LOWER EXTREMITY STRENGTH AND ITS ASSOCIATION WITH PHYSICAL FUNCTION AND DISABILITY

By

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To my family: To Margaux for being a great sister who has shown an unbelievable ability to overcome.

To Lee, who I can always count on to keep things in their proper perspective.

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LOWER EXTREMITY STRENGTH AND ITS ASSOCIATION WITH PHYSICAL FUNCTION AND DISABILITY

This thesis is under the direction of Anthony P. Marsh, Associate Professor of Health and Exercise Science.

The aims of this study were 1) to determine if the relationship between isometric lower extremity strength and 5 indices of physical performance was non-linear and 2) to examine a simple model of the disablement process in older adults. Forty-six (34 females, 12 males) elderly (81.6 +/- 0.9 years) individuals living in two retirement communities completed a comprehensive physical and psychosocial testing battery. Transformed strength summary score was significantly correlated with preferred ($r = .420$, $p = .006$) and fast ($r = .462$, $p = .002$) gait velocity, the timed up and go ($r = -.340$, $p = .026$), and modified Guralnik score ($r = .461$, $p = .002$); but not with 5 timed chair rises ($r = -.219$, $p = .157$). None of the relationships between strength and physical performance were non-linear. Strength, in addition to all physical performance measures, was significantly correlated with self-reported physical disability (r = .435-.715). A factor analysis was used to create a single mobility score from the 5 physical performance measures. Lower extremity strength was significantly correlated with this mobility score ($r = .420$, $p = .006$), and the mobility score was significantly correlated with self-reported physical disability ($r = .696$, $p < .001$). After controlling for age and sex, strength was

related to self-reported disability (Standardized β weight = .580, p = .002) but the relationship was attenuated when we included mobility in the model (Standardized β weight = .421, p = .010), indicating that mobility was a partial mediator in the relationship between strength and self-reported physical disability. In conclusion, lower extremity strength was a significant contributor to both physical function and self-reported disability. Mobility, or the ability to move effectively in society, partially mediated the relationship between strength and disability, suggesting that both strength and mobility are important components of the disablement process. These data have implications for researchers and health care professionals seeking to design and implement interventions to ameliorate the disability problem in society.

The United States Census Bureau projects that by 2040, the average life expectancy for American women and men will be 83.1 and 75.0 years, respectively (83). By contrast, in 1900 the average life expectancy was under 50 years. Therefore, the number of individuals over age 65 in the United States, both in absolute and relative terms, will continue to grow in the foreseeable future. Based on Census Bureau projections, the number of people over age 65 will increase to 52 million by the year 2020 and to 68 million by 2040. Similarly, in the over 85 year-old category, the increase in longevity is expected to result in 6.7 and 12.2 million people in 2020 and 2040, respectively (83). Especially troubling about this aging of the population is the potential for a substantial increase in the number of disabled individuals living in the United States. For example, in the population over age 85, approximately 62% of women and 46% of men are dependant on another person to live or are living in nursing homes (83). The cost of this phenomenon is enormous and will contribute to exponential increases in health care costs unless great strides are made in preventing or treating disability (83). Fortunately, preventing physical disability has become a top priority in geriatrics research (48, 91).

The disablement process, as described by Nagi (63), begins when an active pathology interrupts the body’s normal processes, eventually causing impairments in one or more of the body’s systems. If not corrected, impairments then progress to functional limitations, and ultimately to disability, or the inability to carry out basic, essential activities of daily living (ADLs). ADLs are the abilities to eat, toilet, transfer into or out of a chair or bed, dress, and bathe (91). Physical functional status, a multifactorial concept encompassing muscular strength, balance, joint range of motion, and cardiovascular endurance (16), is closely related to disability. Physical function is defined as the underlying physiological capacity to perform activities of daily living (25). Disability is linked to an individual's capability to function in society as they want and in the ways in which society demands (91). It is also important to recognize that disability has a significant social component. Thus, just because an individual possesses the physical capability to perform a task does not mean they will always complete it (91). For example, an older adult who is capable of walking a mile might complete the task successfully when walking with others en route to a concert or other activity, but feel incapable of walking a mile alone for exercise.

As a way of objectively measuring physical functional status, physical performance tests have been developed. These tests require an individual to perform a specific task as instructed, and their physical function is determined objectively according to their performance (39). Depending on the nature of the test, performance can be quantified by time to complete the task or number of repetitions completed. The relationship of physical function, measured with physical performance tests, to the prevalence and severity of disability has received much attention (15, 40, 42, 48, 66, 72). Physical characteristics such as strength, flexibility, cardiovascular endurance, and balance are all important, but in a given situation one characteristic might influence disability the most. For instance, strength and balance are important when carrying a sack of groceries to the kitchen after a shopping trip. However, with a compromised cardiovascular system, this task may not be possible at all despite the requisite strength and balance capacity. Likewise, an individual with balance problems or poor flexibility may be unable to step into a bath tub or shower to bathe themselves. This makes it difficult to identify a single factor as a primary cause of disability. However, as an individual develops deficits in additional physical functional domains (i.e. strength and balance or cardiovascular endurance), it appears that disability increases in severity and scope (29, 71).

Non-linear relationships have been proposed to exist between impairments in the body's systems and physical function (20, 32). Such relationships suggest that it is possible to identify a threshold on the physical functional continuum below which individuals are at increased risk for becoming disabled. Thus, identifying the physical characteristics that are most closely related to physical function and disability is important in order to identify individuals at increased risk of becoming disabled.

Fried et al. (35) used the term "preclinical disability" to describe that group of individuals who are at increased risk of becoming disabled. Individuals at this stage in the disablement process are on the "slippery slope" of progressive decline in function that will eventually lead to disability. It is theorized that early detection and intervention in preclinically disabled populations will increase the likelihood that individuals will regain the slight loss of physical function characteristic of this population (35). In contrast, it is generally accepted that once an individual becomes disabled, fully regaining lost physical function is unlikely to occur.

One physical characteristic that is consistently identified as a major factor in the disablement process is sarcopenia (22, 65). Sarcopenia is the loss of muscle mass and strength that occurs with aging (78). Thus, regardless of an individual's physical functional status or physical activity habits, as they age they will lose muscle mass and become progressively weaker. Declines in strength are associated with declines in physical function (13, 86), and declines in physical function are associated with increases in disability (42, 43, 48), in line with the disability model of Nagi (63).

It has been proposed that mobility has an impact on the disability status of an individual (1, 24). There is not a universally accepted definition of mobility, but all references refer to the ability to perform basic movements associated with daily living such as walking, getting into and out of a chair or bed, and climbing steps (35, 69). Recently, mobility has been identified as a potential mediator in the relationship between strength and disability (48). In other words, the impact of strength on disability may be affected by how effectively an individual is able to move.

The purpose of this study is to examine the relationships between lower-extremity strength, physical function, and disability in an elderly population living in retirement communities. The inconsistent use of terminology in the disability literature often obscures the true meaning of an investigation. To minimize the ambiguity in this thesis, physical function will be defined as the underlying physiological capacity to perform activities of daily living, and physical performance measures will be used to objectively measure physical function. Additionally, we will use a combination of lower extremity physical performance measures to indicate mobility. Lastly, physical disability will be self-reported difficulty in performing physical activities.

Disability results most commonly when individuals suffering from a chronic condition(s) become unable to carry out the roles and tasks that they wish to perform, or those that might be demanded of them by society (63, 90). Nagi (63) characterized the pathway to disability beginning with an active pathology, progressing to an impairment, followed by a functional limitation, and eventually, disability. This process commences when an active pathology interferes with the normal processes of the body. If uncorrected, eventually the pathology will cause an impairment in one or more of the body's systems. Functional limitation occurs when an impairment causes performance to suffer at the whole body level. When this occurs, and a person becomes unable to perform as expected in society, they are considered disabled.

While functional limitation and disability are closely related, it is important to understand their inherent differences. Functional limitations refer to an individual's ability to complete a task, while disability involves viewing a functional limitation in a social context (91). In other words, a person may be functionally limited in that they are unable to walk a mile, but because they are still able to ambulate effectively in society (i.e. moving around in their living quarters, getting to and from work, etc.), they may not consider themselves to be disabled. Thus, an increase in functional impairment may not translate into an increase in disability (48, 91).

Fried et al. (35) has proposed preclinical disability as a hypothetical intermediate range of function on the pathway from high function to disability (Figure 1). In this functional range of preclinical disability, interventions are likely to be most effective in preventing disability. Once an individual becomes disabled, restoring physical functional ability is difficult, and the primary goal of rehabilitation shifts from attempting to improve function to preventing further decline (35). However, in preclinically disabled populations, only small declines in function have occurred, declines which are reversible if addressed with an intervention at an optimal point in time, early on in the preclinical stage. Determining the onset of preclinical disability could revolutionize disability prevention strategies as it would identify those individuals who are most likely to be affected by disability early in the disablement process when interventions are especially effective at increasing physical function.

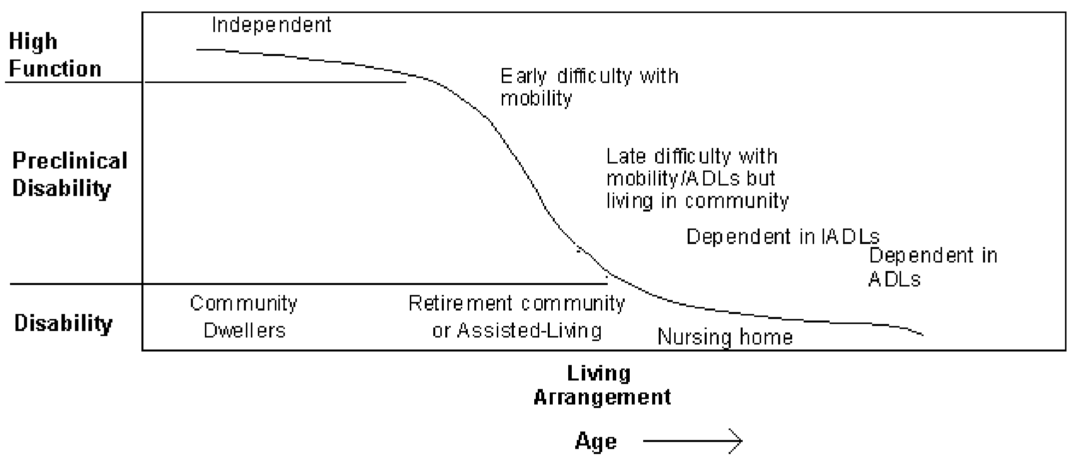

Figure 1. Schematic diagram illustrating the intermediate stage of preclinical disability on the pathway from high function to disability. Adapted from Fried et al. (35).

A person's capacity to perform a given task is dependent on a number of physiological and psychosocial variables (91). Physiological determinants of performance include, but are not limited to, strength, flexibility, aerobic capacity, and balance. Similarly, psychosocial variables include depression, self-esteem, and self-efficacy (91). It has been suggested that physiological variables determine maximal capability, while psychosocial variables modulate a person's performance in a given situation (90). Each physiological and psychosocial domain affects disability differently, thus it is important to examine each domain independently. Equally important, though, is seeking to understand how the domains overlap and the effects of one on another. This idea of coimpairments has been investigated in some depth and has been shown to greatly impact disability (71, 92).

Measuring disability, in light of its multifactorial nature, is a rather challenging task. Disability is most commonly measured by self-report questions aimed at determining the extent to which an individual has difficulty performing a task. Self-reports are often used because they are easy to administer and cost-effective. Two self-report questionnaires commonly used in disability research are the Sickness Impact Profile (7, 8) and the SF-36 (93, 94). Both instruments contain a number of subscales that test for disability in various domains, e.g., physical, work. Therefore, depending on the nature of the population being tested or the research being done, the disability measure may vary.

Observational techniques for disability measurement, whereby a trained evaluator watches as a person completes a task, then rates their ability to do so, are more costly and time-consuming (39, 90). There are benefits of having a person actually perform a task to assess their degree of disability; however, a subjective assessment on the part of the rater is required which reduces the utility of these performance-based measures in disability research (57, 69).

The next sections describe a number of potential impairments in the disablement model of Nagi (63) that contribute to disability. The association of each of these factors to physical function has been investigated in some detail in the literature, and a summary of that research is included.

Psychological factors are among the numerous variables included in contemporary models of disability (91). Examples of such factors include depression (17, 53, 56, 89) and self-efficacy (58, 60, 77). These psychosocial factors are important to consider because of the social aspect of disability, i.e., disability is a gap between personal capability and environmental demand (91). Psychosocial factors play a significant role in an individual's ability to deal with the environmental demand and may be very different between two individuals in a given situation, or within an individual in two different situations.

The influence of psychosocial variables on physical function in the elderly was shown in a six month randomized, controlled trial by Buchner et al. (17). The study was designed to examine the effects of an exercise intervention on gait velocity in 152 community-dwelling older adults. At baseline, gait velocity was significantly correlated with depression as well as strength and aerobic capacity. Following the exercise intervention, a slight, non-significant improvement in gait velocity was observed (0.32 $m \cdot min^{-1}$). This gait velocity improvement was significantly correlated with a reduction in depressive symptoms from baseline, but was not significantly correlated with improvements in strength or aerobic capacity.

Self-efficacy is defined as an individual's belief in their ability to successfully complete a given task (3). Self-efficacy is situation-specific and depends on four sources of information related to the task in question. The four information sources are past performance accomplishments, vicarious experiences, social or verbal persuasion, and interpretation of physiological arousal (3). Through self-efficacy, these informational sources affect an individual's physical performance. As an example of past performance accomplishments affecting performance, an individual who has stairs in his/her house and walks up and down them frequently is likely to have higher self-efficacy in performing a stair climb physical performance test compared to an individual who lives in a house with no stairs. Assuming that both individuals possess identical physical capacity to perform the test, the individual with higher self-efficacy will probably perform better. A significant relationship between self-efficacy and physical performance has been observed in previous studies (1, 58, 75).

Mendes de Leon et al. (60) examined self-efficacy longitudinally over 18 months in a population whose physical performance capacity was declining due to age. They sought to determine if high self-efficacy would buffer the age-related decreases in physical performance. Their findings indicated a significant interaction effect between self-efficacy and physical performance such that those who had lower self-efficacy experienced greater declines in physical performance over the follow-up period. Conversely, higher self-efficacy was evident in individuals who maintained physical performance despite age-related decreases in physical capacity. In other words, an individual's belief in their ability to perform a task and their motivation to do so is important and should be considered along with their actual physiological capability.

Reductions in joint range of motion (ROM) are common with advancing age (10). Although ROM restrictions have been associated with declines in physical performance (15, 61), it is apparent that ROM reductions are rarely severe enough to significantly contribute to declines in physical function and disability (9, 89). For example, Brown et al. (15) examined nine separate ROM assessments and found that only two, shoulder flexion and external rotation, were significantly related to physical performance. Van Huevelen et al. (89) investigated 409 men and women aged 65 years or more and reported that flexibility of the hip and spine, measured with the sit-and-reach test, and shoulder flexibility were not independent predictors of disability.

In a nine-year longitudinal study involving 89 men and women who were 79 years old, Bergstrom et al. (10) reported significant correlations between restricted hip and knee ROM and mobility limitations such as getting out of a chair, climbing stairs, and entering public transportation. The sample population exhibited significant increases in disability at follow-up when compared to baseline values, yet 80% of the sample was able to climb stairs and walk over 1000 meters, and 69% of the sample were still ambulating without the use of walking aids. Therefore, the joint ROM restrictions that were present in this population were generally well tolerated and did not contribute significantly to disability.

As the heart, lungs, and blood vessels are responsible for providing oxygen to the body to produce the energy necessary for muscular contraction and mechanical work, it is important to understand the relationship of the cardiovascular system to physical function in the elderly (11, 61).

Generally speaking, aerobic capacity is positively associated with physical function (11, 17, 26, 61, 89). For example, Binder et al. (11) examined aerobic capacity and a number of physical performance tests in 101 apparently healthy, sedentary women aged 75 years or older. They reported that VO_{2peak} was a significant independent predictor of overall physical function as measured by seven different physical performance tests that emphasized gross motor function in both the upper and lower extremity (11). Included in the assessment were tests of gait velocity, repeated chair rises, time to climb one flight of stairs, and lifting a seven pound book onto a shelf.

Morey et al. (61) also reported a positive relationship between aerobic capacity and physical performance. A symptom-limited maximum exercise tolerance test was administered to 161 individuals with an average age of 72 years. Interestingly, of the five indices of functional limitation that were used, only one, timed bed mobility, was a physical performance test. The other four were self-reports of physical function that could also be considered tests of disability.

Buchner et al. (17) examined the relationship between aerobic capacity and gait velocity, a commonly used index of physical function that has been shown to predict disability (41). At baseline, VO_{2max} was significantly correlated with, and was a significant independent predictor of gait velocity (17). Following a 6-month exercise intervention, VO_{2max} improved by 7%, and a slight increase of 0.32 $m \cdot min^{-1}$ in gait velocity was also observed. As a result of the increase in VO_{2max}, regression analysis predicted a 2% increase (1.50 $m \cdot min^{-1}$) in gait velocity which was not observed. These findings indicate that relatively large increases in aerobic capacity are necessary to elicit meaningful increases in gait velocity, something that should be considered when designing training interventions to address disability.

Maintaining one's balance with advancing age is essential for elderly individuals seeking to maintain their independence. A wide variety of physical attributes determine an individual's balance performance. Included among them are lower extremity strength (23, 47, 71, 82, 96), vision (51) and vestibular input (51). In general, the literature pertaining to the relationship between balance and physical performance is equivocal.

Ringsberg et al. (76) reported contrasting results between static balance and performance on a 30 m walking test. One balance test was a non-computerized test measured as the time a person could stand on one leg. The other test involved a computerized balance platform on which participants performed 20 s balance trials both with their eyes open and their eyes closed. The results of the study indicated that balance performance on the non computerized test was significantly related to gait performance while the computerized test was not. These results suggest that the index of balance used affects the relationship between balance and physical performance.

Podsiadlo and Richardson (69) developed the timed up and go as a physical performance test of functional mobility for older adults. Included in their definition of functional mobility were balance, gait velocity, and ADL functional capacity. The balance measure used in this study was the Berg balance scale (6), a 14-item testing battery that includes both static and dynamic balance assessments. Performance on the

Berg balance scale was significantly related to performance on the timed up and go, a commonly used test of physical performance (21, 48, 49, 86).

Functional reach, a clinical measure of balance, was associated with a number of performance variables related to a chair rise test in 58 men and women aged 66-96 years (81). Balance was significantly correlated with the lowest height from which an individual could rise and also the time it took participants to rise from a chair. However, in the chair rise test, balance was not a significant predictor of performance while lower extremity strength was, indicating that strength is perhaps more important to chair rise performance than balance.

It has been clearly established that declines in strength accompany the aging process (50, 62, 78). This process is termed sarcopenia, or “the involuntary loss of skeletal muscle mass and consequently of strength seen with healthy aging” (78). A host of potential mechanisms exist that may explain sarcopenia (78), but only a rudimentary understanding of most of these mechanisms is available at this time. Examples of these mechanisms are shown in Figure 2 and include loss of alpha motor neurons in the spinal column, inadequate protein intake, and decline in estrogen and androgen production.

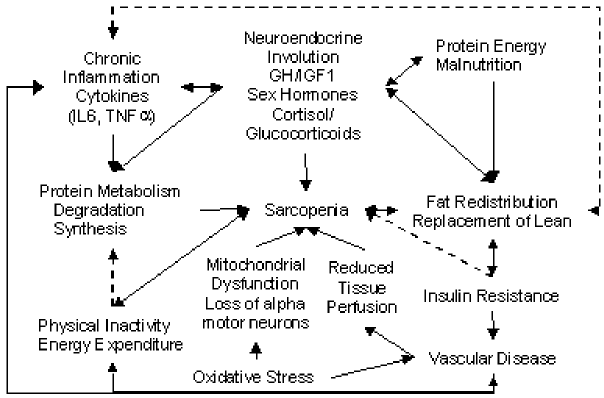

Figure 2. Factors contributing to sarcopenia.

Sarcopenia affects everyone, but some individuals are affected more than others for reasons that are not fully understood. For instance, fit, athletic older adults engaged in competition experience the same age-related losses in strength as their sedentary counterparts. However, the fit individuals maintain their physical function more effectively compared to sedentary individuals (37, 79). The extent to which reductions in strength and subsequent mobility impairments are related to disability in older adults has not been adequately investigated (48).

Muscular strength can be defined as the greatest force output a muscle is capable of generating. Three general techniques exist to assess strength: isometric, isotonic, and isokinetic. Testing with isokinetic or isometric techniques are advantageous in research settings because these techniques measure forces generated by the muscle group being tested. Isotonic testing involves lifting or moving a constant external load. This load becomes the measure of strength which may not reflect the maximal force production of the muscle. An example of isotonic testing is the one-repetition maximum (1RM) strength measure.

The main difference between isokinetic and isometric testing is the presence or absence of joint movement. With isokinetic testing, a joint moves at a constant velocity through its range of motion while attached to an isokinetic dynamometer that measures the torque generated by the muscle moving the joint. Conversely, isometric testing is movement-free and requires the subject to exert a maximal force against an immovable strain gauge that measures the force produced.

From a research standpoint, isokinetic testing is often favored because the load is variable and changes instantaneously to match the force exerted by the subject, thus optimizing the loading of the muscle throughout the entire dynamic movement. Unfortunately, the size, cost, and movement restrictions of isokinetic dynamometers reduce their use, especially in larger trials. Portable dynamometers for measuring isometric strength are cheaper and more practical, especially when conducting onsite or community-based testing. However, their utility as a research tool is justified only if the results of isometric and isokinetic dynamometry are similar.

Reed et al. (74) evaluated strength in 32 healthy, elderly men and women using isometric and isokinetic testing. In four different muscle groups (knee and elbow flexors and extensors), they reported statistically significant correlations, ranging from 0.74-0.85, between isometric and isokinetic average peak torques. While the correlations are indeed strong ($p < .0001$), there is more variability associated with the isometric test compared to the isokinetic test, such that the researchers cautioned against using isometric testing for smaller, highly controlled clinical trials where measurement precision is essential.

However, for large, population-based studies and/or community-based studies that make isokinetic testing impractical if not impossible, isometric strength testing can be utilized effectively.

Strength, specifically in the lower-extremity, is strongly related to physical functional status (19, 84) and physical performance in older adults (4, 15, 16, 20, 70). Also, it has been established that strength training can produce significant and meaningful strength increases in older adult populations (2, 21, 34). Thus, there is considerable evidence supporting research that focuses on strength and its potential impact on mobility and disability in older adult populations.

Buchner and de Lateur (19) reported significant correlations between strength and disability in one of the earliest projects involving these two measures. In this study, strength was measured at the knee and ankle joints using an isokinetic dynamometer, while disability was assessed using the physical domain of the Sickness Impact Profile (SIP) that emphasizes behaviors necessary for independent living in older adults. This research indicated a moderately strong correlation of –0.41 between strength and disability indicating that the stronger subjects reported less disability. Furthermore, strength accounted for approximately 25% of the variance in disability.

Preferred Gait Velocity

Gait velocity is often used as a physical performance test in older adults because it is closely related to subsequent disability (35, 41, 52). A common observation in a number of cross-sectional studies is a decline in preferred gait velocity with advancing age (31, 44, 86). Buchner et al. (18) conducted a randomized controlled trial to investigate the relationship between strength and preferred gait velocity, and to determine the effects of six months of resistance and/or endurance training on strength and gait velocity. They found that leg strength and gait velocity were significantly correlated in this population of 152 individuals 68-85 years old (17). Somewhat discouraging, though, was their finding that after the six month exercise intervention, significant strength increases did not translate into gait velocity improvements. Regression analysis predicted a 2% increase in gait velocity based on the observed 8% increase in strength, but the actual gait velocity was unchanged. The authors proposed that the increase in strength did not improve gait velocity in this sample because the individuals were already at a relatively high physical functional level at baseline.

In a subsequent study, Buchner et al. (20) reexamined the strength versus gait velocity relationship, this time in a random sample of elderly individuals encompassing a broad range of strength and function. Whereas nearly all research in this area to date had assumed a linear relationship between strength and gait velocity, Buchner et al. (20) hypothesized a non-linear relationship between the variables. To illustrate this idea they proposed the curvilinear relationship shown in Figure 3. Furthermore, they divided the curve into three regions, each of which represented a different relationship between strength and gait velocity. In region A, strength is adequate for normal gait velocities and no relationship between the two exists. Conversely, in region B, individuals with decreased strength will walk slower; thus, strength and gait velocity are related. Region C indicates that strength is below a threshold required for walking. Using this non-linear model, significantly more variance (22%) in gait velocity was accounted for by strength compared to just 17% with the linear model (20).

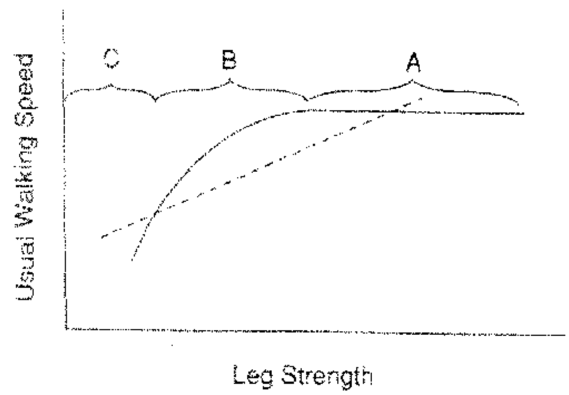

Figure 3. Proposed non-linear relationship between strength and gait velocity.

Brown et al. (16) reported a non-significant relationship between knee extensor strength and gait velocity. However, after creating a summary score of muscular strength by summing maximal strength values from three muscle groups (hip extensors, knee extensors, and ankle plantarflexors) and dividing the sum by the subject's body mass, the relationship was reexamined. This change in the strength index resulted in a significant association, with strength explaining 40% of the variance in gait velocity (16). Unfortunately, this study did not use a non-linear model to describe the strength-function relationship which may account for the non significant relationship between knee extensor strength and gait velocity.

Fast Gait Velocity

Research on strength and its relationship with physical function can also be tested using maximal, or fast gait velocity. In fact, strength is typically more strongly correlated to fast gait velocity than to preferred gait velocity (12, 13, 73, 80). Bohannon (12) illustrated that the age-related rate of decline in fast gait velocity is much greater than the decline in preferred gait velocity. Results of this study supported the viewpoint that strength is more highly correlated to fast gait velocity (r = .292-.500) than to preferred gait velocity (r = .190-.250) (12).

Brown et al. (15) investigated both preferred and fast gait velocities and their relationships to physical function determined by a nine-item physical performance battery. They reported that fast gait velocity, but not preferred, was a significant predictor of physical function. However, a limitation associated with this investigation was the use of one physical performance test (fast gait velocity) to predict performance on a battery of performance tests. Nonetheless, the importance of older adults possessing a functional reserve capacity so that they are able to increase their gait velocity above their preferred pace was underscored. A prime example of this in everyday life is safely crossing a signal-controlled intersection, which in the United States requires walking at a velocity of at least 1.22 $m \cdot s^{-1}$. It is alarming that less than 1% of individuals over 72 years of age have normal walking velocities at or above this value (54).

Based on the idea of a non-linear relationship between lower extremity strength and gait velocity, Rantanen et al. (73) sought to determine strength thresholds at both ends of the strength continuum. On the lower end, a threshold below which a walking velocity of 1.22 $m \cdot sec^{-1}$ was impossible, and on the other end of the spectrum, a strength ceiling above which increases in strength were unrelated to increases in fast gait velocity. Over 1,000 disabled, yet community-dwelling women participating in the Women's Health and Aging Study were tested. Isometric strength measures of the knee extensor and hip flexor muscle groups were collected, along with fast gait velocity. For the analysis, right and left knee extensor torques (N·m) were summed and divided by body mass (kg) resulting in a normalized strength measure expressed in $N \cdot m \cdot kg^{-1}$ (73). Both hip flexor and knee extensor strength were significantly correlated with fast gait velocity, but only knee extensor strength was a significant independent predictor of gait velocity.

With regard to the strength thresholds discussed earlier, 1.1 $N \cdot m \cdot kg^{-1}$ was identified as the minimum strength necessary to walk at 1.22 $m \cdot s^{-1}$. Additionally, for those individuals who exhibited knee extensor strength above 2.3 $N \cdot m \cdot kg^{-1}$, the association between strength and maximum walking velocity disappeared. These findings by Rantanen et al. (73) are encouraging from the standpoint of identifying a minimum strength threshold that elderly individuals must maintain if they want to remain independent. Secondly, the results substantiated the idea of a non-linear relationship between muscular strength and gait velocity.

Chair Rise

Rising from a chair is an essential task that an individual must be capable of performing to maintain an independent lifestyle. Moreover, it has been reported that elderly individuals use significantly more of their available strength to get out of a chair compared to younger adults (46). Thus, older adults are likely required to change the way they perform the task of rising from a chair as they age. For these reasons, using a chair rise test as a tool to assess functional ability in elderly individuals has become commonplace (39, 43, 81, 84).

Skelton et al. (84) timed how long it took 100 elderly men and women to stand up from a chair and used performance time as an index of physical function. They reported that those participants with greater isometric knee extensor strength performed the chair rise test significantly faster than those with lower knee strength.

The chair rise test has been used extensively by Guralnik and his colleagues in their research on older adults (32, 41, 43, 66). In this test a subject attempts one chair rise to determine whether or not they are capable of completing the task. If successful on the initial trial, the subject is timed while they stand up and sit down five times as quickly as possible. Performance on a repeated chair rise test is included in the Short Physical Performance Battery (SPPB), a testing battery which has been shown to be closely related to self-reported disability (42, 43).

Get up and go

Both gait velocity and chair rise tests have been identified as predictors of disability in elderly populations, but each involves a distinctly different action. Thus, it is possible, albeit unlikely, that an individual could perform adequately in one test while being incapable of performing the other. Without administering both tests, however, it would be impossible to know if this was the case. To address this complication, another physical performance test, the get-up and go was developed, incorporating both a chair rise and a walking test (57). Combining these two tests resulted in a simple, yet effective test of gait, balance, and strength. The test involves rising from a chair, walking three meters, turning around, and returning to a seated position in the chair. Subjects were videotaped performing the task, and the video was scored on a five-point scale from Normal to Severely Abnormal by trained medical professionals. This made using the test for research problematic because no clear guidelines were defined for differentiating performance between the five options. Furthermore, it was necessary to have individuals with significant amounts of training and/or practice to do the scoring.

To address this limitation, Podsiadlo and Richardson (69) modified the test by eliminating the five-point scale and instead timing the task. This eliminated the subjectivity in the scoring of the test and made it a more effective measure for research, as time is easy to report and interpret. To test their modifications in the test, 60 frail individuals with a mean age of 80 years performed the timed up and go along with tests of balance, gait velocity, and an ADL index. The results of the project indicated that the timed up and go was significantly correlated with balance and gait velocity, as well as with the ADL index (69). Thus, they concluded that the timed up and go can be used effectively as a physical performance test in the elderly.

Davis et al. (28) reported that hand grip strength was significantly associated with the timed up and go, but quadriceps strength was not. It is intriguing that an upper extremity strength test was significantly associated with a test of lower extremity performance, while a test of lower extremity strength in the same sample was not. The reasons for this are unclear, and they are in contrast to the findings of Lawrence and Jette (55) who have suggested that lower extremity function is more closely related to disability than is upper extremity function.

Jette et al. (48) reported that both upper and lower extremity strength were significantly associated with timed up and go performance. Furthermore, the test was a significant independent predictor of disability in a community-dwelling sample of older adults between the ages of 60 and 94. Unlike Davis et al. (28), the results of Jette et al. (48) showed that lower extremity strength explained more of the variance in disability than upper extremity strength. Thus, the expected result of lower extremity strength being a more effective predictor of disability, as suggested by the results of Lawrence and

Jette (55), were supported by Jette et al. (48). The proposed non-linear relationship between strength and physical function was substantiated by these data with the quadratic model explaining significantly more variance in physical performance than the linear model (48). However, as Figure 4 indicates, a small number of extremely low functioning participants may have driven the non-linear relationship between strength and physical performance.

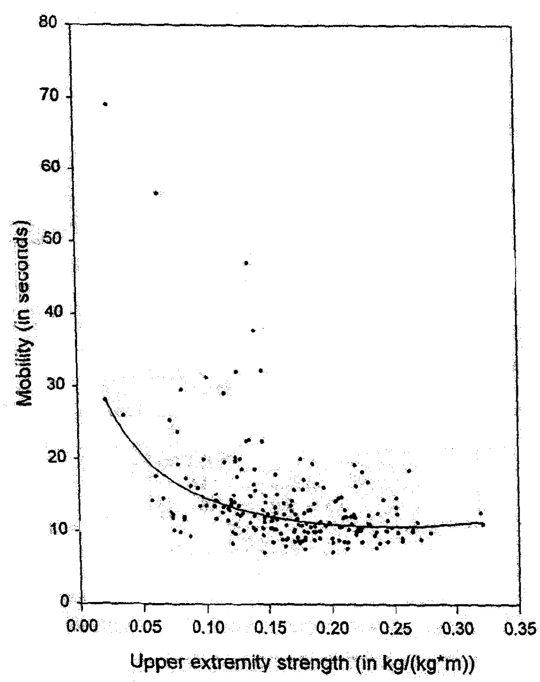

Figure 4. Graph from Jette et al. (48) showing a significant non-linear relationship between strength and mobility.

Guralnik's Short Physical Performance Battery

As physical performance tests were gaining popularity in disability research, Guralnik et al. (43) developed a Short Physical Performance Battery (SPPB) of tests to be used for determining lower extremity function in elderly individuals. The battery involves three physical performance measures; preferred gait velocity, repeated chair rises, and a standing balance test. Results from each of the three tests are scored with 0 indicating inability to perform the test. If the subject completes the task, their performance is scored from 1-4, with 4 indicating the highest function. The 4 quartiles are based on the evaluation of over 5,000 individual performances from three communities in the Established Populations for Epidemiologic Studies of the Elderly (EPESE) (43). The scores from each of the three tests are then summed so that each subject receives a score ranging from 0-12 according to their level of physical function. The results of this initial trial of the SPPB demonstrated that an individual’s score was strongly associated with their self-report of disability, in addition to rates of mortality and the likelihood of being institutionalized (43). Even more encouraging, though, was the fact that the SPPB discriminated between individuals across the complete range of lower extremity function, something that had not been previously reported.

The SPPB is also a significant predictor of subsequent disability (42). In this study, only the 1,122 individuals from the Iowa EPESE who reported no disability at baseline were examined. In the subsequent four year follow-up period, those individuals with the lowest performance scores at baseline were over four times as likely to have become disabled compared to individuals with the highest baseline performance scores (42). Disability rates were also increased nearly two times in the group with intermediate scores when compared to the highest scoring group (42).

The SPPB also predicted the onset of disability in the Hispanic EPESE, a population-based group of 3,050 elderly Mexican-Americans (64). Moreover, Ostir et al. (64) reported that of the three tests in the SPPB, the gait velocity test was an especially good indicator of future disability, while the standing balance test was the least effective.

This is an intriguing finding because gait velocity is the simplest measure of the three to obtain, and a significant amount of time could be saved during testing by omitting the balance and chair rise testing. This would only be advantageous, though, if the predictive power of gait velocity alone compared favorably with that of the complete performance battery.

Following up on the findings from the Hispanic EPESE that suggested that gait velocity was an especially powerful predictor of disability, Guralnik et al. (41), included data from the four EPESE sites and the Hispanic EPESE to investigate the use of gait velocity alone versus the SPPB as a predictor of disability. What is more, given the marked increase in size and heterogeneity of the study's sample, it also allowed researchers to determine the ability of the SPPB to predict disability between populations and for different follow-up periods ranging from 1 to 4 years, depending on the sample.

With regards to using gait velocity alone to predict disability, the results indicated that gait velocity was nearly as good as the SPPB (41). The SPPB was a significantly better predictor of ADL disability at one year, and mobility disability at both one year and four years, but the differences between the SPPB and gait velocity alone were relatively small, ranging from 3-5% (41). However, as the researchers were quick to point out, a more comprehensive testing battery incorporating more tests yields more information, and as a result, likely increases reliability. Along with increased reliability, assessing change over time is probably accomplished more accurately with the SPPB versus gait velocity alone. Conversely, if there is a premium on time, as in an office visit, substituting gait velocity alone for the SPPB would likely be sufficient. What is apparent from this research is the importance of preferred gait velocity as a predictor of disability.

And given the relative ease and safety with which it is collected, it is one variable that should be collected when performing research of this nature.

While the relationship between strength and physical function is clear, less is known about the relationship between strength and disability. Strength in the upper extremity, measured via hand grip dynamometry, has been shown to correlate significantly with disability (38, 72, 89). However, Lawrence and Jette (55) reported that lower extremity functioning, i.e. strength, was more closely related to disability than function in the upper extremity.

Jette et al. (48) incorporated both upper and lower extremity strength testing into their investigation on disability. They reported first that isometric strength of three upper extremity and three lower extremity muscle groups were significantly related to mobility, as measured with a timed up and go test. Furthermore, they observed a significant relationship between strength and self-reported disability which was mediated by mobility (48). More specifically, this implies that strength losses per se do not account for disability increases, but when the loss of strength inhibits an individual's ability to move independently, disability is affected (48).

Quantifying functional impairments in relation to disability in older adult populations is somewhat problematic. Self-reports of physical function are common (35, 36), but in many instances they fail to detect subtle changes that occur in functional ability over a period of time. As a result, numerous quantitative physical performance tests are now widely used in disability research. The use of physical performance tests allows researchers and clinicians alike to more readily detect small changes in function over a period of time, changes that may not be noticeable using self-report disability measures (14).

However, it is important to realize that disability and functional impairments, also termed reductions in physical function, are separate constructs in the disability model (48, 63). In other words, a decrease in an individual's physical function does not necessarily imply an increase in disability. Since walking and transferring into and out of chairs are integral to maintaining functional independence, these activities are included in the majority of the physical performance tests in use today in disability research.

In summary, there are a multitude of factors that have an impact on disability. There is also considerable evidence suggesting that the accumulation of deficits in more than one domain is to blame for increasing disability. The effects of age-related changes in strength due to sarcopenia have been associated with a number of physical functional limitations in the disablement process. Thus, the focus of this study is on lower extremity strength, its relationship with commonly used performance measures of physical function, and with self-reported disability.

Based on existing literature concerning strength, physical function and disability, we hypothesized that:

1) The relationship between lower extremity strength and physical function is non-linear.
2) Mobility is a mediator in the relationship between lower extremity strength and physical disability.

    Three steps were required prior to testing for this mediational relationship, thus we further hypothesized that:

    a. Strength is significantly associated with physical disability
    b. Strength is significantly associated with mobility
    c. Mobility is significantly associated with physical disability

Participants (n = 46, 12 males: mean age = 81.3 ± 6.43 years, 34 females: mean age = 81.7 ± 5.63 years) were recruited from two local retirement communities (Homestead Hills (HH) and Heritage Woods (HW), Winston-Salem, NC) as part of the Lifelong Independence and Function for the Elderly: Toward Interventions on Muscle and Efficacy (LIFE:TIME) project. Inclusion criteria were: (a) 60 years of age or older, (b) no preexisting medical conditions that could be exacerbated by testing, and (c) a score of 8 or above (out of 10) on the Pfeiffer Mental Status Questionnaire (68).

Testing was conducted in three, one hour sessions, separated from the previous session by approximately 5-7 days. The first session involved the subject completing the informed consent and then the psychosocial questionnaire packet. Demographic information, an extensive health history, and a series of questionnaires to measure self-efficacy, depression, satisfaction with function, and self-reported disability were included in the psychosocial questionnaire packet. Generally, the second testing session included a number of anthropometric measures (e.g., height, weight, girth, body composition), balance tests, and physical performance tests. In the final session, flexibility and isometric strength were measured. The complete testing battery included extensive functional testing, in part, to determine the feasibility of conducting such research in the retirement community setting. The testing related to the data analysis for this study are described in detail below.

Gait Velocity

Gait velocity was measured with a 3.66m long instrumented carpet (GAITRite, CIR Systems Inc., Clifton, NJ). The carpet is composed of 13,824 force sensing sensors arranged in a 48 wide x 288 long grid. Data are sampled at 80 Hz. The GAITRite is interfaced with a portable computer (IBM Thinkpad A20m, IBM Corp., White Plains, NY) that runs software to calculate variables related to gait performance. The GAITRite system has been shown to be a valid instrument for determining gait velocity and other related parameters (27).

In the testing procedures, participants walked bare-foot across the carpet beginning each test four feet in front of the carpet and walking four feet past the end of the carpet to allow for acceleration and deceleration. Participants made a total of 8 passes over the carpet. The first six trials were performed at the participant's preferred velocity. For these trials, the instructions given were to walk at "the speed you would walk going to the mailbox or dining room." The last two trials were fast velocity trials for which the instructions were to walk "as if you were in a hurry—late for an appointment or hurrying to catch a bus." An average preferred gait velocity was calculated from the six trials collected at preferred velocity. Likewise, the two fast velocity trials were averaged. These average values were calculated by the GAITRite system and exported to SPSS for further analysis.

Strength Testing

Knee extensor and ankle plantarflexor muscle strength was measured isometrically with a Chatillon CSD 500 dynamometer (John Chatillon & Sons, Inc., Greensboro, NC). Testing was done with the participant on an examining table equipped with a series of hooks attached to a rigid frame. The dynamometer was attached at one end via chain links to the hooks on the table frame. The individual being tested was attached to the dynamometer using a padded strap positioned two finger widths above the lateral malleolus. Thus, the dynamometer measured isometric force in series with the chain link.

The knee extensors were tested with the participant seated (hip joint at 90°) and the knee joint at 135° of flexion, measured 45° below the horizontal. The participant was strapped in with a belt to restrict them from coming out of the testing position during the trial, and they crossed their arms across their chest. The participant was instructed to "kick out as hard and fast as you can against the strap and continue pushing for 3 seconds." A practice trial was allowed and when the participant felt comfortable with the procedure, the first trial was administered. To begin the trial, after receiving a verbal "Ready" from the participant, the tester said, "Ready. Go," and counted to three aloud to indicate the duration of the test to the participant. No verbal encouragement was given during the test, and a "Relax" command was given to end the test. Approximately a one minute rest period was allowed between trials, and a minimum of three trials were administered. Typically, one of the first two trials produced a maximal effort, but if the third trial produced a maximal value, subsequent tests were administered until the strength value on a trial was less than the preceding trial, up to a maximum of six trials. Of 43 participants in the study, approximately 75% performed a maximal trial within the third or fourth trials on each strength test. The remaining 25% was evenly distributed between those participants who performed five or six trials to get a maximal value.

Ankle plantarflexors were tested with the subject supine and the dynamometer connected to the participant's forefoot at one end, and directly via the strap to the frame connected to the examining table. Testers made every possible effort to orient the strap connecting the foot and the table frame so that it was parallel to the lower leg. However, the frame of the table restricted a completely parallel alignment. The ankle joint was slightly dorsiflexed for testing, and the shoulders were held in position with a padded neck and shoulder restraint. Instructions to the participant were to "point your toes as fast and hard as you can, like you were pressing the gas pedal in a car, and hold it for three seconds." Beyond the instructions, the testing procedures were identical to those used for the knee extensors.

All strength testing was done on the right side of the body. Strength was quantified as the maximal strength value achieved from each test.

Chair Rise

A standard, armless folding chair with a seat height of 16" was used to conduct the chair rise test. Participants were first asked to "rise from the chair without using your arms." If successful on this initial task, the subject watched as one of the testers demonstrated the test by repeating the chair rise five times. The instructions given during the demonstration were, "You are now going to stand-up and sit-down five times in a row as quickly as you can. We will start timing when you begin to get-up the first time, and will stop timing when you sit-down for the fifth time. We will count out loud for you so you just need to focus on the task. Do you have any questions?" If not, the participant began the test following a "Ready. Go." command from the tester. A stopwatch was used to time the task to the nearest 0.01 s. Participants completed just one trial because the test is a relatively high intensity test.

Timed up and go

This test was administered as described by Podsiadlo and Richardson (69). Participants rose from an armless chair (16" chair height), without using their arms, walked around a cone positioned 3 m in front of the chair, returned to the chair, and sat down. The participants first observed as one of the testers demonstrated the task, and gave the following instructions. "You will begin sitting in this chair. When I say, 'Go,' you will stand up without using your arms, walk quickly, yet safely, around this orange cone, walk back to the chair, and sit down. We will begin timing when you stand up and stop timing when you are seated. Do you have questions?" If there were no questions, the participant performed the test after the tester's command, "Ready. Go." A stopwatch was used to time the task to the nearest 0.01 s. Participants performed 2 trials of the timed up and go with approximately 1 min between trials, and the better score of the two was used for analysis.

Modified Guralnik Summary Score

A physical performance summary score was developed by Guralnik et al. (43) that incorporates an individual's performance on three separate physical function tests, preferred gait velocity, repeated chair rise, and a standing balance test. Each test is scored 0-4 with 0 indicating inability to complete the test, and scores of 1-4 indicating performance quartiles established through the EPESE studies by Guralnik et al. (43). The three scores are then summed, resulting in a discrete summary score of 0-12, with 12 indicating the highest level of function and 0 indicating the lowest level.

Our testing procedures involved slight modifications of the original physical performance tests. These differences were purely methodological and should have little, if any, bearing on the utility of the measure in this project.

For the gait velocity test, the average preferred gait velocity collected with the GAITRite System was used. Scoring the test was done using the performance quartiles established by Guralnik et al. (43). However, since their measure of preferred gait velocity was time to walk 8 feet and our measure was produced from the GAITRite system, which calculated velocity in $cm{\cdot}s^{-1}$, the performance quartiles were converted to $cm{\cdot}sec^{-1}$. The quartiles were: 1: < 43.17 $cm{\cdot}s^{-1}$; 2: 43.17-60.21 $cm{\cdot}s^{-1}$; 3: 60.22-77.42 $cm{\cdot}s^{-1}$; and 4: ≥ 77.43 $cm{\cdot}s^{-1}$.

The chair rise test was administered and scored in the same way as the original test (43). The participant was timed while performing five timed chair rises. The scoring quartiles were: 1: ≥ 16.66 s; 2: 13.66-16.65 s; 3: 11.15-13.65 s; and 4: < 11.15 s.

The standing balance test was modified slightly from the original testing battery (43). Originally, the participants were asked to assume a semi-tandem stance position with the heel of one foot beside the big toe of the other foot. If the participant successfully held this position for 10 s, they next attempted the fully tandem stance position (i.e., heel of one foot directly in front of and touching the toes of the other foot). If unsuccessful on the initial semi-tandem test, participants attempted the side-by-side standing test (i.e., feet together and touching). A score of 0 indicated the inability to stand safely and independently. A score of 1 indicated the participant held the side-by-side position for 10 s and held the semi-tandem position for less than 10 s. A participant scored a 2 if they successfully completed 10 s on the semi-tandem test but could not hold the fully tandem stance position for more than 2 s, a 3 if they performed the fully tandem stance for 3-9 s, and a 4 if they could stand in the fully tandem position for 10 s.

The testing battery used in this project included the 14-item Berg Balance Test (6). Two of the 14 items were combined to generate categories that resembled those of Guralnik et al. (43). The inability to stand safely and independently with the feet side-by-side for one minute was scored 0. A score of 1 meant successful completion of the side-by-side stance test, but an inability to step independently and attempt a semi-tandem position of the feet. Taking an independent step less than the length of the foot and holding it for 30 s was scored a 2. Successfully holding the semi-tandem position, where the step length exceeded the length of the other foot, for 30 s was scored a 3. A 4 was scored if the fully tandem stance position, where the toes of the back foot touched the heel of the front foot, was held for 30 s. To summarize the differences between the two standing balance methodologies, the positions associated with each score were very similar. There were differences in time, though, as Guralnik et al. (43) used 10 s time intervals at each position compared to our time intervals of 1 min in the side-by-side test, and 30 s in the semi-tandem and fully tandem positions. Therefore, the practical differences between the two tests were minimal, and if anything, our test was more stringent because of the increased time requirements.

Self-Reported Physical Disability

The SF-36 (59, 94) was developed to measure eight health concepts that are often used in health surveys of various diseased populations (93). The test can be administered in three different ways: self-administration, computerized administration, or trained interviewer. Regardless of administration procedure, the test can be completed within 5-

10 min, making it an attractive measure from the standpoint of time. Furthermore, the subscales, each of which corresponds to one of the eight distinct health concepts, can be scored independently, or the entire questionnaire can be scored and used as an overall index of health status.

Of the eight subscales in the questionnaire, the Physical Functioning subscale “has been shown to be the best all around measure of physical health” (93). Consequently, we used the 10-question Physical Functioning subscale of the SF-36 as our measure of self-reported physical disability (23). The questions that comprise the subscale are shown in Appendix D.

When the data collection was completed, all pertinent data were entered into a computer database for analysis and checked for accuracy. Next, using SPSS 10.1 for Windows (SPSS Inc., Chicago, IL), missing data were identified through the use of the variable Explore function. The normality of the distribution of each variable was also examined.

In the case of a missing ankle plantarflexor or knee extensor strength variable, linear regression was used to interpolate the missing data point. A regression equation based on those subjects who had complete strength testing results was generated using ankle plantarflexor strength to predict knee extensor strength, and vice versa (87). The two regression equations were then used to interpolate missing strength values for those individuals who were missing either one of the strength scores. If a subject had no valid measurement for either strength test, they were simply excluded from any analyses involving strength. Missing strength data often occurs in individuals who are the lowest functioning in a given sample. However, we do not feel that was the case in this sample because the three individuals who lacked strength data did so because they: 1-missed the entire third session of testing, 2-declined the strength testing but successfully completed the rest of the testing battery, and 3-had a bladder problem that restricted giving a maximal effort, not because they were physically unable to complete the testing. Missing data points on the ten-question Physical Functioning subscale of the SF-36 were replaced with the subject's mean item score calculated from those questions that were completed correctly, as described in the scoring procedures for the SF-36 (59, 94).

A strength summary score was generated by adding knee extensor and ankle plantarflexor strength variables for each individual. Strength summary scores are commonly used in older adult research as they are thought to both simplify analyses involving multiple muscle groups, and to yield statistically better models describing the strength to physical function relationship (16, 48). The strength summary scores were not normally distributed, a violation of the assumption of normality required to perform regression analysis, so they were transformed logarithmically. The transformation resulted in a normal distribution according to the Shapiro-Wilk test of normality, and eliminated the only outlier in the non transformed strength summary score distribution (Appendix E). The transformed strength summary score was used in all subsequent analyses.

Independent samples t-tests were used to test for statistical differences between retirement communities on all test measures. Our interest was not to examine differences between communities, but to include a broad range of individuals in the analysis. It is necessary include a broad range to examine the presence or absence of non-linear relationships in the population. Thus, data from each retirement community were collapsed into a single group for analysis despite the presence of significant differences.

Pearson product moment correlations were calculated between transformed strength summary score and all physical performance variables, and between the physical performance variables and the self-report disability measure. Because the five physical performance measures were highly intercorrelated and were all considered to be tests of mobility, a principle components analysis was used to combine all five physical performance measures into a mobility factor score that was used for all subsequent analyses.

Multiple regression was used to test for non-linear relationships between transformed strength summary score and the physical performance measures. A strength squared term was added to the regression model that used transformed strength summary score to predict physical performance. To test the disability model proposed by Nagi (63), and to examine if mobility is a mediator in the relationship between strength and disability, a second multiple regression analysis was carried out. Several steps were required prior to testing this mediational model. Initially, we determined if strength was significantly associated with physical disability. Next we examined if strength was significantly associated with the mobility factor score. Finally, we determined if mobility was significantly associated with disability. In the multiple regression model, we examined the change in the standardized beta weights associated with strength and mobility to determine the extent to which mobility mediated the relationship between strength and disability.

Baseline characteristics of participants from both facilities and those of the combined sample are contained in Table 1. The HW sample was significantly older than the HH sample. The overall sample was predominantly female, with an average age of 81.6 ± 5.8 years. The sample's SF-36 Physical Functioning subscale score of 58.1 is substantially lower than the average U.S. population score of 84. However, gait velocity, both preferred and fast, are similar to age-group norms published elsewhere (12, 13). A modified Guralnik summary score of nearly 9 indicates a moderately functional sample as 54% of the initial community-dwelling individuals tested with the SPPB scored at or below 9 (43).

The transformed strength summary score was significantly correlated with both preferred and maximal gait velocity, the modified Guralnik summary score, and the timed up and go, but not with the chair rise (Table 2). Furthermore, these five physical performance measures, which were all tests of mobility, were strongly correlated with each other. As a result, a Principle Component Analysis was performed on the five physical performance measurements of mobility and one mobility factor was extracted that explained nearly 81% of the variance in these five dependent variables. The solution was not rotated because only one factor was extracted.

We examined the possibility of a non-linear relationship between strength and physical function by including a squared strength term in the regression model for each physical performance test. However, this term did not add significantly to the relationship between strength and any of the physical performance tests. Therefore, our data do not support the hypothesized non-linear relationship between strength and physical function.

The transformed strength summary score was significantly correlated with self-reported physical disability (Table 2). Also, the transformed strength summary score was linearly related to, and accounted for 18% of the variance in, the mobility factor score (Table 2, Figure 5). The relationship between the mobility factor score and physical disability was statistically significant ($r = .696$, $p < .001$), and mobility accounted for nearly 50% of the variance in physical disability (Figure 6). Thus, all three prerequisites to test the mediational role of mobility in the disablement model were met.

Two regression models were used to examine Nagi's disablement model (Table 3 and Table 4). Model one (Table 3) indicated that strength explained 41% of the variance in physical disability after adjusting for age and gender. The mobility factor score was added to the regression analysis in model two (Table 4), which increased the variance accounted for by the model to 58%. The added variance accounted for by the second model is easily explained by the strong relationship between mobility and physical disability (Figure 4). However, as hypothesized, adding the mobility term to the regression analysis attenuated the relationship between the strength score and physical disability. This is shown by the reduction in the strength beta coefficient in the two regression models from .580 in model one (Table 3) to .421 in model two (Table 4). However, strength remained a statistically significant independent predictor of physical disability, suggesting that mobility is a partial mediator in this relationship. Thus, in line with Nagi's (63) disability model and research by Jette et al. (48), mobility was a partial mediator in the relationship between strength and disability.

In summary, non-linear relationships were not observed between strength and physical performance; thus, hypothesis one was rejected. Hypothesis two was supported since mobility was a partial mediator in the relationship between strength and physical disability.

Table 1. Descriptive Statistics. Data are presented for both facilities separately, in addition to the mean of the combined sample.

	Facility	Mean	Standard Deviation	Minimum	Maximum
Age *†	HH	79.0	6.0	66.0	88.0
	HW	84.4	4.1	73.0	90.0
	Combined	81.6	5.8		
Leg extensor strength (N)	HH	229.4	79.6	120.0	414.0
	HW	207.5	65.7	115.0	382.0
	Combined	218.7	73.1		
Plantar flexor strength (N)†	HH	260.5	113.1	123.0	471.0
	HW	168.1	85.5	55.0	344.0
	Combined	215.4	109.8		
Strength summary score (N)‡	HH	489.9	178.1	243.0	885.0
	HW	375.7	136.9	209.0	707.0
	Combined	434.1	167.7		
Preferred gait velocity (cm/s)†	HH	104.7	20.7	70.2	141
	HW	86.2	20.7	47.8	134
	Combined	96.0	22.5		
Fast gait velocity (cm/s)†	HH	135.9	24.2	89.9	168.2
	HW	113.0	32.1	61.9	190.7
	Combined	125.2	30.1		
Chair rise time (s)‡	HH	15.1	3.3	8.6	24.6
	HW	18.1	5.5	11.6	35.6
	Combined	16.5	4.7		
Timed up & go (s)†	HH	9.9	2.5	6.2	16.0
	HW	12.9	3.8	7.7	24.3
	Combined	11.3	3.5		
Modified Guralnik summary score‡	HH	9.3	1.5	6.0	12.0
	HW	8.1	2.0	3.0	11.0
	Combined	8.8	1.8		
Physical functioning subscale SF-36 (0-100)‡	HH	66.2	20.3	30.0	95.0
	HW	49.2	23.7	10.0	90.0
	Combined	58.1	23.4		

*N=46 (34 women, 12 men) for Age, Chair rise time, Timed up & go, and Phys. Funct. subscale SF-36; N=45 for gait velocity (preferred & maximal) and Modified Guralnik score; N=43 for LE strength, PF strength, and Strength summary score
Difference exists between facilities: † = $p \leq 0.01$. ‡ = $p \leq 0.05$

Table 2. Correlation coefficients between strength, physical function tests, and disability.

	1	2	3	4	5	6	7	8
1.Transformed Strength Score	1	.420‡	.462‡	-.219	-.340†	.461‡	.420‡	.539‡
2.Preferred gait velocity		1	.943‡	-.565‡	-.805‡	.746‡	.906‡	.715‡
3.Fast gait velocity			1	-.531‡	-.797‡	.750‡	.897‡	.680‡
4.Chair rise time				1	.833‡	-.794‡	-.825‡	-.435‡
5.Timed up & go					1	-.830‡	-.951‡	-.629‡
6.Modified Guralnik score						1	.916‡	.661‡
7.Mobility factor score							1	.696‡
8.Phys. funct. subscale SF-36								1

† p≤ 0.01. ‡ p≤ 0.05

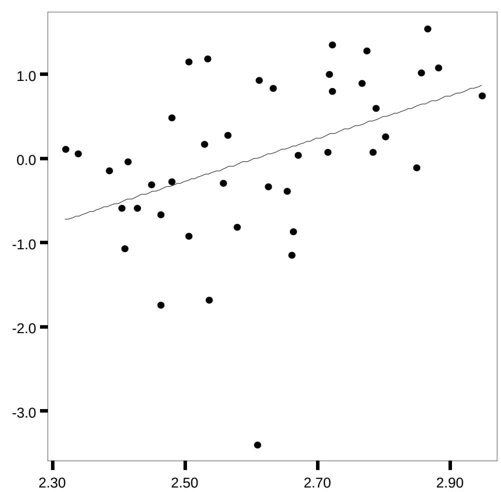

Figure 5. Relationship between strength summary score and mobility factor score. Strength was linearly related to mobility (r = .420, p = .006) and accounted for 18% of the variance in the mobility score.

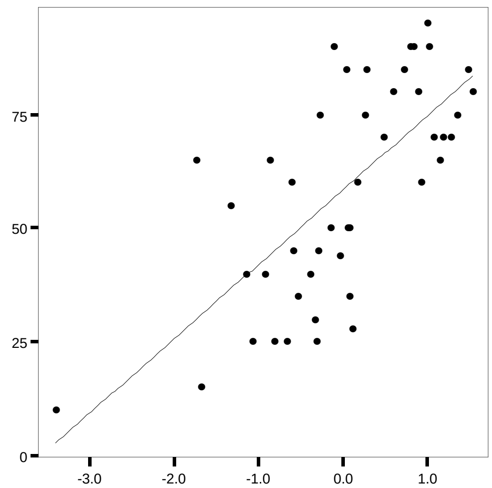

Figure 6. Relationship between mobility factor score and physical disability. Mobility was linearly related to physical disability (r = .696, p < .001) and accounted for 48% of the variance in physical disability.

Table 3. Model 1-Multivariate regression analysis using transformed strength summary score to predict physical disability. Age and gender are included in the model as covariates. Strength was a significant independent predictor of physical disability.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-89.048	101.142		-.880	.384
Age	-1.112	.530	-.282	-2.096	.043
Gender	10.830	8.512	.209	1.272	.211
Strength	84.026	25.100	.580	3.348	.002

Table 4. Model 2-Multivariate regression analysis using transformed strength summary score and mobility factor score to predict physical disability. Age and gender are included in the model as covariates. Strength remained a significant independent predictor of physical disability. However, the addition of the mobility term reduced the standardized beta coefficient and significance values from the previous model (Table 3).

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-99.936	87.236		-1.146	.259
Age	-.237	.510	-.060	-.466	.644
Gender	10.187	7.343	.196	1.387	.174
Mobility factor score	12.485	3.174	.518	3.934	.000
Strength	61.306	22.434	.421	2.733	.010

The disablement process experienced by the growing older adult population is a significant contributor to the escalating cost of health care in the United States (83). As a result, a better understanding of the factors contributing to disability is necessary so that effective treatments can be developed and employed that will reduce the burden on the health care system. The purpose of this thesis was to examine the relationships between lower extremity strength, physical performance, and disability in older adults living in retirement communities.

We observed a significant relationship between lower extremity strength and four of the 5 measures of physical performance, in addition to the mobility factor score. Thus, an individual's ability to complete a variety of movements related to independent living was, in large part, determined by their muscular strength. We anticipated this result given that all the physical performance tests employed emphasized the use of the lower extremity. We focused on tests of gait velocity, the timed up and go, and the chair rise test because these lower extremity function tests have been shown to predict disability (33, 39, 41-43, 48, 55, 66). Furthermore, these tests are easy to administer in a limited amount of time and are performance-based, making the results of the tests easy to quantify and interpret. Thus, the tests could easily be incorporated into a clinically-based assessment of physical function. In fact, several studies now suggest that gait velocity is predictive of future disability and may have utility as a screening tool to identify those older adults with increased risk for future disability (24, 45). The relationship between strength and each physical performance descriptor (preferred gait velocity, fast gait velocity, timed up and go, repeated chair rise, and modified Guralnik score) will now be discussed in more detail.

Preferred Gait Velocity

Lower extremity strength was significantly correlated with preferred gait velocity, with strength accounting for 18% of the variability in preferred gait velocity. Significant relationships between lower extremity strength and preferred gait velocity have been reported in a number of previous investigations (4, 13, 16, 17, 20). We used a lower extremity strength summary score that summed the maximum strength values of the knee extensors and plantar flexors. Our data were consistent with those of Buchner et al. (17, 20) who also used a strength summary score as their strength index. Their summary score was calculated by summing strength scores of the knee extensors and flexors, and the ankle plantar flexors and dorsiflexors. In contrast, non-significant relationships between lower extremity strength and gait velocity have been observed in studies that test only a single muscle group (12, 13, 16). In fact, Brown et al. (16) reported a non-significant relationship between knee extensor strength and preferred gait velocity, but a significant relationship when using a summary score of hip extensor, knee extensor and plantar flexor strength. They concluded that perhaps the most effective way to study the relationship between strength and physical function is to combine strength values from a number of key muscle groups specific to a functional task (16). Thus, individuals with greater strength in the lower extremity selected higher preferred gait velocities than individuals with lower strength summary scores.

Fast Gait Velocity

Lower extremity strength was also significantly associated with fast gait velocity, with strength accounting for a higher percentage (21%) of the variance in fast gait velocity compared to preferred gait velocity. Again, this result is intuitive as fast gait velocity is likely to be less a matter of personal preference, and more related to the strength of the knee extensors and plantar flexors, than preferred gait velocity. These results are comparable to previous studies that have reported significant relationships between strength and fast gait velocity (12, 13, 70, 73). Our data agree closely with those published by Bohannon et al. (12, 13) who reported that lower extremity strength in a variety of muscle groups was more strongly related to fast gait velocity (r = .292-.558) than to preferred gait velocity (r = .190-.251). Therefore, declines in leg strength due to sarcopenia may have more of an impact on an individual's ability to walk at velocities above normal than their ability to walk at their preferred gait velocity. Moreover, the effects of sarcopenia may explain why fast gait velocity declines with aging at a much faster rate than preferred gait velocity (12). Finally, a small change between an individual's preferred and fast gait velocity may be indicative of a low functional reserve. A suggestion for future work is to examine the utility of using this velocity change score as a screening tool for disability.

Timed up and go

Lower extremity strength was significantly related to the timed up and go. The timed up and go is essentially a walking test that begins and ends with a chair rise. The correlations between the timed up and go and both preferred and fast gait velocity tests were highly significant (Table 2), as the two gait velocity tests each accounted for 64% of the variance in up and go time. Podsiadlo and Richardson (69), who developed the timed up and go test, reported a significant correlation of -.61 between up and go time and gait velocity. This finding is consistent with subsequent research published by Davis et al. (28), Carmeli et al. (21), and Jette et al. (48) who reported that greater strength was correlated with faster performance of the timed up and go. Our data suggest that it is probably unnecessary to include the timed up and go and tests of preferred and fast gait velocity in a testing battery for older adults because of the redundancy in the tests.

Chair Rise

Lower extremity strength was unrelated to performance on the repeated chair rise test. This result was not consistent with a number of previous studies that have reported significant relationships between lower extremity strength and chair rise time (16, 80, 84). However, Brown et al. (16) had participants complete the chair rise test with chairs of three different heights, (18”, 16”, and 14”). They found that as chair height decreased, the test became more difficult, and strength became significantly associated with time to complete five consecutive chair rises. Thus, the 14” chair rise test was the most demanding of the three, and was the only test significantly correlated with strength (16).

We used a chair height of 16” in this study. This may have resulted in a performance test that was not demanding enough to produce significant relationships between lower extremity strength and chair rise time. Other authors have reported that strength is closely related to the minimum chair height from which an elderly individual can successfully rise (46, 81). Thus, lowering the chair height could increase the intensity of the test and may lead to a significant correlation between strength and chair rise performance. However, if the test becomes too difficult for participants to perform without using their arms, the test will be less effective as well since a larger number of individuals will, unfortunately, be unable to complete the task. Because the relationship between strength and chair rise performance appears to be partially a function of the chair height used, selecting an appropriate height for a given sample population is important. It also leads to problems when attempting to compare results between studies which will become apparent in the next paragraph.

Ferrucci et al. (32) reported a non-linear relationship between strength and chair rise time. The relationship was such that in individuals possessing knee extensor strength below 10 kg-force, a significant association between strength and chair rise performance was observed. Above 10 kg-force, however, no significant associations were detected (32). It should be noted that units of kg-force are not SI standard, so we converted the 10 kg-force to 98.1 N so that we could compare our data to that of Ferrucci et al. (32). The knee extensor strength values in our population ranged from 115-414 N (Figure 7). Thus, because our entire sample was above the 98.1 N strength threshold, a significant relationship between strength and chair rise time would be unlikely (Region A, Figure 3). However, Ferrucci et al. (32) used a chair height that averaged 17.5", which based on the results of Brown et al. (16), suggests the intensity of the test was relatively low. Consequently, using the low intensity test in a rather high functioning population created an artificially low threshold. In other words, the only individuals who had difficulty performing the test, i.e. had slow performance times, were those who were extremely weak. Had the chair height used been 14", the range of performance would likely have been more normally distributed and the strength threshold, if still evident, would have been higher. Therefore, the reasons for the non-significant relationship between repeated chair rise time and lower extremity strength in our sample may be related to either the chair height used or the physical functional status of the sample. In future studies using chair rise tests, the height of the chair should be low enough to create a test of adequate intensity in the sample population, but not so low that the chair is lower than any chair likely to be encountered in society. In research involving moderately functional older adults, a chair height of 14" appears to be optimal.

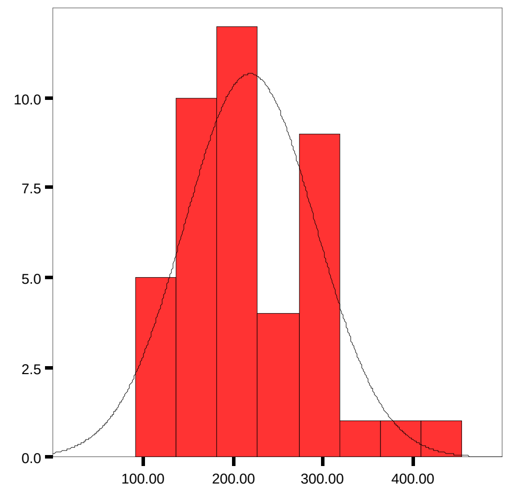

Figure 7. Distribution of knee extensor strength in the study population. All participants scored above the 98.1 N force threshold identified by Ferrucci et al. (32). This may account for the non-significant relationship between lower extremity strength and chair rise performance.

Modified Guralnik Summary Score

Strength was significantly correlated with our modified Guralnik summary score measure, with strength explaining 21% of the variance in the summary score. The Short Physical Performance Battery (SPPB) involves three tests (preferred gait velocity, repeated chair rise, and standing balance) which are scored independently based on performance quartiles generated from an earlier study (43). The three scores are then summed to produce a summary score. The SPPB has been used extensively in research on older adults (33, 42, 66). This scoring technique of the SPPB changes the nature of the measure from a continuous variable to a discrete variable. Thus, the fact that lower extremity strength is significantly correlated with preferred gait velocity but not with the chair rise test in the present study does not confound the use of the SPPB because of the inherent differences in the scoring of the measures. Furthermore, the SPPB includes a standing balance test that introduces new information into the analysis. Only recently has the relationship between lower extremity strength and performance on the SPPB been investigated. In that study, Bean et al. (5) observed a significant relationship between leg strength and SPPB score, with leg strength accounting for 12% of the variance in SPPB score, somewhat lower than the 21% accounted for in our study. A potential explanation for the stronger association of muscle strength seen in our study could be the fact that the repeated chair rise test used in Bean et al. (5) involved ten repetitions compared to five repetitions in our study. The ten repetition test likely places more emphasis on lower extremity endurance compared to strength, and therefore reduced the association of lower extremity strength to SPPB performance.

Recently there has been research comparing the SPPB versus gait velocity alone to predict disability (41, 64). These studies suggest that because gait velocity alone is such a strong predictor of disability, it may be unnecessary to administer the chair rise and standing balance tests because they do not add significantly to the ability of the SPPB to predict disability (41, 64). The results of these studies showed that the SPPB was a slightly better predictor of disability, but that gait velocity alone was nearly as effective (41). The difference in predictive power between the two measures was just 3-5% (64).

Moreover, the added time and effort required to administer and perform the additional two tests may not be justifiable considering the slight increases in predictive power that were observed. If used as a tool to track change in physical performance over time, the conclusion drawn was that the SPPB may be a better instrument than gait velocity alone because of the increased reliability that results from incorporating the chair rise and standing balance tests. However, if used as a tool to predict incident disability, gait velocity alone could be used with confidence in place of the SPPB (41, 64). In our study, gait velocity alone accounted for 18% of the variance in physical disability, while the modified Guralnik score accounted for only an additional 3% of the variance in physical disability. We did not assess the power of each measure to predict disability, but our results seem to support the premise that performance tests of gait velocity alone and the SPPB produce similar results.

In this thesis, all the physical performance tests were in large part related to the mobility of the individual. Furthermore, the self-report disability questions emphasized mobility (Appendix D). Of the ten self-report questions, three were related to walking, two to climbing stairs, and two to moderate or vigorous activities. Only one question related specifically to upper extremity activity, i.e. lifting and carrying groceries, and two questions were novel movements, i.e. self-care and bending, stooping, or kneeling. Thus, the focus of the testing clearly emphasized the lower extremity. This focus on the lower extremity increased the likelihood that the physical performance measures would be associated with disability because as Lawrence and Jette (55) reported, lower extremity function is more closely related to disability than function in the upper extremity. Thus, the relationships between the physical performance tests and disability were influenced by the nature of the tests. This finding indicates that, in this population of older adults, physical performance tests measuring functional limitations were related to self-reported disability.

The relationships between lower extremity strength and physical performance were significant, but were not non-linear as hypothesized; thus, hypothesis one was rejected. The proposed non-linear relationship between strength and physical function assumes that a given sample population includes individuals across a broad strength range. Furthermore, it implies that there would be a significant relationship between strength and physical function within the group individuals with strength below an identified strength threshold, but within the group of individuals with strength above the threshold, no relationship between strength and physical performance would be evident. However, this hypothesis was not supported in this study.

Buchner and his colleagues (19, 20) were among the first to suggest a non-linear relationship between strength and physical performance. Significant non-linear relationships between lower extremity strength and physical performance in older adult populations have been observed for preferred gait velocity (17, 20, 32), fast gait velocity (73), repeated chair rises (32), and the timed up and go (48). The discrepancy between our study and previously published literature may be accounted for by our sample population. In the two retirement communities where data were collected for this study, only a small number of residents presented with either very low or very high physical functional capacity. Thus, it is possible that our subjects were largely in the middle of the physical function continuum where a linear relationship exists between strength and physical performance (Region B, Figure 3).

A reexamination of the graph of lower extremity strength versus mobility (Figure 4) from the research of Jette et al. (48), who reported a significant non-linear relationship between strength and mobility, shows a relationship that is potentially being driven to significance by a small number of extremely low function participants. When comparing our graph of lower extremity strength versus mobility (Figure 5) to Figure 4, it is not difficult to envision that the addition of a number of very low functioning participants to our sample could potentially produce a significant non-linear relationship in our sample. Recently, Bean et al. (5) in a sample of 45 older adults also failed to detect non-linearities in the relationship between strength and physical function. They concluded, as do we, that the power to detect non-linear associations is weak in a sample of this size.

Mobility was a partial mediator in the relationship between strength and physical disability supporting hypothesis two. This result was reached in a series of steps. First, we showed that lower extremity strength was significantly related to self-reported disability such that individuals with greater strength reported less disability. Next we showed that strength was significantly related to the mobility factor score, and four of the five physical performance measures that composed it. Furthermore, all five physical performance measures, and the mobility factor score, were significantly correlated with self-reported physical disability. Previous research has shown that a number of physical performance tests including gait velocity (41, 64, 66), the timed up and go (48), and the SPPB (41-43, 64, 66), were significantly associated with disability. These physical performance tests have also been linked to mortality (43, 97) and institutionalization (43, 66, 97), which are closely related to disability.

Thus, all three prerequisites to test the mediational role of mobility in the disablement model were met. We used a multiple regression model to show that strength was a significant independent predictor of self-reported physical disability. A second regression model was used that incorporated the mobility factor score. The addition of this factor to the multiple regression model reduced the lower extremity strength standardized beta coefficient. The reduction in the strength beta coefficient was not large enough to eliminate the statistical significance of the relationship between strength and physical disability, indicating that mobility was a partial mediator in the relationship between strength and disability. More specifically, this implies that strength losses per se do not account for disability increases, but when the loss of strength inhibits an individual's ability to move independently, disability is affected (48). These data suggest the need to educate older adults about the synergistic effects of strength and mobility so that they can realize the benefits associated with improvements in strength.

The disability model used by Jette et al. (48) was a simple model based on the original disablement model of Nagi (63). Our model was similar to that used by Jette et al. (48), with some measurement differences in each domain. These differences included the use of a summary score combining muscular strength variables of the knee extensors and ankle plantar flexors, while Jette et al. (48) used a summary score involving hip abductor, hip extensor, and knee extensor strength divided by an individual's height and body mass. Our mobility measure was a factor score generated using a principle components analysis that combined an individual's performance on all five physical performance tests into a single variable. Jette et al. (48) used the timed up and go as their mobility measure. Finally, our physical disability measure was the Physical Functioning subscale of the SF-36, while Jette et al. (48) used the Basic Physical Disability subscale of the SIP. Despite these methodological differences, the conclusions reached in this study are similar to those of Jette et al. (48), i.e., mobility is a partial mediator in the relationship between strength and disability.

In the regression model reported by Jette et al. (48), lower extremity strength accounted for 25% of the variance in degree of physical disability after controlling for age and gender. Similarly, in this study we controlled for age and gender, and 41% of the variance in disability was accounted for by lower extremity strength. The discrepancy between the two studies could be accounted for by the self-reported disability measures used, the SIP in Jette et al. (48), and the SF-36 in this study. Furthermore, when the mobility term was added to the model in each study, the variance in physical disability accounted for by the new model containing age, gender, mobility, and strength increased to nearly 40% in Jette et al. (48), and to 58% in this study. This highlights the importance of physical function to independence in older adult populations. Our finding that mobility has an impact on disability illustrates the importance of older adults maintaining their ability to walk as they age.

The efficacy of resistance training to increase strength in older adults has been established in numerous studies (17, 23, 34, 82). The strength gains made by participants in studies by Chandler et al. (23) and Schlicht et al. (82) were associated with significant increases in gait velocity, thus supporting the idea that strength gains can lead to improvements in physical function.

Since strength and disability appear to be related in cross sectional analyses, several investigations have examined whether improving strength would lead to reductions in disability. Chandler et al. (23) concluded that increases in strength did not lead to reductions in disability. They cautioned, though, that their results may have been skewed by their self-report disability scale, the Physical Functioning Subscale of the SF-36, which may not have been sensitive enough to detect changes in disability in their relatively low functioning sample.

Conversely, the Fitness Arthritis and Seniors Trial (FAST), a randomized controlled trial that included 439 community-dwelling older adults with osteoarthritis, showed a significant increase in strength after an 18 month strength training intervention (30). Furthermore, the strength gains were associated with a significant reduction in self-reported disability (30). Subsequent analyses in this population involving only those participants who were not disabled at baseline showed that strength training was associated with a significant reduction in risk of ADL disability at the end of the 18 month intervention (RR = .60 compared to the attention control group) (67). Additionally, participants in the most compliant exercise tertile, i.e., those who attended 81% or more of the exercise sessions, had an even greater reduction in risk of developing disability (RR = .43) compared to the attention control group (67). These data suggest that increases in strength are associated with significant reductions in self-reported disability and in the risk of becoming disabled.

Clearly, strength and mobility appear to be especially important in ensuring that older adults continue living productive lives free of disability, or functional lives in spite of their disability. Although 58% of the variance in self-reported disability was accounted for in the regression model containing both strength and mobility, nearly half of the variance in disability is still yet to be explained. Recent disability research has chronicled the importance of the social component of disability (91, 92). This social component stresses the idea that disability is a social phenomenon dependant on how an individual acts in a given situation. Thus, an individual's capacity to walk a block is considered in light of the social context (i.e., the purpose for walking, who is also walking, who is watching, etc.) before a decision is reached whether or not to walk. For example, an elderly individual who is capable of walking a block might choose not to walk a block alone for exercise, but will walk a block with their young grandchild. Psychosocial factors such as self-efficacy (58, 77) can have an impact on a person's decision to engage in ADLs. Likewise, depression (17, 53, 88) is another factor that can alter an individual's motivation to be active which will affect, therefore, their disability status.

This study focused on the relationships between lower extremity strength, a series of physical performance tests related to mobility, and physical disability. It appears, however, that physical activity patterns are also related to physical function and disability (14, 55, 85, 90). For example, Lawrence and Jette (55) found that self-reported frequency of walking a mile was a significant predictor of lower body function. Furthermore, Brach et al. (14) observed that an objective measure of physical activity, average daily step count determined by a pedometer, was related to physical performance and disability. In a follow-up analysis using our data set, we included physical activity, measured with the Physical Activity Scale for the Elderly (PASE) (95), in the multiple regression analysis. However, the conclusions drawn from the model that included the PASE were essentially the same as our original analyses (Appendix H). This does not mean that physical activity is not important as there is evidence suggesting that physical activity is likely to play a role in the disablement process (30, 55).

There are limitations associated with this project that restrict its generalizability to the older adult population. One limitation is the cross-sectional design of the study. Cross-sectional investigations can not determine causal relationships between variables, in this case, lower extremity strength and disability. Long-term resistance training intervention studies are required to determine if changes in strength can significantly impact the incidence of disability.

Secondly, there are limitations with regards to the sample population. The size of the sample was fairly small and this prevented us from using a more complex disablement model such as that used by Lawrence and Jette (55). It also may have limited the power of our sample to detect non-linearities in the relationship between strength and physical performance. Furthermore, the sample consisted of older adults who lived in two retirement communities where the residents were predominantly white, well-educated, and possessed a high socioeconomic status. Whether or not these results apply to other racial and ethnic groups is unknown.

In conclusion, lower extremity strength is a significant contributor to both physical function and self-reported disability. Mobility, or the ability to move effectively in society, partially mediates the relationship between strength and disability, suggesting that both strength and mobility are important components of the disablement process. Today, as the burden of disability impacts the health care system and a substantial percentage of the older adult population in the United States, caring for and treating disabled individuals is critical. The information presented here has implications for researchers and health care professionals seeking to design and implement interventions to ameliorate the disability problem in society.

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THEODORE JAMES HOVDA III

BORN:

September 30, 1977, Mason City, IA

EDUCATION:

8/00-5/02 Wake Forest University, Winston-Salem, NC, MS – Health and Exercise Science

8/96-4/00 Pepperdine University, Malibu,CA, BS- Major: Sports Medicine

ACADEMIC AND PROFESSIONAL EXPERIENCE

8/00-5/02 Wake Forest University Department of Health and Exercise Science

Teaching Assistant: Taught HES 100: Exercise for Health, a required course for all Wake Forest undergraduates. Biomechanics TA: assisted undergraduate HES majors with video analysis project for biomechanics class.

PROFESSIONAL CERTIFICATIONS:

Basic Life Support
ACSM Registered Exercise Specialist

PRESENTATIONS:

Lower extremity strength and its association with physical function and disability, Student Biomechanics Symposium, 2002 Southeast American College of Sports Medicine Conference, Atlanta, GA, February 2, 2002.

Date ☐☐ ☐☐ ☐☐ **ID** ☐☐☐☐

LIFE: TIME
08-21-01
PfeifferMSS.doc

Now I am going to ask you a few questions concerned with memory. These questions ask about particular bits of information that many people seem to forget from time to time. They are routine questions we ask everyone, and may or may not apply to you directly.

CODE: 1=CORRECT; 2=INCORRECT OR DON'T KNOW; 9=REFUSE CODE

1. When were you born? (Would you give me the exact date?)
   ____/____/______ ______
   MO/ DAY/ YEAR

2. What is the date today? ______________________ ______
   (Correct only if exact month and date is given. If month not given, ask "What month is it?")

3. What day of the week is it? ______________________ ______

4. What is your telephone number? ______________________ ______
   (If no telephone, ask 4a)

4a. What is your street address? ______________________ ______

5. Who is the President of the United States now?______________________ ______
   (Correct requires only last name of President)

6. Who was President just before him? ______________________ ______
   (Only last name needed)

7. What was your mother's maiden name? ______________________ ______
   (Correct if last name other than subject's is given)

8. Now, let's try something a little different...a little arithmetic. Subtract 3 from 20 and keep subtracting 3 from each number all the way down. ______
   (Correct ONLY if response is 17, 14, 11, 8, 5, 2)

AGREEMENT TO PARTICIPATE IN A RESEARCH PROJECT

Principal Investigators: Anthony P. Marsh, Ph.D.
Shannon L. Mihalko, Ph.D.
Jeff D. Williamson, M.D., M.H.S.

Institution: Department of Health and Exercise Science
Department of Internal Medicine
Wake Forest University

Location: Heritage Woods

Participant Name: ______________________________

Title of Study: Understanding the relationship between physical and psychosocial function in assisted-living community-dwellers over time: The feasibility of a mobile assessment unit.

1. Description of Study

The purpose of this project is to collect information on your health, physical, and psychosocial function at two points in time about 2 weeks apart. This information is important for understanding the relationship between disease and disability in older adults. You will be asked to participate in a physical fitness assessment involving: a) activities that you might typically do during the day (e.g., walking, reaching up overhead, getting up and down from a chair, climbing several stairs), b) strength tests to measure strength of several of the muscle groups of the body, c) walking at a comfortable pace several times, and d) standing quietly while we measure how much you sway. You will also be asked to complete a packet of questionnaires to assess social and physical function. During the course of the study, you will be asked to write down all that you eat and drink over a 3 day period. You will be instructed to record the time, amount of food, and detailed description of food. Finally, we ask your permission to record some basic information from your medical records (e.g., medications that you may be taking, major medical procedures/events that you may have experienced). We will contact your personal physician to obtain this information.

2. Potential Risks

Risks of participating in this study are small. A slight risk of injury exists, but precautions will be taken to minimize that risk. You may work at your own pace on all physical performance measures. The tests will be performed by trained individuals and you will be given instructions prior to each test to minimize the possibility of injury. Walking may include a risk of falling or tripping, as well as the risk of soreness if you are not used to physical activity. You will also be asked to complete tests of muscular strength. These tests may lead to general fatigue and soreness if you are not accustomed to physical activity. Mild soreness is normal and is no cause for concern. Severe soreness may be an indication of injury and if you experience this, you are encouraged to contact one of the primary investigators. You will be lead through a general full-body warm-up prior to testing in order to minimize soreness and risk of injury.

3. Confidentiality

The information obtained from this study will be used for research purposes only, with your right to privacy retained. Your information will be referred to by using your initials and a number to maintain confidentiality. Your file will be maintained in a locked cabinet. Only those individuals directly involved with this research project will have access to these files. Information obtained during the review of your medical history will be held in the strictest confidence.

4. Voluntary Participation

Participation in this study is voluntary. You are under no obligation to begin or complete this study. You are free to withdraw from participation at any time without penalty to you. You will not be paid for participation. The investigators will not attempt to deceive you at any time.

5. Inquiries/Questions

You are encouraged to ask questions at any time during the study. Any questions regarding the study should be directed to any of the principal investigators,

Dr. Tony Marsh, Ph.D.	758-4643
Dr. Shannon Mihalko, Ph.D.	758-1945
Dr. Jeff Williamson, M.D., M.H.S.	713-8583

or the Director of the Division of Research Partnerships and Programs at Wake Forest University:

Ms. Julie Cole	758-5888

6. Freedom of Consent

I understand that permission to participate is voluntary and that I am free to deny consent if I so desire, both now and at any time during the study. I acknowledge that I have read this document in its entirety and that I fully understand it, and all questions have been answered to my satisfaction.

________________________________ ____________________

Participant’s signature Date

____

Investigator’s signature

Date ☐☐ ☐☐ ☐☐ **Acrostic** ☐☐☐☐☐☐

ID ☐☐☐☐ **Visit** ☐☐

LIFE: TIME
08-21-01
HealthQuest.LIFETIME

THE QUESTIONS THAT FOLLOW WILL ASK FOR SOME INFORMATION ABOUT YOUR HEALTH HISTORY.
PLEASE ANSWER THEM AS COMPLETELY AS POSSIBLE

	YES	NO	Don't Know
1. Have you ever experienced..			
A. Pain or discomfort in the chest, neck, jaw, arms or other areas that may be related to poor circulation	☐	☐	☐
B. Heartbeats or palpitations that feel more frequent or forceful than usual or feeling that your heart is beating very rapidly.	☐	☐	☐
C. Unusual dizziness or fainting	☐	☐	☐
D. Shortness of breath while lying flat or a sudden difficulty in breathing which wakes you up while you ar sleeping	☐	☐	☐
E. Ankle swelling unrelated to injury	☐	☐	☐
F. Shortness of breath at rest or with mild exertion (like walking two blocks)	☐	☐	☐
G. Feeling lame or pain in your legs brought on by walking	☐	☐	☐
H. A known heart murmur.	☐	☐	☐
I. Unusual fatigue with usual activities	☐	☐	☐
2. A. Has a doctor ever told you that you have diabetes?	☐	☐	☐
B. If YES, are you taking insulin?	☐	☐	☐

		YES	NO	Don't Know
3.	A. Has a doctor ever told you that you have high blood pressure?	☐	☐	☐
	B. If YES, do you take any medications for your high blood pressure?	☐	☐	☐
4.	A. Have you ever been diagnosed or treated for skin cancer?	☐	☐	☐
	B. If YES, was it melanoma?	☐	☐	☐
	C. If the type of skin cancer was melanoma, was this diagnosis made within the last 5 years?	☐	☐	☐
5.	A. Have you ever been diagnosed or treated for any other types of cancer besides skin cancer?	☐	☐	☐
	B. If YES, what kind of cancer?___________________________			
	C. Was this within the last 5 years?	☐	☐	☐
6.	Has a doctor ever told you that you have had a heart attack?	☐	☐	☐
7.	Has a doctor ever told you that you may have had any of the following?			
	A. Angina (chest pain, discomfort, pressure or heaviness due to a blocked or clogged blood vessel in the heart)	☐	☐	☐
	B. Heart failure or congestive heart failure	☐	☐	☐
	C. Heart rhythm problem (irregular heartbeat)	☐	☐	☐
	D. Heart conduction problem (heart block)	☐	☐	☐
	E. Heart valve problem Specify type of valve problem:____	☐	☐	☐

		YES	NO	Don't Know
8.	Has a doctor ever told you that you have had a stroke or TIA (mini-stroke)?	☐	☐	☐
9.	Has a doctor ever told you that you have a blood circulation problem in any of the following areas:	☐	☐	☐
	A. In your head or neck?	☐	☐	☐
	B. In your legs or feet?	☐	☐	☐
	C. In any other area of your body?	☐	☐	☐
	D. If in another part of your body, where? ______________________			
10.	A. Has a doctor ever told you that you have asthma, emphysema, chronic bronchitis, or chronic obstructive pulmonary disease(COPD)?	☐	☐	☐
	B. If YES, have you taken any medications to treat it in the last 6 months?	☐	☐	☐
11.	A. Has a doctor ever told you that you have arthritis?	☐	☐	☐

B. If YES, where? (please check all that apply)

Neck ☐ Hands ☐ Feet ☐ Back ☐

Shoulders ☐ Hips ☐ Knee ☐

		YES	NO	Don't Know
12.	A. Has a doctor ever told you that you have kidney disease?	☐	☐	☐

B. If YES, what kind? ______________________

		YES	NO	Don't Know
13.	A. Has a doctor ever told you that you have liver disease?	☐	☐	☐

B. If YES, what kind? ______________________

		YES	NO	Don't Know
14.	Have you been hospitalized for any reason within the past year?	☐	☐	☐

If yes, please list the reason, the name and address of the hospital, and the month and the year of hospitalization.

REASON	MONTH/YEAR	NAME OF HOSPITAL	CITY AND STATE
14.			
15.			
16.			
17.			
18.			

15. CLINIC NAME OR DOCTOR:____

16. Which answer best describes how often you drink wine, beer, whiskey, or liquor? (check only one)

☐ A. Never drink

☐ B. Used to drink, but don't now

☐ C. One or two times a year, or very occasionally

☐ D. Less than once a week or only at parties

☐ E. Once or twice a week

☐ F. Three or four times a week

☐ G. Nearly every day

☐ H. Every day

YES NO Don't

B. If YES, how old were you when you began smoking cigarette regularly?______.

18.. A. Do you currently smoke cigarettes? ☐ ☐ ☐

B. If YES, on an average day, how many cigarettes do you smoke?_________

C. If NO, when you WERE smoking, on an average day, how many cigarettes did you smoke? _________

D. If NO, how old were you when you quit smoking?

19. A. Do you presently use any forms of tobacco other than cigarettes? ☐ ☐ ☐

B. If YES, what other forms of tobacco do you use?

☐ A. Cigars

☐ B. Cigarillos

☐ C. Pipe tobacco

☐ D. Chewing tobacco

☐ E. Snuff

☐ F. Other

If other, please specify: ____

	YES	NO	Don't Know
20. Vision			
A. Do you have a vision impairment?	☐	☐	☐
B. Do you wear corrective lenses? (glasses/contacts)	☐	☐	☐
C. Do you currently have any other problems that cannot be corrected with corrective lenses? (glasses/contacts)	☐	☐	☐

If yes, list any of these current problems: ___________________________
____

The following items are about activities you might do during a typical day.

Does your health now limit you in these activities? If so, how much?

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

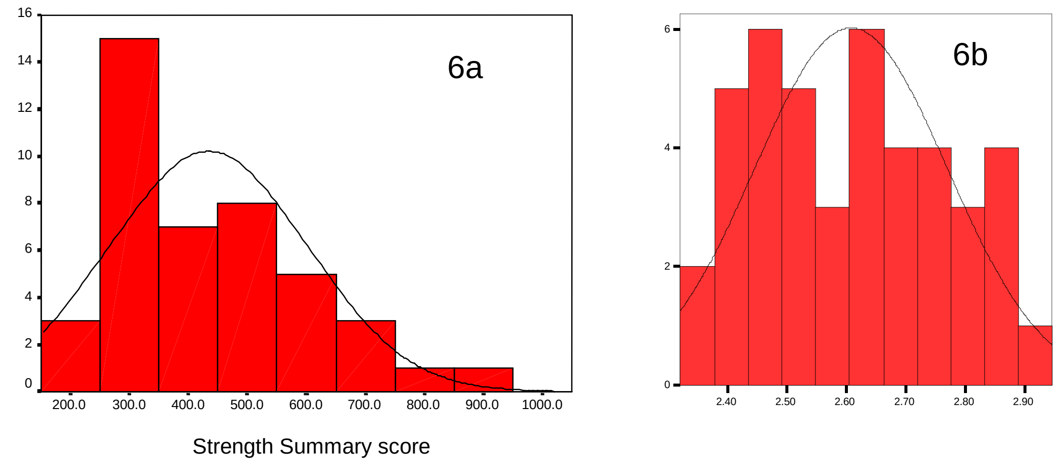

Figure 8. Strength summary score normality plots before (6a) and after (6b) logarithmic transformation. The transformation altered the distribution such that the transformed strength summary score was significantly more normal than the strength summary score. The Shapiro-Wilk test, a test used to determine distributions that are not normally distributed, showed the distribution of strength summary score was significantly not normal (6a, $p = .010$), and the distribution of transformed strength summary score was more normal (6b, $p = .354$).

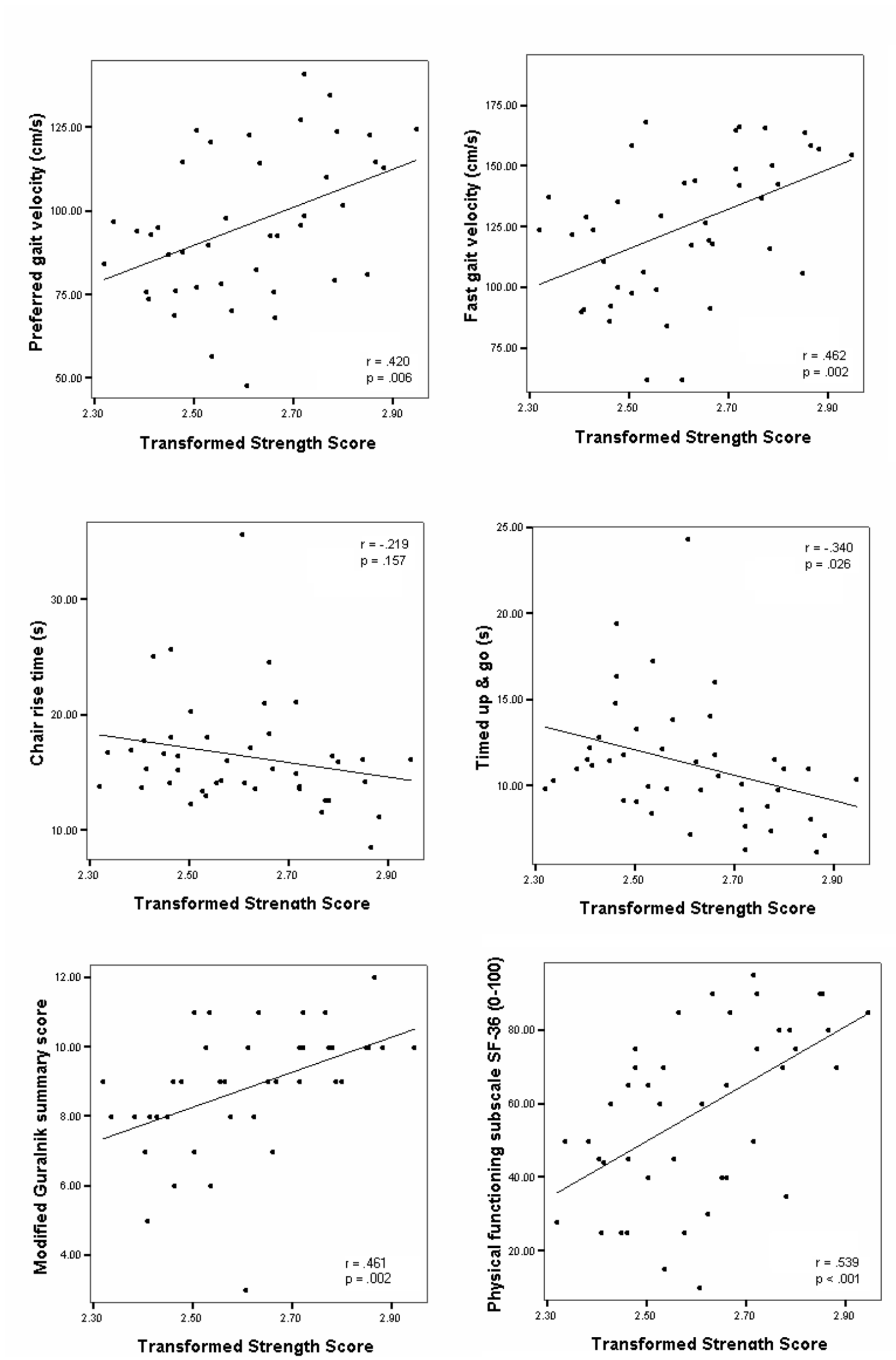

Figure 9. Relationships of strength to all physical performance tests and physical disability.

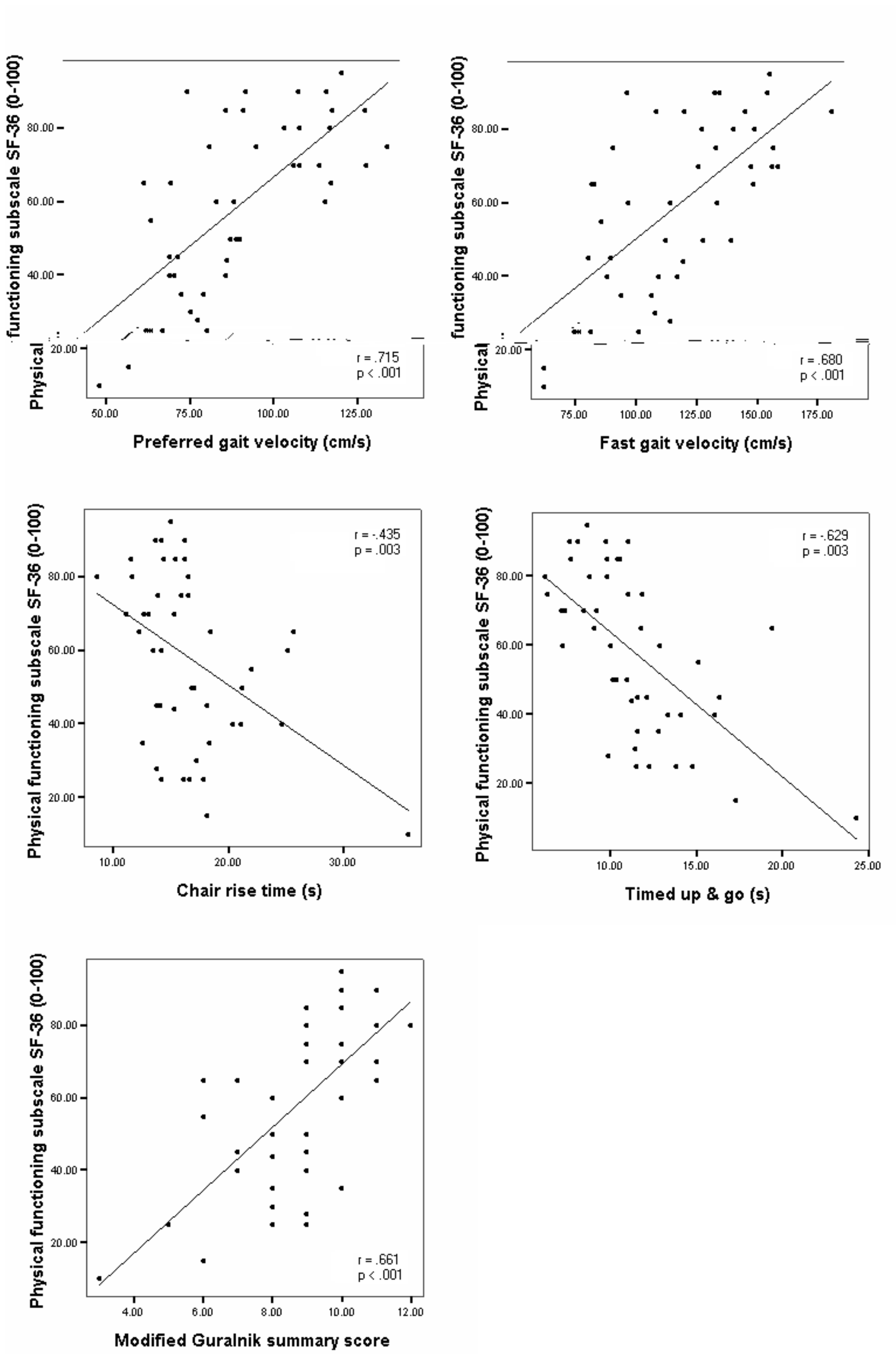

Figure 10. Relationships of physical performance measures to physical disability.

Table 5. Model 3-Multivariate regression analysis using transformed strength summary score and physical activity to predict physical disability. Age and gender are included in the model as covariates. Strength and physical activity were both significant independent predictors of physical disability.

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-86.740	98.077		-.884	.382
Age	-.820	.524	-.213	-1.564	.126
Gender	8.245	8.268	.163	.997	.325
PASE	.118	.050	.302	2.360	.024
Strength	72.470	24.474	.510	2.961	.005

Table 6. Model 4-Multivariate regression analysis using transformed strength summary score, physical activity, and mobility factor score to predict physical disability. Age and gender are included in the model as covariates. Strength remained a significant independent predictor of physical disability. However, the addition of the mobility term eliminated physical activity as a significant independent predictor of physical disability and reduced the strength beta coefficient and significance values from the previous model (Table 5).

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-95.334	87.504		-1.089	.283
Age	-.191	.507	-.050	-.378	.708
Gender	8.524	7.374	.168	1.156	.256
PASE	7.443E-02	.047	.190	1.595	.120
Mobility factor score	10.530	3.286	.445	3.204	.003
Strength	57.138	22.344	.402	2.557	.015