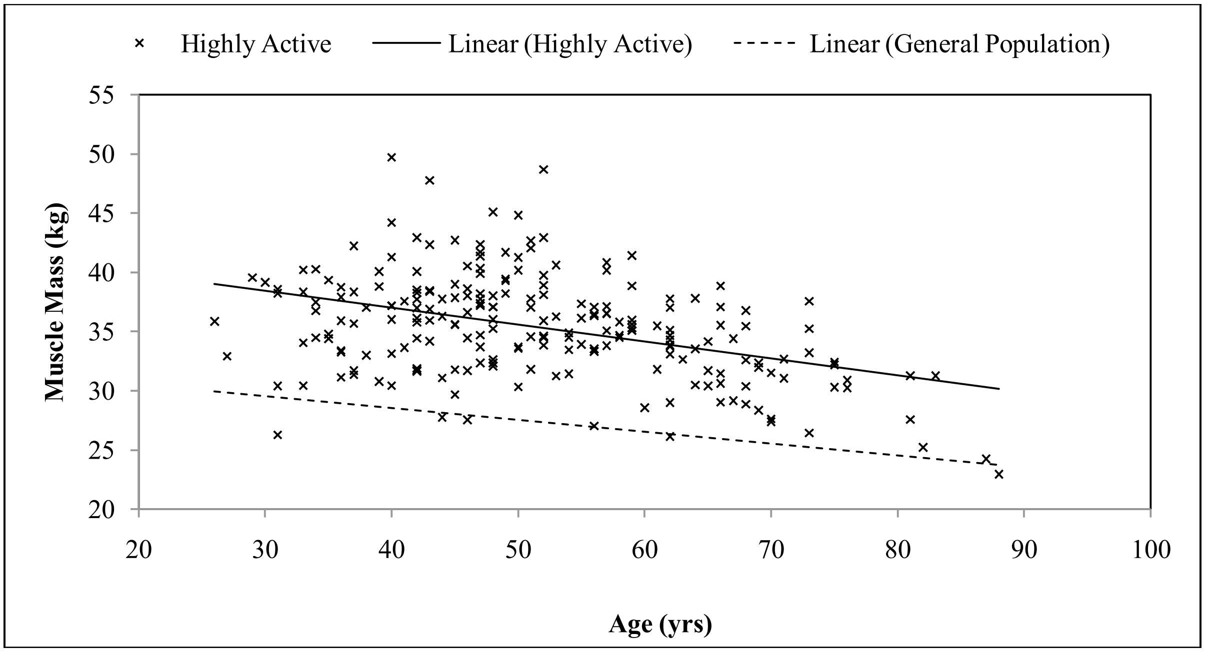


Figure 4.9. Regression analysis of men's muscle mass (as measured by BIA) vs age. HA muscle mass (kg) = -0.148 (age) + 43.04 kg, r = 0.416, p< 0.001, GP mass (kg) = -0.10 (age) + 32.52 kg, r = 0.52 (Gallagher *et al.* 1997)

Comparisons of Gallagher *et al.* (1997) with the data from the USMS are shown in Figure 4.7 and Figure 4.8 for women and men, respectively. Following the methods described in Wright (1978), y-intercepts were significantly different ($p < 0.05$) for both women and men. Results of slope comparison for both groups yielded no difference between the slopes of the USMS and GP.

CHAPTER 5

DISCUSSION

The first finding of this study was most of the masters swimmers are more active than the general population. Not only do they participate in more planned exercise, but also a small cohort of this group is highly active. Whereas highly active weekly activity $\geq \bar{x}_{USMS} + 1$ std dev; $\bar{x}_{USMS} = 579$ min/wk. The hypothesis that an aging population exceeds the ACSM & CDC guidelines for healthy lifestyles was confirmed by this study. Those tested engage in 125% more moderate exercise than suggested by the guidelines and 500% more vigorous activity than what is recommended. Conversely, some subjects were not included in the analyses for failure to meet the ACSM & CDC guidelines. This indicates that being a registered member of a competitive sport organization does not guarantee an active lifestyle.

Researchers have long studied masters athletes because of their lifetime activity (Kasch & Wallace, 1978; Wiswell *et al* 1998; Trappe 1998; Short *et al* 2004). This lifetime activity may be responsible for countering inactivity-associated problems (e. g. decreases in functional capacity and loss of independence) typically related with advancing age (Doherty, 2003; Kirkendall & Garrett, 1998; Roubenoff, 2000). In the present study, physical activity participation averaged 579 ± 276.9 minutes a week. For comparison, the general population does not share these same patterns. According to the CDC, most Americans (55.5 %) do not meet the minimal recommendations for physical activity. Table 5.1 illustrates the findings from a national survey (Behavioral Risk Factor Surveillance System, BRFSS), showing percent of people engaging in the recommended, insufficient, inactive or no leisure-time amount of physical activity, respectively.

Physical Activity Guidelines	Women (%)	Men (%)
Recommended: at least 30 min/day 5 days of the week of moderate activity or 20 min/day vigorous intensity activity 3 days/week, or both	47.1	50.7
Insufficient: more than 10 min/day of moderate or vigorous-intensity exercise, but less than recommended	38.7	36.7
Inactive: less than 10 min/week moderate or vigorous-intensity activity	14.2	12.6
No leisure-time physical activity	26.2	21.7

Table 5.1. Percentages of physical activity participation by sex (CDC, 2006).

As per the ACSM & CDC guidelines, healthy adults under 65 years of age are minimally recommended to participate in 150 minutes of moderate aerobic activity or 60 minutes of vigorous activity per week. Based on data from BRFSS and the ACSM & CDC recommendations for an active lifestyle only 45.5% of the adult American meets an active lifestyle; engages in 150 minutes of moderate exercise and/or 60 minutes of vigorous exercise a week (Hawkins *et al.,* 2000). This indicates most Americans are not meeting minimal recommendations for physical activity. The finding that the aging population in this study is exceeding this recommendation is promising for attenuation of age-related illnesses. It is possible this population may be 'successfully' aging.

The next main finding was that some of the USMS men have more muscle mass than the general population. This is true for the age groups starting at age 50 (yrs) and older. The 20-29 (yrs), 30-39 (yrs) and, 40-49 (yrs) age groups did not show differences in muscle mass. A possible explanation for the discrepancy between age groups is due to differences in body mass. The USMS and general population may have similar absolute muscle mass, whereas relative muscle mass maybe much greater in the USMS.

The body mass values from the present study could not be compared with the body mass of the general population as those values were not available. However, research on masters athletes typically uses endurance trained individuals, who have smaller total body mass but are very lean (Heath *et al,* 1981; Faulkner, 2008). Trained subjects typically have less body mass; they may also have less fat and muscle mass. Therefore relative skeletal muscle mass may remain elevated compared to their inactive counterparts. As shown in Table 5.2, untrained men have similar muscle mass to that of the general population.

	Untrained				Sprint-Trained		Endurance-Trained	
Group	**Young**	**Adult**	**Old**	**Oldest Old**	**Young**	**Old**	**Young**	**Adult**
N	25	9	12	4	16	20	16	16
Age (yr)	28 ± 1	50 ± 2	65 ± 1	84 ± 1	24 ± 1	75 ± 1	22 ± 1	59 ± 1
Height (cm)	174 ± 1	175 ± 3	178 ± 2	168 ± 4	178 ± 1	171 ± 1	176 ± 1	173 ± 1
Weight (kg)	72 ± 1	85 ± 4	81 ± 2	69 ± 8	77 ± 1	70 ± 2	65 ± 2*	65 ± 2*
Fat (%)	16 ± 1	20 ± 1	28 ± 1	-	17 ± 1	15 ± 1	9 ± 1*	10 ± 0*
LBW (kg)	59 ± 1	68 ± 2	59 ± 1	-	65 ± 3	56 ± 3	59 ± 1*	57 ± 2*
VO_{2max} (ml/kg/min)	40	30 ± 1	27 ± 1	-	-	-	69 ± 1*	59 ± 1*

Table 5.2. Body composition differences in untrained and trained men (Faulkner *et al,* 2008). *indicates muscle mass different from untrained adult men.

Additionally, USMS women are different from the general population in all age groups except for the youngest, 20-29 (yr). This is true for two methods of muscle mass assessment: BIA and CG. What's more is that the creatinine excretion did not show any differences between the USMS and GP for all age groups in women. However, in the men it showed differences between three age groups, 40-49 (yrs), 60-69 (yrs) and 70-79 (yrs). Although muscle mass was measured utilizing three different techniques; it was expected that the methods would share similar results. This discrepancy between methods is somewhat perplexing, yet is explained in the literature.

According to Heymsfield *et al.* 1983, creatinine excretion can be greatly affected by many different stressors (e.g. menstruation, illness, intense exercise) therefore making it a highly variable measurement. This measure would be more appropriate for a clinical setting where conditions, stressors, and diet can be closely monitored. Based on these reasons, creatinine excretion as a field measure for assessing skeletal muscle mass is not recommended. However, BIA and corrected girth measurements are reliable field methods for measuring skeletal muscle mass. This is in agreement with Wang *et al.* 1999 and Pietrobelli *et al.* 2004, whereas researchers in both studies validated the measures (Corrected Girth and BIA, respectively) for use in the field. As such, the USMS men were tested using the same methods.

Another main finding is that USMS men and women do not lose muscle mass at different rates than the general population (-0.094 and -0.06, respectively). However, they do have different amounts of muscle mass which may act as a protector. The USMS in this study had greater muscle mass at a younger age than did the general population. Therefore, it may be possible to conclude that at any given age, the USMS have more muscle mass than the general population. This is comparable to data presented by Faulkner *et al.* (2008) who showed along with greater muscle mass, the protective benefit is a performance measure as well. Many active adults are competing in masters competitions which suggest higher training loads than those who do not compete. Additionally, masters athletes show similar age-related declines in VO_2max to the declines in muscle mass (Faulkner *et al.,* 2008; Tanaka and Seals, 1997). It is not surprising to see these parallels, considering as individuals' muscle mass decreases so too will their VO_2max. Additionally, when losses of muscle mass, independence, strength, and mobility reach 40 %, mortality soon follows (Doherty, 2001 & 2003; Roubenoff, 2000).

The decrease in muscle mass with aging is partially due to bigger, faster fibers (type II) decreasing in size, as they are used less frequently with advancing age (Fitarone, 1990; Laurentani, 2003; Pette 2005; Trappe 2001). Additionally, muscle mass decreases may be due to the specific type of training. Whereas the smaller endurance (type I) fibers remain intact from daily use and most activities performed with advancing age requiring endurance not power

(Faulkner *et al.,* 2008). The loss of the type II fibers decreases individuals' maximal strength and muscle mass thus leaving them susceptible to decrease in performance from lifting heavy objects to sprinting in the pool (Roubenoff, 2000; Faulkner *et al.,* 2008; Tanaka and Seals, 1997). The USMS subjects spend a considerable amount of time swimming or engaged in activity that is not an activity that would prevent the loss of type II fibers (Faulkner *et al.,* 2008). Trappe (2001) showed decreases in skeletal muscle mass with endurance training. Resistance training has been shown to increase muscle mass and is therefore useful in the prevention of sarcopenia (Roubenoff, 2003). The muscle mass lost with chronic endurance training may be attenuated or completely avoided if supplemented with a resistance training program.

In this study a group of aging individuals were compared with the general population. The results suggest that muscle mass is lost in both groups however, it is attenuated by physical activity. Furthermore, in order to determine the degrees which aging and physical activity respectively affect muscle mass, a different type of study is needed. Although it may be appropriate to initially evaluate population differences through cross-sectional methods. In order to examine the true differences a highly active lifestyle can have upon an individual a longitudinal design may be the most appropriate. In order to assess muscle mass in a more definite manner, it may be useful to use such techniques as DXA. For the purposes of this study, in the field setting, it was necessary to use methods that were suitable for easy transport as well as testing numerous subjects. In further study, it would be of interest to compare the health status of highly active individuals and examine the outcomes of this lifestyle choice.

Although muscle mass is lost in both populations, the USMS, regardless of sex, fair much better than the general population. Multiple age-related problems are coupled with the loss of muscle mass. Active adults demonstrate the need for rigorous guidelines to prevent disease and disability in the population. As indicated by this study, the minimal daily recommendations for activity are not enough to prevent the age-related decline in muscle mass. Further research should quantify activity and assess what factors are essential to maintaining health with advancing age.

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APPENDICIES

APPENDIX A

Physical Activity Questionnaire and Medical History Form

SURVEY # __________

PHYSICAL ACTIVITY AND HEALTH STATUS QUESTIONNAIRE

- **Indiana University Human Performance Laboratories**

Bloomington, Indiana, 47405

PART I: SECTION I
BACKGROUND INFORMATION

1. Age: ________________   2. Date of birth: _______________ Day/Month/Year

3. Sex: Male Female

4. Years of school completed
   A. Some high school
   B. High school graduate
   C. Some college
   D. College graduate (B.S. or B.A.)
   E. Some graduate school
   F. Completed Post-Graduate (M.A.,M.D., PhD)

5. Race or ethnicity
   A. African American
   B. Asian Pacific Islander
   C. Caucasian - Non Hispanic
   D. Hispanic
   E. Native American
   F. Other

6. What is your current marital status?

   A. Divorced
   B. Living with significant other
   C. Married
   D. Separated
   E. Never married
   F. Widowed

7. Please indicate your current household income in U.S. dollars

   A. Less than $20,000
   B. $20,000 - $34,999
   C. $35,000 - $54,999
   D. $55,000 - $74,999
   E. Greater than $75,000

8. Height __________feet __________ inches

9. Weight __________pounds

10. During a typical week, how many hours of television do you generally watch? __________ hours

SECTION II

SWIMMING HISTORY

1. How old were you when you began swimming?

2. Have you ever competed in swimming?

   [ ] yes [ ] no

   If you answered no, go to Section III (Swimming Training)

3. What was your age at your first competitive swimming competition? ______________years

4. Are you currently competing as a registered member of United States Masters Swimming?

   [ ] yes [ ] no

   If you answered no, go to Section III (Swimming Training)

5. Age at first competitive swim meet as a masters swimmer? __________ years old

6. How many years have you been in master's competition? ____________years

7. As a masters swimmer, what was the highest level you competed? Circle one

   a. Local b. State c. National d. International

8. Age group at first Masters swim meet (other than Nationals)? Check one only.

   [ ]20-24 [ ]25-29 [ ]30-34 [ ]35-39 [ ]40-44 [ ]45-49 [ ]50-54 [ ]55-59
   [ ]60-64 [ ]65-69 [ ]70-74 [ ]75-79 [ ]80-84 [ ]85-89 [ ]90-94 [ ]95-99

9. Competitive swimming experience (other than Masters)? Check all that apply.

   [ ] age group [ ] high school [ ] college [ ] National/International [ ] none

10. On average, how many times a year do you compete in swim competitions?_____________________

11. In 2005 were you ranked in the top ten in at least one event? [ ] yes [ ] no

12. In the last 5 years, were you ranked in the top ten in at least one event? [ ] yes [ ] no

13. In which category was your best competitive performance (rank or finish)? Check one only.

    [ ] sprint 50-100 [ ] middle distance 200-500 [ ] distance 500-above

1. Do you have an on deck swimming coach?
   [ ] yes [ ] no

2. Do you follow an annual training plan?
   [ ] yes [ ] no

3. How many months per year do you train for swimming? _________________months

4. On average, how many weeks per year do you take off from training?
   ____________weeks

5. During this past winter that you were involved in swim training, estimate below:

   a) Average number of yards/meters swum per day
   ____
   b) Average number of days swum per week
   ____

6. During this past summer that you were involved in swim training, estimate below:

   a) Average number of yards/meters swum per day
   ____
   b) Average number of days swum per week
   ____

This following section will aid us in gaining information about your past and current training history. Please fill out the questions only if they are relevant to you, if they are not relevant please leave them blank.

7. We are interested in what you presently would do in a typical swim practice session.

Activity: In the Pool	Time spent in one practice
Warm-up, Cool down & Stretch	____________________(min)
Speed & Power (sprints, intervals)	____________________(min)
Endurance (long distances e.g. repeat 400's, 800's)	____________________(min)
Technique (drills, kicking, flip turns, breathing)	____________________(min)
Total typical swim practice session	____________________(min)

In addition to swim training in the water, how much time do you spend weekly on;

Weights ___________________(min)

Running ___________________(min)

Total typical dry land training ___________________(min)

8. What is the date you started training for the 2005-2006 swimming season?

_______/_______/_______
month day year

9. During the past twelve months that you were involved in intensive swim training, please estimate
    a. The average number of yards/meters swum per day
    b. The average number of days swum per week
    c. The average number of workouts per day

	June 2005	July 2005	August 2005	Sept 2005	Oct 2005	Nov 2005	Dec 2005	Jan 2006	Feb 2006	March 2006	Apr 2006	May 2006
Average daily yrds/mtrs												
Average days per week												
Average workouts per day												

SECTION IV

HEALTH RISK APPRAISAL

American Heart Association Health Risks

AGE

1. If you are a man, are you over age 45?

[ ] yes [ ] no

2. If you are a woman are you over age 55 or are you post-menopause?

[ ] yes [ ] no

FAMILY HISTORY

3. Do you have a close male blood relative who had a heart attack before age 55 (grandfather, father or brother)?

[ ] yes [ ] no [ ] don't know

4. Do you have a close female blood relative who had a heart attack before age 65 (grandmother, mother or sister)?

[ ] yes [ ] no [ ] don't know

5. Do you have a close blood relative who had a brain attack (stroke)?

[ ] yes [ ] no [ ] don't know

SMOKING

6. Do you currently smoke?
[ ] yes [ ] no

7. Do you live or work with people who smoke every day?

[ ] yes [ ] no

8. Are you subject to second-hand smoke?

[ ] yes [ ] no

CHOLESTEROL

9. Is your total cholesterol level 240 mg/dL or higher?

[ ] yes [ ] no [ ] don't know

10. Is you HDL (good cholesterol) level less than 35 mg/dL

[ ] yes [ ] no [ ] don't know

BLOOD PRESSURE

11. Is your blood pressure higher than 140/90 mmHg, or have you been told that your blood pressure is too high?

[ ] yes [ ] no [ ] don't know

PHYSICAL ACTIVITY

12. Do you get LESS than a total of 30 minutes of physical activity on at least 3 days per week?

[ ] yes [ ] no

BODY WEIGHT

13. Are you 20 pounds or more overweight?
[ ] yes [ ] no [ ] don't know

DIABETES

14. Do you have diabetes or need medicine to control your blood sugar?
[ ] yes [ ] no [ ] don't know

MEDICAL HISTORY

15. Do you have coronary artery disease or have you had a heart attack?
[ ] yes [ ] no [ ] don't know

16. Has a doctor ever told you that you have carotid artery disease or have you had a stroke?
[ ] yes [ ] no [ ] don't know

17. Do you have an abnormal heartbeat?
[ ] yes [ ] no [ ] don't know

18. Have you ever been diagnosed with any form of cancer?
[ ] yes [ ] no [ ] don't know

SECTION V
PHYSICAL ACTIVITY APPRAISAL

In this section, we would like to ask you about your current physical activity and exercise habits that you perform regularly, at least once a week. Please answer as accurately as possible. Circle your answer or supply a specific number when asked.

For the last three months, which of the following moderate or vigorous activities have you performed regularly? (*Please circle YES for all that apply and NO if you do not perform the activity; provide an estimate of the amount of activity for all marked YES. Be as complete as possible).*

1. Walking

NO YES ≡ How many session per week? _____
How many miles (or fractions) per session _____
Average duration per session _____ minutes

What is your usual pace of walking? Please circle one.

Casual or Strolling (< 2 mph)	Average or Normal (2 to 3 mph)	Fairly Brisk (3 to 4 mph)	Brisk or Striding (4 mph or faster)

2. Stair Climbing

NO YES ≡ How many flights of stairs do you climb **UP** each day? _____
(1 flight = 10 steps)

3. Jogging or Running

NO YES ≡ How many session per week? _____
How many miles (or fractions) per session? _____
Average duration per session _____ minutes

4. Treadmill

NO YES ≡ How many session per week? _____
Average duration per session? _____
minutes
Speed? _____ mph Grade? _____ %

5. Bicycling

NO YES ≡ How many session per week? _____
How many miles per session? _____
Average duration per session? _____
minutes

6. Swimming Laps

NO YES ≡ How many sessions per week? _____
How many miles per session? _____
(880 yds = 0.5 miles)
Average duration per session? _____
minutes

7. Aerobic Dance / Calisthenics / Floor Exercise

NO YES ≡ How many session per week? _____
Average duration per session? _____
minutes

8. Moderate Sports
[e.g. Leisure volleyball, golf (not riding), social dancing, doubles tennis]

NO YES ≡ How many sessions per week? _____
Average duration per session? _____
minutes

9. Vigorous Racquet Sports
[e.g. Racquetball, singles tennis]

NO YES ≡ How many sessions per week? _____
Average duration per session? _____
minutes

10. Other Vigorous Sports or Exercise Involving Running
[e.g. Basketball, soccer]

NO YES ≡ Please specify ________________________________
How many session per week? _____
Average duration per session? _____
minutes

11. Other Activities

NO YES ≡ Please specify ________________________________
How many sessions per week? _____
Average duration per session? _____
minutes

12. Weight Training
(Machines, Free Weights)

NO YES ≡ How many sessions per week? _____
Average duration per session? _____
minutes

13. Household Activities
(Sweeping, vacuuming, washing clothes, scrubbing floors)

NO YES ≡ How many hours per week? _____

14. Lawn Work and Gardening
NO YES ≡ How many hours per week? _____

15. How many times a week do you engage in vigorous physical activity long enough to work up a sweat?

__________ times per week

SEVEN DAY PHYSICAL ACTIVITY RECALL

During the last seven days, how much total time did you spend doing *vigorous* physical activity and *moderate* physical activity? Record only time actually engaged in the activity (ignore breaks, rest periods, etc.). Please do not record any *light* physical activity (office work, light housework, very light sports such as bowling, or any activities involving any sitting).

Moderate activity (sports such as golf or doubles tennis, yard work, heavy house cleaning, bicycling on level ground, etc).

Total Hours for Last 7 days ________

Vigorous activity (jogging or running, swimming, strenuous sports such as singles tennis or racquetball, digging in the garden, chopping wood, brisk walking, etc.).

Total Hours for Last 7 days _________

SECTION IV:

SF-36® Health Survey

This survey asks for your views about your health. This information will help you keep track of how you feel and how well you are able to do your usual activities.

Answer every question by selecting the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

---

1. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
☐	☐	☐	☐	☐

---

2. *Compared to one year ago*, how would you rate your health in general *now?*

Much better now	Somewhat better now	About the same	Somewhat worse now	Much worse now
☐	☐	☐	☐	☐

---

3. The following questions are about activities you might do during a typical day. Does your health *now* limit you in these activities? If so, how much?

	Yes, limited a lot	Yes, limited a little	No, not limited at all
Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports			
Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf			
Lifting or carrying groceries			
Climbing several flights of stairs			
Climbing one flight of stairs			
Bending, kneeling, or stooping			
Walking more than a mile			
Walking several blocks			
Walking one block			
Bathing or dressing yourself			

4. During the *past 4 weeks*, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

	Yes	No
Cut down on the amount of time you spent on work or other activities		
Accomplished less than you would like		
Were limited in the kind of work or other activities		
Had difficulty performing the work or other activities (for example, it took extra effort)		

5. During the *past 4 weeks*, have you had any of the following problems with your work or other regular daily activities *as a result of any emotional problems* (such as feeling depressed or anxious)?

	Yes	No
Cut down on the amount of time you spent on work or other activities	☐	☐
Accomplished less than you would like	☐	☐
Didn't do work or other activities as carefully as usual	☐	☐

---

6. During the *past 4 weeks*, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

Not at all	Slightly	Moderately	Quite a bit	Extremely
☐	☐	☐	☐	☐

---

7. How much *bodily* pain have you had during the *past 4 weeks*?

None	Very mild	Mild	Moderate	Severe	Very severe
☐	☐	☐	☐	☐	☐

---

8. During the *past 4 weeks*, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
☐	☐	☐	☐	☐

---

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the *past 4 weeks*...

	All of the time	Most of the time	A Good Bit of the Time	Some of the time	A little of the time	None of the time
Did you feel full of pep?						
Have you been a very nervous person?						
Have you felt so down in the dumps that nothing could cheer you up?						
Have you felt calm and peaceful?						
Did you have a lot of energy?						
Have you felt downhearted and blue?						
Did you feel worn out?						
Have you been a happy person?						
Did you feel tired?						

10**.** During the *past 4 weeks*, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
☐	☐	☐	☐	☐

---

11. How TRUE or FALSE is *each* of the following statements for you?

	Definitely true	Mostly true	Don't know	Mostly false	Definitely false
I seem to get sick a little easier than other people	☐	☐	☐	☐	☐
I am as healthy as anybody I know	☐	☐	☐	☐	☐
I expect my health to get worse	☐	☐	☐	☐	☐
My health is excellent	☐	☐	☐	☐	☐

APPENDIX B

Urine Collection Procedures

Urine Collection Procedures:

1. You must abstain from meat for a total of 72 hours:
   The first 48 you will abstain from meat(red meat, fish, poultry, pork) and continue to abstain from meat during the 24 hour collection period.
2. Upon rising in the morning of your collection period, void your bladder in the toilet as normal. From this point on you will collect all of your urine in the sample container.
3. All Urine passed for the next 24 hours should be collected
4. Upon rising the next morning you should void your bladder into the sample container.
5. Write down the total volume of urine collected over the entire 24 hour period.
6. Record the total volume on the small sample test tubes.

How to collect the sample:

1. Write down the start time on the slip provided, immediately after the first morning's void into the toilet
2. Collect all urine provided in containers for the next 24 hours.
3. After final collection (next morning's void into container) record **TOTAL VOLUME** of all urine collected on the slip provided.
4. Full up test tube with sample using funnel and cup provided.
5. Tightly secure cap and seal tube in provided materials.
6. Detach slip
7. Send in mail and discard remaining materials.

Thank you for taking time to participate in this important part of the study. Your information is extremely valuable to us. If you have any questions or concerns please feel free to contact Dr. Joel Stager at stagerj@indiana.edu

Please detach the slip below and include it with your sample! Thank you!

Subject # ______________ Total 24 Hr. Collected Volume __________________ml

Start time______________ Stop time______________

APPENDIX C

Informed Consent Documents

Study # 04-9389

INDIANA UNIVERSITY – BLOOMINGTON
INFORMED CONSENT STATEMENT

Project Title: Age Associated Changes in Total Body Skeletal Muscle Mass and Strength in the Master Swimmers Population

You are invited to participate in a research study. The purpose of the proposed research is to determine whether or not individuals who can be described as having participated in a lifetime of physical activity have a higher level of physical function (as reflected by total skeletal muscle mass, swim performance and strength) and quality of life. The information collected during this investigation will be used to compare total skeletal muscle mass, physical activity patterns, and quality of life of Master Swimmers to values obtained from the general population.

INFORMATION

All of the procedures described below will take place at the regional practice sites or the Human Performance Laboratory in Bloomington, Indiana. Please review the description of the appropriate procedure and its risks, then sign your initials in the space provided. You are free to discontinue participation in these tests at any time without penalty. Testing for this study will occur over a period of 1 ½ days. The measurement of body composition, strength and the completion of the questionnaire will require approximately 80 minutes of your time. You will then be provided instructions regarding the collection of your urine for a 24-hour period. The actual collection time is minimal, but you will be actively engaged in this part of the study for a 24-hour period.

_____ **Body Composition:** Your skin will be pinched at 8 different sites to determine your body composition. The amount of fat and muscle mass will be calculated from these measurements. Bioelectric impedance (BIA) is an additional method which will be employed to measure the fat and muscle components of your body. The bioelectric impedance procedure involves stepping on a scale with electrodes built into the scale and hand grips to determine lean body mass. The cross sectional area of your forearm, upper arm, waist, upper leg muscle, and calf will be measured with a cloth tape. An ultrasound machine will be utilized to estimate muscle mass. The ultrasound technique involves holding a transducer covered in gel ~ 0.5 mm above 9 different sites.

Risks:

Lifting a skinfold requires a mild pinching of the skin that seldom leads to discomfort. There are no significant risks associated with the bioelectric impedance measure. The risks associated with ultrasound measurements may include skin irritation and a possible rash around the transducer sites. Should a rash occur warm compresses will be applied and oral Benadryl® will be provided if needed. Standardized testing procedures will be utilized to minimize the risks associated with the procedures.

_____ **<u>Measurements of Strength</u>:** A measurement of your overall upper body strength will be taken using a small device that measures hand grip strength. You will squeeze as hard as you can a total of three times. You will be asked to jump as high as you can to determine your lower body strength. A measurement of your overall strength will be taken using a small device that measures hand grip strength. You will squeeze as hard as you can a total of three times. A measure of your leg power will be taken using the Newtest Power Timer system. You will be required to stand on a mat and jump as high as you can a total of three times.

<u>Risks:</u>

These strength-testing procedures involve minimal risk. The risks associated with the strength testing are minimal and may include muscle strain or soreness due to brief maximal exertions. You are free to discontinue the test if you feel discomfort.

_____ **<u>Urine Collection:</u>** You will be required to collect your urine in a plastic container (s) for a 24 hour period. You will be required to avoid consumption of red meat, poultry and fish for three days prior to the data collection, and during the urine collection,

<u>Risks:</u>

There are no significant risks associated with 24 hour urine collection.

_____ **<u>Questionnaire:</u>** As a participant in this study, you will be asked to complete a survey which will require approximately 35 minutes of your time. Please answer the questions as accurately as possible. You may decline to answer questions if you choose.

<u>Risks:</u>

There are no known risks associated with completing the questionnaires.

EMERGENCY MEDICAL TREATMENT

In the unlikely event of physical injury resulting from your participation in this research, emergency medical treatment will be provided at no cost to you. Be certain that you immediately notify the researcher if you are injured. If you require additional medical treatment you will be responsible for the cost. No other compensation will be provided if you are injured in this research.

BENEFITS

Other than information regarding body composition, strength, and overall level of health, the subjects will gain little benefit *per se*. All subjects will be provided with feedback concerning their own results and the general findings of the study upon request. No monetary compensation will be included in this project.

CONFIDENTIALITY

Information collected in this study will be kept confidential. Data will be made available only to person's conduction the study unless you specifically give permission in writing to do otherwise. No reference will be made in verbal or written reports which could link you to the study. Codes that have been utilized by the researcher will be destroyed at the completion of this study, which will occur in December of 2010.

CONTACT

If you have any questions at any time about the study or the procedures, (or you experience adverse effects as a result of participating in this study), you may contact the researcher, Joel Stager, Ph.D., at HPER 032, and (812) 855-1637.

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the office for the Human subjects Committee, Carmichael Center, Suite L03, 530 E. Kirkwood Ave, Indiana University, Bloomington, IN 47408, (812) 855-3067, by email at iub_hsc@indiana.edu.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty and without loss of benefits. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits. If you withdraw from the study prior to its completion your data will be returned to you or destroyed.

CONSENT

I have read this form and received a copy of it. I have had all of my questions answered to my satisfaction. I agree to take part in this study.

Subject's Printed Name ____

Subject's Signature ____Date ______________

Investigator's Signature ____Date ______________

Consent Form Date: November 21, 2006

APPENDIX D

Data Collection Sheet

Date: Subject Number Name: ______________________________

Email Address ______________________________

Mailing Address ______________________________

____

Height (cm) ______________ Weight (kg) ______________

Circumferecnces

	Waist	Hip	Thigh	Calf	Mid-Upper Arm
1					
2					
3					
Average					

Sum of Skinfolds

	Biceps	Triceps	Suprailiac	Thigh	Calf
1					
2					
3					
Average					

Lung Volumes

Vital Capacity	Total Lung Capacity	Residual Volume	Peak Expiratory Flow	FEV1	MVV

	SBP (mmHg)	DBP		Left Hand Grip	Right Hand Grip	Vertical Jump (in)
1			1			
2			2			
3			3			
			Max			

APPENDIX E

Raw Data

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI (kg*(m^2)$^{-1}$)	SMM (kg)	% BF	% SMM
1002	USA	1	51	4	34.57	8.3	22.8	31.1	36.00	79.9	23.14	31.15	11	39.0
1007	USA	0	53	4	24.43	4.5	14.5	19	21.60	66	26.78	16.25	31.6	24.6
1022	USA	0	72	6	24.32	3.6	13.2	16.8	18.98	60.2	21.79	9.07	26.5	15.1
1023	USA	0	39	2	24.12	3.7	13.2	16.9	19.10	53.5	20.09	21.59	21.2	40.4
1028	USA	1	41	3	33.65	8.4	21.4	29.8	34.45	78.4	24.74	25.98	13.7	33.1
1029	USA	1	64	5	33.53	8.9	22.7	31.6	36.59	86.2	26.31	21.97	16.3	25.5
1037	USA	1	73	6	35.23	8.1	22	30.1	34.81	86.7	26.03	27.56	18.7	31.8
1038	USA	0	60	5	31.28	5.3	16.2	21.5	24.58	78.7	29.55	16.86	36.8	21.4
1040	USA	0	51	4	24.16	5.2	16.3	21.5	24.58	69	21.06	24.06	21.6	34.9
1049	USA	0	59	4	26.68	5.5	16.3	21.8	24.93	70.5	24.25	15.24	24.7	21.6
1050	USA	0	47	3	29.79	4.9	15.4	20.3	23.15	68.4	25.34	29.74	28.8	43.5
1058	USA	1	44	3	27.77	6	17.9	23.9	27.43	65	22.98	22.66	14.4	34.9
1060	USA	1	45	3	29.67	7.7	19	26.7	30.76	69.3	20.34	34.23	6	49.4
1061	USA	0	46	3	27.16	5.20	15.00	20.20	23.03	60.3	19.10	18.25		30.3
1062	USA	1	52	4	42.93	11.5	25.4	36.9	42.90	86.6	24.35	47.92	5	55.3
1063	USA	1	62	5	34.68	9.1	23.6	32.7	37.90	91.1	26.47	39.41	18.6	43.3
1082	USA	1	50	4	40.18	8.3	23.9	32.2	37.31	89.7	28.25	29.84	20.6	33.3
1084	USA	0	78	6	26.52	4.60	13.70	18.30	20.77	67.9	26.49	13.07	31.3	19.2
1094	USA	1	47	3	38.22	9.3	23.7	33	38.26	88.3	25.74	36.17	15.9	41.0
1095	USA	0	60	5	22.63	4.1	13.5	17.6	19.93	56	21.15	18.55	18.7	33.1
1105	USA	0	81	7	21.18	4	13.2	17.2	19.46	59.5	19.65	14.99	19.9	25.2
1107	Canada	1	55	4	36.14	9	23.4	32.4	37.55	83.1	23.76	29.41	11	35.4
1108	USA	1	62	5	33.76	6.50	20.20	26.70	30.76	77.4	26.04	27.23	17.8	35.2
1124	Canada	0	56	4	25.75	5.2	16.7	21.9	25.05	75.2	26.05	17.66	30	23.5
1131	USA	1	66	5	38.86	10.1	26.4	36.5	42.43	98	29.26	35.94	17.8	36.7
1132	USA	1	61	5	35.48	9	23.3	32.3	37.43	86.8	27.15	33.67	16.5	38.8
1137	USA	0	70	6	30.16	5.5	16.1	21.6	24.69	74.3	27.62	16.97	31	22.8
1139	USA	1	68	5	32.58	6.6	20.2	26.8	30.88	70.4	23.80	28.85	10.8	41.0
1140	USA	0	72	6	18.44	2.7	10.7	13.4	14.94	45.8	19.67	24.71	18.9	53.9
1142	USA	1	47	3	34.71	7.7	20.9	28.6	33.02	76.6	25.33	18.96	15.1	24.7
1148	USA	1	56	4	37.08	8.1	23	31.1	36.00	76.4	24.39	24.85	8.7	32.5
1153	USA	0	44	3	30.39	5.8	17.7	23.5	26.96	75.4	25.91	19.70	26.7	26.1

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI $(kg*(m^2)^{-1})$	SMM (kg)	% BF	% SMM
1158	?	1	75	6	32.18	7.9	23.8	31.7	36.71	87.5	29.44	148.39	19.7	169.6
1166	USA	1	47	3	37.18	9.4	25.6	35	40.64	95.8	26.54	50.77	17.6	53.0
1170	USA	0	46	3	25.08	4.5	14.5	19	21.60	58.2	20.23	20.51	17.1	35.2
1175	USA	1	45	3	37.86	8.1	23	31.1	36.00	83.9	24.78	35.57	16.3	42.4
1180	USA	0	51	4	29.65	5.2	16.9	22.1	25.29	71	24.00	24.98	25.6	35.2
1181	USA	1	82	7	25.23	7.2	20.5	27.7	31.95	73.3	23.66	16.84	8.9	23.0
1182	USA	0	36	2	25.25	4.8	15.1	19.9	22.67	60.6	19.79	22.73	17.1	37.5
1183	USA	1	62	5	33.09	8.9	23.5	32.4	37.55	86	25.13	28.82	15.6	33.5
1185	USA	1	60	5	28.56	5.80	18.60	24.40	28.03	61	19.04	28.51	3.9	46.7
1190	USA	1	49	3	38.22	8.9	26.3	35.2	40.88	84.7	26.03	32.26	10	38.1
1202	USA	0	71	6	19.90	3.80	12.20	16.00	18.03	58.6	23.38	11.13	27.9	19.0
1204	USA	0	25	1	32.75	6.60	18.70	25.30	29.10	75.8	22.63	34.83	20.5	46.0
1209	USA	0	48	3	21.92	3.90	12.50	16.40	18.51	56.9	21.16	14.95	26	26.3
1212	USA	1	62	5	34.29	7.40	21.50	28.90	33.38	79	26.58	27.70	18.1	35.1
1218	USA	0	69	5	29.47	3.80	13.10	16.90	19.10	61.2	21.50	18.55	27.5	30.3
1220	USA	0	52	4	25.16	4.30	15.00	19.30	21.96	64.9	24.85	18.18	29	28.0
1221	USA	1	68	5	28.86	7.00	20.50	27.50	31.72	67.8	19.81	21.97	4	32.4
1232	USA	1	67	5	29.17	7.90	22.40	30.30	35.05	79.7	24.46	30.41	11.9	38.2
1236		1	70	6	27.62	6.10	16.20	22.30	25.53	59.6	20.38	62.93	6.4	105.6
1239	USA	0	61	5	21.41	4.30	13.30	17.60	19.93	59.2	21.61	14.09	22.3	23.8
1242	UK	1	71	6	31.06	7.20	20.10	27.30	31.48	71.9	23.21	15.70	10.8	21.8
1247	USA	1	56	4	36.48	8.20	22.30	30.50	35.29	82.7	27.95	27.24	17.9	32.9
1255	USA	0	42	3	25.12	4.60	14.60	19.20	21.84	55.4	19.19	28.82	11.8	52.0
1257	USA	1	52	4	34.49	8.80	22.60	31.40	36.36	87	28.25	33.04	19	38.0
1259	Costa Rica	0	46	3	22.73	4.80	15.80	20.60	23.50	61.6	21.75	21.70	18.2	35.2
1260	CAN	1	70	6	31.52	6.50	19.70	26.20	30.17	73.5	27.13	29.26	18.6	39.8
1264	USA	0	75	6	20.97	3.60	12.50	16.10	18.15	60.1	25.18	18.84	30.1	31.3
1272	UK	0	33	2	36.36	6.50	18.00	24.50	28.15	77.6	26.45	27.35	26	35.3
1273	CAN	1	35	2	39.35	8.70	23.60	32.30	37.43	79.2	24.86	36.52	10.9	46.1
1277	SCOT	1	66	5	35.54	8.10	23.10	31.20	36.12	76.2	24.88	31.26	7.4	41.0
1284	USA	1	81	7	31.28	6.00	17.50	23.50	26.96	80.1	26.16	25.87	27.5	32.3

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI $(kg*(m^2)^{-1})$	SMM (kg)	% BF	% SMM
1285	USA	0	42	3	41.70	7.30	21.10	28.40	32.79	98.4	31.55	34.41	35.7	35.0
1286	USA	0	51	4	29.17	6.50	18.30	24.80	28.50	74.9	25.14	26.63	20.3	35.6
1293	USA	1	43	3	38.36	8.50	21.60	30.10	34.81	76.2	23.41	48.20	11	63.3
1294	NZ	0	53	4	23.50	3.90	13.60	17.50	19.82	53.6	19.59	36.63	14	68.3
1307	USA	1	49	3	39.46	10.5	26.9	37.4	43.50	106.5	29.75	46.14	22.7	43.3
1315	USA	0	50	4	26.88	5.1	15.5	20.6	23.50	60.2	20.30	8.09	11.6	13.4
1324	USA	0	30	2	27.49	5.5	16.7	22.2	25.41	65.1	20.09	21.64	15.6	33.2
1326	USA	1	39	2	38.79	9.2	22.9	32.1	37.19	83.5	23.85	48.98	12.5	58.7
1337	USA	1	40	3	33.14	6.6	18.5	25.1	28.86	65.2	20.81	20.59	10.6	31.6
1338	USA	1	70	6	27.37	6.3	18.7	25	28.74	73.4	24.70	21.08	19.3	28.7
1340	USA	0	47	3	23.39	4.8	14.2	19	21.60	61.8	21.36	19.77	22.7	32.0
1342	USA	0	40	3	27.82	4.1	13.4	17.5	19.82	56.1	22.64	23.40	23.5	41.7
1345	S. Africa	0	61	5	25.11	4.5	14.5	19	21.60	66.3	26.90	24.47	30.6	36.9
1346	S. Africa	1	57	4	35.08	8.2	24	32.2	37.31	89.3	26.96	28.95	19.7	32.4
1348	USA	1	47	3	37.74	6.1	19.2	25.3	29.10	72.1	24.51	31.64	20.2	43.9
1351	USA	0	54	4	23.86	4.4	14.8	19.2	21.84	61.7	22.26	20.90	22.4	33.9
1354	UK	1	59	4	41.41	9.1	25.6	34.7	40.28	91.3	25.67	39.67	15.3	43.4
1367	USA	1	64	5	30.49	7.2	20.5	27.7	31.95	72.6	20.96	27.90	11	38.4
1372	USA	0	50	4	22.28	3.7	13.9	17.6	19.93	57	23.57	20.17	24.4	35.4
1376	USA	1	57	4	33.80	8.4	21.9	30.3	35.05	81.3	24.57	38.77	14.1	47.7
1379	USA	0	51	4	24.71	4.7	14.7	19.4	22.08	60.5	20.47	16.27	17.4	26.9
1384	USA	1	49	3	41.68	10.3	24.5	34.8	40.40	87.6	25.82	45.22	11.4	51.6
1386	USA	1	48	3	38.02	8.4	23	31.4	36.36	80.6	25.27	50.28	12.3	62.4
1387	USA	0	65	5	27.18	4.5	14.3	18.8	21.36	67.3	25.80	30.79	30	45.7
1388	USA	0	53	4	26.81	5.8	17.1	22.9	26.24	74.5	24.22	32.19	24.1	43.2
1391	USA	0	49	3	29.73	5.1	15.5	20.6	23.50	74.2	24.48	22.13	31.6	29.8
1392	USA	0	45	3	27.10	5.5	16.4	21.9	25.05	65.8	20.11	23.36	16.3	35.5
1393	USA	0	36	2	27.07	4.2	14.9	19.1	21.72	57.7	19.73	21.47	17.3	37.2
1396	USA	0	30	2	26.86	4.8	15.1	19.9	22.67	58.2	21.07	20.17	16.9	34.7
1397	USA	1	42	3	35.77	6.9	20.2	27.1	31.24	69.4	22.15	44.30	10.7	63.8
1398	USA	0	53	4		4.1	13.7	17.8	20.17	66.3	25.11	4.23	34	6.4
1399	USA	0	42	3	26.32	5.8	15.7	21.5	24.58	63	22.32	19.26	16.5	30.6

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI $(kg*(m^2)^{-1})$	SMM (kg)	% BF	% SMM
1404	USA	1	58	4	34.49	9.70	24.71	34.41	39.94	84.5	23.76	54.58	7.7	64.6
1419	Croatia	1	42	3	38.53	8.7	23	31.7	36.71	75	21.73	35.80	4.1	47.7
1421	USA	1	48	3	37.07	9.30	24.70	34.00	39.45	87.9	26.54	34.38	12.9	39.1
1422	USA	0	63	5	19.67	4.4	13.5	17.9	20.29	53.6	18.97	10.23	10.1	19.1
1423		1	41	3	37.57	10.80	26.40	37.20	43.26	92.2	24.91	81.16	11.1	88.0
1425	UK	1	42	3	38.25	8.8	23.9	32.7	37.90	85.2	23.93	32.23	13.2	37.8
1428	CAN	1	54	4	34.89	8.00	21.90	29.90	34.57	77.1	24.25	36.84	10.6	47.8
1436	USA	1	59	4	35.32	8.90	23.30	32.20	37.31	88.5	25.04	41.29	16.2	46.7
1437	USA	1	73	6	26.43	5.4	18.3	23.7	27.19	64	22.41	27.55	12.8	43.0
1447	USA	0	40	3	24.42	4.9	15	19.9	22.67	56.7	19.32	13.84	10.8	24.4
1448	USA	1	43	3	34.19	7.1	20.3	27.4	31.60	72.7	24.55	34.71	14.4	47.7
1458	US	1	40	3	36.02	8.7	22.7	31.4	36.36	86.1	26.05	28.63	18	33.2
1459	US	0	42	3	24.34	4.3	13.5	17.8	20.17	54.6	21.95	33.90	19.2	62.1
1462	US	0	55	4	21.78	4.2	13.3	17.5	19.82	59.8	22.37	19.78	26.4	33.1
1463	USA	1	69	5	32.34	7.4	22	29.4	33.98	83.1	25.94	15.50	18.3	18.6
1464	USA	0	72	6	19.86	3.90	12.90	16.80	18.98	67.3	26.09	14.62	36	21.7
1465	USA	1	43	3	38.47	9.10	23.20	32.30	37.43	87.1	26.18	28.05	17.4	32.2
1466	USA	1	64	5	37.79	9.80	26.00	35.80	41.59	91.1	26.76	26.32	13.6	28.9
1467	USA	1	56	4	27.02	6.6	16.9	23.5	26.96	65.2	20.58	16.05	10.1	24.6
1477	USA	0	33	2	25.64	4.70	14.50	19.20	21.84	59	20.90	19.66	20.2	33.3
1481	USA	0	55	4	24.64	4.40	14.30	18.70	21.24	55.3	21.90	23.75	15.6	42.9
1491	USA	0	42	3	30.22	5.70	18.60	24.30	27.91	80.7	28.09	26.47	32.2	32.8
1494	n/a	1	81	7		7.4	23.3	30.7	35.52	80.6	25.73	18.30	14.4	22.7
1496	USA	0	58	4	21.64	4.00	12.50	16.50	18.63	52.8	17.24	20.34	14.1	38.5
1500	USA	1	52	4	38.09	8.90	25.30	34.20	39.69	92.4	26.42	20.72	16.9	22.4
1512	USA	0	48	3	21.31	3.00	11.30	14.30	16.01	46.8	18.75	13.87	18.8	29.6
1514	USA	0	55	4	26.07	5.50	16.40	21.90	25.05	76.9	27.91	19.11	32.9	24.9
1516	USA	0	65	5	32.84	5.70	16.70	22.40	25.65	83.7	29.94	12.76	37	15.2
1524	Portugal	1	45	3	31.79	8.80	21.90	30.70	35.52	72.8	22.59	20.61	4.2	28.3
1525	USA	1	43	3	47.77	11.60	28.60	40.20	46.83	104.5	28.29	41.43	15.9	39.6
1526	CAN	1	66	5	30.61	7.30	20.20	27.50	31.72	75.8	25.27	24.34	16	32.1
1537	USA	0	50	4	22.72	3.60	12.60	16.20	18.27	53.2	19.49	12.94	20.6	24.3

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI $(kg*(m^2)^{-1})$	SMM (kg)	% BF	% SMM
1542	USA	1	76	6	30.24	7.00	21.90	28.90	33.38	79.7	24.76	23.68	16.2	29.7
1548	USA	0	55	4	26.11	5.60	15.80	21.40	24.46	64.8	21.90	19.60	16.2	30.2
1549	USA	1	48	3	32.64	6.70	21.60	28.30	32.67	73.2	22.34	15.74	10	21.5
1550	USA	1	38	2	37.02	8.65	23.50	32.15	37.25	82.1	21.64	36.70	9.2	44.7
1554	USA	1	51	4	37.78	9.60	23.00	32.60	37.78	84.7	23.51	42.14	11.1	49.8
1556	USA	0	53	4	21.42	4.10	13.00	17.10	19.34	58.7	22.23	25.13	25.1	42.8
1558	USA	1	42	3	37.73	8.00	22.80	30.80	35.64	89.6	29.94	32.84	23.6	36.6
1560	UK	1	75	6	30.30	7.10	20.60	27.70	31.95	75	24.77	14.80	14.1	19.7
1561	SPAIN	1	62	5	37.03	7.90	22.80	30.70	35.52	73.9	25.27	32.86	7.2	44.5
1563	Spain	1	66	5	31.47	6.9	20.8	27.7	31.953	79	27.34	22.98	19.4	29.1
1700	USA	1	62	5	37.77	7.9	20.4	28.3	32.667	85	26.77	23.08	19.2	27.1
1701	USA	1	48	3	32.09	6.9	20.5	27.4	31.596	72.8	22.98	30.89	13.4	42.4
1702	USA	0	54	4	23.30	4.6	15.3	19.9	22.671	70.7	24.58	18.47	30.6	26.1
1705	USA	1	63	5	32.64	9.2	22.6	31.8	36.832	76.9	23.47	26.19	4.5	34.1
1706	USA	1	50	4	41.26	9.8	24.4	34.2	39.688	90.9	24.92	45.14	13.6	49.7
1707	USA	0	56	4	23.03	5.1	14.9	20	22.79	67.8	25.99	14.88	28.1	21.9
1710	USA	0	45	3	19.73	3.9	12.8	16.7	18.863	52.9	19.24	16.43	18	31.1
1712	USA	1	54	4	34.50	7.2	21.1	28.3	32.667	78.2	23.56	17.23	16.5	22.0
1713	USA	0	45	3	21.18	4	12.5	16.5	18.625	54.4	19.79	28.43	21.9	52.3
1714	USA	1	47	3	40.33	11.1	25.8	36.9	42.901	98.2	25.25	41.86	14.3	42.6
1715	USA	1	52	4	48.68	10.2	26.9	37.1	43.139	106.3	33.47	39.83	24.2	37.5
1716	USA	1	66	5	29.02	7.6	21.4	29	33.5	84.8	30.26	19.88	23.5	23.4
1718	USA	1	36	2	38.74	10.1	25.2	35.3	40.997	102	30.23	35.20	23.4	34.5
1719	USA	1	57	4	36.50	9.1	22.8	31.9	36.951	85.7	24.61	31.63	13.8	36.9
1720	USA	0	50	4	26.73	4.5	14	18.5	21.005	60.3	19.36	78.98	19.9	131.0
1721	USA	1	36	2	37.90	8.3	22	30.3	35.047	77.4	23.11	30.14	11.3	38.9
1722	USA	0	36	2	29.57	5.8	17	22.8	26.122	72.3	23.37	11.14	23	15.4
1725	USA	1	52	4	39.76	9.3	24	33.3	38.617	94.9	26.15	30.67	19.4	32.3
1726	USA	1	52	4	34.61	7	21	28	32.31	80.9	28.90	39.71	22.9	49.1
1728	USA	0	51	4	18.68	2.9	11.1	14	15.65	45.6	17.75	15.04	18.9	33.0
1729	USA	1	27	1	32.91	6.5	18	24.5	28.145	62.1	20.89	26.69	9.1	43.0
1730	USA	0	29	1	24.85	4.8	14.8	19.6	22.314	60.2	23.08	19.01	21.6	31.6

Subject#	Citizen	Sex	Age (yrs)	AC	SF Est (MM kg)	BIA Arm (kg)	BIA Leg (kg)	BIA APP (kg)	BIA Total (kg)	Weight (kg)	BMI $(kg*(m^2)^{-1})$	SMM (kg)	% BF	% SMM
1731	USA	1	34	2	36.76	8.5	21.8	30.3	35.047	83.4	25.83	63.25	17.7	75.8
1733	USA	1	52	4	35.90	7.9	20.5	28.4	32.786	72.3	23.05	27.73	8.8	38.4
1734	USA	0	50	4	23.62	4.2	12.6	16.8	18.982	55.1	21.34	17.97	20.1	32.6
1736	USA	0	42	3	29.01	5.6	15.9	21.5	24.575	68.9	23.73	21.12	26	30.6
1737	USA	1	47	3	37.37	10	21.5	31.5	36.475	79.8	25.33	32.58	12.3	40.8
1738	USA	1	52	4	33.83	7.6	21.5	29.1	33.619	85.2	29.41	15.40	23.5	18.1
1739	USA	0	44	3	24.78	4.7	14.4	19.1	21.719	67.2	25.20	19.21	30.4	28.6
1741	USA	1	57	4	40.83	9.9	23.7	33.6	38.974	87.9	25.46	43.44	12.7	49.4
1753	USA	0	47	3	27.65	7.7	15.3	23	26.36	70.4	20.73	20.70	15.8	29.4

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Education

M.S. Exercise Physiology, December 2009
Indiana University

B.S. Exercise Science, May 2004
Minor: Chemistry
Indiana University

Professional Experience

Teaching:

Associate Instructor Indiana University School of HPER (2004-Present)

Teach core principles crucial to students' understanding of exercise physiology, structural kinesiology, personal fitness, swimming, and overall wellness

Courses Taught:
- P409 Exercise Physiology Laboratory
  - Lab Instructor (9 semesters, 2005-present)
  - Lab Coordinator (3 semesters, 2008-present)
  - Lecture A.I. (2 semesters, 2008-present)
- P205 Structural Kinesiology Laboratory
  - Lab Instructor (2 semesters, 2007-2008)
- E119 Personal Fitness Laboratory (2 semesters, 2006-2007)
- E287 Intermediate Swimming (2 semesters, 2007-2008)
- E187 Beginning Swimming (1 semester, 2007)
- A187 Introduction to Swim Coaching (2 semesters, 2006-2007)
- T142 Living Well (2 semesters, 2004-2005)

Undergraduate Teaching Assistant (2004) Indiana University

Instructed various lectures and laboratory sections for the undergraduate course, "*Methods of Personal Training"*

Research:

Councilman Center for the Science of Swimming (2004-Present)

"USMS Masters Swimming Analysis Camp" (2005)
"Muscle Mass and Physical Activity in Adults" (2006)
"Quality of Life and physical Activity in Highly Active Adults" (2006)
"Influence of post-exercise carbohydrate, protein, and fat ingestion on endurance exercise performance" (2007)
"Cognitive Profiles of Highly active Aging population" (2009)
"Cardiovascular Profiles of Highly Active Aging Population" (2009)

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Lindeman, A.K.; Johnston, J.D.; Shepherd, C.; Stickford, J.L.; **McCracken, C.M.;** Stager, J. M. FACSM Palatability, Preference and Tolerance of Possible Recovery Beverages Following Exhaustive Exercise. Medicine & Science in Sports & Exercise. 40(5) Supplement 1:S400-S401, May 2008.

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Service

Yoga Instructor, Vibe Yoga and Pilates Studio (Present)
Group Exercise Leader, Indiana University (2003-Present)
Swim Coach, Counsilman Center Swim Team (2005-2008)
Coach and Counselor, IU Swimming Camp (2004 & 2005)
Assistant Women's Swimming Coach, Martinsville High School (2003-2004)

Certifications and Memberships

American Red Cross AED, CPR, PDT, & First Aid (1996-present)
American Red Cross Lifeguard (2008-present)
American Red Cross Swim Coaches Safety (2006)
A.C.E. Fitness Professional (2003-2008)
Member American College of Sports Medicine (2005-present)