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Leg-extensor strength and continuous-scale physical functional performance in independent-living older adults

Kathryn O'Bryan Wilson

Louisiana State University and Agricultural and Mechanical College

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LEG-EXTENSOR STRENGTH AND CONTINUOUS-SCALE PHYSICAL FUNCTIONAL PERFORMANCE IN INDEPENDENT-LIVING OLDER ADULTS

A Thesis

Submitted to the Graduate Faculty
of the Louisiana State University
Agricultural and Mechanical College
in partial fulfillment of the
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Master of Science

in
The Department of Kinesiology

by
Kathryn O'Bryan Wilson
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DEDICATION

I would like to dedicate my thesis to my wonderful husband, Dwayne Wilson, and my loving parents, Nancy and Don O'Bryan. My husband has stood by my side throughout my graduate career and has helped me strive to do my best and maintain a positive attitude during trying times. My parents have helped me become the person I am today, and I am forever grateful for their guidance. I would not have been able to achieve the heights I have without all of the undivided love from each of these individuals. Thank you all!

ACKNOWLEDGEMETNS

I would like to express a great thanks to Dr. Robert Wood for helping me from the beginning to the end of my graduate career. I would not have finished if it were not for his guidance and support. I would also like to thank Amy Dunbar and Kellye Ferrachi for helping in the data collection. Finally, I would like to express thanks to the St. James Place Residents, who participated in my research, and the administrators, for allowing me to collect my data on their campus.

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ABSTRACT

A clear relationship between age-related decrements in leg strength and physical function have been reported. The purpose of this investigation was to describe the relationship between quadriceps strength tested at various velocities and the CS-PFP 10 items. Thirty-three older adults (ages 70-95 years) were assessed using the CS-PFP 10 test battery and performed quadriceps strength testing at 0, 90, 180º/sec using the Biodex dynamometer. Values for torque are reported as peak torque (PT) and relative peak torque (AdjPT) in Nm/kg body weight. The range of values for PT was (PT0: 20.2-144.3 Nm; PT90: 14-113.6 Nm; PT180: 9.6-86.4 Nm). Simple correlation revealed age was inversely related to quadriceps strength (with PT0, r=-0.368; PT180, r=-0.384), while nearly significant at PT90 (r=-0.339, p=0.54), and the overall CS-PFP 10 scores (r=-0.657, p<0.001). However, when treating the data according to gender, the relationship between age and strength did not achieve significance for either males or females. Age was associated with several of the individual CS-PFP items. Results also revealed relationships between absolute strength and CS-PFP 10 scores (PT0 r=0.622 p<0.001; PT90 r=0.683 p<0.001; PT180 r=0.614 p<0.001). Moreover, the association between age and function appeared somewhat similar for males (-0.621) and females (-0.678). However, the male subjects also showed associations between relative strength (AdjPT90 and AdjPT180) and CS-PFP10 scores, while females revealed an association between relative strength and function at 0 per second, only. Lastly, curve fitting revealed that the association between strength and function in this group of older adults is linear, thereby suggesting the absence of an identifiable functional threshold above which an increase in strength would not result in an increase in function. The results are consistent with age-related decrements in functional fitness and quadriceps strength. In each case these correlation coefficients suggest that greater levels of strength were associated with greater functional performance. Furthermore, these data suggest that absolute strength may be better associated with physical functioning than relative strength. Future research should continue to search for thresholds of strength as they relate to physical functional ability.

CHAPTER 1. INTRODUCTION

Throughout last century, the proportion of the population aged 65 and older steadily increased. According to the United States Census, in the year 2000 there were 35,322,000 individuals aged 65 and older, or approximately 12.8% of the population. It is estimated that the number of individuals aged 65 and older will increase to 70,175,000 or 20.1% in the year 2030, and further increase to 80,109,000 or 20.4% in the year 2050 (US Census, 2000).

This increasing of numbers of the older population raises concerning questions about the aging process. The aging process and the process of aging are two different terms, but strongly interact with each other. The aging process signifies the overall changes with age within a species or population that are independent of disease or environmental influences (Spirduso, 1995). For example, the onset of puberty in children and menopause in women are age related changes that are not influenced by disease. The process of aging refers to clinical symptoms and it is dependent on the environment and disease. This is an interaction of the aging process with disease and environmental influences (Spirduso, 1995). The process of aging can decrease functionality as well as strength. If functionality and strength are decreased, maintaining independence in activities of daily living (ADL's) may be hindered, as physical function is an integral constituent of ADL's (Cress et. al., 1995). According to Cress et. al. (1996), physical function is the integration of physiological capacity and physical performance capability intervened with by psychosocial factors, such as confidence, motivation, perceived ability, depressive symptomology, and social role. Physiological capacity relates to basic cellular and anatomic functions such as nerve conduction and cardiac ejection fraction, while physical performance is the ability to combine these physiological systems into synchronized, proficient movements to achieve maximum physical function. A decrease in physical activity can lead to low muscle strength, which is associated with poorer physical function, but there is limited research available to establish the relationship between physical function and muscle mass (Visser et. al., 2000). This lowered muscle strength leads to difficulties with ADL's such as transfers, gait, balance, falling, dressing, shopping, stair climbing, and getting up from a seated position (Brown et. al., 1995; Carmeli et. al., 2000).

1.1 Justification for Research

Due to the growing number of individuals aged 65 and older, there needs to be some way to overcome the decline in functionality due to the process of aging. Physical performance tests have become widely used because of concerns that self-reported function does not provide enough information about the type of impairment and that they lack sensitivity to change (Cress et. al., 1996). These physical performance measures are appealing to investigators because of their insight into the severity of functional limitations, sensitivity to change, and their face validity (Cress et. al., 1996). With this new interest for these performance tests, several new tests have been published. These new performance-based tests pose some limiting factors; they either focus on mobility dysfunction or on people with severe limitations (Cress et. al., 1996). The previously utilized performance based tests have some limitations as well. They do not solely focus on ADL's, rather they measure movements that may or may not be associated with ADL's.

Therefore, it was the aim of Cress et. al. (1996), to develop a reliable measure of physical functional performance test that was not inhibited by ceiling or floor effects, that used many physical areas, and applied to a wide spectrum of abilities. This physical functional performance test is known as the Continuous-Scale Physical Functional Performance test (CS-PFP). This CS-PFP looks at all areas of ADL's and provides a widespread, in-depth measure of physical function that exposes abilities in several separate physical domains (Cress et. al., 1996).

In the older adult population, strength seems to be positively related to functional abilities and/or ADL's (Bassey, 1992; Buchner, 1992; Carmeli, 2000; Ferrucci, 1997; Jette, 1998; Visser, 2000). In order to determine the relationship between muscular strength and physical performance, the valid and reliable method by Cress and colleagues (the CS-PFP) is needed to measure the aspect of physical performance, and a valid and reliable method of measuring strength is needed.

One of the critical issues in selecting a strength measure is choosing the velocity of movement. Clearly, velocity is known to influence peak torque production. Therefore, it is of interest to examine whether speed of movement influences the relationship between peak torque and function. In addition, Jette et. al. (1998) concluded that the relationship is curvilinear, and that understanding this relationship will allow the recognition of a minimum level of strength required for maintaining or recovering function. Therefore, it would help identify those weak individuals experiencing unequal and sizable gains in function from intervention (Jette et. al., 1998). Thus, examining linear and curvilinear regression models for fitting quadriceps strength (at various velocities) to function curves also poses interest.

1.2 Purpose

Therefore, it was the purpose of this project to examine whether speed of movement influences the relationship between peak torque and function. The second purpose of this study was to examine linear and curvilinear regression models for fitting quadriceps strength (at various velocities) to function curves.

1.3 Research Hypotheses

While the question as to which speed of movement will be most closely associated with function is empirical, many of the CS-PFP tasks are time to completion items (i.e., a speed component). Therefore, we hypothesized that the relationship between peak torque and function will be strongest at the faster velocities. Based on Jette et. al. (1998), we also hypothesized that curvilinear models will provide a better fit for describing the strength vs. function curves, as compared to linear models.

1.4 Limitations of the Study

This study was limited to only Caucasian male and female residents of St. James Place Retirement Community. Moreover these residents reflect a generally well-educated and affluent group of seniors. Lastly, all participants were volunteers and most participated in an aerobics class on a weekly basis or participated in an exercise program.

CHAPTER 2. REVIEW OF LITERATURE

2.1 Deterioration of Function with Age

Men and women between the ages of 65 and 69 can plan to spend, on average, 30% and 46%, respectively, of their remaining years with significant dependent-care needs. The evidence is clear, that the primary cause is a decrease in physical functional ability (Evans, 1996).

Thus, considerable research has been conducted regarding the deterioration of function in later life. York and Biederman (1990) studied the effects of age on tapping performance. They indicate that mean time decreased from the 2nd to the 3rd decade of life, but steadily increases up until the 8th decade. Samson et. al. (2000) agrees with the decline in functionality with age. They studied 155 men and women (20-90 years of age) and noted that the times for the 'get up and go' test were longer and the distances in the modified Cooper test were shorter in the older subjects (for men: 42% and 21% respectively; for women: 47% and 28% respectively). These studies indicate that functionality does decline with age.

Concurrent with the age-related decline in function is the appearance of an age-related decrease in general measures of physical fitness, including measures of muscular strength and maximal oxygen consumption. Samson et. al. (2000) investigated isometric knee extensor strength, handgrip strength, and leg extensor power, and noted a progressive decline with age (for men: 42%, 34%, and 49% respectively; for women: 46%, 34%, and 61% respectively). This is representative of the literature, Vandervoort (1992) agrees with the decline in strength with age, as well as, Doherty (2001). With respect to maximal oxygen consumption (VO_{2max}), Booth et. al. (1994) reported that by age 65 mean VO_{2max} decreases to roughly 70% of that of a 25 year-old. They suggest that the VO_{2max} decreases at a rate of approximately 0.45 $ml \cdot kg^{-1} \cdot min^{-1} \cdot yr^{-1}$.

Of particular relevance to the present investigation are age-related decrements in muscle strength and the concomitant effects on physical function. Age-related weakening of skeletal muscle may be a direct manifestation of true biological changes that occur as a result of aging. However, these changes may also arise as a result of disuse atrophy, undernutrition, and/or the accumulation of chronic diseases and the use of medications to treat those diseases (Fiatarone et. al., 1993). The purpose of this review is to examine the different aspect of the aging process, whether it is the normal aging process or those related to a biological or a contractile change, disease oriented, a reduction in use, or malnutrition. It is also the purpose of this review to examine the different functionality tests available for the older adult, and possiblely to see what strength test are most closely related to function.

2.1.1 Biological Changes with Age

Many biological changes occur with advancing age. Due to the reduction in physical activity level that frequently accompanies age, it is hard to distinguish the separation between “normal aging” and the biological changes that occur through disuse and incidence of hypokinetic diseases (i.e. cardiovascular disease, adult onset diabetes, etc.). Nonetheless, it is believed that several distinct changes occur with age. Perhaps, most notorious of all age-related changes, is the quite apparent change in the human physique, characterized by the well-documented increase in percent body fat. Between the ages of 20 and 65 average percentage of body fat increases from 18-36% for males and 33-44% for females. Interestingly, while percent fat continues to increase throughout life, body weight reaches its peak at approximately 50 years of age and starts to decline at about 70 years (Spirduso, 1995). Thus, the continued increase in percent fat beyond age 50 has been ascribed to not only an accumulation of fat mass, but also a decrease in muscle mass (Evans, 1996). It is this age-related loss of muscle mass (a.k.a. sarcopenia) that plays a large role in the age-related loss of muscle strength (Evans, 1996).

A loss of muscle mass may be explained by one or more of several mechanisms that include a decrease in the size of muscle fibers, particularly the larger glycolytic or type II muscle fibers, a loss of motor units and potentially either a concomitant loss of muscle fibers or an abnormal grouping of one fiber type suggestive of neuropathic processes. Regardless of the specific mechanism, however, there is little question that total muscle fiber cross sectional are changed with age. As demonstrated by, Booth and colleagues (1994), muscle area decreases tremendously with age (see figure 2.1). This reduction in muscle area, due to contractile changes, biochemical changes, and disuse, can lead to functional impairment.

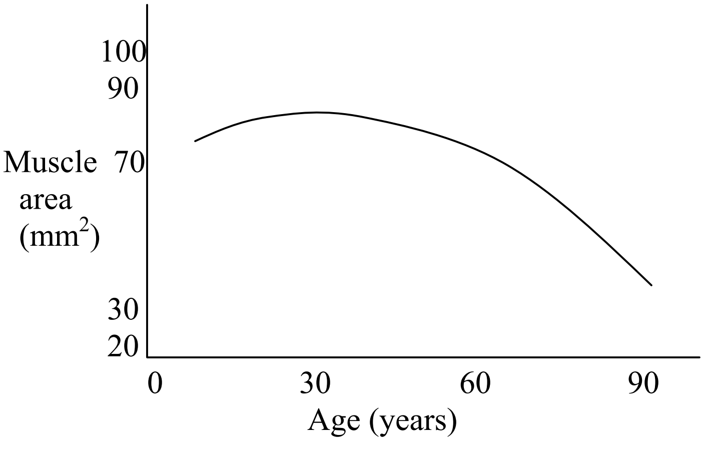

Figure 2.1 Muscle Mass Deterioration with Age: Line of best-fit showing how muscle mass is decreased with age. There seems to be a 40% reduction in total muscle mass between the ages of 24 to 80. There is a 10% reduction between 24 and 50 years and an additional 30% reduction between the ages 50 and 80.

As to the extent to which the total loss of muscle mass is due to a ***loss*** in type II fiber numbers is somewhat controversial. Early studies indicated that the number of type II muscle fibers decrease with age and there is a shift toward a higher percentage of type I fibers (Klitgaard et. al., 1990; Vandervoort, 1992; Fiatarone et. al., 1993; Rogers and Evans, 1993). This issue is controversial, and more recent data suggest that the reduction in strength is not due to and higher percentage of type I fibers, but rather a relatively greater decrease in type II fiber cross-sectional area (Rogers and Evans, 1993). Thus, our most recent information suggests that quantitative changes, not qualitative changes, in the muscle accounts for the majority of age-related muscle weakness (Fiatarone et. al., 1993).

Closely associated with the loss of muscle mass are the appearance of changes in the contractile and biochemical properties of skeletal muscle. These contractile and biochemical changes may be of unique consequence in that some investigators have shown that the decrease in muscle strength is greater than that of muscle mass loss with age.

Of particular interest has been the age-related decrement in maximal force production of between 35% and 55% (Roger and Evans, 1993). Larsson and colleagues (1978) noted that quadriceps strength increased up to the age of 30 years, remained rather constant to the age of 50 years, and then decreased with increasing age, a decrease of 24-36% between the ages of 50 and 70 years. Vandervoort and McComas (1986) also note a reduction in force production. Their results show a 56 and 55% (63 and 48% for women) reduction in dorsiflexor and plantarflexor torques, respectively, between the youngest group (20-32 years) and the oldest group (80-100 years). Maximal voluntary force (MVF) is related to muscle cross-sectional area (CSA) (Bruce et al., 1989). While the relationship of MVF/CSA (a.k.a., specific tension) appears to be fairly stable within narrow age ranges, it is 73±4% less in the elderly than in young adults. Also, there seems to be a specific decrease in normalized force (27±4%) in the older subjects in the human adductor pollicis muscle, which is a smaller muscle. Thereby indicating that the MVF/CSA decreases even in the smaller muscles and supports the notion of age-related changes in specific tension (Bruce et. al., 1989). This is in agreement with Vandervoort and McComas (1986), where the mean cross-sectional area values, of the triceps surae complex, were from 31.1cm^2 to 36.5cm^2 in the younger subjects and then decreased to a range of 20.9cm^2 to 28.0cm^2 in the older subjects. These reductions were less than the decrease in the maximum voluntary plantarflexion contraction, indicating that the tension decreases with a reduction in cross-sectional area (Vandervoort and McComas, 1986). Rogers and Evans (1993) found similar differences; however, their MVC/CSA was only slightly different between the young and the old female subjects, even though the older women were weaker than the younger women. This was also true of the male subjects. The appearance of age-related changes in specific tension suggest that part of the age-related decrement in muscle strength are qualitative, perhaps due to alterations in neural recruitment capacity with age, and that such qualitative changes may also contribute to the functional decline (Fiatarone et. al., 1993).

In addition to the age-related reductions in maximal force production, and specific tension there are is also an age-related reduction in time to peak force and an increase in ½ relaxation time. Vandervoort and McComas (1986) demonstrated that the contraction was significantly longer for women then for men and for the older subjects then for the younger subjects. For the 20-32 year age group the contraction time was between 144ms and 146ms for men and women, respectively, and in the 80-100 year age group, the contraction time increased to 186ms to 195ms for men and women, respectively. Vandervoort and McComas (1986) report that with increasing age, the ½ relaxation time is prolonged in both sexes, from the youngest age group to the oldest age group there was ~75 and 72% increase in the ½ relaxation time in males and females, respectively, for the ankle plantarflexor muscle.

Consistent with the decrease in muscle fiber size and contractile properties are a number of biochemical changes in muscle tissue. These include a lowering of ATPase activity, a decrease in the numbers and size of the mitochondria and a diminished activity of oxidative enzymes (Fiatarone et. al., 1993). According to Rogers and Evans (1993), there seems to be no change in the enzymatic activity of the muscle with age. However, later studies indicate that myokinase activity declines approximately 45% with age in both type I and type II fibers. The authors believed this to be a result of the decrease in the physical activity pattern of the older adult, in that the reduction in the activities that recruit fast-contracting type II muscle cells with the addition of the stimulus training of myokinase activity.

2.1.2 Disease and Medication

The accumulation of multiple acute and chronic illnesses and the associated pharmacologic interventions may also impair strength and physical functional in older adults (Fiatarone, 1993). In addition, acute and chronic infections may negatively affect skeletal muscle metabolism and performance, and may lead to the wasting of muscle tissue. Endocrinologic diseases may also lead to muscle weakness and atrophy (Fiatarone, 1993). Drew and colleagues (1988) studied how disease affects skeletal muscle size and contractile properties. After infecting hamsters with Leishmania donovani, a parasite that causes chronic disease in humans (characterized by fever, anorexia, weight loss, weakness, and muscle wasting), they anesthetized them to extract the plantaris, soleus, and diaphragm. Further examination concluded that if infected with Leishmania donovani all three muscles decrease in weight, had a reduction in cross-sectional area, and a decrease in optimal length as compared to the control. In addition, all three muscles had a decrease in weight and cross-sectional area if there was a caloric restriction as compared to the control. On the other hand, there was an increase in optimal length in the plantaris and soleus, and a decrease in the diaphragm when caloric restriction took place (Drew et. al., 1988). Besides these factors, the uses of chronic medication may lead to impairments within the muscle. The chronic use of diuretics, which has shown to deplete potassium, may lead to the reduction of skeletal muscle electrolytes, which could lead to muscle weakness and impaired function (Dorup et. al., 1988). In addition, another frequently prescribed group of medications are corticosteroids. These drugs have catabolic effects on muscle tissue, which may lead to proximal muscle weakness and atrophy (Santidrian and Young, 1980). Moreover, Danneskiold et. al. (1986) also demonstrated that treatment with corticosteroids induced a decrement in physical function (i.e. significantly lower walking speed) as compared to no change in the untreated group. Due to the disease, a reduction in muscle mass and strength may occur because of bedrest or immobility. This atrophy from disuse can cause a further decline in functionality.

2.1.3 Disuse Atrophy

A third factor associated with the deterioration of function with age is disuse atrophy. Both occupational and leisure time activities decline with age in most countries, and the addition of sedentary lifestyle has been linked to impaired motor performance, when compared to more active peers (Fiatarone, 1993). Only approximately 10% of the United States adult population is active enough to generate beneficial physiological adaptations. There seems to be a 10% reduction in maximal oxygen uptake capacity (VO_{2max}) per decade, but the question is, is it due to just the aging process or disuse (Rogers and Evans, 1993). A problem arises when the term active is used. In most questionnaires, the word “active” usually refers to endurance exercises which have shown to be of little, or no, benefit to increase muscle strength or to prevent muscle atrophy associated with aging (Fiatarone, 1993). The physiologic manifestations of disuse include: a loss of muscle weight, a reduction in sarcomere number, an increase in subcutaneous fat, possible atrophy of type II fibers, disintegration of myofibrillar architecture, and a decrease in the oxidative capacity of the muscle (Fiatarone, 1993).

Research on master’s athletes has provided some basis for describing age-related changes that occur independent of disuse. However, even masters athletes report a decrease in the volume and intensity of activity with age. Galloway and colleagues (2002) investigated the aging effect on male and female master athletes' performance in strength and endurance activities. They measured endurance using a rowing machine, which emphasizes the cardiorespiratory system, and they measured strength using power lifting, which will be influenced by the contractile properties of skeletal muscle. They noticed that between the ages of 25 to 85 years, rowing performance decreased 29% in heavyweight men. They further described the time course of these changes between the ages of 25 and 55 as decreasing 0.12% per year in men and 0.23% per year in women.

They also noted that power-lifting performance peak in the third decade of life, and decreases by 3% per year until age 37, and thereafter decrease by 0.9% per year until the age of 85 (Galloway et. al., 2002). With regards to maximum oxygen uptake capacity (VO_{2max}), Rogers and colleagues (1990) performed a longitudinal study on 18 master athletes and 14 sedentary subjects. They were originally tested between 1977 and 1980, and the second evaluation began at a 7.5-year follow-up. They noted that the master athletes' VO_{2max} reduced approximately 5.5% per decade, whereas the sedentary subjects' VO_{2max} declined 12% per decade (Rogers et. al., 1990). This indicates that no more than half of the 10% reduction in VO_{2max} reported in early studies is due to aging, while at least half of this "age-related" change is actually due to a reduction in physical activity, and therefore preventable (Rogers et. al., 1990).

2.1.4 Malnutrition

Nutritional deficiencies are prevalent among the elderly. This is particularly true of the frail, institutionalized, or impoverished (Fiatarone, 1993). In both animal and human studies, inadequate intake of energy and protein has been linked to muscle dysfunction. This inadequacy provides evidence for defects in morphology, physiology, and function of the muscle. Morphologic deficiencies consist of decreased fiber area, selective fiber atrophy, and disorganization of myofibrils. The physiologic changes include a decreased oxidative enzyme capacity, glycogen depletion, electrolyte imbalance, and an increase in water content. The functional changes that occur are seen in a decrease in strength, abnormal force/frequency ratios, and a prolonged relaxation time (Fiatarone, 1993).

2.2 Physical Function

Cress and colleagues has defined physical function is the integration of physiological capacity, physical performance, and psychosocial factors. Where physiological capacity refers to "the basic cellular and anatomic function such as cardiac ejection fraction, nerve conduction velocity, or muscle strength per cross-sectional area; physical performance is the ability to integrate these physiological systems into coordinated, efficient movements to achieve optimum physical function; and psychosocial factors (relate to those) such as confidence, motivation, perceived ability, depressive symptomology, and social role" (Cress et. al., 1996). A conceptual model is shown in the figure 2.2.

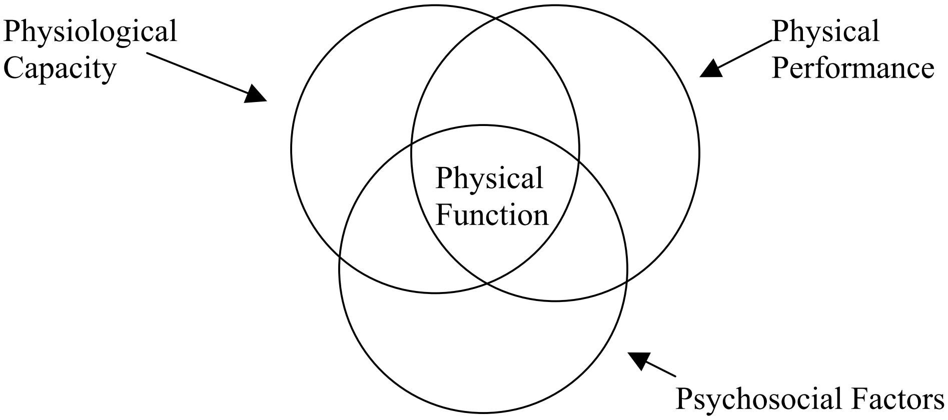

Figure 2.2 Components of Physical Function: Venn diagram illustrating the relationships among the components of physical function.

This rather broad definition of physical function, while appropriate, presents researchers with difficulty in terms of developing a single standardized discrete measure of function. As a result, research is fraught with dozens of measures of function. This makes, but many different means of identifying functional decline in the aging population. There are physical tests demonstrating this as well as activities of daily living (ADL)-based tests. The physical tests include functional reach, rising form a chair, static balance measures, and gait speed tests. The ADL-based tests include the Continuous Scale – Physical Functional Performance (CS-PFP) and the American Alliance of Health Physical Education Recreation and Dance (AAHPERD) physical function test.

2.2.1 Physical Tests Demonstrating the Deterioration of Function with Age

Identifying a battery of physical test to measure the deterioration of function in the older adult population is needed to hopefully reduce the decline in function with age.

2.2.1.1 Functional Reach

Functional reach (FR) is a balance measure incorporates the dynamic postural control theory and a practical measurement system. FR represents the maximal distance an individual can reach forward beyond arm’s length while standing and maintaining a fixed base of support. Weiner and colleagues (1992) developed this test in an effort to quantitate the “balance frailty” in the elderly. The rational behind this FR test was that, from a biomechanical standpoint, reaching tasks simulate age-sensitive leaning tasks used to assess postural control and reaching adds a functional dimension to the leaning; it makes it more relevant to a real world incident (Weiner et. al., 1992).

The use of FR in the clinical setting is very applicable. It is easy to apply and the only equipment necessary is a yardstick. FR can also be performed in a variety of settings, such as a doctor’s setting, clinical setting or home setting (Weiner et. al., 1992).

Weiner et. al. (1992) researched 128 individuals aged 21-87 years and found that FR was age-sensitive and when associated with age, it had a negative correlation. This indicates that as age increases, functional reach declines (Weiner et. al., 1992).

2.2.1.2 Chair Rising

Over two million non-institutionalized individuals over the age of 65 have difficulty in getting in and out of chairs and beds (Alexander et. al., 1991). Of these, approximately 3% need assistance in these tasks. Assessing functional capacity using the time to rise from a chair, may be more accommodating and helpful than the traditional medical evaluations of function for diagnosing and treating problems areas, such as mobility, in the older adult (Alexander et. al., 1991).

Alexander and colleagues (1991) investigated three different groups of individuals, the “young-old”, “old-able”, and “old-unable” and their time and ability to rise from a chair. The differences between the “old-unable” and the “old-able” were, age range (mean age for old-unable = 84 years; mean age for old-able = 72), the “old-unable” had more medical problems, and more of the “old-unable” were living in a retirement community. Their data showed that the mean total time to rise was similar in “young-old” and “old-able”, but significantly longer in “old-unable”. There was also no gender effect, but “old-unable” were all women (Alexander et. al., 1991).

2.2.1.3 Static Balance

Much research has stimulated from the concentration on postural sway and limits of static ability (Rossiter-Fornoff et. al., 1995). The use of these measurements is not routine in the clinical setting because the force-plate interfaces for measuring balance are expensive and not easily portable. However, the measures are accurate and unbiased.

Some investigators have incorporated balance measures in their functional performance test to provide a measure of the participants general ability, these tests include the mobility score of the Fall Risk Index, get up-and-go tests, and the Physical Performance test. These tests are more easily performed and administered, however, they are not specific for balance (Rossiter-Fornoff et. al., 1995).

Rossiter-Fornoff and colleagues (1995) investigated subjects form the FICSIT (Frailty and Injuries: Cooperative Studies of Intervention Techniques) group to examine the test-retest reliability and construct validity of a composite balance measure. The subjects varied, some were healthy while others were much frailer, all with varying ages. The measures showed that the frailer subjects, mainly from the nursing home population, had generally lower stance times than the community-dwelling population. At each site, gait speed was collected, which is highly correlated with balance status. The measures confirmed that slower gait speed resulted in less balance. The test-retest reliability was 0.66 and there was good evidence of the content validity of the balance scale (Rossiter-Fornoff et. al., 1995).

2.2.1.4 Gait Speed

Gait speed is used very frequently as a functional marker for independence. It is used as a useful measure in rehabilitation settings and it is related to placement and discharge from the hospital (Potter et. al., 1995). With regards to gait speed, there are several possible explanations as to why gait speeds slow down with age. With age, strength and aerobic capacity declines, which is one reason for the possible reduction in gait speed. Another rationale is that many neurological and musculoskeletal diseases can impair gait speed (Buchner et. al., 1996). Therefore, the use of gait speed is a useful tool for measuring function.

Potter and colleagues evaluated inpatients and outpatients individuals in a geriatric hospital (mean age 78.5 years). They compared the patients' gait speed to their independence based on the Barthel ADL Index. They noted that with an increase in gait speed there was an increase in functional independence (Potter et. al., 1995).

2.2.2 ADL Tests Demonstrating the Deterioration of Function with Age

In the more advanced age groups, where disease is prevalent, there seems to be a reduction in flexibility and the ability to perform activities of daily living (ADLs) (Aniansson et. al., 1980). With this diminished ability there needs to be a battery of tests that concentrate on examining ADLs, and not only one aspect of them.

2.2.2.1 Continuous-Scale Physical Functional Performance Test

The Continuous-Scale Physical Functional Performance (CS-PFP) is a test designed to provide an all-inclusive, detailed measure of physical function that reflects abilities in several separate areas. Cress and colleagues (1996) piloted the CS-PFP on 138 participants using 15 tasks relevant to activities of daily living. These participants were from three different living statuses, community dwelling (n=78), long term care – independent (n=31), and long term care – dependent (n=39). Cress et. al. (1996) found that the CS-PFP was capable of identifying physical functional performance among all three groups. The total CS-PFP score varied between groups, community dwelling participants scored higher than the long term care – independent which scored higher than the long term care – dependent. The CS-PFP is unique, valid, and reliable measurement of physical functional performance (Cress et. al., 1996).

2.2.2.2 AAHPERD

The American Alliance for Health, Physical Education, Recreation, and Dance has developed a physical function test for adults over 60 years of age (Osness et. al., 1996). The test includes measures of Flexibility, Muscular Strength & Endurance, Agility/Balance, Coordination, Aerobic Endurance, and Ponderal Index. Osness and colleagues (1996) have test-retest reliability with correlation coefficients reported in the range of r = 0.82 to 0.98. The flexibility task is measured by the standard sit and reach. The muscular strength & endurance task is a typical bicep curl, where the female participants lifts a 4lb. object and the male participants lifts an 8 lb. object as many times as possible in 30 seconds. The agility task requires the participant to stand up from a chair walk around a cone, return to the chair, sit down, stand up again, walk around another cone, and sit down in the chair as fast as they can. The coordination task requires the subject to turn three 12 oz. "soda pop" cans upside down and then return them upright. The aerobic endurance test was an 880-yard walk for time. The Ponderal Index is a height-weight ratio and serves as an index of body composition. For a more comprehensive discussion of the AAHPERD test items please see Osness et al. (1996).

2.3 Clinical Relevance of the Decline in Function with Age

2.3.1 Functional Decline and its Relation to Mortality

Several studies have verified the benefit of routine physical exercise for improving health, reducing the event of coronary heart disease, and increasing longevity in middle-aged men and women (Simonsick et. al., 1993). Therefore, the reduction of physical activity can lead to physical decline, chronic disease onset, acute events, and mortality (Simonsick et. al., 1993). Many studies have investigated the linked between self-reported measures of health/function and mortality/morbidity (Bernard et. al., 1997; Greiner et. al., 1996; Simonsick et. al., 1993; Wolinsky et. al., 1995;). Simonsick and colleagues (1993) performed a longitudinal study examining the relationship between the activity levels and mortality in over 5,000 subjects from three different sites (East Boston, New Haven, and Iowa). After a three-year follow-up, those individuals who were highly active had one half to two thirds the mortality rate than those who were inactive (Iowa was the only site that achieved statistical significance), and those who were moderately active experienced similar mortality rates than those who were inactive. However, after a six-year follow-up, all sites found that the highly active subjects had significantly lower mortality rates than those who were inactive (about two-thirds less). Moreover, a study conducted on 629 Nun's indicate that those who self-rate their function as good, fair, or poor, had an increase in the probability of mortality compared to those who rated their function as very good or excellent (Greiner et. al., 1996).

Additionally, Wolinsky et. al. (1995) performed a longitudinal study over an eight year period. They noted that the probability of dying increase about 7% per year and the chance of women dying is three-fifths of those for men. They also report that disability and functional limitation, such as basic ADLs (4%), household ADLs (11%), and lower body limitations (11%) increase the risk of mortality.

Another longitudinal study conducted on over 3,000 subjects also examined the relationship between self-reported measure of function and health to mortality. They noted that as dependency increases so does the percentage of deaths (i.e. those who reported "completely able" had a percentage of deaths of 11.7 compared to those who reported "not at all able" who had a percentage of 69.4) (Bernard et. al., 1997).

Also of concern is the effect of a decrease in physical activity impact on quality of life. The increased rate of mortality with the reduction in physical activity would indicate that a decline in physical activity would indicate deterioration in quality of life.

2.3.2 Functional Decline and its Relation to Quality of Life

The aging process can cause a decline in health, but it is not solely responsible. The reduction in physical activity can also cause a reduction in the quality of life. Presented by Simonsick et. al. (1993), the subjects who reported highly active, exhibited a significant lower rate and risk of angina in the East Boston group and stroke in the Iowa group as compared to those who reported inactivity at the three-year follow-up. At the six-year follow-up, those individuals who were highly active had significantly lower rates of myocardial infarction in the East Boston group and stroke in the Iowa group; and those in the East Boston and New Haven groups showed lower rates and risk of angina and diabetes. Additionally, Greiner et. al. (1996) indicates that the subjects who report excellent on the self-reported health was associated with a lower probability of loosing the ability of performing activities of daily living. These statistics indicate that the reduction in physical activity can ultimately result in a decline in quality of life and an increase in mortality.

2.4 Historical Approach of the Relation between Function and Strength

Strength and function have been explored throughout the decades. Many new advances have been made, and new avenues are being explored. The general overview of the previous research indicates a strong trend for strength and function to be related. This relation varies between which functionality test has been correlated to strength, and on the reverse side, what strength test has been associated with a certain functionality test.

There seems to be a trend throughout the literature that strength is significantly related to function, in that as strength increase, functionality improves; and when strength decreases, functionality is lost. Starting with Aniansson et. al. in 1980 to the present, researchers have noticed a significant positive relationship between gait speed, balance, chair rising time, and ADL based tasks and strength. Researchers have also noted a significant negative relationship between falling and strength.

When strength is improved through training, there also seems to be a trend for an increase in functionality. Various types of training, including aerobic and resistive training, have been shown to improve physical functioning in the older adult.

2.5 Linking Strength and Function

A more detailed look into the relationship between strength and functionality is examined in two ways, as strength declines so does function and as strength is improved there also is an improvement in functionality.

2.5.1 Strengths Relationship to Function

Considerable research has been conducted relating strength and function. Many of the functionality tests have been related to strength to determine a correlation. The functionality tests used vary (i.e. gait speed tasks, step tests, reaching tasks, balance tasks, chair rising tasks). Most of the literature agrees with one another, but there are a few that contradict.

Most all of the literature agrees in that greater strength will improve walking speed (Aniasson et. al., 1980; Bassey et. al., 1988; Bassey et. al., 1992; Brown et. al., 1995; Buchner et. al., 1996; Carmeli et. al., 2000; Chandler et. al., 1998; Danneskiold et. al., 1986; Davis et. al., 1998; Ferrucci et. al., 1997; Judge et. al., 1993; Judge et. al., 1994;

Wolfson et. al., 1995; Visser et. al., 2000). An earlier study demonstrates that walking speed is significantly related to calf strength in men (r=0.42; p<0.001) and women (r=0.36; p<0.01) (Bassey et. al., 1988). A more recent study illustrates that an improvement in strength resulted in 8.9-12.6% increase in walking speed (Carmeli et. al., 2000). On the other hand, only one study reveled no association between an increase in strength and an increase in gait speed (Buchner et. al., 1997). Buchner and colleagues (1997) studied three different exercise training groups (endurance trained only, strength trained only, and a strength and endurance trained group) plus a control group. After 6-months of training, there was only a 4% improvement on gait speed, which was not significant. The statistical power was adequate to rule out clinically important changes, so the only true explanation is that there was a ceiling effect (Buchner et. al., 1997).

When it comes to stepping tests, there seems to be a trend toward greater strength equals a greater stepping performance (Aniansson et. al., 1980; Bassey et. al., 1992; Danneskoid et. al., 1986). Aniansson et. al. (1980) examined the relationship between strength and multiple step heights. They noted that there was a positive correlation between strength and their maximum step height (50 cm). In a more recent study, Bassey et. al. (1992) investigated lower extremity power versus stair climbing time, and noted that with an increase in strength there was an increase in stair climbing time. On the other hand, Skelton et. al. (1992) and Berg et. al. (2000) disagrees with these outcomes. Skelton et. al. (1992) noted that there was no significant association between lower extremity power and stepping performance, but there was an age effect. Their data showed a wide variety in stepping ability, some subjects with low strength scores were able to step onto the higher steps, while stronger subjects were unable to step onto the highest steps. Therefore, it was not possible to determine a lower limit at where stepping performance became impossible. Berg et. al. (2000) agrees with the lack of association between strength and stepping performance. This could be due to the fact that the older subjects (age range = 69-81 years) were all healthy, able to walk unaided, and participating in some sort of physical activity.

The literature shows a difference in the association between strength and reaching tasks. Davis et. al. (1998), showed and increase in reaching ability with increasing strength. Davis and colleagues evaluated functional forward reach and strength. They concluded that functional reach was significantly correlated with quadriceps and grip strength. On the other hand, Chandler et. al. (1998), found no association between functional reach and strength. This could be due to the fact that they were investigating the effect that strength training has on functional reach. They found only a 0.1-inch difference between the control (9.4 inches) and intervention group (9.3 inches).

Balance is used as a functional maker in a variety of ways, they are the one-footed balance stands, tandem stands, tandem gait, and postural sway tests. As for one-footed balance, the literature agrees that with an increase in strength there is an increase in the ability to stand on one foot (Gehlsen et. al., 1990; Hopkins et. al., 1990). Tandem standing, standing with the heel of one foot up against the toe of the other foot, is consistent throughout the literature, with one exception. Both Buchner et. al. (1991) and Ferrucci et. al. (1997) agrees that the more strength an individual has, the longer the individual is able to maintain a tandem stand, and Buchner et. al. (1991) also states that with an increase in strength, there is an increase in tandem gait. On the other hand, Buchner et. al. (1997) contradicts all of these outcomes and concluded that there is no significant change in balance ability with an increase in strength. He does note a small amount of change with exercise training, but it is not significant. This could be related to the multiple interventions, such as a strength training group, an endurance training group, a strength plus endurance training group, and many different functionality and strength tests; therefore, it limits the efficacy of any single intervention. As for postural sway, most of the literature suggests that with strength training there is no significant association between strength and the postural sway test (Barry et. al., 1966; Buchner et. al., 1997; Crilly et. al., 1989). Wolfson et. al. (1995) disagrees with this outcome. They found a significant negative correlation between postural sway and strength; indicating that those subjects who lost their balance five or more times had a 39% reduction in ankle dorsiflexor strength and 34% reduction in ankle plantar flexor strength. The difference in the outcomes could lie within the strength measurements. For example, Wolfson et. al. (1995) used ankle dorsiflexor and plantar flexor muscles, while Barry et. al. (1966) used elbow flexor and knee extensor muscles.

Another functional test that has been associated with strength is the chair rising task. The literature is mostly in agreement that with an increase in strength there is a decrease in the time it takes to rise out of a chair and sit back down (Bassey et. al., 1992; Brown et. al., 1995; Davis et. al., 1998; Ferrucci et. al., 1997; Visser et. al., 2000). On the other hand, Judge et. al. (1994) disagrees with these conclusion. They suggested that there was no significant change in the association between strength and chair rising time. Judge and colleagues (1994) investigated the usefulness of inexpensive resistive training machines and sandbags in increase leg strength. They noted that there was no significant change from baseline after the training (1.23 s at baseline to 1.16 s after training). This could be caused by the ineffectiveness of the machines and sandbags used; they may not have increased strength enough to compensate for an increase in chair rise time. Table 2-1 summarizes the studies that have investigated the relationship between strength and function.

2.5.2 Overall Strength Training Effects on Strength and Function

Throughout the literature, strength training provides great improvement in strength and endurance (Agre et. al., 1988; Barry et. al., 1996; Buchner et. al., 1996; Buchner et. al., 1997; Carmeli et. al., 2000; Chandler et. al., 1998; Cress et. al., 1999; deVries et. al., 1970; Frontera et. al., 1988; Hopkins et. al., 1990; Judge et. al., 1993; Judge et. al., 1994; Wood et. al., 2001). Barry et. al. (1966) found a mean increase in static leg strength of 15.2 lbs. and a mean increase of 0.9 inches in leg power (vertical jump). More recently, Carmeli and colleagues (2000) noted that 82% of all participants in the 79-83 year old age group demonstrated some improvement in strength. These strength improvements ranged from 6 to 12.5% increase in knee extensor muscle strength and from 2.2 to 14.8% increase in knee flexor muscle strength (Carmeli et. al., 2000). This is very representative of the literature.

The literature expresses that training has a mixed results on its effect on function. The majority of the literature suggests that training improves overall function (Buchner et. al., 1996; Carmeli et. al., 2000; Cress et. al., 1999; deVries et. al., 1970; Hopkins et. al., 1990; Judge et. al., 1993; Judge et. al., 1994; Wood et. al., 2001). On the other hand, some of the literature indicates that training has no effect on functionality (Barry et. al., 1966; Buchner et. al., 1997; Chandler et. al., 1998; Crilly et. al., 1989). Barry et. al. (1966) and Crilly et. al. (1989) possibly found no effect on functionality due to the exercise regimen. Barry and colleagues primarily worked at modifying the circulatory-respiratory system; while Crilly and colleagues aimed at improving breathing, balance, coordination, and flexibility and their training session lasted only 15-35 minutes. Buchner and colleagues (1997) had a possible ceiling effect that caused the lack of change, while Chandler and colleagues (1998) could not have had proper stimulus to induce a change. Their exercise session was an in-home program using therabands and body weight for resistance. Table 2-2 summarizes the studies that have investigated the influence of strength training on strength and physical function.

Throughout most of the literature, it is seen that an increase in strength can lead to improvements in functionality. This increase in strength can come through training, and it is most beneficial to do resistance training. Table 2-3 below provided more detail on each study.

Table 2-1: Strengths Relationship to Function

Author and Year	Walking Speed	Step Test/ Climbing	Reaching Task	One-footed Balance	Tandem Stand	Tandem Gait	Postural Sway	Chair Rising
Visser et. al., 2000	↑						↓	↓
Carmeli et. al., 2000	↑							
Berg et. al., 2000		↔						
Davis et. al., 1998	↑		↑				↓	↓
Chandler et. al., 1998	↑		↔				↔	
Ferrucci et. al., 1997	↑				↑			↓
Buchner et. al., 1997	↔			↔	↔	↔	↔	
Buchner et. al., 1996	↑							
Buchner et. al., 1996	↑							
Wolfson et. al., 1995							↑	
Brown et. al., 1995	↑							↓
Skelton et. al., 1994		↑						
Judge et. al., 1994	↑							=
Judge et. al., 1993	↑							
Bassey et. al., 1992	↑	↑						↓
Buchner et. al., 1991					↑	↑		
Hopkins et. al., 1990				↑				
Gehlsen et. al., 1990				↑				
Crilly et. al., 1989							↔	
Bassey et. al., 1988	↑							
Danneskiold et. al., 1986	↑	↑						
Aniansson et. al., 1980	↑	↑						
Barry et. al., 1966							↔	

Table 2-2: Effects of Strength Training on Function and Strength

Author and Year	Overall Effect on Function	Overall Effect on Strength
Wood et. al., 2001	↑	↑
Carmeli et. al., 2000	↑	↑
Cress et. al., 1999	↑	↑
Chandler et. al., 1998	↔	↑
Buchner et. al., 1997	↔	↑
Buchner et. al., 1996	↑	↑
Judge et. al., 1994	↑	↑
Judge et. al., 1993	↑	↑
Hopkins et. al., 1990	↑	↑
Crilly et. al., 1989	↔	
Frontera et. al., 1988		↑
Agre et. al., 1988		↑
deVries et. al., 1970	↑	↑
Barry et. al., 1966	↔	↑

Table 2-3: In-Depth Description of Each Study

Author and Year	Study Sample	Design	Major Findings
Wood et. al., 2001	n=45 (60-84 years)	Function test: AAHPERD, GXT; Strength test: 5RM of knee-extension, knee-flexion, seated row, chest press, lateral raise, seated dip, and biceps-curl; Exercise: 4 groups (cardio training only 60-70%, resistance training only 75% and >, both, and control), for 12 weeks	All exercise groups improved equally on 5Rm strength for the leg-extension, leg-curl, seated row, and lateral raise; and AAHPERD flexibility, coordination, and CV endurance.
Berg et. al., 2000	n=16 (19-22 years old); 24 (69-81	Function test: step-test; Strength test: hip and knee extension and flexion and ankle dorsiflexion and plantar	Nearly complete lack of association between relative strength and stepping performance. Slight tendency for

Table 2-3 continues on next page

	years old) all women	flexion peak force	stronger to move faster.
Carmeli et. al., 2000	n=28 healthy adults (78-87 years old); 29	Function test: time up-and-go, balance, and gait; Strength test: 3MVC at 60˚/s and 180˚/s for knee flexion and extension; Exercise: 3x's/wk for 12 wks	The older the individual the slower time on the time up-and-go test, slower walking speed, and shorter distance. Oldest had significantly lower strength than younger. After training, 82% showed improvement in all functions.
Visser et. al., 2000	n=216 men; 233 women (>65 years)	Function test: 3-m walking course and timed chair stand; Strength: grip strength	Grip strength was positively associated with function. Suggest a potential threshold for men between grip strength and lower extremity performance.
Cress et. al., 1999	n=23 (>70 years); 26 control	Function test: CS-PFP, gait, balance, reaction time, self-report; Strength test: elbow flexion, knee flexion and extension at 60˚/s, grip strength; Exercise: 3x's/wk for 6 months, ~1 hour for each session.	Exercise group increased 14% in CS-PFP total; knee flexion increased 9%; aerobic capacity increased 10.5% over control.
Chandler et. al., 1998	n=50 men and 50 women	Function test: functional reach, postural sway, chair rise, fall efficacy scale, mobility skills; Strength test: knee extension at 60˚/s and 0˚/s and ankle dorsiflexion at 30˚/s and 0˚/s; Exercise: 3x's/wk for 10 weeks, theraband	Improvement in strength was significantly associated with gains in gait velocity and fall efficacy; not related to functional reach or sway.
Davis et. al., 1998	n=705 women (55-93 years)	Function test: chair stands, walking speed, functional reach, get up-and-go, reaction time; Strength test: hand grip, isometric knee extension	Stronger subjects had faster gait velocity, better functional reach, and decrease in time to complete the chair rise (5x's)
Buchner et. al., 1997	n=105 (68-85 years)	Function test: balance, gait, physical health status; Strength test: isokinetic strength; Exercise: 3x's/wk for 24-26 weeks – 75% HRR, 75% 1RM	No significant effect on gait and balance due to exercise. Strength and endurance improved.
Ferrucci et. al., 1997	n=985 women (>65 years)	Function test: walking speed, time to rise from a chair, and balance; Strength test: isometric knee extension and hip flexion both at 90˚.	Association between knee extensor strength and walking speed and chair stands. Stronger women were able to hold balance longer than weaker subjects.
Buchner et. al., 1996	n=434 (60-96 years)	Function test: gait speed; Strength test: knee flexion and extension at 60˚/s and ankle dorsiflexion and plantar flexion at 30˚/s	High correlation between strength and gait speed (strength explained 17% of the variance in gait speed). Threshold of 275Nm between strength and function.
Buchner et. al., 1996	n=152 (68-85 years)	Function test: gait speed; Strength test: isokinetic knee rotation at 60˚/s and ankle rotation at 30˚/s; Exercise: 3x's/wk for 3 months of supervised exercise and 3 months of non-supervised exercise - ~1 hour each session.	Improvement in knee extension and ankle dorsiflexion. Gait velocity was increase in resistive trained group only; chair rise time was not faster with exercise.
Brown et. al., 1995	n=16 (75-88 years)	Function test: walking speed, rising from a chair, and obstacle course; Strength test: hand held dynamometer	Significant association between gait speed and strength, only when compared to 35 sedentary but healthy men,

Table 2-3 continues on next page

		and isometric knee extension at 45˚	indicating gait speed for frail older adults is less apparent because gait speeds are low.
Wolfson et. al., 1995	n=22 fallers, 18 nonfallers, 21 young control	Function test: Balance (Postural Stress Test); Strength test: isokinetic peak torque at 60˚/s knee flexion and extension, ankle dorsiflexion and plantar flexion, and hip ad/abduction (reported as sum of peak torques)	Strength was significantly less in the faller group. There was a strong relationship between the quality of gait as measured by stride length and walking speed and the incident of falls. The weaker subjects lost balance more frequently.
Judge et. al., 1994	n=110 (mean age 80)	Function test: gait velocity and chair rise time; Strength test: isokinetic right knee extension / flexion at 60˚/s and 180˚/s and hip and ankle at 30˚/s and 60˚/s; Exercise: 3x's/wk of resistive or balance training	Gait velocity increased form 1.1 to 1.14 ms^{-1} and the improvements only occurred in the resistive training group. Chair rise time was not faster for either group.
Skelton et. al., 1994	n=50 men and 50 women (65-89 years)	Function test: chair rise time, box stepping, lifting a bag; Strength test: isometric knee extension (90˚), elbow flexion (90˚), and hand grip	Significant association between strength and box stepping. Lower extremity performance correlated strongly with chair rise time, but not significantly. Strength significantly decreased with age.
Judge et. al., 1993	n=31 (71-97 years)	Function test: gait velocity; Strength test: isokinetic knee extension at 60, 120, and 180˚/s; Exercise: 3x's/wk for 12 weeks lasting 60-70 mins per session	Possible threshold of 45Nm for knee extension. Significant improvement in knee extension strength for exercise group, not control. Gait speed increased 8%.
Bassey et. al., 1992	n=13 men (mean age 88.5 years); 13 women (mean age 86.5 years)	Function test: chair rising, stair climbing, and 6.1m walking course; Strength test: maximal push against the "rig"	Significant correlation between knee extension and lower extremity performance. Power output during stair climb was significantly related to lower extremity performance. Possible threshold of 1.2 W/kg body weight mass
Buchner et. al., 1991	n=434 (60-96 years)	Function test: tandem stand, 8-step tandem gait, and SIP; Strength test: knee and ankle flexion and extension at 60˚/s	Relative strength is more related to function. Curvilinear relationship between strength and function. No definite threshold.
Gehlsen et. al., 1990	n=25 fallers and 30 nonfallers	Function test: balance test; Strength test: concentric contraction of hip, knee, and ankle	An increase in strength decreased the possibility of falling.
Hopkins et. al., 1990	n=53 women (57-77 years)	Function test: AAHPERD; Exercise: 3x's/wk for 12 weeks lasting 60-70 mins per session	Significant main effect for exercise vs control. Significant improvement in strength. Gait increased by 8%
Crilly et. al., 1989	n=47 institutional female (71-91 years)	Function test: postural sway; Strength test: 3x's/wk for 36 classes lasting 15-35 mins	No improvement in sway in any group, and in some deterioration occurred. Function affected by exhaustion of reserved in nonregenerating system cannot be improved by retraining.
Agre et. al., 1988	n=47 (>63 years)	Strength test: R arm and leg elbow and knee flexion and extension and shoulder internal and external rotation at 60˚/s; Exercise: 3x's/wk for 25 weeks lasting 1 hour	Exercise group had significant improvement in strength in shoulders, elbow extension, and knee flexion. 17 or 29 had decrease joint pain

Table 2-3 continues on next page

Bassey et. al., 1988	n=56 males 66 females (>65 years)	Function test: 7 day stepscope and walking speed; Strength test: isometric plantar flexion	Strength significantly correlated with walking speed. No association between stepscope and strength in females, but there is a relationship with males. Negative correlation with age
Frontera et. al., 1988	n=12 (60-72 years)	Strength test: isokinetic knee extension and flexion at 30,60, 120, 180, 240, and 300˚/s; Exercise: 3x's/wk for 12 weeks – worked all muscle groups in each leg at 80%RM	All muscle groups improved in dynamic strength and isokinetic strength. An increase in strength can lead to an increase in function.
Whipple et. al., 1987	n=17 fallers and 17 nonfallers	Function test: Fallers vs nonfallers; Strength test: isokinetic knee and ankle at 60 and 120˚/s	Fallers are weaker. Inability of fallers to reach higher velocities of movement and a slower transition from slow to fast velocity
Danneskiold et. al., 1986	n=46 arthritic subjects (31-76 years)	Function test: walking 30m and climbing different height steps; Strength test: isokinetic knee extension at 30, 60, 120, and 180˚/s and isometric knee extension	Walking speed significantly slower in treat group. With the treated group, there was a correlation between knee extension peak toque and walking speed and climbing.
Aniansson et. al., 1980	70 year old population in Goteborg, Sweden	Function test: walking test, step test, reaching tasks, basal tasks, pronation and supination; Strength test: isometric and isokinetic right quadriceps	Significant correlation between walking speed and peak values of isokinetic at 30, 60, and 120˚/s in healthy women, but not total group. Positive correlation between step height and isometric angle.
deVries et. al., 1970	n=112 males (51-87 years)	Function test: BP, O2 pulse, max O2 consumption, physical work capacity, CO; Strength test: 3 MVC of elbow flexor; Exercise: 3x's/wk for 42 weeks – 3 phases	O2 pulse improved 29.4%. Arm strength improved by 11.9%. Physical work capacity improved by 15.8%. BP fell significantly. All changes suggest improvement in CV function.
Barry et. al., 1966	n=13 (mean age 71)	Function test: balance, hand speed, card sorting, reaction time, motor preservation; Strength test: elbow flexion, knee extension, vertical jump, v-sit, agility	Significant posttraining effect in leg power, agility, muscular endurance. Static strength showed significant increases. Significant change in imaging. No change in balance, personality, cognition, or motivation.

CHAPTER 3. METHODS

3.1 Study Participants

The subjects included 21 adult females and 12 adult males aged 65 years and older who were apparently healthy, that is they had no overt signs or symptoms of cardiovascular or metabolic diseases. All participants were volunteers from St. James Place Retirement Community, Baton Rouge, Louisiana. Each participant was screened for disease and/or chronic conditions that are recognized as contraindications for physical activity (ACSM, 1995), and physician as well as client consents for participation were obtained. Specifically, patients with a history of multiple myocardial infarction, poor left ventricular function (ejection fraction < 30%), survivor of sudden arrhythmic death, presence of complex and uncontrollable cardiac rhythm disturbances, unstable angina, or the presence of high grade occlusive coronary lesions (>75%) known to influence cardiac function were excluded from the study.

3.2 Experimental Measurements

The participants made three visits to the laboratory within a 4-week period. The order of the sessions were as follows: (1) selected surveys regarding health behavior and quality of life; (2) the administration of the Modified Continuous Scale – Physical Function Performance; and (3) administration of an isometric and isokinetic quadriceps strength test protocol.

3.2.1 Session 1: Consent Form, Medical Records, and Health History Forms

An informed consent form was reviewed with the participant at the beginning of this session. Following the consent form, the participant was asked some general questions about their health history, and medical records were subsequently obtained from the participant's physician.

3.2.2 Session 2: The Modified CS-PFP

At the beginning of the session, resting heart rate, resting blood pressure, height, and weight were measured. The Modified Continuous Scale-Physical Functional Performance (MCS-PFP) test was performed following the preliminary measurements. A standard dialogue was read to each participant. The test began with a brief statement about the purpose of the test, the order of the activities, and the way to approach each task. A description of the 10-item test is below in the order in which the subject was asked to perform them. They are performed in order of increasing difficulty.

<u>Weight Carry:</u> This task consists of carrying two 5-lb sandbags from one counter to another counter approximately 63 inches away. The subject had the option of carrying the weight in one trip or two. Once the subject decided if one or two trips were more appropriate for him or her, they were instructed to start with their hands by their sides, and at the command, “ready, set, go,” the subject carried the pan of weights from one counter to the other. The subject was timed throughout the test.

<u>Scarves Test:</u> The subject had to pick up four scarves, one at a time, from the floor, in this task. The subject began at the command, “ready, set, go,” and was timed during the test.

<u>Jacket Test:</u> The subject was instructed to put on a light "windbreaker" type jacket and pull the jacket together without zipping it up. Once the jacket was pulled together, the subject had to take it off and set it on the table. The subject began at the command, “ready, set, go,” and was timed during the test.

Reach Test: During this test, the subject reached up as high as possible, while pushing up a shelf, which is an 8-foot high adjustable shelf mounted on the wall. The subject then placed a sponge on a shelf without going on their toes. The subject then removed the sponge, with the option of going on their toes, and placed their hands by their side. The subject was not timed throughout this task; it is measured by how high the individual can reach upward.

Floor Sweep Test: This task was a timed test that required balance and coordination, as well as strength. The subject was asked to sweep up a ½ cup of kitty litter in a 4' x 3' block square rectangle. At the command, "ready, set, go," the subject swept up the kitty litter into a dust pan as quickly as possible, and then placed the dust pan onto a shelf. They were timed during the test.

Laundry 1 Test: This task was a timed test in which the subject empties a top loading washer into a side loading dryer. The subject was unloading and loading three 2 lb and one 3 lb bags of sand and 4 lbs of dry clothes. The washer began closed, but the dryer began open. Once all the items were put into the dryer, the subject must close the dryer door.

Laundry 2 Test: This is also a timed test and the subject was asked to unload the dryer. They were instructed to put just the 4 lbs of dry clothes into a laundry basket. The dryer door began closed, and the subject was asked to close the door once all articles were removed. The subject then had to pick up the basket and place it on top of the dryer. The subject began at the command, "ready, set, go."

Floor Down/Up Test: In this task the subject was asked to start in the standing position and on the command, "ready, set, go," sit down on the floor and then immediately stand up and put their hands by their sides. There were two chairs on either side of the subject for support, and the examiner held onto the subject's belt to guard the subject from falling the last few inches of the sit-down. The subject was timed throughout this task.

Stair Climb Test: This test requires the subject to climb one flight of stairs, 11 steps, 12 inches in depth, 6.5 inches high. This was a timed test and they may use the handrail, but cannot pull themselves up the steps.

Grocery Test: This was a timed test. The subject carried a predetermined amount of groceries 42.3 yards. They could take the groceries in one or two trips. At the command, "ready, set, go," they picked up the groceries walk 16.3 yards to three steps, ascended the steps, turned around, descended the steps, carried the groceries 26 yards to the door. They then opened the door, and placed the groceries on the table.

Endurance Walk: This was a 6-minute endurance walk. The subject was asked to walk up and down a hallway as many times as possible within the 6-minutes. If the subject decided to stop, their total distance within the 6-minutes was the distance until that point. Their score was determined by how many feet they could walk within 6-minutes.

The CS-PFP 10 also allows for the quantification of various subscales that combined the different individual tasks together. These subscales are upper body strength, upper body flexibility, lower body strength, balance and coordination, and endurance.

3.2.3. Session 3: Isometric and Isokinetic Knee Extensor Tests

During this session the participant performed three different tests, an isometric test (at 60°flexion) and two isokinetic tests (90 and 180 $^{\circ}\cdot\text{sec}^{-1}$) using the Biodex Medical Systems. While the subject was performing the strength tests, the lever arm was attached to the midleg, and its axis of rotation was aligned with the anatomic axis of knee rotation. All of the tests were performed in the sitting position, and to stabilize the hip joint, the subjects were seated in a chair with a solid back support with straps across the chest, pelvic, and leg region.

The protocol for the isometric and isokinetic tests were linked together so there was no interruption. The isometric test was preformed first. The subject's knee was at an angle of 60° of flexion, and was asked to push against the dynamometer as hard as possible for 5 seconds. They were given vocal motivation throughout the test.

For the isokinetic tests, the subject performed five repetitions during each condition, the 90 and $180^{\circ}\cdot\text{sec}^{-1}$. The $90^{\circ}\cdot\text{sec}^{-1}$ was the first condition, followed by the $180^{\circ}\cdot\text{sec}^{-1}$. The subject was able to have a practice extension before the beginning of the each test.

The three tests were linked together. There was a slight rest between the isometric and the isokinetic $90^{\circ}\cdot\text{sec}^{-1}$ and a sixty second rest between the $90^{\circ}\cdot\text{sec}^{-1}$ and $180^{\circ}\cdot\text{sec}^{-1}$ strength tests. The outcome measure was peak torque, as well as relative peak torque [PT/body weight (Kg.)].

3.3 Statistical Analysis

All data were analyzed by SPSS 11.0 for Windows. Relationships among variables were examined using Pearson correlation coefficients. The independent variables were strength and age, while the total CS-PFP, CS-PFP subscales, and the individual items of the test battery served as the dependent variables. Moreover, correlation coefficients were not only derived for the group as a whole, but these coefficients are also reported for male and female participants treated separately. Regression curves were estimated using linear, logarithmic, logistic, and power models for the total data. For the purpose of this study, the curve of best fit was determined by comparing the F values for each curve fitting technique. An alpha level of $p<0.05$ was required for statistical significance.

CHAPTER 4. RESULTS

4.1 Participant Characteristics

Thirty-three of the 35 subjects completed all aspects of the investigation. One of the subjects was excluded as a result of symptoms of chronic heart failure and the other could not participate due to hospitalization for cellulitis. The participant characteristics of the 33 subjects are found in Table 4.1.

Table 4.1: Participant Characteristics

INDEX	Mean	Standard Deviation	RANGE
Gender	--	--	21 Females/12 Males
Age	79.5 years	6.0 years	70 - 95 years
Weight	71.4 kg	14.5 kg	45.9 - 97.7 kg
Height	168.7 cm	9.7 cm	152.5 - 194.4 cm

4.2 Age-related Changes in Strength and Function

4.2.1 Age vs. Strength

Age was inversely associated ($p<0.05$) with absolute peak torque at PTO and PT180 ($r= -0.37$; $p= 0.035$ and $r= -0.38$; $p= 0.027$, respectively) (see figures 4.1 and 4.2), and approached significance with torque at PT90 ($r= -0.34$, $p= 0.054$). After adjusting the peak torques for body weight [PT/body weight (Kg.)] strength was not associated with age (Adj PT0 $r= -.231$, $p= 0.195$; Adj PT90 $r= -.195$, $p= 0.277$; Adj PT180 $r= -.251$, $p= 0.158$).

The associations between age and peak torque were also examined by gender. The results of the investigation indicate no statistically significant associations between age and any of the strength measures when treating the male and female subjects separately. The gender specific correlation coefficients for age and strength are listed in Table 4.2.

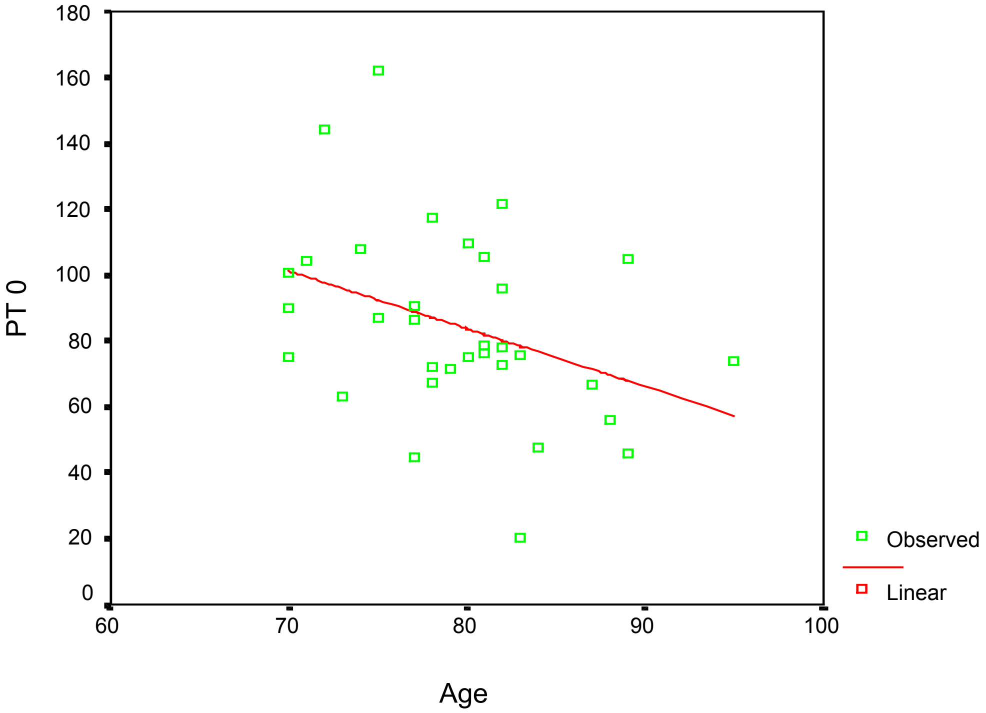

Figure 4.1: PT0 and Age

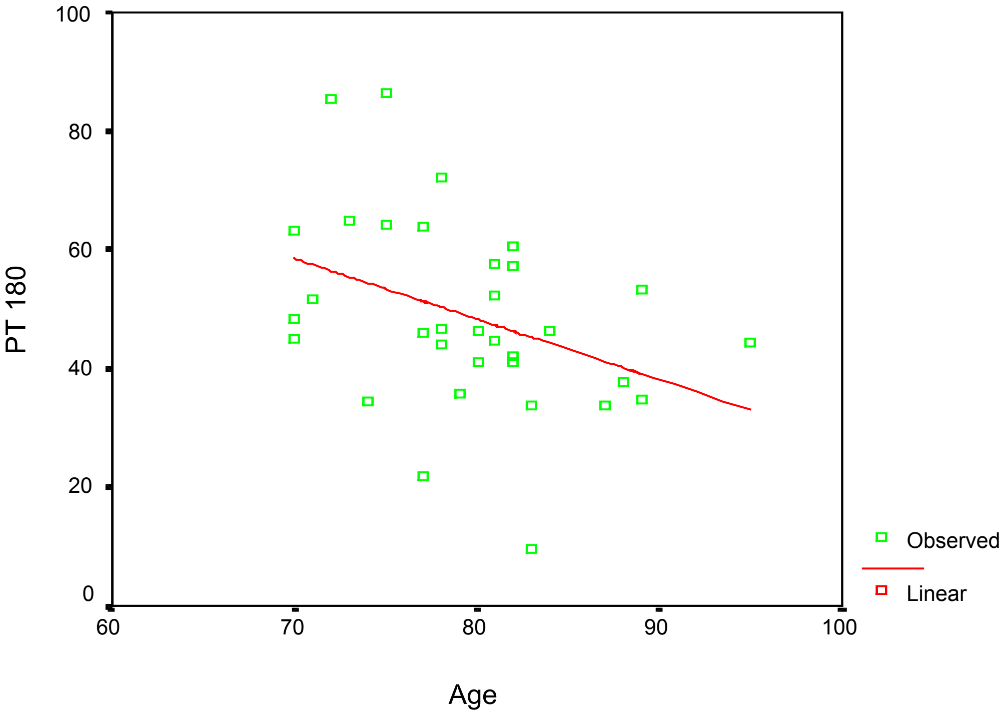

Figure 4.2: PT180 and Age

Table 4.2: Correlation Coefficients Between Strength and Age by Gender

Gender	PT 0	PT 90	PT 180	Adj PT 0	Adj PT 90	Adj PT 180
Males	-0.481	-0.491	-0.570	-0.256	-0.272	-0.405
Females	-0.195	-0.126	-0.132	-0.215	-0.124	-0.131

4.2.2 Age and Physical Function

With an increase in age, there appeared a strong negative correlation with the total CS-PFP functional score (see Figure 4.3). With regard to the individualized functional tasks, performance on the weight carry, jacket, reach, floor sweep, and laundry items were inversely associated with age (see table 4.2). The weight carry, jacket, floor sweep, and laundry items are time to completion tasks, therefore the positive correlation coefficient suggests that advancing age is associated with increased time to completion, and therefore poorer performance.

Table 4.3: Correlation Coefficients Between Function and Age

Item	Age
Weight Carry	**.453****
Jacket	**.378***
Scarves	.318
Reach	**-.391***
Floor Sweep	**.379***
Laundry 1	**.565****
Laundry 2	**.527****
Floor Sit	.172
Stair Climb	.240
Groceries	.177
Walk	-.331
Total	**-.657****

* indicates correlation is significant at the 0.05 level (2-tailed)
** indicates correlation is significant at the 0.01 level (2-tailed)

Additionally, the CS-PFP total scores were analyzed according to gender. The resultant correlation coefficient for the males was –0.621 (p=0.031), while the correlation coefficient for the females was –0.678 (p<0.001).

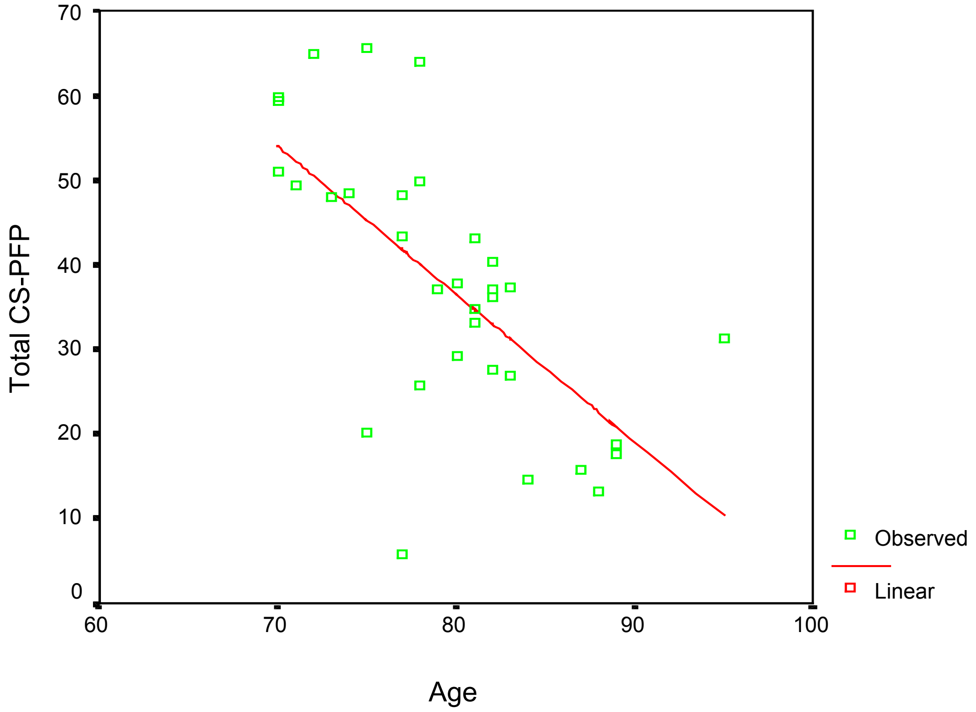

Figure 4.3: CS-PFP Total Score and Age

4.3 Association Between Strength and the Modified CS-PFP

The following Table (4.4) presents the Pearson correlation coefficients for the associations between strength (i.e., isometric (PT0), isokinetic at 90˚/sec (PT90), isokinetic at 180˚/sec (PT180), relative isometric (Adj PT0), relative isokinetic at 90˚/sec (Adj PT90), and relative isokinetic at 180˚/sec (Adj PT180)) and functionality (CS-PFP individual items and the total score).

Table 4.4: Strength vs. Functional Performance Scores

Item	PT0	PT90	PT180	Adj PT0	Adj PT90	Adj PT180
Weight Carry	**-.426***	**-.405****	**-.374***	-.230	-.245	-.206
Jacket	**-.394***	**-.483****	**-.429***	-.181	-.340	-.267
Scarves	-.168	-.224	-.223	-.080	-.138	-.133
Reach	**.462****	**.379***	.037	.288	.242	.170
Floor Sweep	-.002	-.009	-.059	.086	.110	.049
Laundry 1	**-.660***	**-.673****	**-.621****	**-.431***	**-.500****	**-.440***
Laundry 2	**-.654****	**-.664****	**-.609****	**-.416***	**-.478****	**-.430***
Floor Sit	-.051	-.025	-.036	-.167	-.137	-.148
Stair Climb	-.091	-.011	-.044	-.054	.035	-.022
Groceries	-.070	-.014	-.004	-.041	.014	.020
Walk	**.466****	**.483****	**.359***	**.409***	**.492****	**.360***
Total	**.622****	**.683****	**.614****	**.385***	**.503****	**.435***

* indicates correlation is significant at the 0.05 level (2-tailed)
** indicates correlation is significant at the 0.01 level (2-tailed)

The relationships between knee-extensor strengths and function were fitted with several different regression models including linear, logarithmic, logistic, and power (i.e., log/log). The results of the curve fitting analyses are presented in Table 4.4. By comparing the F-values for each of the models, one can surmise that the linear model is as effective as any other for examining the relationship between absolute strength and CS-PFP performance scores. When modeling function using the body-weight adjusted peak torques (Adj PT0, Adj PT90, and Adj PT180) the F-values for the logistic model are slightly higher.

Table 4.5: Strength vs. Function Curve Fitting Results

Condition	Model	Intercept	Beta 1	F	Significance
Absolute PT0	Linear	8.03	.35	19.58	<0.001
	Logarithmic	-66.73	23.81	15.41	<0.001
	Logistic	.12	.97	24.74	<0.001
	Power	1.11	.78	13.79	.001

Table 4.5 cont' on next page

Absolute PT90	Linear	4.46	.54	27.11	<0.001
	Logarithmic	-62.53	24.65	18.52	<0.001
	Logistic	.16	1.0	36.02	<0.001
	Power	1.18	.82	17.64	<0.001
Absolute PT180	Linear	7.44	.61	18.8	<0.001
	Logarithmic	-43.23	21.09	12	.002
	Logistic	.13	.95	24.7	<0.001
	Power	2.5	.68	10.32	.003
Adjusted PT0	Linear	18.77	15.5	5.38	.027
	Logarithmic	35.2	17.51	5.75	.023
	Logistic	.05	.31	5.97	.02
	Power	31.04	.55	4.74	.037
Adjusted PT90	Linear	9.81	31.77	10.5	.003
	Logarithmic	41.51	21.38	8.61	.006
	Logistic	.1	.09	12.14	.001
	Power	38	.7	7.73	.009
Adjusted PT180	Linear	12.83	35.7	7.22	.012
	Logarithmic	44.49	16.7	4.93	.034
	Logistic	.08	.06	8.44	.007
	Power	41.18	.5	3.78	.061

The data was also separated by gender. For females, there was a significant association between PT 0 and function only. For males, there was a significant association between all aspects of strength, except Adj PT 0, and function.

Leg-extension strength was also associated with many of the CS-PFP subscales (i.e., upper body strength, upper body flexibility, lower body strength, balance and coordination, and endurance). In this respect, all of the absolute strengths were significantly related to the various subscales and the relative strength scores were also associated with many of the subscales. The following table (4.6) presents the p values between leg-extension strength scores and the CS-PFP subscales.

Table 4.6: Correlation Coefficients of the Functional Groupings and Strength

Strength	**Upper Body Strength**	**Upper Body Flexibility**	**Lower Body Strength**	**Balance and Coordination**	**Endurance**
PT 0	**<0.001****	**.017***	**<0.001****	**.001****	**<0.001****
PT 90	**<0.001****	**.008****	**<0.001****	**<0.001****	**<0.001****
PT 180	**<0.001****	**.027***	**<0.001****	**<0.001****	**<0.001****
Adj PT 0	**.015***	.166	**.006****	.062	**.022***
Adj PT 90	**.002****	.056	**<0.001****	**.008****	**.002****
Adj PT 180	**.006****	.133	**.002****	**.024***	**.010****

* indicates correlation is significant at the 0.05 level (2-tailed)

** indicates correlation is significant at the 0.01 level (2-tailed)

CHAPTER 5. DISCUSSION

The chief purpose of this research was to examine whether speed of movement influences the relationship between peak torque and function. The main focus was to examine the relationship between an isometric and two isokinetic (90º/sec^{-1} and 180º/sec^{-1}) strength tests and the individual and total scores on the CS-PFP. The second purpose of this study was to examine linear and curvilinear regression models for fitting quadriceps strength (at various velocities) to the various function curves in an effort to identify a possible threshold effect. That is, we were interested in detecting the value for quadriceps strength below which decreasing strength is associated with a precipitous decrease in function.

In general, the observed scores for the CS-PFP and strength tests were in the range of expected values for this age group (79.5 +/- 6.0 years). With respect to the CS-PFP, the ranges of scores, including the individual tasks and the total score, are very similar to those observed by Dr. Elaine Cress and colleagues (1996; 1999). Cress et. al. (1996; 1999) had three different dwelling-status groups: Community Dwelling (CD), Long-Term Care - Independent (LTC-I), and Long-Term Care - Dependent (LTC-D). Their total CS-PFP scores were as follows: CD 54.2 ± 11.0; LTC-I (42.3 ± 15); and LTC-D (23.6 ± 8.7). The total CS-PFP mean score of the present investigation (37.4 ± 16.0) was slightly under Cress' LTC-I group (42.3 ± 15). This is as expected inasmuch as the subjects of the present investigation were primarily independent-living long-term care facility residents (i.e., LTC-I) with the exception of one or two who had existing disabling conditions (i.e. Parkinsonism).

With respect to the knee-extensor strength of the study sample, the PT strength scores ranged from 14.0-144.3 Nm throughout the entire range of velocities (0-180°/ sec^{-1}). The mean values for PT0, PT90, and PT180 are 83.0 ± 29.0, 61.7± 21.1, and 49.4 ± 16.3, respectively. These data seem reasonable in comparison to those reported by Harries and Bassey (1990), who noted a 34-65 Nm range in strength with older women, and Frontera (1991), who indicated a mean PT values of 89 ± 15 Nm at 60°/sec^{-1} and 46 ± 12 Nm at 240°/sec^{-1}. However, the observed scores were somewhat lower in comparison to previous reports from our own laboratory. Sabatier et. al. (2001) earlier reported mean values for PT0, PT60, and PT180 in a group of older adults to be 104 ± 25 Nm, 85 ± 25 Nm, and 69 ± 18 Nm, respectively. The lower values reported herein are likely the differences in the mean age of the participants. The average age of the present study sample was nearly 80 years in comparison to a mean age of 69.5 years in Sabatier's investigation. Thus, the relatively low strength observed in this group of older adults is consistent with the plethora of data revealing a decrease in strength with advancing age.

Likewise, within the present study sample, the data revealed an age-related decrement in absolute muscle strength. These data are consistent with Harries and Bassey (1992). This reduction can be the result of physical inactivity or the normal aging process. The normal aging process certainly includes a reduction in muscle cross-sectional area, and more controversially, a potential decrease in type II fiber cross-sectional area (Rogers & Evans, 1993). The question as to whether age-related changes in muscle strength are primarily due to decreased muscle mass vs. changes in the contractile properties of muscle has sparked very interesting debate. While the purpose of the present investigation was not to provide evidence on one side or the other, the present data, which indicate that there seems to be no relationship between relative strength (force per kg of body weight) and age, is consistent with the thinking that contractile properties change very little with advancing age and that the loss of muscle mass is the primary cause of age-related decay in strength. Data from this investigation cannot be considered direct evidence of this as there was no measure of cross-sectional area or specific tension or the like, but the observation that age was not associated with ability to generate force per unit body weight seems important to report nonetheless.

As expected, age was also associated with physical function, as noted by an age-related reduction in total CS-PFP scores. This age-related decline was also detected in several, but not all, of the individual scores of the CS-PFP (weight carry, jacket, reach laundry 1 & 2). The composite score is a generalized score based on different aspects of function (i.e., upper body strength, lower body strength). This generalized score may help indicate specific areas that need improvement. Cress and colleagues (1996) grouped the tasks into five different domains (upper body strength, upper body flexibility, lower body strength, balance and coordination, and endurance). However, as of yet Cress et. al. (1999) have not reported an association between the total CS-PFP and age. Therefore, the reports showing age-relate decrements in CS-PFP score from our laboratory, including previously unpublished data as well as the present data have the potential to make a unique contribution to the literature.

The main purpose of this investigation was to examine the strength and nature of associations between CS-PFP scores and peak knee extension torque at a variety of movement velocities. Absolute PT was closely associated with total CS-PFP scores at all velocities with statistically significant relationships appearing at angular velocities of 0°

per second (isometric) and 180˚ per second, and nearly significant at 90˚ per second. Interestingly, however, while absolute strength was clearly associated with physical function scores, relative strength (peak torque per Kg body weight) was not associated with function. This is interesting in that there seems to be some absolute strength requirements regardless of one's body weight or size, with respect to maintaining independence. Strength norms are typically associated with percent body weight, and the present data argues against this when dealing with older adults. This indicates that smaller individuals may have a disadvantage in maintaining independence later in life. Additionally, the associations between strength and function are consistent with those of Cress and colleagues (1996) reported associations between knee extension strength (60º/sec) and the total CS-PFP score. Cress and colleagues also report the subcategories for their data (upper body strength total = 41, upper body flexibility total = 47, lower body strength total = 33, balance and coordination total = 40, and endurance total =. 41). The data at hand show associations between the different aspects of each of these groups and nearly all conditions of strength (i.e., mean score on upper body strength total (25.3), upper body flexibility total (52.7), lower body strength total (30.7), balance and coordination total (42.7), and endurance total (36.7)). This indicates a close relation between Cress's data and the present data on all subscale except upper body strength.

The hypothesis that the relationship between peak torque and function would appear to be strongest at the faster velocities was based on the fact that nine of the ten CS-PFP items are time to completion tasks. This hypothesis was not supported, rather, the statistical analysis indicated that association between peak torque and total CS-PFP (for all participants) was highly significant at all velocities of movement. Furthermore, the strength of the associations between peak torque and the performance of the individual CS-PFP items did not appear to differ with velocity of movement. When inspecting the individual components of the test, however, the reach task and the endurance walk appeared to be more closely associated with peak torque as measured during the isometric contraction. Moreover, when evaluating these relationships according to gender, males showed relationships between function and all absolute strength at all velocities; however, the female data indicate a significant relation between function and strength during the isometric condition only. Therefore, these data suggest that if it is only feasible to employ one testing velocity for examining leg-extensor strength as it relates to function, the best choice might well be 0° per second or isometric.

The interest in the association between strength and function goes beyond the simple question as to whether a relationship exists, but rather whether the relationship is linear or curvilinear in some fashion so as to suggest that a critical threshold for strength exists. Based on the work of Jette et. al. (1998), we hypothesized that curvilinear models would provide a better fit for describing the strength vs. function curves as compared to linear models, and therefore, a distinct threshold would be identified. As an initial test, we investigated the sums of the squares for a number of curve fitting models (linear, logarithmic, logistic, and power or log/log). With respect to the absolute peak torque curves (PTO, PT90, and PT180 vs. CS-PFP), the sums of squares associated with the linear models were at least as small as in any other case, suggesting that the linear model is an appropriate model for the data. This is further substantiated by the results of log/log (or power) curve plots for these data (see figure 5-1 through figure 5-3). In each case the beta-1 value (i.e., slope of the curve) was between 0.8 and 1.0. This confirms the linearity of the association, and renders the detection of a threshold a moot point. With respect to the adjusted peak torque curves, the result of the curve fitting revealed that the logistic regression was a potentially stronger model than the linear model (see figure 5-4 through figure 5-6). This suggests that there may be both floor and ceiling effects when relating relative peak torque to physical function as defined by CS-PFP. However, visualization of the logistic curves indicates that logistic curve only modestly strays from linear, and that the sum of squares is only modestly smaller when compared to the linear model. Lastly, as one might surmise from the simple correlation results, under no condition was the adjusted PT better fit to the function data than the absolute power scores.

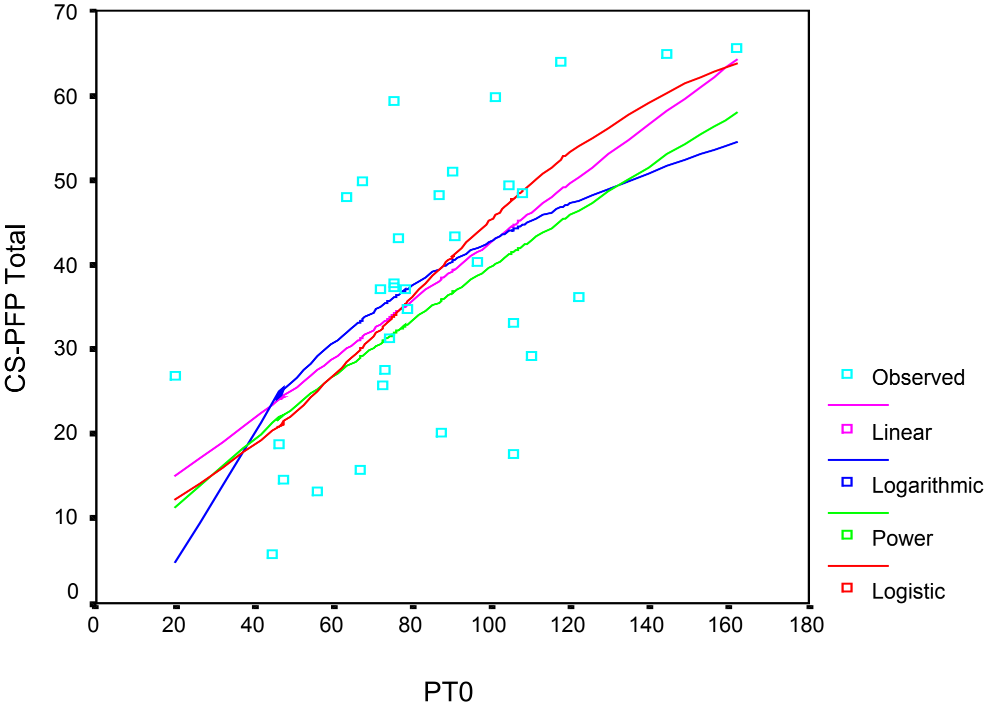

Figure 5.1: Modified CS-PFP Total Score vs. PT0 at Various Regression Models

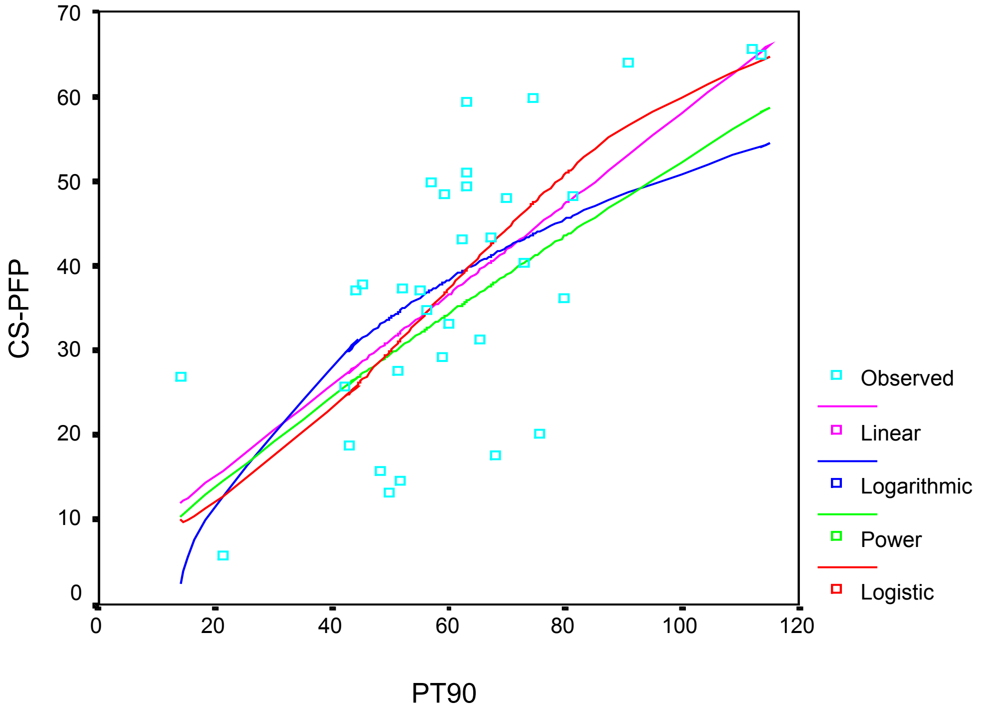

Figure 5.2: Modified CS-PFP Total Score vs. PT90 at Various Regression Models

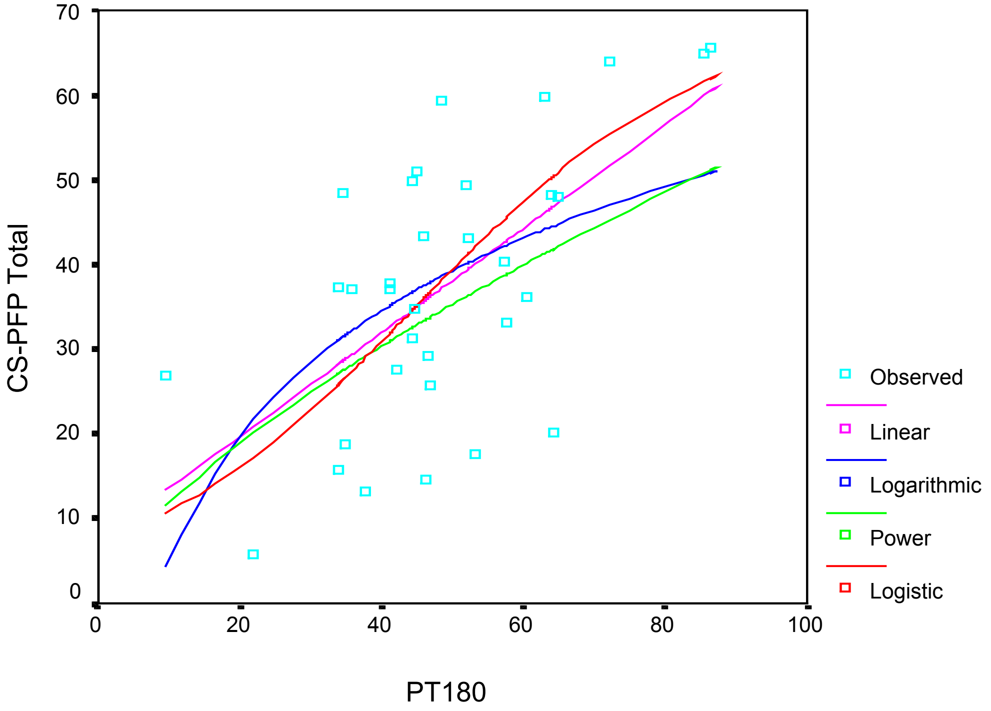

Figure 5.3: Modified CS-PFP Total Score vs. PT180 at Various Regression Models

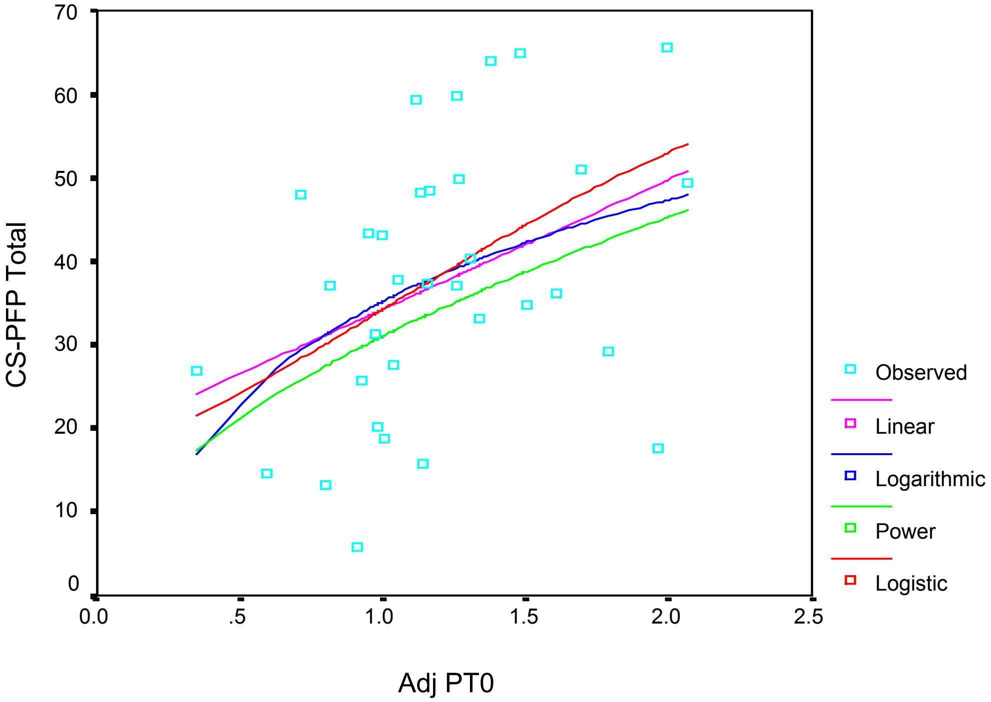

Figure 5.4: Modified CS-PFP Total Score vs. Adj PT0 at Various Regression Models

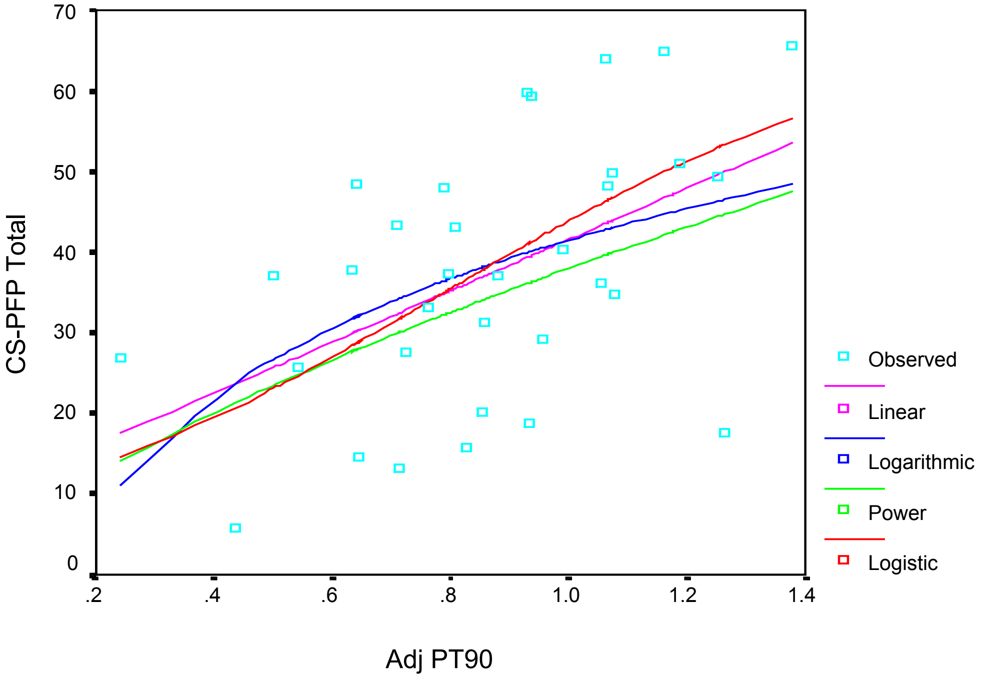

Figure 5.5: Modified CS-PFP Total Score vs. Adj PT90 at Various Regression Models

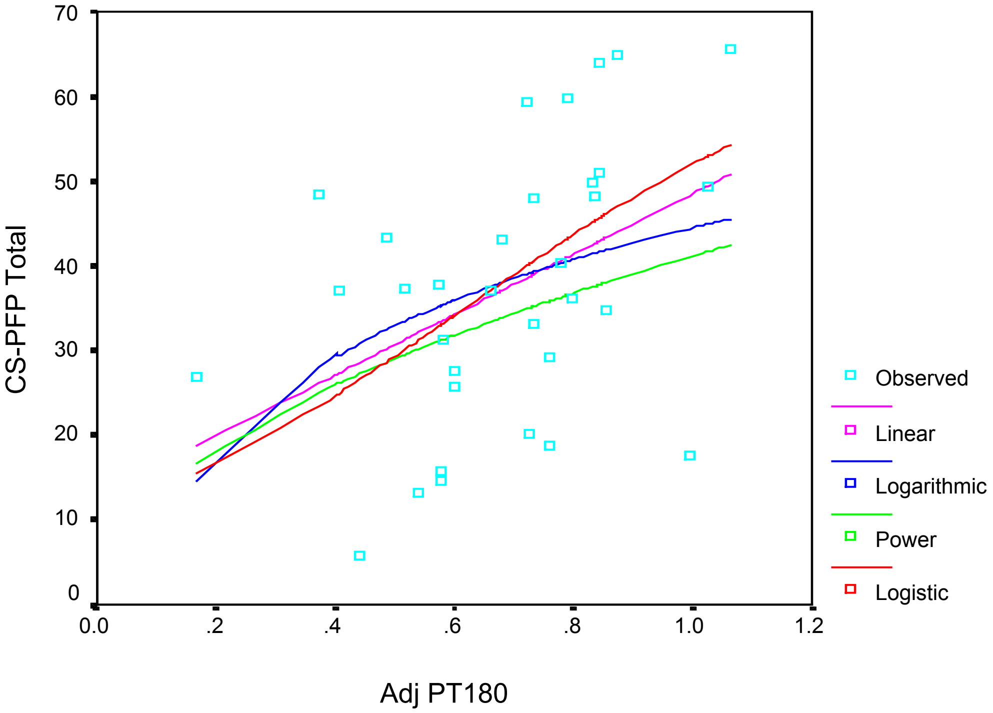

Figure 5.6: Modified CS-PFP Total Score vs. Adj PT180 at Various Regression Models

In summary, several conclusions can be drawn from these data. First, there does not appear to be a particularly important influence of velocity of movement in terms of predicting physical function from leg-extensor strength. However, isometric strength testing may provide some advantages in that it appeared to be predictive of certain elements of the CS-PFP, and appeared to be the best predictor of function among female participants.

Secondly, the linearity between strength and function, while in contrast to other reports such as Jette, who suggest that a threshold for strength will appear in most functional tasks, has implications for the specificity of the CS-PFP. The results of this experiment suggest that the CS-PFP discriminates among a wide array of strength observed in independent living residential community dwellers. Inasmuch as scientists have struggled to find tests that discriminate well throughout a wide range of physical fitness, such findings are very encouraging and most certainly noteworthy.

Additionally, strength tests that replicate a typical daily activity may be more informative about musculoskeletal health as it relates to function, and perhaps more specific to functionality tests such as the CS-PFP. For example, exercises or strength measures that require the subject to bend or squat may be more informative about functional limitations than single-joint activities.

Lastly, exercise-training interventions must be examined to ascertain the extent to which an increase in strength results in an increase in function in older adults. While this subject has been addressed in a few studies, most of these have been limited to the young-old and/or subjects with few limitations. The results of this investigation suggest that the CS-PFP is an excellent candidate as a choice of functional measures that can be used to investigate the influence of strength training in an important subset of older adults (i.e., those residing in long-term care facilities, but striving to maintain independence).

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APPENDIX A
GENERAL INFORAMTION ON EACH SUBJET

Gender	Age	Height (cm)	Weight (in)
Female	82	168.48	75.91
Female	83	158.47	65.46
Female	78	169.47	78.18
Male	75	173.48	88.86
Female	89	161.47	45.91
Female	81	163.47	76.82
Male	87	194.36	58.64
Female	82	161.47	73.64
Female	83	161.29	57.73
Male	70	179.48	80.00
Female	71	152.48	50.46
Female	78	159.39	53.18
Female	82	165.48	70.46
Female	81	167.46	52.27
Female	89	155.98	53.64
Female	82	171.48	62.27
Female	81	183.11	78.64
Female	88	165.07	70.00
Male	75	173.48	81.36
Female	77	154.99	95.00
Male	77	168.12	76.36
Male	95	169.47	76.36
Male	78	185.47	85.46
Male	72	181.61	97.73
Female	70	170.97	53.18
Male	73	171.45	88.64
Female	70	165.48	67.27
Female	80	157.48	71.36
Female	79	163.47	88.18
Female	77	165.99	49.09
Male	84	168.48	80.00
Male	80	175.49	61.36

APPENDIX B
MODIFIED CS-PFP RAW DATA

Weight Carry (time - sec)	Scarves Test (time - sec)	Jacket Test (time - sec)	Reach Test (distance in cm)	Floor Sweep Test (time - sec)	Laundry 1 Test (time - sec)	Laundry 2 Test (time - sec)	Floor Down/Up Test (time - sec)	Stair Climb Test (time - sec)	Grocery Test (time - sec)	Endurance Test (distance in ft)
3.13	21.56	9.03	195.98	32.74	38.28	18.06	13.93	8.66	80.56	900.00
4.85	5.75	11.13	200.48	25.10	34.25	18.97	0.00	10.38	67.22	1210.00
4.25	9.87	14.86	214.08	29.34	49.40	20.02	0.00	0.00	0.00	0.00
5.50	11.98	16.46	208.48	38.34	37.44	24.06	0.00	20.72	238.53	895.00
6.65	11.72	17.19	202.98	57.84	62.50	26.00	19.88	10.77	133.28	1005.00
3.32	5.85	10.09	214.48	31.22	33.19	13.44	0.00	8.13	0.00	0.00
4.69	9.28	19.13	214.48	37.44	63.22	25.13	25.97	19.06	0.00	719.00
4.00	4.62	13.41	207.48	25.72	43.81	13.34	33.00	7.10	93.53	800.00
3.56	4.59	17.46	199.48	34.72	55.22	25.09	0.00	7.53	131.28	982.00
2.56	3.62	11.32	237.48	34.35	31.81	9.34	5.90	6.34	42.32	1000.00
4.03	6.47	9.72	191.48	34.84	39.38	13.66	6.84	6.16	55.69	1231.00
3.59	5.81	12.19	208.98	23.81	33.68	15.22	10.34	6.53	59.75	1617.00
3.60	5.53	22.50	197.48	59.85	40.75	19.38	18.63	7.28	73.15	1040.00
4.66	5.07	17.29	194.68	33.75	42.19	15.38	9.69	7.00	58.79	1479.00
5.91	9.62	26.81	195.98	48.29	49.60	21.78	0.00	9.53	155.66	918.00
4.90	4.47	11.88	215.48	42.59	38.75	15.50	19.72	8.75	66.84	977.00
3.75	5.78	16.10	202.58	29.50	35.53	15.20	23.44	8.69	76.59	1313.00
14.37	20.97	21.50	184.58	40.60	57.19	17.41	0.00	0.00	0.00	800.00
2.41	2.69	11.69	223.98	36.15	19.47	8.43	8.50	3.50	43.34	1715.00
2.88	4.22	11.28	198.48	44.93	29.34	13.59	44.75	7.50	97.72	1281.00
2.84	7.85	11.69	209.48	44.34	37.50	12.57	13.62	3.60	41.75	1343.00
4.25	4.44	20.13	214.48	49.19	51.06	19.57	14.18	7.81	59.17	957.00
2.91	3.78	7.81	234.48	24.31	27.81	11.03	7.27	5.25	36.37	2165.00
2.69	3.00	13.22	238.48	20.91	27.07	10.78	8.12	4.44	35.81	1583.00
2.97	6.50	11.50	219.48	35.03	29.91	17.44	8.25	5.69	40.28	1777.00
3.56	3.32	12.97	221.48	34.56	30.32	16.50	11.41	7.44	51.21	1107.00
2.31	4.38	11.78	219.48	26.45	29.00	11.03	7.41	6.00	47.06	1589.00
4.25	4.22	12.00	206.48	34.94	42.03	24.69	34.56	6.78	61.37	1394.00
2.87	8.15	15.31	205.48	38.41	42.88	12.81	26.81	7.91	68.34	1140.00
9.35	12.09	41.40	196.48	0.00	77.78	25.88	0.00	0.00	0.00	0.00
5.53	9.22	21.03	111.48	38.66	78.68	24.72	41.54	9.88	140.72	900.00
4.63	7.88	22.69	224.48	68.15	43.56	15.94	13.78	7.31	98.96	1472.00

APPENDIX C
MODIFIED CS-PFP TOTALS FOR EACH ITEM

Weight Carry	Scarves Test	Jacket Test	Reach Test	Floor Sweep Test	Laundry 1 Test	Laundry 2 Test	Floor Down/Up Test	Stair Climb Test	Grocery Test	Endurance Test	Total CS-PFP Score
100	1	100	5.29	32.27	24.32	55.85	28.77	26.9	25.45	22.26	36.23
54.45	24.64	87.82	46.04	49.7	32.22	51.65	0	15.6	36.82	39.49	37.28
71.12	0.44	60.75	45.3	38.91	9.2	47.29	0	0	0	0	25.63
40.5	1	52.9	20.7	23.9	25.82	34.05	0	1	1	21.98	20.13
22.49	1	49.81	42.84	7.42	1	29.15	16.83	13.54	2.8	28.1	18.76
100	23.65	98.93	64.8	35.06	34.62	85.9	0	31.35	0	0	43.22
58.48	2.59	42.73	1	25.08	1	31.25	10.28	1	0	12.19	15.87
79.55	38.82	69.49	53.98	47.9	15.84	86.78	5.72	41.89	17.51	16.7	40.32
97.24	39.29	48.73	34.71	29	3.71	31.35	0	37.14	3.33	26.82	26.81
100	58.75	86.01	69.27	29.59	37.98	100	83.05	51.86	77.2	27.82	59.75
78.48	18.19	100	42.32	28.82	22.44	84.01	70.11	54.58	51.03	40.66	49.31
95.9	24.04	78.44	64.47	53.75	33.49	72.16	42.62	49.15	45.4	62.12	49.81
95.45	26.94	33.33	17.35	6.33	20.25	49.89	18.71	39.83	31.25	30.04	27.52
59.27	32.41	49.4	5.01	30.56	18.09	71.08	46.22	43.07	46.66	54.45	34.75
33.27	1.32	24.76	42.57	13.83	8.99	40.92	0	20.67	1	23.26	17.63
53.25	41.24	81.01	42.65	19.02	23.5	70.29	17.06	26.2	37.21	26.54	37.13
89.09	24.34	54.53	1	38.56	29.52	72.3	12.59	26.66	28.42	45.22	33.03
1	1	35.81	1	21.18	2.11	59.11	0	0	0	16.7	13.2
100	90.58	82.65	56.43	26.87	89.21	100	54.25	100	74.63	67.57	65.54
100	45.66	86.38	52.24	16.73	44.79	84.61	1.3	37.45	15.39	43.44	43.43
100	9.13	82.65	38.4	17.29	25.71	94.03	29.68	100	78.69	46.89	48.31
71.12	41.74	39.61	46.24	13.12	7.5	49.1	28.07	34.32	46.15	25.43	31.21
100	54.85	100	45.7	52.13	49.61	100	65.31	71.2	95.03	92.59	63.89
100	77.78	70.77	65.26	64.67	52.13	100	57.31	91.73	97.02	60.23	64.96
100	17.95	84.35	53.5	28.53	43.12	58.96	56.23	62.5	82.72	71.02	50.98
97.24	67.07	72.52	56.72	29.25	41.95	64.11	37.58	38.08	58.27	33.77	47.89
100	42.77	81.87	70.53	45.89	45.81	100	63.86	57.14	66.22	60.56	59.24
71.12	45.66	80	64.46	28.66	18.32	32.37	4.96	45.81	43.36	49.72	37.73
100	7.57	58.38	42.78	23.82	17.11	91.68	9.61	33.37	35.69	35.6	36.99
1	1	8.99	13.48	0	1	29.43	0	0	0	0	5.74
39.93	2.82	37.06	1	23.5	1	32.29	2.26	18.48	0.97	22.26	14.7
60.06	8.97	32.89	51.67	2.51	16.17	67.48	29.2	39.5	14.8	54.06	29.19

APPENDIX D
STRENGTH PT FOR EACH SUBJECT AT EACH CONDITION

PT 0	PT 90	PT 180	Adj PT 0	Adj PT 90	Adj PT 180
121.8	79.9	60.5	1.60	1.05	0.80
75.4	52.1	33.8	1.15	0.80	0.52
72.3	42.3	46.8	0.92	0.54	0.60
87.3	75.7	64.3	0.98	0.85	0.72
46.1	42.8	34.8	1.00	0.93	0.76
76.3	62.1	52.3	0.99	0.81	0.68
66.9	48.4	33.8	1.14	0.83	0.58
96.1	72.8	57.2	1.31	0.99	0.78
20.2	14	9.6	0.35	0.24	0.17
100.9	74.3	63.1	1.26	0.93	0.79
104.3	63.2	51.8	2.07	1.25	1.03
67.3	57.1	44.2	1.27	1.07	0.83
72.8	51.1	42.2	1.03	0.73	0.60
78.6	56.3	44.6	1.50	1.08	0.85
105.1	67.8	53.3	1.96	1.26	0.99
78.1	54.9	41.2	1.25	0.88	0.66
105.4	59.9	57.6	1.34	0.76	0.73
56	49.8	37.8	0.80	0.71	0.54
162	112.1	86.4	1.99	1.38	1.06
90.4	67.3	46	0.95	0.71	0.48
86.4	81.3	63.9	1.13	1.06	0.84
74.1	65.5	44.3	0.97	0.86	0.58
117.6	90.8	72.1	1.38	1.06	0.84
144.3	113.6	85.5	1.48	1.16	0.87
90.2	63.1	44.9	1.70	1.19	0.84
63.4	69.9	64.8	0.72	0.79	0.73
75.2	62.9	48.5	1.12	0.94	0.72
75.2	45.3	41	1.05	0.63	0.57
71.6	44.1	35.7	0.81	0.50	0.40
44.5	21.3	21.7	0.91	0.43	0.44
47.5	51.6	46.2	0.59	0.65	0.58
109.7	58.7	46.5	1.79	0.96	0.76

VITA

Kathryn O'Bryan Wilson was born at Fort Belvoir, Virginia, on May 9, 1977. For the first few years of her life, she was an "Army Brat". She moved from Virginia to Korea, back to Virginia, then to New York, and at age 10 she finally made Slidell, Louisiana, her home. She attended University of Louisiana at Monroe and received a Bachelor of Science degree in exercise science in May 2000. There she met her husband, Dwayne Wilson. They were married on June 30, 2001. She then attended LSU, and will graduate with a Master of Science degree in kinesiology in December 2002. After graduation, she will continue to work at St. James Place Retirement Community, directing the Kinesiology Lab designed for the Residents. She will continue to reside in Baton Rouge, Louisiana.