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Lower Extremities Muscle Strength Associated With Early Signs of Mobility Dependence among Older Adults Age 65 Years and Older

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Abstract

Background: Loss of muscle strength is evident even in apparently healthy older adults. functionally limited due to an increasing discrepancy between their own physiological capabilities (i.e. physiological impairments) and the challenges set forth by the environment. Functional limitations lead to clinical mobility disability. Clinical mobility disability is associated with physical dependence, poor quality of life, and mortality. Treatment of age-related clinical mobility disability should focus on the prevention of the condition rather than its consequences. Identifying opportunities for early screening and prevention of clinical mobility disability requires a better understanding of the functional loss prior to this medical condition.

To overcome functional limitations and physical dependence, many older adults modify the way they negotiate daily tasks, as in relying on rails to climb stairs, use of a cane to walk, or use of the arms to rise from a chair. Many older adults who utilize daily task modifications report no functional limitations or physical dependence and therefore may not seek medical help. Regardless of level of independence, the need to modify daily tasks is a sign of functional limitation and is considered a major symptom of pre-clinical disability. Pre-clinical disability denotes an intermediary phase between a state of no mobility disability and a state of outright clinical mobility disability. Clinically, the ability to screen for pre-clinical mobility disability can provide more opportunities for prevention of the onset of clinical mobility disability. Accordingly, it is important to know whether this intermediary phase of pre-clinical mobility disability has physiologic bio-markers (e.g. muscle strength). Identifying such bio-markers would provide clinical insight into the basis for such a condition, allowing clinicians to provide more efficient, targeted care when it matters the most.

Aims: The global aim of this dissertation was to examine if measures of leg strength are clinically relevant bio-markers of daily task modifications among community dwelling older adults living independently. Accordingly, the specific aims of the following paper were:

- To determine if there is a relationship between lower extremity muscle strength and daily task modifications in older adults living independently. It was hypothesized that: a) mean lower extremity strength measures will be significantly decreased in older adults who are classified as task-modifiers compared to those who are classified as non-task-modifiers; b) that there will be a significant and strong association between lower extremity strength measures and classification of daily task modifications.
- To identify levels of isometric and isokinetic lower extremity strength cut-off points that can be used to optimally predict task-modification vs. non-task-modification group membership? It was hypothesized that lower extremity isometric and isokinetic strength cut-off points will provide a clinically relevant bio-marker discriminating between the groups of task-modifiers versus non-task-modifiers.

Methods: Data were analyzed from 53 community dwelling male (21) and female (32) older adults (76.4 ± 5.2 years). All volunteers were asked to read and sign an informed consent approved by the local human research ethics committee, to complete the Mini Mental State Exam (MMSE), to complete the physical function domain of the second version of the Short-Form Health Survey (PFSF-36v2), and to complete a health

questionnaire. Also, height and weight measurements were obtained so a body mass index (BMI) could be calculated.

Task modifications were assessed by observing the participants perform eight (8) commonly observed daily mobility tasks. Specifically, participants were asked to perform a chair rise from three different sitting heights (30 cm, 38 cm, and 43 cm), to ascend and descend 14 stairs without rest (stair height = 6 inches), and to move from a left and right kneeling position, and from a supine position on the floor to a standing position. Modifications during these tasks were assessed using a previously described tool (i.e. summary modifications score (MOD) [1] The MOD showed excellent reliability and within-participant repeatability (Spearman rank and ICCs > .90). To calculate a MOD score, each one of the eight tasks was attributed a score between 0 (no modification) to 5 (refusal). Scores were then summed across tasks to create a summary of task modification score (i.e. the MOD), with a range of 0-40. An a priori decision was to set a MOD score of ≥ 5 as the cut-off point between the classification groups of daily task-modifiers (TM) and non-task-modifiers (NTM). We hoped to avoid categorizing study participants as "task-modifiers" when they were non-task-modifiers.

Measurements of isometric and isokinetic (at an angular velocity equals to 60^0 per second) lower extremity muscle strength Newton*meters) were obtained first by measuring peak isometric and isokinetic strength of hip and knee extensors and ankle plantar flexors from both the right and left legs using a Biodex testing device. Combined peak strength was generated separately for each level by calculating the mean peak score from the right and left sides. For example, once isometric and isokinetic measures of strength were obtained from the left and right hip extensors, the combined mean peak strength for the hip extensors was calculated such that mean peak score for the hip = (peak left hip extensors + peak right hip extensors)/2. Next, both isometric strength to body weight ratios and isokinetic strength to body weight ratios were calculated. Lastly, a net anti-gravity composite measure of isometric and isokinetic lower extremity muscle force production in the sagittal plane (NETforce) was calculated by summing the peak strength to weight ratios (Newton*meter per kilogram body weight (N*m/KgBW) from the three muscle groups.

To address the first aim, an independent t-test was used to compare groups (TM vs. NTM) across the dependent measures of isometric and isokinetic NETforces. Next, two separate logistic regression models were used to predict the odds associated with observed task modifications based on isometric and isokinetic measures of leg strength (NETforces) among older adults living independently. The odds ratio (OR) was defined as the likelihood of being classified as a non-task modifier in the absence of risk factors. Odds ratio (OR) can be estimated from the exponentiation of the beta coefficients [Exp(B)] such that OR = 1/Exp(B).

To address the second aim, a *discriminant* analysis followed by an ROC analysis was conducted separately with either the isomeric or the isokinetic NETforces as the predictor variables. This *discriminant* analysis yielded the optimal sensitivity and specificity. Then, an ROC curve analysis was performed to determine the actual isometric and isokinetic NETforces cut-off values associated with the formerly identified optimal measures of sensitivity and specificity. For all statistical tests, a *p*-value, set a priori, of less than .05

were considered statistically significant. All data analyses were performed using SPSS (version 18, SPSS Inc., Chicago, IL, USA).

Results: Of the 53 participants, 26 were classified as TM. Compared to the NTM, the TM group was older (mean ± SD = 78.8 ± 4.8 year versus 73.9 ± 4.3 years respectively (t_{51} = -4.957, $p < 0.001$, 95% CI = -7.5, -2.4)), and they self-reported more mobility difficulties (PFSF-36V2 scores (mean ± SD) = 69.23 ± 26.52 versus 89.44 ± 12.27 points respectively (t_{51} = 3.583, $p = .001$, 95% CI = 8.88, 31.54)). Compared to the NTM, the TM group exhibited 30% and 33.5% reduction in lower extremity isometric and isokinetic strength deficits respectively. Specifically, compared to the NTM group, on average, the TM group presented with a 1.51 N*m/KgBW isometric NETforce deficit (mean ± SD isometric NETforce equals to 3.52 ± 0.88N*m/KgBW versus 5.03 ± 1.29 N*m/KgBW respectively (t_{51} = 4.964, $p < 0.001$, 95% CI = 0.9, 2.13). Compared to the NTM group, the TM group presented with an average of 1.09 N*m/KgBW isokinetic NETforce deficit (2.26 ± 0.69N*m/KgBW versus 3.35 ± 1.04N*m/KgBW respectively (t_{51} = 4.477, $p < .001$, 95% CI = 0.6, 1.58)).

The results of the logistic regression for the isometric NETforce showed that influence of lower extremity muscle strength on task modifications is strong. Without controlling for other covariates, the odds ratio for task modifications for high leg strength compared to low leg strength was 3.31 (Exp(B) = 0.302, 95% CI = 0.16, 0.59 *)* Essentially, the direction of the association between the isometric NETforce and the dichotomous outcome measure of task modification classification (TM versus NTM) did not alter (OR = 3.7;Exp(B) = 0.27, 95% CI = 0.09, 0.79*)* after controlling for sex, age, body mass index, Mini Mental State Examination, self-reported physical function (PFSF-36v2), and

number of reported medical conditions. These findings suggest that the isometric NETforce uniquely contribute to the multiple regression model predicting task modifications among older adults living independently. The results of the logistic regression analysis using the isokinetic NETforce as the sole predictor variable yielded an odds ratio of 3.98 (Exp(B) = 0.251, 95% CI = 0.113, 0.557). In contrast to the isometric NETforce, peak isokinetic strength was not a significant predictor of task modification in the multivariate LR model 2 In this case [OR = 3.22; (Exp(B) = 0.31, 95% CI = 0.09, 1.04]. Thus, there was no evidence that compared to the other variables, the isokinetic NETforce had a unique contribution to the ability of the model to predict task modifications among older adults living independently. Both the isometric and isokinetic *discriminant* analysis models resulted in a sensitivity of 74.1% and specificity of 80.8%. Using these values in an ROC analysis, two independent lower extremities functionally relevant NETforce cut-off points were found. High risk of task modification corresponded to isometric and isokinetic NETforce cut-off points of $\leq$ 4.24 and 2.77 Newton-meters (N*m) per kg body weight, respectively.

Conclusions: A composite measure of lower extremity isometric and isokinetic strength cut-off points both provide objective bio-markers to identify community dwelling older adults who modify daily tasks. Further, our data suggest that, compared to isokinetic measure of strength, isometric is a better screening tool for task modification. The results suggest that a targeted strengthening program may reduce need to modify daily tasks, and hence may help to delay clinical physical disability in older adults.

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Figure 5b: Distribution of isometric test scores of study participants who were task modifiers (squares) versus non-task modifiers (triangles). Each square or triangle simultaneously represents a subject's isometric leg strength score and the score's associated percentile rank. Consequently, 20 (81%) of the 26 study participants who were classified as task modifiers had an isometric leg strength of 4.24 (N*m/KgBW) or less, whereas only 7 (26%) of the 27 non-task modifiers had an isometric strength of 4.24 (N*m/KgBW) or less.

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Preface

This section provides clarifications about the aims of this dissertation. In addition, acknowledgements to individuals who have significantly contributed to the completion of this work are included.

Loss of muscle strength is evident even in apparently healthy older adults. The premise of this field initiated research dissertation is that many older adults become functionally limited due to an increasing discrepancy between their own physiological capabilities (physiological impairments) and the challenges set forth by the environment. To minimize the effects of the physiological impairments, and hence narrow the discrepancy, many older adults adapt to the environment by modifying the way they perform daily tasks. Regardless of observed or perceptible level of independence, the need to modify mobility tasks of daily living is a symptom of pre-clinical mobility disability. Older adults who present with symptoms of pre-clinical disability are at a higher risk to develop full clinical disability within a relatively short time. Treating older adults who are at this intermediary phase of disability requires methods of identification. Specifically, a medical condition such as the pre-clinical disability requires methods of patient classification and the identification of possible bio-markers. This would then provide clinical insight into the basis for such a condition, allowing clinicians to better identify and treat individuals who are diagnosed as pre-clinically disabled. Accordingly, the global aim of this dissertation was to examine if measures of leg strength are clinically relevant bio-markers of daily task modifications among community dwelling older adults living independently. To that end, the specific aims of the following paper were:

- to determine if there is a relationship between lower extremity muscle strength and daily task modifications in older adults living independently. It was hypothesized that: a) mean lower extremity strength measures will be significantly decreased in older adults who modify daily tasks compared to those who do not.; b) that there will be a significant and strong association between lower extremity strength measures and daily task modifications.
- to identify levels of isometric and isokinetic lower extremity strength cut-off points that can be used to optimally predict task-modification versus non-task-modification group membership. It was hypothesized that lower extremity isometric and isokinetic strength cut-off points will provide a clinically relevant bio-marker discriminating between the groups of task-modifiers and non-task-modifiers.

For clarity, a glossary to define scientific concepts and terms, and a table with definitions of abbreviations that often appear in the text, are also included.

Operational Definitions:

Activities of Daily Living (ADL): Commonly used criteria used to categorize disability within an older adult population. These describe basic tasks such as bathing, feeding, dressing, toileting, and transferring (bed to stand).

Composite Peak Lower Extremity Strength: also known as "the total lower limb extension pattern" this term represents the idea that level of mobility and the ability to perform daily tasks in upright positions depends on the ability of muscles around the hip, knee, and ankle joints to produce lower extremity NET extensor force in the sagittal plane.

Daily Task Modifications: To maintain physical independence, many older adults modify the way they perform daily tasks. These modifications may include walking slower, relying on the handrail to climb the stairs, or pushing on the armrest to rise from a chair. Task modification is a major symptom of pre-clinical disability.

Disability: In the context of models of disablement, a state of disability follows functional limitations and refers to an inability to perform a normal societal role, e.g. Margret can't lift a 10 lb. weight (impairment), she will most likely have difficulty lifting a grocery bag (disability), and therefore she refrains from going out for grocery shopping (disability). From medical perspective, disability is considered a health-related condition signifying difficulty or dependency in tasks essential to independent living.

Discriminant Analysis: *Discriminant analysis* builds a predictive model for group membership. The model is composed of a *discriminant function analysis* (or, for more than two groups, a set of *discriminant functions*) based on linear combinations of the predictor variables that provide the best discrimination between the groups.

Dynapenia: Age-related decrease in skeletal muscle strength.

Force: Force is a quantity that is commonly measured using the standard metric unit known as the Newton. One Newton (N) is the amount of force required to give a 1-kg mass an acceleration of 1 meter/second^2.

Frailty: a global concept to describe a biologic syndrome, which appears common in older persons (> 65) especially in the very old (> 80). This syndrome consists of impaired muscle strength and endurance and is accompanied by vulnerability to trauma and external stressors. Frail people are at much higher risk for morbidity, disability, and mortality.

Functional Limitations: In the context of models of disablement, limitation/s in the ability to perform mobility tasks like gait, negotiating stairs, chair rises, walking and turning, e.g. Margret can't lift a 10 lb. weight (impairment), she will most likely have difficulty lifting a grocery bag (functional limitation).

Functional Task: a task used to define a functional limitation, e.g. walking 25 yards, going up and down the stairs.

Functional/Physiological Reserve: capability of body tissue, organ, system, or organism as a whole to perform beyond the minimum needed for maintaining function under non-demanding conditions.

Functionally Relevant Strength Cut-Off Points: levels of physiological performance (e.g. muscle strength, maximal oxygen consumption) below which independent performance on ambulatory tasks is significantly reduced.

Impairment/s: In the context of models of disablement, a consequence of a disease process. A physical or physiological loss, which in turn, substantially limits the ability to perform functional activities, e.g. Margret can't lift a 10 lb. weight (impairment).

Instrumental Activities of Daily Living (IADL): These tasks are needed to live an independent lifestyle within the community. They include stair climbing, writing, keeping finances, cooking, etc.

Isometric Muscle Strength: Relates to the muscle force production when the joint angle and muscle length do not change during contraction. Isometrics are done in static positions, rather than being dynamic through a range of motion. The joint and muscle are either worked against an immovable force (overcoming isometric) or are held in a static position while opposed by resistance (yielding isometric).

Isokinetic Muscle Strength: An isokinetic muscle contraction is obtained by using special training equipment that increases the resistance as it senses that the muscle contraction is speeding up. Therefore, the muscle contracts and shortens at constant rate of speed (angular velocity). For the purpose of this paper an angular velocity of 60° per second was applied

Mild Physical Activity: i.e. yoga, archery, fishing from riverbank, bowling, horseshoes, golf, snowmobiling, easy walking.

Models of Disablement: Theoretical framework used to delineate the consequences of *disease at the level of the person as well as society.*

Moderate Physical Activity: i.e. fast walking, moderate weight lifting (low intensity/high repetitions), baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing.

Muscle Quality: Defined as maximal voluntary contractile force or torque per unit regional muscle area .

Muscle Strength: The greatest amount of force that can be put forth by a muscle. It can be measured either isometrically and/or dynamically (e.g. isokinetically). Muscle strength can be calculated as an absolute value (e.g. kilograms, Newton, pounds) or as a relative value, e.g. force muscle per cross sectional area (i.e. muscle quality), force per total body weight, or force per total lean body mass.

Older Adult: an adult 65 years of age or older.

Odds Ratio (OR): After performing a logistic regression, the researcher will usually report the odds ratio. This is analogous to r^2 in that it measures the strength of the association between the study's dependent and independent variables. Odds ratio can be easier to interpret than the B coefficients, which is in log-odds units. Specifically, using SPSS statistical program to perform a logistic regression provides B coefficients (i.e. B) as well Exp(B). Odds ratio can be easier to interpret than the B coefficients, which is in log-odds units. B coefficients are the values for the logistic regression equation for predicting the dependent variable from the independent variable. Exp(B) is the exponentiation of the B coefficient from which odds ration can be estimated. For the purpose of this study this is the odds ratio: 1/Exp(B).

Physical Activity: Physical activity (PA) is any body movement that uses more energy than when resting. Walking, running, dancing, swimming, yoga, and gardening are examples of physical activity. Specifically, health benefits are associated with moderate-intensity aerobic PA for a minimum of 30 minutes, 5 days each week or vigorous-intensity aerobic PA for a minimum of 20 minutes, 3 days each week.

Physical Exercise: Compared to physical activity, physical exercise is physical activity that is planned, structured, and repetitive in nature. The purpose is to improve conditioning, function, or physiological reserve of any part or system of the body. Exercise is associated with improved health, maintenance of fitness, and is important as a means of physical rehabilitation.

Physical Therapist: A healthcare provider involved in rehabilitative health. A physical therapist uses specially designed exercises and equipment to help patients regain or improve their physical abilities.

Pre-Clinical Disability: The stage before the onset of disability. In this stage, people usually have difficulty performing everyday tasks (i.e., chair rising) but they are still able to complete them.

Sagittal Plane: A longitudinal plane that divides the body of a bilaterally symmetrical animal into right and left sections.

Receiver Operating Characteristic (**ROC**) **Curve:** Constructing an ROC curve requires the setting of several cut-off points for a test and then calculating the sensitivity and specificity at each point. Accordingly, the curve is plotted on a square with values of 1.0 for sensitivity and 1 – specificity at the upper left and lower right corners, respectively. A perfect test would yield a sensitivity of 1.0 and 1 – specificity of 0.0. This procedure is a useful way to evaluate the performance of classification tests. Moreover, by comparing the areas under the ROC curves constructed for each test, a clinician can see which curve more closely approximate the perfect curve and therefore which the better diagnostic test is.

Sarcopenia: Age-related decrease in skeletal muscle mass.

Torque: Torque is a measure of how much force acting on an object causes that object to rotate. The object rotates about an axis. The distance from the axis of rotation where the force acts is called the moment arm. In reference to muscle performance, torque is the force that for example, the quadriceps muscles need to generate in order to move the lower leg between 10-90 degrees of knee joint extension-flexion. Units of measure are Newton*meters (N*m). For the purpose of the current dissertation we normalized torque to body weight measured in kilograms (N*m/KgBW)

Chapter I: Introduction and Justification

Introduction

The tremendous progress made in the field of biomedicine with regard to preventing and treating many of the diseases known to mankind has resulted in a significant rise in the number of people who are living well into old age. [2] Aging has been associated with increased risk for disability. [3-5] In general, disability has a social aspect related to one's ability to fulfill societal roles (i.e. "participation") in the society in which he or she lives. Disability also has a physical aspect, involving decreased mobility, which is the focus of this work. Specifically, mobility disability, a common medical condition among older adults,[6] signifies any difficulty or dependency in carrying out activities essential to independent living in the community (e.g. shopping, socializing, meal preparation, driving or handling finances) or in one's home (e.g. bathing, dressing, transferring, grooming).[7] Data obtained between 1982 and 2004 show declines in mobility disability in the elderly United States population. [8] At the same time, by the year 2050, it is expected that there will be more than 85 millions older adults, age 65 years or older living in the United States. As a result, the rate of decline in the incidence of chronic disability among older adults does not seem to match the rate of growth in the number of older adults. It makes sense, then, that the absolute number of older adults presenting with mobility disability in the United States will rise. Mobility disability is associated with dependency, overall lower quality of life, and mortality.

In the context of the models of disablement [9], the path to age-related mobility disability involves complex interactions between pathology, impairments, functional limitations and the environment. [10-13] In essence, mobility disability is the end result of a chronically increasing discrepancy between one's personal abilities and the challenges set forth by the environment. [14]

While the rate of regression towards functional limitations and mobility disability among older adults may be impacted by reduced cognitive abilities [15, 16], vision and hearing acuity, [17] as well as changes in the immune [18] and endocrine systems [19-21], it appears, that age-related changes in musculoskeletal performance serve as independent predictors and strong determinants of the rate at which one regresses towards mobility disability. [22-25] For example, aging is associated with sarcopenia, a condition originally defined as an age-related chronic loss of skeletal muscle mass. [26] An average person loses 10% of his or her muscle mass between the third and the fifth decades of life, with an additional 40% lost between the fifth and the eight decades of life. [27-30] Furthermore, traditionally, age-related reduction in muscle mass has been considered a direct cause of age-related decrease in muscle strength [31] and mobility decline [32, 33]. Recent evidence suggests that dynapenia (age-related loss of muscle strength) is a stronger predictor of mobility decline among older adults [33-35] As a result, there has been a shift in focus toward a better understanding of how dynapenia is related to mobility in older age [36], which is the focus of this study.

Previous studies have found a lower extremity strength cut-off point, beyond which the relationship between muscle strength and age-related mobility disability becomes less direct. [37-39] These findings suggest the existence of cut-off points beyond which increased strength does not improve mobility function. Instead, the thought is that above the cut-off points, added strength contributes to physiological reserve. [40] Theoretically, physiological reserve can serve as a "margin of safety," allowing older persons to maintain mobility independence even as they lose strength. In the context of the models of disablement [9], the idea of a margin of safety may help explain the commonly observed non-direct relationship between age-related loss of muscle strength and clinical mobility disability. [40, 41] Specifically, [42-44] Fried and Schwartz proposed that an observed clinical mobility disability is merely the "tip of the iceberg," and that declining mobility performance in old age is actually associated with multiple sub-clinical "functional status breakpoints" embedded along the pathway toward actual, outright mobility disability. Consequently, there are multiple key impact points where changes in physical or physiological performance may be more directly related to functional improvements [41], offering more opportunities to detect mobility decline and to provide interventions.

Many older adults modify the way they carry out tasks of daily living so they can maintain independence. [14] Regardless of the level of mobility independence, the need to modify tasks of daily living is a sign of declining mobility. Yet, many older adults who modify daily tasks neglect to report mobility decline. [45] Persons who maintain functional independence by modifying tasks of daily living can be classified as "pre-clinically disabled". [46] Pre-clinical disability condition predicts future mobility disability in apparently healthy older adults. [47] Neglecting to self-report task modifications may delay intervention until, or shortly before, a person becomes clinically disabled. From a clinical point of view, delaying intervention to that point would likely render a poor prognosis. [48, 49] Our study used a unique task modification scale (MOD) [50, 51] that allowed us to objectively quantify task modifications among older adults based on observation.

In order to treat an individual with a pre-clinical disability, it is important to know whether this condition has physiologic bio-markers. Identifying such bio-markers would provide an objective clinical insight into the basis for such a condition, allowing clinicians to better treat individuals who are classified as "high risk." In healthcare, a cut-off point optimally differentiates between "healthy" and "ill." Lower extremity strength cut-off points associated with daily task modifications can therefore be used to estimate physiological reserve, help to determine if and how close a person is to possibly becoming pre-clinically or clinically disabled, and help to assess the need and the goals for targeted interventions for either one of the conditions.

The global aim for this dissertation paper was to examine measures of leg strength as clinically relevant bio-markers of daily task modifications among apparently independent older adults. Accordingly, the first aim was to examine the relationship between lower extremity muscle strength and daily task modifications in older adults who are living independently, and are therefore assumed not to be clinically disabled. It was hypothesized that a) mean lower extremity strength measures would be significantly lower in older adults who modify daily tasks compared to those who do not, and b) there would be a significant and strong relationship between lower extremity strength measures daily task modifications. The second aim was to identify levels of isometric and isokinetic lower extremity peak strength cut-off points that could be used to optimally differentiate between task-modifiers vs. non-task-modifiers. It was hypothesized that lower extremity isometric and isokinetic strength cut-points would provide a clinically relevant bio-marker discriminating between the groups of task-modifiers versus non-task-modifiers. A subsequent aim was to compare isometric versus isokinetic lower extremity strength cut-off points in terms of providing the best discrimination between the task-modifications versus the non-task-modification groups. It was hypothesized that lower extremity isometric and isokinetic strength cut-points have comparable discrimination accuracy.

Justification

Following the tremendous progress in bio-medical research, life expectancy in the Western world grew by 30 years between 1900 and 2000. By the year 2050, older adults age 65 years or older will constitute 20% of the population in the United States (about 70 million) [52] Age-related chronic diseases and clinical disability are very costly and create social and economic burdens on individuals, families, caregivers, and society as a whole. Therefore, a main goal in healthcare is to accomplish a compression of morbidity, where older adults live independently until shortly before the natural end of their lives.

Age-related clinical disability is a significant component of illness in older adults. Accomplishing compression of morbidly requires a better understanding of ways to treat clinical disability in this population. To do this, healthcare providers need to have a better understanding of the events leading to clinical disability. For example, preventive measures such as increased muscle strength, appropriate nutrition, and even smoking cessation may help to stall the functional decline associated with aging and accomplish a compression of morbidity.

Treating disability should focus more on prevention, rather than treating its consequences. Interestingly, despite the notion that early detection can improve care for older adults who are at risk for developing clinical disability, at the present, there seems to be insufficient information regarding screening tools to identify these individuals who are at risk for future disability.

There are some novel aspects to this project. First, the investigation of functionally relevant lower extremity strength cut-off points associated with early signs of mobility decline (i.e. observed task modifications) is fairly original as most previous studies investigated functionally relevant lower extremity strength cut-off points associated with true clinical disability. Second, this is the first study to use an to use an objective tool to systematically quantify daily task modifications among community dwelling older adults. Third, in contrast to other studies that looked at the association between muscle performance and ability to perform isolated daily tasks under standardized conditions (e.g. gait speed or chair rise), the current study assessed the association between muscle performance in the lower extremities and task modifications in a group of independently living older adults. Accordingly, a more complete elucidation of the underlying physical and physiological demands associated with pre-clinical disability will allow for the development of preventive methods and countermeasures to mitigate the physical and functional dysfunctions associated with "abnormal" aging.

Chapter II: Review of the Literature

Preface

By the year 2050, it is projected that there will be more than 85 million adults age 65 or older living in the United States.[2] This is significant because aging is associated with increased incidence of frailty, chronic conditions, functional decline and the risk for clinical disability, all of which lead to physical dependence, hospitalization, institutionalization and death. [5, 51, 53-59]

This chapter will cover and summarize the pertinent research related to the disablement process associated with aging. Additionally, technical and methodological issues relevant to this dissertation will be addressed.

Frailty

According to Webster's College Dictionary, [60] frailty refers to "the quality or state of being frail." Frail means "fragile", "easily broken or destroyed", "physically weak". The terms "frailty" and/or "being frail" are global terms often used in healthcare environments to describe a condition of general weakness and reduced physical capacity associated with a variety of medical conditions (e.g. HIV, chronic renal insufficiency, heart disease etc.) and/or aging. Especially with older adults, healthcare professionals and policyholders tend to use "frailty" or "being frail" synonymously with functional limitation, disability and even with the process of aging itself [13, 61] (i.e. aging = frailty). In young people, frailty is usually the result of a congenital condition or a catastrophic event such as a disease or a specific trauma. Age-related frailty is the result of an accelerated rate of the typical physical and physiological decline associated with the aging process. [62] It is estimated that between 6% and 25% of apparently independent adults age 65 and older, and 40% of age 80 years or older show signs of frailty. [12, 63] Frailty is a biologic syndrome [13, 61, 64-67] caused by a cumulative decline in multiple physical and physiological reserves. Attempting to better define and understand frailty, Hamerman[61] suggested that frailty is a bio-medical condition, and like any other medical condition, frail persons should present with identifiable medical signs and symptoms associated with specific physical, physiological, laboratory, and biological indicators. For example, Leng et al.[68] reported that frailty is associated with symptoms of chronic inflammation. Moreover, previous evidence suggests marked increases in serum interleukin-6 (IL-6) in frail persons.[69] Leng et al.[68] also reported that frailty is associated with lower hemoglobin and hematocrit levels. The authors argued that this subclinical anemia is unlikely due to iron deficiency, but rather caused by the chronic inflammation commonly found in frail older adults.

Fried et al.[13] developed a risk profile for age-related frailty. As such, this approach mimics the development of, for example, a risk profile for metabolic syndrome, which includes such risk factors as hypercholesterolemia, hyperglycemia, hypertension, high triglycerides, and central obesity. Attempting to build the risk profile for the complex etiology of the age-related syndrome of frailty, Fried et al.[13] suggested a working decision algorithm. Specifically, a clinician should obtain information on the following risk factors: 1) rate of musculoskeletal shrinkage measured by the magnitude of unintentional weight loss within the last six months, 2) muscle function measured by grip strength, 3) poor endurance and energy measured by short self-report questionnaire [70], 4) movement slowness measured by gait speed controlled for gender and height, and finally, 5) rate of weekly physical activity measured by energy expenditure (i.e. Kcal used per week). A person presenting with zero findings should be considered non-frail. Between one to two positive findings renders a diagnosis of a pre-frailty state. Three or more "symptoms" render a diagnosis of clinical frailty (for more detailed information refer to appendix A).

Preventing and treating the syndrome of frailty is important because frailty is associated with disability, poor quality of life, institutionalization and

A variety of interventions addressing age-related frailty among older adults have been suggested over the years. Examples of such intervention include aerobic and/or resistance exercise programs, hormone replacement therapies, use of vitamins (e.g. vitamin D) and food supplements, improved nutrition, and improved social support and community services. [72-77]

Defining Age-Related Disability

The emergence of disability as a commonplace, generic medical term used by healthcare agencies, providers, and policyholders to describe an individual's ability to perform daily activities necessary for physical independence and even survival prompted inquiry into its definition, as well as the process leading to it. The United States Department of Justice Americans with Disabilities Act (ADA), defines disability as a physical or mental impairment that substantially limits one or more major life activities. The World Health Organization (WHO) refers to the state of disability as a limitation or complete loss of the ability to perform daily activities in a normal manner. According to Verbrugge & Jette [11], disability is a hindrance in performing any number of daily activities in any domain of life due to either illness or physical deficiencies. The Guide to Physical Therapists Practice [78], uses disability as a broad term to describe the level of ability or inability of individuals or populations to perform necessary actions and activities related to self-care, home, family, community, work and leisure. Clinical disability, signified by difficulty or dependence in tasks required for independent living, is common in old age affecting between one-fifth and one quarter of people over age 60 [8,] [8, 7980]. Age-related clinical disability is associated with morbidity, functional dependence, institutionalization, and death. [11] rendering increased burden on both formal and informal healthcare services. [79, 81];[82-84]

Level and severity of age related clinical disability can be placed on a continuum because in essence, this condition and its consequences may be regarded as the discrepancy between actual personal abilities and the challenges presented by the surroundings within which the individual lives and function [11] Such environmental demands may be socio-cultural, physiological, emotional, or physical. For instance, an older adult living in a Western society can overcome loss of the ability to walk long distances by using a car. This may not be the case for a person living in a developing country where it is necessary to walk long distances to get fresh water.

Models of Disablement

Age-related disability is a chronic, multi-factorial, dynamic medical condition[12, 59] As with any medical condition, a common understanding of the sequence of events leading to the state of disability, and the ability to recognize the signs and symptoms of the condition is critical to tailoring a goal-oriented, efficacious, specific, realistic, and timely treatment plan. In an attempt to establish an effective communication tool to be used across disciplines, and to better understand the pathway leading to "chronic" (e.g. age-related) disability, scholars have contemplated conceptual frameworks commonly known as "models of disablement".[11, 85] In general, models of disablement present the concept of progression (i.e. "main pathway"[11]) from a state of disease or pathology to the development of disability. The general path towards disability is as follows:

Pathology → Impairments → Functional Limitations → Disability

The term "pathology" or "disease" refers to an interruption or disruption in the normal functioning of tissues or systems [11] Such pathologies precede and may give rise to impairments, which can be conceived of as abnormal function, or loss of normal function in an anatomical, psychological or mental system. Examples of impairments include loss of vision as well as declines in cognitive ability, motor and postural control, muscular control and joint mobility, among others.

Left untreated, impairments can progress to a stage of functional limitation, manifesting as difficulty with or inability to perform a host of daily physical tasks such as rising from a chair, balancing, ambulating safely, or climbing stairs, all of which are fundamental tasks of daily living. In the context of the models of disablement, limitations in fundamental tasks of daily activities are associated with increased likelihood of clinical disability. [10, 11]

A cursory examination of models of disablement might seem to indicate a unidirectional relationship from pathology to impairment, to functional limitations, and on to disability. If this were the case, disability would be the inevitable end result of rigid interactions between events and their effects, as well as between possibilities and probabilities [11] Such an interpretation of models of disablement would suggest that once on the "main path", regression toward disability is the unavoidable outcome, regardless of internal changes (e.g. increased muscle strength) or external changes (an individual's adjustment to environmental demands). In point of fact, however, numerous studies have demonstrated that the interaction between components of disablement models is multidirectional, such that one component can potentially influence one or more of the other components in the model. Specifically, considering all the evidence, it appears that although prevalent as medical condition, age-related disability can, indeed, be treated. [86-88] To do so, however, there is a need to develop methods to examine, evaluate, and diagnose the sequential events leading to the state of age-related functional limitation and disability.

Pre-Clinical Disability

Age-related disability and frailty are serious medical conditions that may be prevented. As previously discussed, the increasing discrepancy between an individual's abilities and the challenges set forth by the environment is the result of a chronic regression towards functional limitations and disability, leading to dependency. This discrepancy may be reduced either by elevating one's personal abilities (e.g. improving muscle strength, muscle power, emotional status) or by lowering the environmental demands. To lower the external demands, many older adults modify the way in which they perform daily tasks, as in relying on a cane for walking, using the handrail to negotiate stairs, pushing on armrests to rise from a chair, or relying on furniture to stand up from a kneeling position.[89, 90] Such task modifications, while allowing many individuals to continue and function in the community, may be the first sign of the transitional stage between independence and clinical disability (i.e. dependence). Studies show that up to 18 months prior to the onset of actual task difficulty (i.e. disability), many older adults are able to compensate for their underlying disease and maintain their independent level of function without the perception of difficulty. This clinical transitional stage has been identified as "pre-clinical disability" condition . [47, 91] This condition may be compared to the pre-clinical stage of cardiovascular disease that is predictive of onset of clinical cardiovascular disease in older adults. [47, 91] Accordingly, because a "diagnosis" of a pre-clinical disability is a precursor of future disability, it can be a very useful way to identify those older adults who are apparently disability free but are also at a higher risk of developing physical disability. Identifying such at risk older adults will allow clinicians to address the condition when treatment matters the most.

In order to "diagnose" an individual with a pre-clinical disability condition, first it is important to know whether this pre-clinical stage has physiologic "symptoms." Daily task modification is a key symptom of pre-clinical disability. Yet, up to 40% of pre-clinically disabled older adults fail to report any mobility difficulty. [14, 23] Manini et al.[50] found that initially, use of task modifications actually helps older adults to complete daily tasks more efficiently. Gregory et al.[14, 23, 90] showed that older adults reported task difficulty only when they realize that it takes them longer to complete a daily task or when they feel that they needed to expend more energy in order to complete daily tasks. Collectively it appears that when older adults can no longer maintain their independence using task modifications, they likely already transitioned from mild-to-moderate mobility difficulty, for which the task modifications can compensate, to a state of actual clinical disability.

Actual clinical disability is also associated with poor prognoses. Previous research indicates that while transitions between states of disability and independence are common, non-frail older adults show significantly lower rates of transition from less to more disability, and significantly higher rates of transition from more to less disability, along with slightly shorter durations of disability [48]. Gill et al.[49] reported that within a period of 18-month intervals, transitions to states of greater frailty were more common (rates up to 43.3%) than transitions to states of lesser frailty (rates up to 23.0%). The probability of transitioning from being "frail" to "non-frail" was very low (rates, 0%-0.9%). The authors concluded that the likelihood and direction of transitioning between frailty states is highly dependent on one's preceding frailty state. Therefore, based on the aforementioned data, clinicians' use of objective measures of pre-clinical disability may help them identify task-modifiers without bias at earlier stages of the "disease", rendering a much more favorable prognosis.

Although many older adults fail to self-report mobility difficulty, most studies examining pre-clinical disability used self-reported information to identify individuals as task-modifiers. [46, 92] In an attempt to better assess and understand one's overall ability, it appears that an objective (rather than subjective) record of task modification can provide both researchers and clinicians with better appreciation of one's true level of functional capacity. An objective task modification scale (MOD) was suggested and tested by Manini et al.[50] A scale was developed categorizing the most common ways in which older adults perform tasks such as rising from a chair (sitting heights 43 cm, 38 cm, and 30 cm), ascending and descending one flight of stairs, kneeling and rising from a supine position (Appendix F). Researchers then created an ordinal scale that indicated a gradient of difficulty performing each task. A score of zero (0) was given if "no apparent modifications" were made, while need for assistance was given a score of four (4). Refusal or inability to perform a task received a score of five (5). A total task modification score is the sum of the individual scores on all eight (8) tasks of the MOD (the kneeling to standing activity is considered two separate tasks, one for each side of the body). A higher MOD score represents more task modifications and or inability/refusal to perform the task. Inter-rater reliability (ICC = 0.98) and subject repeatability (ICC = 0.92) of the MOD were both excellent. [50]

Muscle Function & Mobility Difficulty

Declining muscle strength is predictive of future functional dependence and/or disability even in the absence of other morbidities [93] For example, Jette et al.[94] designed a longitudinal study aimed at investigating the progression of vision, hearing, and musculoskeletal impairments among older individuals. The researchers evaluated the association between these impairments and changes in abilities to perform 10 activities of daily living as a measure of physical disability. The authors reported that vision and hearing impairments were not associated with physical disability, while diminished hand function was a significant musculoskeletal impairment primarily influencing limitations in ADLs. The authors also reported that the ability to perform IADLs (i.e. mobility related tasks) was directly associated with the level of lower extremity muscle dysfunction. In another longitudinal study, Brill et al.[95] studied 3,069 men and 589 women between 30 and 82 years of age. Participants were included if they had no history of heart attack, stroke, diabetes, high blood pressure, cancer, or arthritis at their first visit. A strength index composite score (0 - 6) was calculated using age- and sex-specific tertiles from bench press, leg press, and sit-up tests. The higher strength group consisted of individuals who scored 5 - 6. Functional health status was assessed by self-report questionnaires assessing participants' ability to perform light, moderate, and strenuous daily tasks (i.e. recreational, household, daily living, and personal care). The participants were re-evaluated five years following the first visit. At follow-up, 7% of men and 12% of women reported at least one functional limitation. Moreover, the authors found that, relative to those with lower levels of strength, the odds of reporting functional limitations at follow-up in men and women categorized as having higher levels of strength at baseline were 0.56 (95%CI = 0.34, 0.93) and 0.54 (95%CI = 0.21, 1.39), respectively.

These findings may suggest that maintaining muscle strength throughout the lifespan could reduce the prevalence of functional limitations and/or disability associated with aging.

A study by Bessiner et al.[96] sought to establish a set of hierarchic neuromuscular impairments which cause one to become physically disabled. To do so, the researchers recruited 21 participants who were residents of assisted and skilled nursing facilities at the time. Testing procedures included balance, strength, range of motion (ROM), and level of function. The authors reported that function was primarily related to balance, followed by strength, and finally by ROM impairments. In turn, Daubney & Culham [97] used three different tests of balance (the Berg Balance Scale, the Functional Reach Test, and the Timed Get Up & Go Test [98]) and measured the force generated by 12 lower-extremity muscle groups to identify relationship between balance and lower extremities muscle strength in individuals age 65 and older. The authors reported that, among participants reporting no falls, muscle strength of ankle dorsiflexors and subtalar evertors accounted for 58% of the score on the Berg Balance Scale. Strength of the ankle plantar-flexors and subtalar invertors, on the other hand, accounted for 48.4% of the score on the Get Up & Go test. Finally, strength of ankle plantar-flexors accounted for 13% of the score on the Functional Reach Test. Moreover, weakness of ankle dorsiflexor and hip extensors was identified in participants who reported more frequent falls. The authors concluded that a relationship exists between measurements of lower extremities muscle strength and ability to forecast functional balance scores.

Bessiner et al.[99] attempted to identify extremity musculoskeletal impairments that are best associated with functional limitation and, therefore, disability. The researchers looked at 81 older adults who, at the time of data collection, resided both in independent and dependent care facilities. The authors found that, on average, older adults residing in dependent living settings presented with significantly less muscle strength in both upper and lower extremities when compared to individuals residing in independent settings. Furthermore, the researchers reported that using stepwise regression while looking at the subject population as a whole, the combined effects of age, lower extremity muscle force production and lower extremity ROM explained up to 77% ($p \leq .01$) of the variance in functional ability.

In their study, Chandler et al.[100] sought to ascertain whether there is a relationship between gain of muscle strength, physical performance, and level of physical dependence. The authors recruited 100 functionally impaired community dwelling older adults (77.6 ± 7.6yrs). After random group assignment to exercise (i.e. strengthening exercise for 10 weeks) and non-exercise groups (control, continue with regular activities), participants were tested for muscle strength, physical performance and disability. Using multiple regression, the researchers found that strength gain had significant impact on mobility skills such as sit-to-stand ($p = .04$) and gait speed ($p = .02$).

Schiller et al.[101] looked at age-related loss of lower extremity muscle strength of the knee extensors and its impact on selected physical performances in healthy Hispanic versus Caucasian women. The authors found that both the absolute and the relative (normalized for thigh fat-free mass) knee extensor strength decline with age within both populations. This decline in strength is associated with increased performance time of functions such as 10-meter walk, stair ascent, stair decent, and standing from a chair.

While overall muscle strength is associated with ability to perform daily tasks, it appears that muscle strength in the lower extremities is a better indicator and predictor of future functional limitations and dependence. According to Onder et al.[102], when comparing upper extremities (UE) to lower extremities (LE), older adults suffer from greater decline in LE muscle strength than UE muscle strength. Moreover, the relationship between UE muscle strength and function appears less linear. Accordingly, the authors suggested that LE outcome measures seem preferable for studies that examine prospective changes in physical function associated with aging.

Collectively, the aforementioned studies ought to leave minimal doubt that there exists a direct relationship between muscle strength and functional capacity. Specifically, there is ample evidence supporting the idea that reduced muscle strength in general, and lower extremity strength in particular, is strongly associated with reduction in functional capacity measured in terms of gait speed, balance, stair-climbing ability, and ability to transfer from one position to another (e.g. standing from a seated position). [103] Moreover, the strength of the relationship between lower extremity strength and the ability to accomplish selected functional activities was found to be high (above 50%) in several studies. For example, Brown et al.[103] examined in 16 healthy but frail older adults ranging in age from 75 to 88 years (mean = 80.9 years). Each participant's functional capacity was measured using the following tests: preferred gait speed under laboratory and free walking conditions, five timed chair stand-ups, and time to complete an obstacle course. Also, strength measures of the hip extensors, hip abductors, knee extensors, planter flexors, and dorsiflexor muscle groups were obtained using a handheld dynamometer. The relationship between the time to complete the functional activities and each of the strength variables was determined using Pearson product-moment correlations. Somewhat similar to the design of the present study, functional performance was examined in relation to various combinations of strength measures (e.g., hip, knee, and ankle extension). Interestingly, weak, non-significant relationships between hip, knee and ankle strength-to-functional activity were found. However, when hip extension, knee extension, and ankle plantar flexion strength values were combined and normalized by body weight, the researchers found a significant strength-to-functional activity (i.e. standing up from a chair with a 14 inch sit pan height ($r = .636$, $p < .01$)).

Furthermore, muscle strength is not only a good predictor of functional ability but can also predict level of function, independent of any other pathology. In a study by Kim and Eng [104], the researchers examined the relationship between the torque generated by the muscles of both lower extremities and two mobility tasks, namely gait on level surfaces and stair climbing. Participants were individuals who had experience a stroke (i.e. neurological involvement). The researchers found that even in people who suffered neurological damage, the ability to generate muscle force could still explain 66% to 72% of the variability in gait and stair-climbing speeds.

Sarcopenia

An intact musculoskeletal system is central to functional independence. Mobility independence depends on the ability of skeletal muscle to contract and produce sufficient force and/or power to carry out designated functional tasks [95, 100, 105, 106] Accordingly, muscle performance is an independent predictor of functional independence in older adults. Reduction in muscle mass has been linked with loss of muscle strength, and subsequently with loss of physical independence. [96, 99, 105, 107]

Sarcopenia, from the Greek for "flesh loss"[108] is the common term used to describe a progressive, involuntary decline in lean body mass, particularly skeletal muscle mass, muscle strength, and muscle quality observed with aging [57, 108-112] Muscle mass refers to actual muscle quantity which is measured as lean body mass or fat free mass. Muscle strength refers to the ability of the muscle to generate force. Compared to muscle strength, muscle quality is commonly defined as the ability of a muscle to generate force per unit muscle mass [113], and is actually an indication of how efficient a muscle is in producing movement. Interestingly, even in apparently "healthy" older adults, evidence of age-related decline in muscle mass, followed by a decline in muscle strength and quality, is well documented [114-120] Moreover, symptoms of age-related loss of lean tissue mass can be observed even in elite athletes, despite the fact that they participate in high level physical activities for many years [121-123] Because sarcopenia is such a common occurrence with aging, [107, 108, 124-126] it is not considered a "pure" pathology or disease. [112, 121-123] Nevertheless, sarcopenia is still considered a chronic, debilitating "process", which if not treated, can eventually lead to age-related frailty, functional dependence, and mortality. [109, 112, 127]

Clinically, sarcopenia is defined as appendicular skeletal muscle quantity (i.e. kilogram muscle per height (kg/m^2)) of less than two standard deviations below the mean of a young, healthy reference group. [117, 128] However, in reality, sarcopenia is a broad term used to identify any decline in muscle mass, muscle strength, and muscle "quality" associated with aging. [107, 112, 117, 128-130]

Characteristics of Sarcopenia

Signs of age-related reduction in muscle mass, strength, and quality are evident relatively early, i.e. the third decade of life. [131-134] Between the third and fifth decades of life, the rate of muscle mass loss is relatively slow ($\approx$ 0.5% per year). The rate increases dramatically, however, between the fifth and eighth decades. The average person experiences a 10% loss of muscle mass from his or her thirties to fifties, and an additional 40% loss of total muscle mass from his or her fifties to eighties. Even more surprisingly, Lexell and colleagues [131] reported that starting at age 25, the number of muscle fibers progressively decreases, numbering approximately 40% fewer at age 80. Furthermore, while quantity of type I muscle fiber remains the same or even increases with age (i.e. morphological remodeling), type II muscle fibers, particularly type IIb and type IIx (the more anaerobic fibers), tend to decline in number as well as in size. [131]

Muscle strength is defined as the amount of force that a muscle can produce during maximal effort. [135] Muscle strength is strongly associated with fiber type and muscle mass and, therefore, muscle cross-sectional area (CSA). [135-137] In turn, CSA is the product of muscle fiber size (i.e. cell mass) and the total number of muscle fibers. Hence, age-related decreases in the number of muscle fibers (particularly type II), combined with reduced CSA adversely affect a muscle's ability to generate force, and therefore lead to reduced functional capacity. Studies have shown that along with the decline in "quantity" of muscle mass, sarcopenia also involves a decline in the "quality" of the remaining muscle mass [112, 119, 120, 125]. Muscle quality refers to the ability of a muscle to generate force per unit muscle mass. [113] A variety of muscle properties can affect the quality of muscle work, and aging is associated with physiological changes affecting every one of them. Examples of these properties include mitochondrial protein turnover, myosin heavy chain (MHC) protein turnover and fiber composition, muscle innervation, fatigue characteristics, capillary density, glucose metabolism and uptake, and muscle contractility. [118]

Muscle contractility, which is central to muscle quality, is dependent on the muscle's ability to produce and use adenosine triphosphate (ATP). ATP production occurs in the mitochondria. Mitochondrial DNA, which is responsible for the synthesis of approximately 15% of mitochondrial proteins involved in the process of ATP synthesis, is constantly bombarded with free radical oxygen particles during the process of ATP production. [138] Because mitochondrial DNA has no efficient way to repair itself, over time there is a decreased ability to produce ATP and therefore, decreased contractile efficiency. [138-140] Balagopal and colleagues [139] also reported that aging is associated with a decline in the rate of synthesis of myosin heavy chain protein (MHC). Because MHC is part of the protein myosin, and because protein myosin is central to the development of muscular force and contraction velocity, [135] the decreased production of MHC adversely affects the contractile quality of the aging muscle.

According to Roubenoff [112], the single most important cause of sarcopenia relates to the age-related loss of α-motor neuron input to muscles. Other studies have shown that with aging, there is a "Motor Unit Remodeling" where fast type II muscle fibers are converted primarily to slow, type I muscle fibers. [135] In addition, type IIb and type IIx muscle fibers tend to convert into type IIa which, similarly to type I muscle fibers, have an aerobic metabolic profile. [141] Aging is also associated with a phenomenon referred to as "grouping." Grouping occurs when skeletal muscles tend to lose their "mosaic pattern", or heterogeneity of fiber types. Instead, muscle fibers with similar MHC isoforms (i.e. same type) tend to aggregate and group together. This phenomenon is usually the consequence of chronic denervation. Specifically, changes occur at the neuromuscular junction as a result of denervation, axonal sprouting, and re-innervation. [142, 143]

Advanced age is associated with loss of motor units, which to some extent is compensated for by an increase in the average motor unit size. [144-146] Furthermore, as motor units become larger, advanced age is associated with slower contractile speed [144-146] Loss of motor units was found to be inversely related to muscle strength both in men and women. [144-147]

Prevalence of Sarcopenia

Because signs of sarcopenia are already evident at a young age, any attempt to study the actual prevalence of sarcopenia will depend primarily on how one defines the phenomenon. If sarcopenia is indeed defined as any reduction in lean body tissue or skeletal muscle mass, then given the fact that loss of lean body mass is a universal phenomenon affecting all individuals to some degree, the prevalence of the condition should be 100%. However, since sarcopenia is diagnosed when the quantity of muscle mass is approximately 2 SD below the mean for younger adults [117, 148], the prevalence of sarcopenia among people over age 65 is around 22.6% for women, and 26.8% for men. In individuals older than 80 years of age the prevalence of sarcopenia rises to 31% and 52.9% within the female and male cohorts respectively [114] Because sarcopenia is considered a multi-factorial phenomenon depending on parameters such as gender, ethnicity, environment, age, and even study design [112, 114, 117, 149] it becomes even more difficult to calculate the exact prevalence of sarcopenia in the United States. In their study of a stratified sample of men and women from Rochester, Minnesota, Melton et al.[150] found that the prevalence of sarcopenia ranged from 6% to 15% among participants age 65 and over. The prevalence rates depended on whether researchers were examining lean body mass (exclusive of bone) or actual skeletal muscle mass. In their comparison of the prevalence of sarcopenia in different ethnic groups, Baumgartner et al.[117] found a greater incidence in Hispanics as compared to non-Hispanic whites.

Dynapenia

Traditionally, sarcopenia has been used as the umbrella term to describe age-related loss of muscle mass, loss of muscle strength, and loss of muscle quality (i.e. force per muscle area) [110, 148, 151]. Recent studies show that the rate of age-related loss of muscle mass fails to fully explain observed age-related declines in maximal voluntary force output (i.e. muscle strength)[33-35] A recent longitudinal study over five years (n = 1678), by Delmonico et al.[152] found that a change in quadriceps muscle area explained only ≈ 6-8% of the between-subject variability in the change in knee extensor strength. The authors concluded that force decrements are responsible for lower muscle quality among older adults. Recently, Clark and Manini [34] suggested the term "dynapenia" to more distinctively describe age-related loss of muscle strength, as opposed to muscle mass. To identify opportunities for prevention of age-related mobility decline, it is necessary to define the etiology of physiological decline in older adults. Therefore, from a clinical perspective, based on the recent findings, sarcopenia and dynapenia should be treated as two separate age-related musculoskeletal conditions contributing to age-related mobility decline. [34, 36] A better understanding of the changes in intrinsic contractile properties and neurologic function associated with voluntary force production should be the focus for future studies of and treatment plans for dynapenia if the goal is to prevent mobility disability in older age. [36]

The distinction between "sarcopenia" and "dynapenia" and the focus on the contribution of contractile properties and neurologic components on muscle strength appear critical to the prevention of age-related mobility dependence. Because muscle strength is crucial for mobility independence, and because it is so relatively easy to "fix", national organizations have recommended resistance training for all ages, including the elderly population.[153, 154] However, very little research has evaluated the specific exercise training needs of older adults as related to everyday functioning. Task-specific exercises have been shown to be beneficial in terms of improved athletic performance and ability to perform daily activities. [155, 156] This is because task-specific exercises improve skills like dynamic balance, coordination, and timing of muscle recruitment, among other benefits. [157, 158] To determine whether a functional-task exercise program and a resistance exercise program have different effects on the ability of older people living independently to perform daily tasks, 98 healthy women age 70 and older were randomly assigned to the functional-task exercise program (function group, n = 33), a resistance exercise program (resistance group, n = 34), or a control group (n = 31). Functional-task exercises were found to be more effective than resistance exercises at improving functional task performance in healthy elderly women. These types of exercise tasks may also have an important role in helping such individuals maintain an independent lifestyle . [159] A study by Manini et al.[160] found that task-specific exercises were superior to resistance exercises in terms of improving mobility function especially in low-functioning older adults. In another study, Krebs et al. [161]found that while both high-intensity functional-task exercise and resistance training improved muscle strength, the task-specific regimen resulted in greater improvements in dynamic balance control and coordination while performing daily life tasks. In sum, the above studies further support the idea that treatment of age-related disability should focus more on task-specific exercises aiming at counteracting the effects of dynapenia overall, rather than on just improving muscle mass.

Assessment of Mobility Performance

General Overview

Most rehabilitation professionals have long understood the need for consistent, systematic improvements in the physical and functional performance of their patients. Moreover, because these systematic descriptions or evaluative tools measure changes as the result of rehabilitative treatment methods and/or programs, they ought to be standardized, objective, reliable, valid and sensitive to change. In turn, these qualities will enable clinicians to track changes in patients over time, study their rehabilitation outcomes, and make comparisons among patients and/or rehabilitation programs [98, 162, 163]

In the context of models of disablement, the progression from a state of disease to disability via declining health (i.e. disease or pathology) is addressed at the level of a particular structure or tissue. The adverse effects of disease on declining physical capacity can be addressed at the level of a system or organ (i.e. impairments), the organism as a whole (i.e. functional limitation), or at the level of the individual with relation to the challenges set forth by the environment (i.e. disability) [162, 164] More specifically, based on the theoretical pathway from disease to disability presented by Nagi [9], impairments refer to dysfunction and structural abnormalities in specific body systems (e.g. musculoskeletal, cardiovascular). Functional limitations refer to restrictions in basic physical and mental actions (e.g. ambulate, reach, grasp, climb stairs, speak etc.). Disability refers to "difficulty doing activities of daily life (personal care, household management, job, hobbies)."

Assessing performance relates to any systematic attempt to objectively measure function at the level of a tissue, a system, an organism, or an organism's interaction with the environment. A large number of tools evaluating levels of physical and functional capacities in the aging population have been suggested in the literature. [51, 134, 162, 163, 165-170] Ever-increasing numbers of researchers and healthcare providers have realized the need for "good" (i.e. objective, reliable, valid, and sensitive) assessment tools. The need remains, however, for a continuous, deliberate effort to find the "best" assessment tool. This is likely because levels of functional capacity and disability leading to dependence are multifaceted, and may be impacted by anatomical, physical, psychological, and social elements working either independently or in conjunction with each other. [23, 51, 134, 165, 171, 172] Interestingly, it appear that although many exist, there are no categorically "good" or "bad" assessment tools. [98, 173] Rather, the choice of assessment tools depends on variety of factors that may affect measurements. In choosing the appropriate assessment, researchers and clinicians should consider issues such as the availability of the data, the type of data collection needed, the best design to collect the data, timeframe for data collection, cost effectiveness, applicability, and, of course, the target population. For example, a so-called "generic" instrument would be appropriate when the aim is to measure function, health, or quality of life across a wide range of populations, diagnoses, and interventions. In turn, a so-called "specific" instrument would be preferable when one needs to measure the same parameters in a very particular subpopulation, diagnosis, or intervention. [98, 173]

To collect data on declining physical function, disability, and health-related quality of life (HRQOL) associated with aging, most researchers rely primarily on two measurement methods [174-176, 176, 177] Those methods are:

- Self-report measure/survey (including proxy reports)

- Performance-based measures, which may be made by either direct examination of a group of sample activities related to specific domains (time, distance, weight [134]), or by an examiner trained to rate performance (e.g. categorical rating: "able", "unable", "some difficulties" etc.).

Self-Report Measures/Surveys

Using self-report measures to determine level of independence and HRQOL is a common practice among researchers and clinicians. [173-176, 176, 177] Under the umbrella of self-report measures to assess HRQOL and disability one would find three subcategories, which indicate the method used to gather information. Data can be collected by a) direct self-report, where the participant reads the questions and fills in answers independently, b) interviewer-administered, where an interviewer asks the questions of the participant and fills in the answers, and c) proxy-administered, where a caregiver answers questions regarding the functional capacity of the person under his or her care [178-180] Advantages of using self-report measures of physical function and disability include low cost, accessibility to the participant/patient population, ease of administration and the fact that, for the most part, little or no special training is required for either the interviewer or the participant. [178-180]

Studies have shown that well-designed self-report measures of function and/or disability are reliable, valid and sensitive to change. [173, 181-183] Such self-report measures can also be used to predict future declines in physical functioning and even mortality. To this end, Fried et al. [23] used self-report questionnaires to measure performance in women 70 to 80 years of age who were among the 66% of the top functioning individuals living in the community. Participants were asked to rate their ability to perform 27 daily tasks related to upper and lower extremities, as well as mobility. The researchers indicated that they were able to predict disability even in those who, at the time of the testing, did not self-report or demonstrate any apparent functional difficulties. Despite the obvious benefits and the common use of self-report questionnaires to identify disability, there are some disadvantages associated with these measures to assess HRQOL and physical function. Studies have shown that while older adults do show signs of declining physical function when asked to actually perform activities such as mobility tasks, activities of daily living (ADL), and instrumental activities of daily living (IADL), that are important for achieving and maintaining an independent living status, when asked about their ability to perform these tasks, they may fail to report this decline. [179, 184] In turn, older adults tend to rate their own functional ability as higher than it actually is.[185] One possible explanation for this discrepancy arises from an idea presented by Fried et al. [45] who posited the existence of an unrecognized pre-clinical stage preceding the clinical manifestation of functional decline or disability. The authors argue that this unrecognized stage is the result of progressive chronic conditions that, though real, have not yet crossed diagnostic cut-points, and therefore, are not yet detectable. Because the individual can still complete the task without help, the tendency is to report no difficulty with this task. It is only when the difficulty reaches such magnitude that it renders the individual unable to perform the task independently, and therefore interferes with daily activities, that the individual might report a task difficulty. All together these arguments suggest that the main disadvantage of using self-report measures to assess functional decline and disability relates to the idea that self-report surveys may fail to capture signs of functional decline early enough to allow aggressive interventions and the prevention of chronic disability. The "pre-clinical stage" Fried et al.[23] further argue, can be identified by performance measures such as increased time to complete a task, use of a different strategy to complete it, or a decrease in the frequency with which it is performed, all of which are signs of physical and functional difficulties. Comparing self-administered surveys to interviewer-administered surveys measuring physical function in community dwelling older persons, Reuben et al.[180] noted inconsistencies and weak relationships between the two methods. The authors suggested that these instruments might not, in fact, measure the same construct.

Self-Report Measures/Surveys of Health Related Quality of Life (HRQOL)

The 20th century brought tremendous scientific progress and development in the area of biomedical science. Using these scientific developments, healthcare providers managed to increase longevity by approximately 30 years over the period of 100 years between 1900 and 2000. While the number of years increased, medicine did not necessarily improve the health-related quality of life, especially among older adults. Therefore, it seems that the assessment of health related quality of life (HRQOL) is an essential component of healthcare evaluation in general and geriatric evaluation in particular.

Measuring the health-related quality of life of an individual requires an overall evaluation of one's ability to function physically, emotionally, and socially. There are several self-report performance instruments that can be used to measure HRQOL. Coons et al. [173] conducted a study examining a total of seven generic HRQOL instruments including the 1) Medical Outcome Study 36-Item Short Form (SF-36V2), 2) the Nottingham Health Profile (NHP), 3) the Sickness Impact profile (SIP), 4) the Dartmouth Primary Care Cooperative Information Project (COOP) Charts, 5) the Quality of Well

Being (QWB) Scale, the 6) Health Utilities Index (HUI), and 7) the EuroQol Instrument (EQ-5D). The authors concluded that there were no uniformly "best" and/or "worst" performing instruments. Rather, the choice should be driven specifically by the purpose of the measurement. Further, the choice of instrument depends on the characteristics of the population as well as the environment in which the survey is undertaken.

Medical Outcomes Study 36-Item Short-Form Health Survey Version 2 (SF-36v2)

One of the most widely-used generic health status questionnaires is the Medical Outcomes Study 36-Item Short Form Health Survey also known as SF-36V2. [186-190] The SF-36V2 questionnaire is used to assess one's personal perceived generic health status. The SF-36V2 includes scores in eight domains: 1) physical functioning (PF), 2) role-physical (RP), 3) bodily pain (BP), 4) general health (GH), 5) vitality (VT), 6) social functioning (SF), 7) role-emotional (RE), 8) mental health (MH). Also, the SF-36V2 includes a single item that provides an indication of perceived change in health, or a "reported health transition" (RHT). [191] The SF-36V2 items and scoring rules are distributed by QualityMetric Health Outcome Solutions (www.qualitymetric.com). Strict adherence to item wording and scoring recommendations are required in order to use the SF-36V2 trademark. [192] The SF-36V2 is also quite practical in that the great majority of respondents can self-administer the measure. Moreover, the SF-36V2 is constructed to be administered by a trained interviewer as well, either in person or by telephone, allowing the healthcare provider to reach more patients. [191, 193]

Coons et al.[173] assessed the applicability of different HRQOL questionnaires based on what they described as "administrative burden." The authors found that it takes approximately 7 to 10 minutes to self-administer the survey. Accordingly the authors ranked the "administrative burden" as minimal. Regarding the SF-36V2v2, briefly, low scores for PF indicate significant limitations in ADL's relating to health. In contrast, scoring high on the PF is an indication of no health-related physical limitations. Scoring low on RP indicates problems with work and/or daily activities as a result of physical health, while scoring high on the RP is an indication that the individual's health has no negative impact on his or her ability to perform work or other daily tasks. Low scores on the BP domain mean that pain is a severely limiting factor in one's life. High BP scores, in contrast, are an indication that pain is not a limiting factor. Low scores on the GH domain indicate poor perception of general health associated with the belief that the situation will get worse. High scores on GH indicate a good to excellent perception of personal health. Regarding vitality (VT), low scores are an indication that the individual feels tired and energy-depleted most or all of the time. Higher scores in this area signify high levels of energy and activity. Scoring low on the SF portion implies that low health status extremely and frequently interferes with the individual's ability to engage in social activities (due to physical and/or emotional problems). On the other hand, high scores in this domain mean that the individual's social life is not disrupted by his or her health status. Low RE scores indicate that the individual is limited in his or her ability to perform work or daily activities as a result of emotional problems. High scores in this area indicate the individual's daily activities are not limited or otherwise negatively impacted by emotional problems. With regard to MH, low scores indicate nervousness and depression, while high scores are indicative that an individual is peaceful, happy and calm. Finally, low scores on the RHT means that the individual believe that in comparison to last year, his or her health is better. High scores indicate that the individual perceives his or her health as worse than it was the previous year. [191] The SF-36V2v2 questionnaire has been extensively studied in different populations with variety of medical conditions and was found to be valid, reliable, and sensitive to change (i.e. responsiveness). [134, 170, 194-199] Validation of HRQOL and functional measurement tools is an important consideration if this framework is to have relevance in assessing health status and its effect on function and level of disability. Its validation is also central to designing preventive measures and interventions.

Briefly, validity is the degree to which an instrument measures what it is designed to measure. Construct validity is a type of measurement validity [200] which allows for distinguishing between known groups. [173] Studies have shown that using the SF-36V2, one can reliably discriminate between groups. Specifically, using the SF-36V2, the Nottingham Health Profile, the COOP/WONCA charts and the EuroQol instrument to assess the impact of migraine on health status, Essinik-Bot et al.[201] concluded that the SF-36V2 was the most suitable measure of health-status in a relatively healthy population, and further that the SF-36V2 exhibited the best ability to discriminate between groups (i.e. individuals who suffer from migraines and their matched controls). In another study, Garratt et al. [194, 202] assessed the validity, reliability, acceptability, and responsiveness of the SF-36V2 as a measure of patient outcomes in a broad sample of patients between 16 and 86 years of age (n = > 1700) suffering from four common clinical conditions (i.e. low back pain, menorrhagia (heavy menstrual bleeding), suspected peptic ulcer, or varicose veins). The authors indicated that the SF-36V2 satisfied rigorous psychometric criteria for validity and internal consistency. Construct validity was high, as the SF-36V2 allowed the researchers to distinctly profile each group of patients. [202] Even more relevant to the present study's population, Cress et al. [134] investigated the maximal voluntary and functional performance levels needed for independence in adults age 65 to

97 years. A score of < 65 units on the PF domain of the SF-36V2 was used as a criterion to distinguish between the "dependent" and the "independent" groups. The results of this study indicated the existence of functionally relevant cut-points with regard to aerobic capacity (peak oxygen consumption = 20.13 ml/kg/min and isokinetic knee extensor torque = 2.5 Newton-meter/((body weight in kgs)/(body height in meters))). Moreover, the functionally relevant cut-points identified by Cress et al.[134] were very similar to these found by Ploutz-Snyder et al.[185], Rantanen [39] and Morey. [203] This may further support the use of the SF-36V2 as a tool to distinguish between known groups [173] , such as levels of frailty.

Reliability refers to "the degree of consistency with which an instrument or rater measures a variable"[200] or in other words the degree to which an instrument is free of random error. [173, 200]

The reliability of a measurement tool may be assessed in terms of its items with internal reliability, or time by test-retest and intra-rater reliability, or raters with inter-rater consistency reliability. [173, 200]

The most commonly reported estimate of reliability in the literature relates to internal consistency. Group comparisons require a minimum level of internal consistency coefficients in the range of .50 to .70. [173] A study by Hayes et al.[192] showed in general, the internal consistency reliability estimates of the SF-36V2 were 0.78 or higher. Another study [204] demonstrated that reliability coefficients ranged between 0.65 to 0.94 in subgroups differing in age, gender, ethnicity, education, socioeconomic status, medical condition and disease severity. [173, 204] Similar reliability estimates were found in a variety of other populations under different administration conditions. Andersen et al. [205] evaluated the reliability, internal consistency, and response patterns for a mailed version of the SF-36V2 among adults age 65 or older and found that intra-class correlation coefficients generally were high and ranged from .65 to .87. Moreover, internal consistency coefficients of scales also were high (.802 to .924).

With regard to response patterns, Andersen et al. reported [205] that for each domain, item completion rates were high across all groups (88% to 95%). Furthermore, on average, surveys were complete enough to compute scale scores for more than 96% of the sample. Across patient groups, all scales passed tests for item-internal consistency (97% passed) and item discrimination validity (92% passed). Reliability coefficients ranged from a low of .65 to a high of .94 across scales (median = .85) and varied somewhat across patient subgroups. These findings indicate high reliability of the SF-36V2 survey across

The reliability of a measurement tool may be assessed in terms of its items with internal reliability, or time by test-retest and intra-rater reliability, or raters with inter-rater consistency reliability [173, 200]

Much of the research regarding tools that can assess abstract variables such as function, disability and HRQOL tends to focus on the construct validity of the measure. Essentially, the higher the construct validity, the better the instrument is able to reflect a person's status at any given point in time. On the other hand, if the intent is to use an assessment tool for the purpose of process evaluation, one must be concerned with validity beyond that of mere construct validity. It is important also to consider the instrument's sensitivity to change over time, or responsiveness. Studies have shown that the SF-36V2 questionnaire has a large magnitude of responsiveness in both overall disease (i.e. patient and clinician global assessment)[206] as well as in clinical measures. [207, 208] Fried et al.[45] examined the ability of a self-report measure to identify older women with early declines in performance and to differentiate stages of disease. The authors found that, in fact, self-reported levels of function can be used to predict differences in both the range and mean for tasks such as walking speed, balance and strength. The authors concluded that these findings support a physiologic basis for self-reported function. Accordingly, the authors suggested the use of self-report assessment tools as a reliable and valid approach to screening and the assessment of intervention outcomes aimed at the prevention of functional decline and disability among older adults. A study by van den Brink et al. found a positive association (Odds Ratio = 1.28, 95% CI = 1.21-1.35) between self-reported disability and performance-based limitations in three different European countries [174] Studies comparing self-reported measures to performance-based measures, however [178-180] showed that although self-report assessment tools can predict functional decline and subsequent disability [177], performance tests of functional ability and/or level of disability commonly offer more reliable information regarding one's level of functional capacity and disability than self-report measures [178-180] While performance-based measures of functional status are cross-sectional and longitudinally associated at modest levels with self-reported disabilities, it appears that performance measures and self-report measures are complementary, but do not necessarily, measure the same construct. [177, 179, 209] That is to say, performance-based measures of physical function may identify more deficits than self-report measures of physical function. Perhaps more importantly, performance-based measures of physical function seem more sensitive to change and are better able to identify physical deficits at a much earlier stage when compared to self-report measures of physical decline [179] Although the first version of the SF-36V2 proved to be valid, reliable and therefore useful for many purposes, after more than a decade using the assessment, the authors of the original measure decided that there was both the need and room for improvement. [210] Those improvements were embedded into version 2 of the SF-36V2 (SF-36V2v2™). Changes in the second version involved simplified instructions and item wording, making them easier to understand, improved layout of questions and answers for ease of reading and to reduce the number of missing responses, enhanced ability to reach a variety of populations within and outside of the United States with translations and cultural adaptations. Item response sets were also revised. From seven items in the two role functioning scales (physical and emotional), the authors replaced the dichotomous response choices with a five-level set of response options.

To simplify nine items on the mental health and vitality scales, the response choices were reduced to five from the six choice levels in the original version. Finally, to make scoring easier to understand, the authors created a norm-based scoring algorithm for each of the eight scales. Specifically, the population norm is 50 with a standard deviation of 10. This linear transformation allows simple comparison of a tested population to the general population. [210]

Performance-Based Assessment Tools

In the context of the models of disablement, there are many performance-based assessment tools distinctly measuring impairments (e.g. muscle strength, muscle power), functional decline (e.g. gait speed, climbing stairs), and disability (e.g. feeding, bed transferring, toileting, using the telephone, socializing, shopping). [51, 98, 134, 165-170, 205, 211, 212]

Essentially, performance-based assessments tools test how well an individual is able execute specific tasks. [213] Generally, these tasks relate to the level of body motions and mobility that are required to accomplish many common daily activities. [213] To quantify these tasks, testers may record the time it takes to perform the task, the weight a person is able to lift, or the a distance he or she is able to move. [134] While self- or proxy-reports appear to rely more on subjective information, performance-based assessments rely more on objective information, as they require individuals to actually perform specific tasks. The level of the physical or physiological functioning is then analyzed, evaluated and determined using standardized criteria. [23, 51, 162, 163, 165, 166, 168, 172, 214, 215]

Testing Muscle Strength

Muscle strength is the amount of force that a muscle can generate during a single maximal effort at a specific movement pattern and at a specified movement velocity. [135, 216] Muscle strength is an important component of fitness, affecting levels of physical performance and health status. [217] The ability of muscles to generate an adequate level of force is central to the successful completion of many normal activities of daily living because each activity requires a certain percentage of muscular capacity. [78] In addition to muscle strength, other factors may impact the ability to carry out daily tasks. Such factors include, but are not limited to, pain, tissue flexibility, joint range of motion, aerobic capacity, vision, balance, choice of strategy, and cognitive ability. [15, 45, 58, 59, 134, 164, 167, 172, 218-223] Although many factors may impact level of function, several studies suggest that independent of other pathologies or diseases, increased muscle fitness in both healthy and disabled older populations improves not only muscle performance per-se but also the ability to walk faster and to carry out other daily tasks such as rising from a chair and carrying a box of groceries. [217, 224-228] As with any other evaluative tool, measuring muscle strength requires the use of standardized, objective, reliable, valid, and sensitive measures. [153, 216, 229] Although some overlap does exist, it is important to remember that measures of muscle strength are usually specific to the muscle group tested, the type of muscle contraction, contraction velocity, testing equipment, and joint range of motion. Muscle strength has been extensively evaluated in both young and old persons using a variety of measurement tools, including manual methods [230-232], exercise machines [153, 216], hand grip dynamometers [233, 234], handheld dynamometers [235], back [236, 237] and leg [238] dynamometers as well as isokinetic dynamometry. [239, 240] Because the ability of the muscle to generate maximal force depends on movement pattern and motion velocity [241], muscle strength can be measured either isometrically or dynamically.

Isometric Muscle Strength

Isometric contraction refers to a situation in which the external resistance is equal to the internal force created by the muscle. Specifically, the muscle is prevented from either shortening or lengthening by fixation of its two ends. Instead of performing external work that would be indicated by movement, the muscle builds its tension at its points of origin and insertion. As a result, the muscle develops force without a resultant joint movement. [135, 216] Isometric testing is considered a reliable type of strength measurement both in older men (ICCs > .84) and women (ICCs > .88). [239, 240] The peak force development is commonly referred the maximal voluntary contraction (MVC). [153, 242]

The external validity of an isometric test of muscle strength is somewhat questionable as the interpretation of the test depends on the joint angle at which the test was conducted and the functional performance which it predicts. [243] Specifically, isometric testing of muscle force requires that the tester consider the effect of muscle length on the ability to produce tension (i.e. length-tension relationship) as muscle force production varies throughout the joint range of motion. [241] The classic length-tension curve has an ascending segment which corresponds to the muscle's inner range. [241] This segment represents an increased ability to produce force as the muscle tissue is elongated. The ascending segment ends in a plateau, corresponding to the muscle's middle range. This is followed by a descending segment (the muscle's outer range) and a final ascending limb at maximal physiological lengths (i.e. elastic component). The initial ascending and descending limbs are attributed to increases and decreases in the overlap of actin and myosin filaments as sarcomeres lengthen, while the final ascending limb is attributed to passive stiffness. [241, 243, 244]

Isometric strength testing at a specific joint angle as a measure of overall muscle strength is somewhat limited. In order to accurately assess overall muscle strength with isometric muscle testing, researchers instead attempt to quantify isometric muscle force production throughout the joint range of motion (ROM) by using multiple measures at different joint angles. [185, 245]

Dynamic Muscle Strength

When tests for muscle strength involve motion, it is the muscles' "dynamic strength" that is being evaluated. [153] Dynamic muscle strength can be tested using different methods including Manual Muscle Testing (MMT), Dynamic Constant External Resistance (DCER) (better known as isotonic), and isokinetic methods. Traditionally, the "gold standard" for dynamic strength testing is the one-repetition maximum (1-RM) which refers to the maximal resistance that can be managed once, moving through full joint range of motion in a controlled manner while maintaining good body posture. [153, 216]

Manual Muscle Testing (MMT)

Briefly, despite well-documented clinical limitations of the procedure [246, 247], MMT has been employed to quantify muscle strength since the early 20th century. [248] Bohannon et al. [230] examined the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of manual muscle testing techniques in an acute rehabilitation unit. Participants' were drawn from a convenience sample of 107 consecutive qualifying rehabilitation inpatients. The main outcome measure was knee extension force, measured by manual muscle testing and handheld dynamometry. The researchers found that manual muscle testing's ability to detect 15%, 20%, 25% and 30% between-side differences and deficits in knee extension force was very limited. Although the specificity of manual muscle testing was acceptable (mostly > 80%), its sensitivity to differences between sides, and to deficits relative to normal function, never exceeded 75%. The authors also reported that the accuracy of the manual muscle testing as a diagnostic tool never exceeded 78%. The researchers therefore concluded that the results of their study cast doubt on the suitability of manual muscle testing as a screening measure for strength impairments in older populations.

Frese et al. [247] conducted a study of the reliability of manual muscle testing in a clinical setting. The researchers used a manual muscle testing protocol to assess inter-rater reliability of manual strength testing of the middle trapezius and gluteus medius muscles. Participants were 110 patients with various diagnoses. Examiners were 11 physical therapists. Inter-rater reliability for the right and left middle trapezius and gluteus medius muscles was low. For the four muscles, just 50% to 60% of examiners agreed or were within one third of a grade in their ratings. Based on these findings, the authors concluded that manual muscle testing is of questionable value in making accurate clinical assessments of patient status.

Despite its apparent limitations, MMT testing is still commonly used by healthcare providers to identify musculoskeletal and neurological impairments related to muscle strength. [230, 249-251] The practice of manual muscle testing basically involves the examiner using the force of gravity and manual pressure to grade muscle strength or weakness. [230, 249-251] Testers generally use five basic grades to report their results. Some clinicians use numeric scale between 0 (weakest) and 5 (strongest) while others use a more "descriptive" scale ranging from ""none" to "normal." The ability to move a part of the body through its full ROM against gravity, with no added resistance would receive a grade of "fair" or "3," which is the middle point of the scale. Above this level, the examiner would add resistance to the force of gravity. Below this level (e.g. 2/5), the examiner would change the angle of the body part to test its strength in a position where the effects of gravity are mitigated.

Dynamic Constant External Resistance (DCER) Muscle Testing

Dynamic Constant External Resistance (DCER) muscle testing is another method used by clinicians including athletic trainers, health and fitness professionals and rehabilitation specialists, to quantify strength level, assess strength imbalances, and evaluate training programs. [153, 242, 252] DCER muscle contraction (better known as isotonic muscle contraction) is commonly defined as a muscle contraction associated with motion, in which the muscle produces constant tension throughout the motion. [216, 244] Based on the length-tension principle, however [241], the muscle is capable of producing constant torque, yet different levels of tension (force) along the joint range of motion. This principle undermines the notion that when resistance is kept constant during dynamic contraction, the muscle will produce constant tension throughout the entire range of motion. Because inertia relates to constant velocity of motion as opposed to constant tension, it makes sense to replace the term "isotonic" (constant tension as muscle length decreases) with "*dynamic constant external resistance*" (constant rate of muscle shortening (concentric muscle contraction) or lengthening eccentric muscle contraction).

The gold standard of assessing DCER strength is by determining one-repetition maximum (1-RM). Expanding on the idea of 1-RM, a multiple repetition maximum can also be used. [153, 216] That is to say, it is possible to predict 1-RM using multiple repetitions.

Isokinetic Muscle Testing

The use of isokinetic dynamometers is the most common method for assessing peak dynamic muscle strength for the purposes of research. Using isokinetic dynamometers, which were initially developed for the purpose of isokinetic testing, a researcher can test both isometric and dynamic muscle strength. Isokinetic testing pertains to the assessment of maximal muscle tension elicited throughout a particular joint's range of motion (ROM) while angular velocity (measured as degrees/second) is held constant, allowing for the control of rotation of the tested joint or joints. [153, 216] Consequently, as the angular velocity is kept constant, the resistance of the dynamometer is equal to the muscular forces applied throughout the tested joint's range of motion, thus overcoming limitations associated with "isotonic" testing. That is, using "isotonic" methods to test for muscle strength, the examiner uses a certain load that can be lifted once. Based on the length-tension curve, the muscle generates different tension along the joint's entire range of motion. Therefore, if the load is constant, the muscle can still produce sufficient torque using less force when the moment arm is longer, or when the overlap between the actin and myosin filaments is optimal. Isokinetic testing on the other hand allows the muscle to develop maximum tension along the joint's range of motion because angular velocity is kept constant, regardless of magnitude of the force.

Reliability and Validity of Dynamic Muscle Testing

The one repetition maximum (1-RM = maximum load/resistance that can be moved once through the full joint's range of motion) is the standard for dynamic strength testing. [153, 216]

Reliability is an indispensable requirement for valid test outcomes. As much as MMT procedures are widely used for clinical purposes, due to the previously addressed reliability issues, the overall applicability of MMT procedures for research purposes is questionable. [230, 251] Because, as the name implies, the test is done manually, there may be a considerable subjective component to the test. In one study, Lawson & Calderon [253] found that inter-rater reliability depends on the muscle being tested. According to authors, inter-rater agreement was strong for the piriformis muscle but very weak for the hamstrings muscle. Knepler & Bohannon [251] reported that examiners differed significantly in the amount of force applied at grades above 3/5, yielding weak inter-rater reliability. Bohannon & Corrigan [232] found that when testing at grade 5/5, the range of the force applied by testers exceeded 560 Newtons (i.e. large variability).

Compared to MMT, the DCER approach to muscle testing is considered a more reliable test of dynamic strength. [153, 216] Therefore, while clinicians continue to use MMT as a convenient means of assessing muscle performance, athletic coaches and fitness experts have been using exercise machines such as leg press, chest press, knee extension machines and even free weights to assess 1-RM. The DCER approach to muscle testing was found to be a safe and reliable way of measuring strength in both young and older populations, especially when preceded by orientation and familiarization sessions. [254, 255]

Biodex Isokinetic Testing Instrument Validity and Reliability

A Biodex isokinetic testing instrument was used in the current study to measure strength. This section provides a discussion of the validity and reliability of isokinetic testing methods. The isokinetic approach to muscle testing involves the assessment of maximal muscle force production throughout the range of particular joint's motion while angular velocity is held constant. [153, 216]

Validity of Isokinetic Testing

The validity of the isokinetic approach to muscle strength testing used in the current study refers to the ability to draw inferences from isokinetic test scores to inform a functional construct. Specifically, the premise of this research is that many older individuals become functionally limited due to loss of muscle strength or power. [5, 38, 58, 256, 257] In turn, this loss of strength or power contributes to impaired mobility, adversely affecting the quality of life of older adults. [110, 167, 258] It is important, therefore, to determine whether isokinetic muscle testing can be used as an evaluative tool to study the relationship between specific components of muscle performance and the ability to perform specific mobility tasks. Cress et al. [134] used the Medical Outcome Study 36-Item Short-Form Health Survey [191] to reflect functional limitations in performing daily tasks in older adults between the ages of 65 and 97. The authors classified people as either "dependent" or "non-dependent." Assessing the isokinetic knee extensor torque (IKET), measured at an angular velocity of 60 degrees per second, the authors found that IKET can predict levels of functional dependence. Brown et al. [259] conducted a study aimed at exploring the relative importance and association of physical contributors to level of frailty, which was classified along a continuum from mild to moderate. To test the strength of the knee extensors and flexors, the researchers used an isokinetic dynamometer. Tests were performed at angular velocities equal to 0, 60, and 120 degrees per second. To test the ankle plantar and dorsiflexors, participants were asked to move the ankle joint at speeds of 0, 60, and 120 degrees per second. Functional capacity (i.e. level of frailty) was measured using the physical performance test (PPT) described by Reuben & Siu. [259-261] The researchers found that isokinetic dynamometry strength measures were significantly related to total PPT score.

Reliability of Measuring Muscle Strength Using Isokinetic Tools

In general, isokinetic testing is considered a safe and reliable way to measure muscle strength for upper extremities [262, 263], lower extremities [264, 265] and trunk [266, 267] Levels of reliability can be influenced by varying factors such as testing protocols, angular velocity, which muscle or muscles are tested, the participant's health condition, and level of tester's and participant's familiarity with the procedure. For example, Flansbjer et al.[268] conducted a study in which the researchers wished to assess the intra-rater (test-retest) reliability of isokinetic knee muscle strength measurements in participants with a diagnosis of chronic post-stroke hemi-paresis. The researchers also wanted to see if the threshold for the smallest change indicating real, clinical improvements for stroke patients could be defined using isokinetic equipment to measure knee muscle performance. Participants were asked to perform bilateral (paretic and non-paretic limbs) maximal concentric knee extension and flexion contractions at 60 degrees and 120 degrees and maximal eccentric knee extension contractions at 60 degrees. Participants were tested on two occasions (7 to 14 days apart) using a Biodex dynamometer. The authors reported that test-retest agreements (reliability) were high (ICC(2,1) 0.89-0.96). Reliability was not systematically affected by the limb that was tested, angular velocities, or the type of muscle action. Symons et al. [239] assessed the reliability of isokinetic and isometric knee-extensor force in older women. This was done by assessing the test-retest reliability of concentric, isometric and eccentric strength, concentric work, and concentric power. The results showed relatively good reliability (ICCs > .88). Based on the results, the researchers recommended the use of averaged values (i.e. best three contractions of five) in combination with a familiarization session.

Lower Extremity Strength Cut-off Values

It appears that although aging is associated with loss of muscle mass, strength, and quality (sarcopenia), the ability to perform daily activities remains intact for many years. [121-123]Moreover, even healthy persons who live later into old age experience substantial functional declines associated with anatomical, physiological, psychological, and mental systems. [121, 126, 148] Some of these systems, such as the neuromuscular system, start to show declines as early as the third decade of life. [131-134] While no longer considered to be at their "normal" or peak performance levels, these systems are nevertheless adaptive enough to allow independent functional status for many more years. This phenomenon may be explained by the fact that just 30% of system capacity is generally considered to be the minimum necessary for adequate function, while any additional capacity above and beyond that level is considered a reserve. Based on the idea of functional reserve, Schwartz [71] divided life-expectancy into four major periods of dynamism and vigor. The first period relates to the time in life when all systems are functioning well above the minimum 30%, up to 100% of their capacities. The reserve can be expended on other, non-critical activities. As functional reserves decline, most of the reserve is used to maintain functioning, leaving little, if any vigor available for other activities. As vigor and dynamism continue to decline, they approach the 30% level, which marks the transition to a state of frailty and dependence. As individuals continue to lose vigor, they finally reach a state of systemic failure leading to complete dependence, hospitalization, institutionalization, and ultimately, death.

Using a specially-designed machine (rig), Bassey et al. [269] were able to reliably measure the leg extensor muscle's "explosive" power output over a period of half a second or less. Performance measurements included timing of chair rising, stair climbing, and walking a distance of 6.1 meters. The researchers found that the leg extensor muscle's power was significantly correlated with performance on each of the tasks. Moreover, they found a tendency for performance on each task to reach a plateau. That is, once a particular cut-off point of minimum power production was reached, performance rose less steeply with increased muscle power. Interestingly, more men than women were on this plateau, leading the authors to suggest that higher safety margins of power exist in men, as compared to women. Along these same lines, Ferrucci et al. [38] showed that the relationship between measures of lower extremities muscular strength and gait, standing balance, and the ability to rise from a chair was indirect. These findings suggest the existence of functionally relevant physiological cut-points. Identifying these cut-points will provide healthcare professionals the opportunity to identify at-risk individuals much sooner, allowing early prevention and treatment. Further, at least in principle, physical mobility disability can be predicted by underlying states of physiological decline rather than by the existence of or the severity of impairments and functional limitations. [23-25, 45, 51, 270]

Cress et al. [134] identified a threshold value of maximal oxygen consumption to be at a level of 20 mL of O2 per kilogram body mass per minute. Below this level, older adults were at higher risk for disability and dependence. In their search for potential determinants of independence in mature women (mean age of 69), Posner et al. [271] found that older women whose Vo_{2peak} was below ≈ 16 mL/kg/min were at higher risk for physical disability. Morey et al. found that, in older adults (65-90 years of age), 18.3 mL of oxygen per kilogram muscle mass per minute was the optimal cut-off point distinguishing between individuals who are highly functional to those who required assistance in the performance of tasks such as doing household chores, negotiating stairs, and walking half a mile. Other studies have found strength cut-off points as well. Cress et al. [134] found that cut-off values identified for knee extension torque (2.5 N x m/(kg x m(-1))), accurately predicted which individuals reported functional limitations. Looking at quadriceps femoris strength in older adults, Ploutz-Snyder et al. [185] found that below 3.0 Nm/kg, individuals' performance on ambulatory tasks (chair rise, gait speed, stair ascent and descent) is compromised. Manini et al. [272] reported two sex-specific knee extension strength cut-off points related to high and low risk of incident severe mobility limitation in older adults. Specifically, high and low risk corresponded to less than 1.13 Newton-meters (Nm)/kg (1st decile) and more than 1.71 Nm/kg (6th decile) in men and less than 1.01 Nm/kg (3rd decile) and more than 1.34 Nm/kg (7th decile) in women, respectively. Moderate risk was defined as being between the low- and high-risk cut-off points. Individuals with knee extension strength in the high- and moderate-risk categories were more likely to have a gait speed less than 1.22 m/s (hazard ratio (HR)=7.00, 95% confidence interval (CI)=5.47-8.96 and HR=2.14 7.00, 95% CI=1.73-2.64, respectively) and had a higher risk of death (HR=1.77, 95% CI=1.41-2.23 and HR=1.51, 95% CI=1.24-1.84, respectively) than individuals in the low-risk category. In their study of the association between leg extension power and maximal walking speed,

Rantanen & Avela [273] found that in their sample of 131 men and women, age 80 to 85, men in general exhibited greater leg extension power than did women and that leg extension power decreased with age. Leg extension power was also found to correlate positively with maximal walking speed in all groups. The correlation coefficients were .412 in men age 80 (n = 41, p = .007), .619 in women of the same age group (n = 56, p < .001), .939 in the 85-year-old men (n = 8, p = .001), and .685 in the 85-year-old women (n = 23, p < .001). The minimum power threshold for those with a maximal walking speed of 1.30-1.49 m/s was on the order of 4 Watts per kg of body mass. A maximal walking speed of 1.50-1.99 m/s required 7 Watts per kg of body mass, and at speeds over 2.00 m/s the power threshold was 9.5 Watts per kg of body mass.

Overall Principle of Lower Limb Support

Lower extremity muscle performance is critical for mobility independence. [274, 275] During mobility tasks, the function of the lower extremities is to resist collapse and to allow sufficient propulsion. [276, 277] The neuromuscular system's ability to produce sufficient joint torque to offset functional declines, which would otherwise lead to mobility disability, is a key component in preventing loss of mobility function. [33, 124, 272, 278-280]

In physics, torque can be defined as the magnitude of a force multiplied by the perpendicular distance (i.e. moment arm) to the axis of rotation. [241] During important mobility tasks such as walking, sit-to-stand tasks, and stair climbing, the highest moments of torque occur in the hip, knee, and ankle joints in the sagittal plane, particularly toward the point of extension. [276, 277, 281-285] Rather than concentrating on one muscle group, Winter [276, 286] and Hof [277] suggested that maintaining mobility against gravity depends on a total limb extensor pattern, which McFayden [287] called the "support moment." The support moment is the algebraic sum of the extensor moments generated in the hip, knee, and ankle joints. [276] To resist collapse and allow progression, the support moment must be positive. Some form of compensatory relationship exists between the hip, knee, and ankle extensors, which creates resistance to collapse and permits the walking motion, or gait. During gait, Winter [276] found that when the hip moment was high, the knee moment was relatively low and vice versa. This type of relationship was observed among all three joints. To further validated these findings, Hof [277] used a model providing the concept of support moment with a mechanical interpretation. While supporting the idea of a compensatory mechanism, Hof argues that the equation should be support moment = 0.5*moment hip + moment knee + 0.5*moment ankle, rather than support moment = moment hip + moment knee + moment ankle. That is, the knee extensors contribute more to the support moment than the ankle or hip. Many mobility tasks require an upright body position, which depends on the total extension pattern, as opposed to the performance of one specific muscle. This, combined with the existence of internal compensatory mechanisms, raises the issue of whether researchers and clinicians should address functionally relevant cut-off points only in terms of independent muscles at all. It makes more sense to assess functional cut-off points in terms of weighted total scores, rather than independent cut-off points alone.

Looking at muscle force and range of motion in the upper and lower extremities, Beissner et al. [99] tested muscle force for hip flexion, knee extension and ankle dorsiflexion. Concerns about the number of tested joints and muscles, and the possibility of high correlations among the force variables, lead the authors to aggregate scores from each section such that there was one variable to represent lower extremity muscle force, for example. Aggregated scores were created by averaging the standardized values.

Beyond statistical considerations, taking into account total scores, as well as the weighed contribution of hip, knee, and ankle extensors to the support moment, can give healthcare professionals better insight into the net effect of all agonist muscle activity at each joint. Indirectly, it can also provide information regarding antagonist activity and neural input at each joint.

Chapter III: Summary of the Literature Review

The number of people living well into old age continues to rise significantly. By the year 2030, it is projected that adults age 65 and older will comprise 20% of the population of the United States[288]. Aging is associated with serious risk for disability. [5, 23, 55, 56, 102, 289] Disability, commonly occurs first in mobility (locomotion) [90, 290], and signifies any [291]difficulty or dependency in carrying out activities essential to independent living[6, 291], such as shopping, socializing, [292] meal preparation, driving, bathing, and dressing[7]. The onset of mobility disability involves a complex interaction between functional limitation and societal influences. The severity of mobility disability depends on the physical environment in which older adults live.[7] That is, mobility disability is the end result of a discrepancy between one's personal abilities and the challenges set forth by the environment. Muscle weakness may increase difficulty with stair climbing to the extent that it limits the places a person is able to go in the community. Minimizing the discrepancy may require changing an individual's personal abilities by, for instance, increasing muscle strength, or manipulating the environment, by for example, adding a railing to the stairs. Exploring the relationship between personal abilities and the ways in which older adults commonly manipulate their physical environment is critical for the design of more specific interventions aimed at preventing mobility disability. Furthermore, better understanding of these relationships could be used to target individuals most likely to benefit from those interventions.

Previous evidence indicates that age-related physical and physiological declines among older persons are dynamic processes, characterized by frequent transitions in states of disability and frailty over time. That these transitions are frequent implies there is ample opportunity for clinicians to compress morbidity and minimize the consequences of mobility disability. Results have shown however, that in older adults, the transitions between different states of disability and frailty are for the most part, unidirectional. This is supported by Hardy et al.[48] who reported that frail persons tend to have higher rates of transition from less to more disability, lower rates of transition from more to less disability, and somewhat longer durations of disability overall.

During 18-month intervals, Gill et al. found that transitions to states of greater frailty were more common (rates up to 43.3%) than transitions to states of lesser frailty (rates up to 23.0%). More importantly, the probability of transitioning from being frail to non-frail was very low (rates, 0% - 0.9%), even over an extended period of time [49]. Together, these findings suggest that rather than focusing on recovering previous function or mitigating the impact of a disability, interventions should address the prevention of functional limitation before it rises to the level of mobility disability.[46] Age-related disability is the end result of a complex interaction between capability (i.e. functional limitations) and the socio-cultural and physical environments [9, 293] Accordingly, accurate assessment of functional limitation or disability should reflect both an individual's functional ability, as well as how that person adjusts to his or her physical environment [293] Many of the tools designed to assess older adults' ability to walk use time (e.g. gait speed) or distance (Six-Minute Walk Test) as proxies for functional assessment.[25, 212, 294-297]

While existing scales perform well and are sensitive to change in large population studies, they provide an accurate estimate of functional mobility only when tasks are performed in standardized settings. Such settings, however, fail to take into consideration the ways in which older adults adjust to the socio-cultural and physical environments in which they live. In a study of urban adults, age 65 and older, who self-reported difficulty in crossing busy intersections on foot, Langlois et al.[298] found that the minimal gait speed required to cross safely was 1.22 meters per second. This measure was obtained on a standardized, indoor course, 2.4 meters long. Testing gait speed in a laboratory setting, however, fails to take into account environmental factors, such as the length of the crossing-signal, noise, traffic, or lighting, all of which may impact the speed and manner in which older adults cross a busy street in real-life situations.

The goal of the current study is to assess functional mobility and uncover the ways in which alternative strategies (i.e. daily task modifications) employed by older adults allow them to continue to live successfully in their own adaptable physical environments.

Prior research suggests that older adults who modify daily tasks are at increased risk for future mobility disability.[14, 45, 46, 92] For the most part, these studies rely on self-report, rather than on observed assessment by a trained examiner. Self-report measures may be subjected to differences in personal perception and interpretation of functional limitation or disability. It may also be the case that older adults do not admit to changes in ability out of fear that a loss of function may force them to leave their home. Generally, older adults report functional problems only when they perceive an acute change in their ability to perform a task, or when they can no longer tolerate the functional decline. [90, 299] In a study by Fried et al.[14] the authors gave an example of a 75-year-old woman who reported "no difficulty" with "walking around the home." Upon further evaluation, the woman stated that she walked around the home using furniture for support. The woman also reported that in the last two to three years she did less walking around the home. This demonstrates the extent to which these self-report studies are limited by an individual's perception. From a clinical perspective, by the time older adults recognize and are willing to disclose functional limitations and disability, they may have already transitioned from mild or moderate mobility difficulty, when treatment is most beneficial, to a state of clinical disability. At this stage, the prognosis is relatively poor. [14, 48, 49]

The current study, therefore, employed a direct observation scale that objectively quantified varying degrees of daily task modifications among older adults.[50] The goal here was to identify independent-living older adults who were beginning to rely on task modification to maintain their independence. These individuals were chosen rather than a high risk group, because they could be targeted for intervention in a pre-clinical state of disability, possibly leading to more favorable treatment outcomes.

Current evidence suggests that muscle weakness is associated with age-related mobility decline [99, 275, 278, 300] In many studies, measures of muscle strength are limited to either isometric or isokinetic testing, primarily of knee extension strength. [50, 134, 185, 272, 301, 302, 302] Others have measured strength at different levels along the lower extremity, but have treated each measure as an independent factor contributing to mobility. [99, 278, 300] This approach may have provided limited information about strength capacities of the entire lower extremity and the way muscles of the lower extremity interact with each other. [276, 277] In the current study, peak strength outputs from the hip and knee extensors and the ankle plantar flexors were measured. Thereafter, a composite measure of net normalized force production in the sagittal plane was calculated from these individual measures. A review of the literature reveals that this is the first study measuring both isometric and isokinetic lower extremity muscle strength using the same population.

Chapter IV: Data Analysis

The summary task modification score (MOD) has an intrinsic meaning. That is, a higher score equals more modifications (i.e. more adaptation to the environment). The study's planned design called for a dichotomization of the summary task modification scores, such that participants were categorized as either "task-modifiers" or "non-task-modifiers." While this approach does not take into account the "severity" of task modification, it does provide the most clinically interpretable results, which are better suited for implementation in the reality of a busy clinical practice. Indeed, from both the clinical and practical perspectives, the identification of task modification and pre-clinical disability bio-markers is useful only to the extent that they can be used to improve interventions and clinically relevant outcomes, which in turn may increase patient satisfaction and decrease healthcare costs. The dichotomization of the variable was chosen in the design of this study as the most effective strategy for conveying the results in a manner conducive to that end.

The aforementioned a priori decision required the selection of an MOD score that would optimally diagnose true "task-modifiers." In a study by Cress et al.[134], the authors identified the cut-off points of lower extremity (i.e. knee extension) maximal voluntary performance associated with the performance of ordinary daily functions (for more details about the specific functions see Cress et al., 1996 [134]). Subsequently, the authors conducted a logistic regression analysis to illustrate the relationship between the strength measures and level of functional independence. To form the two groups of "physically independent" versus "physically dependent" individuals, the researchers used a score of 65 on the physical function domain of the Short-Survey Health Questionnaire [303] when clinicians and researchers are assessing the presence or absence of a medical condition (e.g. task-modification versus non-task-modification)[303] Logistic regression analysis yields exponents of the regression coefficients, in this paper presented as Exp(B), from which odds ratios can be estimated. It is, in essence, a measure of effect size, describing the strength of the association between the independent variable and the study's dependent variable.

Ideally, when using any form of regression analysis, the independent variables should be each highly correlated with the dependent variable, yet independent from each other. In planning the study, it was anticipated that the isometric and isokinetic NETforces would be highly correlated and non-independent from each other. Using two highly correlated independent variables in a regression analysis may render near-zero effect sizes when, in fact, the independent variables are significantly associated with the dependent variable.

This potentially problematic situation, where two highly correlated independent variables are used in one particular regression model, is termed multicollinearity. To reduce the risk of multicollinearity, two separate logistic regression models were created with either the isometric or isokinetic NETforces as the independent variable.

One of the main aims of this study was to determine the direction of the relationship between lower extremity muscle strength and daily task modifications in older adults living independently. Specifically, a potential causal relationship between leg strength and task modification among older adults living independently was sought.

At the same time, in a study of association, it is understood that causality cannot easily be established, because other confounding factors may contribute to the relationship being observed. On the other hand, it may also be that these confounding factors actually obscure the relationship between the independent and the dependent variables. Previous studies showed that other confounding factors may contribute to age-related functional decline. Accordingly, in addition to computation of odds ratios, using either the isometric or isokinetic strength measures as the sole independent variable in a bivariate logistic analysis, a multivariate analysis adjusting for age, sex, body mass index (BMI), number of reported medical conditions, the physical function domain of the Short-Survey Health Questionnaire (PFSF-36v2) score, and the Mini Mental State Examination score was also performed.

In the area of medicine, a cut-off point draws a line between "healthy" and "ill." Based on the distribution characteristics of the samples of task-modifiers and non-task-modifiers, calculation of the strength cut-off point involves statistically determining the point where the fewest misclassifications could be expected.

To explore the idea that lower extremity strength cut-off point is associated with increased risk for task modification of commonly observed daily activities among older adults, first the MOD score of ≥ 5 was again used as the criterion to differentiate between the task-modifier (i.e. MOD ≥ 5) and the non-task-modifier (i.e. MOD < 5) subgroups. Similar to previously reported studies[300], a *discriminant analysis* was conducted separately for the isometric and isokinetic NETforces as the independent variables, with the MOD score as the dependent variable. A *discriminant* analysis builds a predictive model for group membership. Similar to ordinal linear regression models, the *discriminant* analysis model is composed of a *discriminant* function based on linear combinations of the predictor variable or variables that provide the best discrimination between the groups. As opposed to ordinal linear regression models where the dependent variable is continuous, in the *discriminant* model, the dependent variable is categorical, and hence, may be used for a binary classification test.

Being a binary classification test, the *discriminant* analysis yields cut-off points that balance sensitivity and specificity. In the area of medical practice, the sensitivity of a diagnostic test indicates the proportion of true positive cases that can be identified by the test. Specificity measures the proportion of true negatives that can be identified by a diagnostic test. An ideal test would render a sensitivity = 1, and a specificity = 1.

A receiver operating characteristic (ROC curve) is simply a graphical plot of the sensitivity (proportion of true positive cases) versus 1-specificity (proportion of false positive cases). The area under the curve measures discrimination, that is, the ability of the test (i.e. leg strength cut-off points) to correctly classify those who are task-modifiers versus those who are not. Hence, for the purpose of this study, ROC curve analysis provided tools to select the actual strength measures of isometric and isokinetic NETforces cut-off values (i.e. N*m/KgBW) that would best discriminate between task-modifiers and non-task-modifiers.

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Chapter V: Lower Extremity Force Decrements Identify Task Modifications among Community Dwelling Older Adults

Abstract

B*ackground*: Age-related loss of muscle strength (impairments) leads to higher risk for functional limitations and subsequent clinical mobility disability. Clinical mobility disability is associated with difficulty or dependency in daily tasks essential to independent living, as well as with poor prognosis, hospitalization, and mortality. Prevention of age-related clinical mobility disability requires a better understanding of the history prior to the onset of mobility disability. Despite reporting physical independence, many older adults modify the performance of specific daily tasks. Regardless of level of physical independence, need to modify daily tasks is a major symptom of pre-clinical disability. Pre-clinical disability is a temporary stage that strongly predicts the onset of clinical mobility disability. Recognizing and preventing the need to modify daily tasks among older adults requires the identification of associated physiologic "bio-markers" which would provide clinical insight into the basis of such a condition allowing clinicians to develop targeted screening and interventions. The premise of this field-initiated research paper is that, regardless of self-reported level of independence, a simple measure of leg strength can be used to discriminate between older adults who modify daily tasks and those who do not.

A*ims*: The primary aim of this dissertation was to examine whether measures of leg strength are clinically relevant bio-markers of daily task modifications among community dwelling older adults living independently. Accordingly, the current study has two specific aims: a) examine the influence of peak isometric and isokinetic leg strength on

daily task modifications in older adults living independently in the community, and b) to identify levels of isometric and isokinetic lower extremity strength cut-off points that can be used to optimally predict task-modification vs. non-task-modification group membership. It was hypothesized that mean lower extremity strength measures would be significantly decreased in older adults who modify daily tasks compared to those who do not and that decreased lower extremity strength measure would significantly predict task modifications among older adults living independently in the community. Lastly, a cut-off point of leg peak isometric and isokinetic strength corrected for body weight would correspond to high and low risk of task modification classification in a group of independently living older adults.

Design: cross-sectional observational study

P*articipants*: Fifty-three (40% males) older adults (76.4±5.2 years) who reported that they were living independently in the community.

M*easurements*: Bilateral hip and knee extensors and ankle plantar flexors isometric and isokinetic (at 60 degrees per second) peak strength relative to body weight were obtained. Participants were observed performing a chair rise (sittings heights: 43 cm, 38 cm, and 30 cm), stair ascent/descent, and kneel and supine rise tasks. Five hierarchically ranked categories (0 - 4) of daily task modifications were created for each task and then summed across tasks (summary modification score, MOD, ranging from 0 - 40). A score of ≥ 5 points on the MOD was set as the criterion for the dichotomized outcome variable, i.e. daily task-modifiers (TM) versus non-task-modifiers (NTM).

D*ata *A*nalysis*: Two separate independent t-tests were used to compare groups (TM versus NTM) according to the dependent measures of isometric and isokinetic peak leg strength. Two separate multivariate logistic regression (LR) analyses (controlling for age, sex, body mass index, self reported level of mobility, and cognitive screening score) were used to identify the association between peak isometric (LR model 1) and isokinetic (LR model 2) leg strength and task modification classification. Two separate *discriminant* [300]analyses, each followed by ROC curve analysis, were conducted to identify lower extremity strength cut-off points most predictive of task modification classification (i.e. TM versus NTM).

R*esults*: High risk of task modification classification corresponded to less than 4.24 Newton-meters/Kilogram body weight (N*m/KgBW) and less than 2.77 (N*m/KgBW) of peak isometric and isokinetic leg strength, respectively. Compared to NTM, persons in the TM group exhibited 30% and 33.5% reduction in lower extremity isometric and isokinetic peak leg strength, respectively. Independent of any of the confounding variables used in the multivariate LR (model 1), with every unit (1 N*m/KgBW) increase in peak isometric strength, the odds that older adults would be classified as task-modifiers were significantly lower (OR = 3.70, Exp(B) = 0.27, 95% CI = 0.09, 0.79*).* In contrast, peak isokinetic strength was not a significant predictor of task modification in the multivariate LR model 2 (OR = 3.23, Exp(B) = 0.31, 95% CI = 0.09, 1.04*).*

Limitations: First**,** while analyzing strength from hip and knee extensors, and ankle plantar flexors is important, there are other muscles in the legs contributing to mobility. Second, the research design was cross-sectional and thus it is not possible to conclusively demonstrate causal relationships. Third, this study employed a modest yet adequate sample size that may limit generalization of the results.

C*onclusions*: Measures of isometric and isokinetic leg strength provide easily field-tested bio-markers to identify community dwelling older adults who are at high risk for modifying daily tasks to maintain mobility independence. Either isometric or isokinetic

peak leg strength may be used to identify independently living older adults who are at high risk for task modifications. In our study population, the isometric leg strength was a more robust predictor of task modification after controlling for individual characteristics (e.g., age, sex, BMI, etc.).

Key words: Aging, Muscle Weakness, Preventive Health Services, Signs and Symptoms

Introduction

Mobility Disability is a common medical condition among older adults.[6] About 27% of adults ages 65 to 74 and 48% adults ages 75 and older living in the United States report at least one mobility difficulty (e.g. walking quarter of a mile, climbing 10 steps without resting, standing for two hours without resting, or lifting 10 pounds).[304] A diagnosis of mobility disability depends on the physical environment within which disability occurs. [7] Mobility disability is the end result of a discrepancy between one's personal abilities and the challenges set forth by the environment. For example, muscle weakness may increase the difficulty of stair climbing, limiting the places in the community a person is able to go. Reducing the discrepancy may require changing ones personal abilities, such as increasing muscle strength, or manipulating the environment, such as adding a railing to the stairs. Exploring the relationships between personal abilities and the ways older adults commonly manipulate their physical environment is important to help design more specific interventions aimed at minimizing the discrepancy, and to target individuals most likely to benefit from those interventions.

Offsetting age-related mobility disability has been linked to ability to produce a sufficient quantity of lower extremity muscle force.[305] [33, 124, 28034] Lower extremity muscle weakness is associated with reduced ability to perform functional tasks such as stooping, crouching, kneeling, rising from a chair, negotiating stairs, or walking at an appropriate speed.[185, 272, 278] Aging is associated with a progressive loss of muscle mass (sarcopenia)[31, 306], and strength (dynapenia). [34, 36] Loss of muscle mass and strength is a strong predictor of functional limitations, mobility disability, and mortality. Previous examination of the relationship between muscle function and mobility in older adults suggests that these relationships become more robust towards the lower end of the strength range. [39, 273134, 307] Specifically, there appears to be a strong linear relationship between the muscle function and mobility only at the lower end of the mobility spectrum while beyond this point, the association appears considerably weaker.[38, 39, 134, 273] Departure from linearity implies a minimal level of lower extremity muscle strength (i.e. strength cut-off point) needed to successfully perform essential mobility tasks.[185, 300]

Clinically, strength cut-off points suggest that improving strength above the minimum is not automatically associated with improved mobility.[38, 39, 273] Rather, it appears that improving strength above the cut-off points may contribute to physical and physiological reserve. [38, 39, 273] In the context of the models of disablement[9], functional reserves may help explain the commonly observed disconnect between the extent of change in physical and physiological performance and functional status, especially in high functioning individuals. [40, 41, 42-44]

In turn, Schwartz [40] proposed that declining mobility performance in old age is associated with multiple sub-clinical "functional status breakpoints" embedded along the pathway to complete mobility disability. Multiple sub-clinical "functional status breakpoints" may actually explain the observed trend towards the upper end of the mobility spectrum. Specifically, multiple sub-clinical "functional status breakpoints" suggest multiple key impact points where changes in physical or physiological performance may be more directly related to functional improvements [41] offering more opportunities for detection of mobility decline and interventions.

One possible "functional status breakpoint" may relate to the increased need to modify tasks of daily living among apparently healthy older adults. Specifically, to maintain independence, many older adults modify the way they carry out daily tasks. These modifications may include walking slower, relying on the handrail to climb the stairs, or on the armrest to rise from a chair. [50, 90] Between 30 to 40% of older adults observed to modify tasks of daily living self-report no mobility disability.[30, 84, 6] This transitional stage of "task-modification" is a key symptom of pre-clinical disability condition [14, 46, 92] and is a consistent, strong predictor of subsequent development of outright mobility limitations and frank disability. [14, 23, 45, 46, 92] Although the idea of a diagnosis of pre-clinical disability has been well established, there is little objective information regarding physiologic symptoms associated with this condition. Identifying lower extremity strength deficits and strength cut-off points associated with task modifications will help establish a criterion for clinical dynapenia and early onset of mobility declines.

Many studies use isokinetic tools to establish lower extremity strength cut-off points. [134, 185, 272, 278] Such a tool (e.g. Biodex) is able to measure both isometric and isokinetic strength outputs. Unfortunately, these tools are fairly complicated, expensive and not portable. Others have used handheld dynamometer (HDD) [300] HDDs are fairly easy to use, inexpensive and portable, but are limited to isometric testing only. Ultimately, identifying strength cut-off points associated with any mobility task is clinically useful only to the extent that this information can be easily obtained by clinicians within the realities of busy, diversified clinical settings. If clinicians are to use portable equipment to measure lower extremity muscle strength in older adults, the first step is to compare the relative diagnostic accuracy of isometric versus isokinetic strength cut-off points.

The primary aims of this study were to examine differences across participants who do, and do not modify daily tasks in their lower extremity muscle strength in the sagittal plane (NETforce), and to identify functionally relevant isometric and isokinetic cut-off points of NETforces below which daily task modifications are more prevalent. Accordingly, three specific hypotheses were tested. First, lower extremity isometric and isokinetic NETforces would be significantly decreased within the TM group. Second, there will be a significant and strong association between lower extremity strength measures daily task modifications. Third, in a population of community dwelling older adults living independently, specific isometric and isokinetic lower extremity strength cut-off points could each provide an independent and accurate functionally relevant indicators of high and low risk of need to modify daily tasks. The results may help clinicians decide whether they should consider using simple, portable tools to test lower extremity muscle strength to classify persons who may experience loss of mobility even before they self-report it.

Methods

Sample Selection

The planned sample for the current study was men and women, age 65 and older, recruited from the greater Syracuse area. A minimum age of 65 was selected because it has been previously used to divide between relatively young and older populations in similar studies [13, 45, 55] and also because physical and physiological changes affecting function become more clinically meaningful during the sixth and seventh decades of life. [309, 310]

Volunteers were recruited by word of mouth and with flyers distributed at synagogues, churches, community centers, and fitness programs for older adults. In designing this cross-sectional study, the intent was to recruit study participants in a manner that would minimize the risk of recruiting a sample that was not, in fact, representative of the population. First, it was determined that older adults who reported mobility difficulties, yet lived independently, were more likely to use task modifications to maintain functional independence. Accordingly, a recruitment method similar to that of a case-control study was used. A true case-control design is an observational design in which study participants are selected on the basis of the presence or absence of a specific outcome variable. It was important, therefore, that for the purpose of this study, participants came from the same (or a similar) background and that the final selected study population included "cases" (high risk for task modifications) and "non-cases" (low risk for task modifications). Second, participants were enrolled only if they reported living independently in their own residence. Third, to maximize the prediction of task modifications and, hence, ensure a sufficient number of "cases" in the study population, a short self-report survey pertaining to physical status (PFSF-36V2) was administered pre-enrollment.

To achieve these recruitment goals, a short telephone or face-to-face interview was first conducted with persons expressing an interest in participating in the study. The purpose of this short oral interview was to make sure that 1) potential participants lived independently in their own residence, 2) they could understand and speak basic English, 3) they were not diagnosed with any uncontrolled orthopedic, cardiovascular, or pulmonary impairment (e.g. restrictions in weight bearing, unhealed fracture, chronic obstructive pulmonary disease), neurological or cognitive diseases (e.g. multiple sclerosis, Parkinson's disease, Alzheimer's disease), and did not have other physical/physiological impairments (e.g. blindness) that could possibly interfere with participation.

Following the initial oral interview, potential participants were invited to a familiarization session. At this session, baseline information on age, gender, height, weight, chronic diseases (Appendix B), mental status (Appendix C), and self-reported functional limitations (Appendix D) was collected. Subsequent planned data analyses would control for these variables.

Baseline information on age and gender was collected because, in general, aging is associated with increased number of chronic conditions, including sarcopenia (loss of muscle mass), and dynapenya (lose of muscle strength) which, in turn, contribute to functional decline. [2, 36, 79, 128, 311] Furthermore, previous evidence showed that in cognitively intact older adults age 85 and older, increasing age was the only significant explanatory variable for moderate, severe, or total disability and for problems with instrumental activities of daily living (e.g. walking or shopping) or activities of daily living (showering, shopping, or preparing meals) [4] Previous evidence also showed that age-related physical and physiological changes may be gender-specific. Among older adults, women are considered to be at higher risk than men for falls [312] In their study, Lindle et al. [313] reported that, in older women, age accounted for less of the variance in peak strength compared to men, and that women tend to preserve muscle quality better with age than men.

Baseline information on height and weight was also collected so that body mass index (BMI) could be calculated. BMI provides a reliable indicator of body size for most people and is used to screen for weight categories that may lead to health problems [314-316], and functional limitations. [317] Specifically, evidence suggests that higher BMI increases the risk for mobility disability in women age 65 and older . [318] In adults between 30 and 74 years of age, higher BMI is also associated with greater risk of death from any cause, and specifically from cardiovascular diseases. [319]

All participants completed a health questionnaire (Appendix B) and the Mini Mental State Exam (MMSE) [320] (Appendix C). These assessments were included because evidence shows that chronic diseases and the cognitive decline associated with aging are significant explanatory variables for functional limitations and disabilities in older adults. [78, 153] and others [321, 322] for participation in both preventive and rehabilitative resistance exercise programs. The health questionnaire was modified for use with an older population and was reviewed and approved by a gerontologist from the State University of New York, Upstate Medical University. Furthermore, completed health questionnaires were sent to a gerontologist from Upstate Medical University for review to ensure that prospective study participants could safely participate in the study.

In planning the study, the cognitive decline associated with aging was identified as a possible confound. [15, 221] Specifically, among older persons, cognitive decline has been found to adversely affect age-related mobility disability. [15, 221] Study, participants were asked to complete the Mini Mental State Exam (MMSE)[320] (Appendix C). The MMSE has been used to identify cognitive status as well as changes in level of cognition over time. [15, 221] It has been validated as a screening test for cognitive loss among older adults participating in rehabilitation programs. The MMSE has a maximum score of 30. For the purpose of this study, a score of 20/30 was adopted as the inclusion criterion following the guidelines set for by Folstein et al. for the classification of moderate cognitive impairment. [320, 323, 324]

Many older adults who show signs of declining mobility report no task difficulty. In a convenience sample of 231 adults ages 59 to 90 years, Fried et al.[308] showed that up to 33% of the study participants who demonstrated task modifications self-report no mobility difficulty whatsoever.

Wolinsky et al.[46] observed a population-based sample of 998 urban-dwelling African Americans performing tasks such as walking half a mile, climbing steps, stooping-crouching-kneeling, lifting and carrying 10 lbs., and doing heavy housework. The authors found that of the participants who were observed modifying a task, between 23% and 40% (depending on the task in question) reported no task difficulty.

Accordingly, baseline information of self-reported functional limitations was collected using participant responses to the Medical Outcomes Study 36-Item Short Form Health Survey Version 2, Physical Function Scale (PFSF-36v2). [191] The global aim of this project was to examine measures of lower extremity muscle strength as clinically relevant bio-markers of daily task modifications among apparently independent older adults. In summary, in an attempt to be as inclusive as possible for generalization of the results, participants were excluded from the study only if:

- They were under age 65.
- They did not understand or speak basic English.
- They reported, or were found to have uncontrolled orthopedic, cardiovascular, pulmonary neurological, or cognitive diseases as identified by the oral interview and the health questionnaire.
- They had other health problems that could potentially interfere with their ability to perform mobility tasks (e.g. blindness), or strength testing (e.g. skin ulcers on the shin)
- They scored 19/30 or below on the Mini-Mental State Examination (MMSE) test.[320, 323, 324]

Study Design (See appendix D for a Schematic Representation):

Prospective participants were scheduled for a familiarization session at the Institute for Human Performance (IHP) in Syracuse, NY. During this familiarization session, volunteers were asked to read and sign an informed consent form. In addition to collecting baseline information (as was described previously in the "sample selection" section), the familiarization session also served to ensure that potential participants were indeed able to perform the functional tasks associated with the MOD. At this session, potential participants were also introduced to the Biodex machine, practicing both isometric and isokinetic testing procedures. This familiarization session was included because previous studies have shown that the validity and reliability of physical and functional testing can be increased by incorporating an instructional session into the study design. [325, 326]

In an attempt to control for training effect, the second visit to the laboratory at the IHP was scheduled no fewer than three days following the familiarization session. A counterbalanced model for the order in which participants performed the functional and muscle strength performance testing was used in an attempt to control for order effects. That is, if the first participant was tested on his or her ability to perform the mobility tasks followed by the strength testing, then the next participant would undergo strength testing followed by the functional testing, and so on.

Instrumentation

Observing task modifications.

Participants were observed performing eight (8) different everyday mobility tasks (Appendix E). Specifically, participants were asked to perform a chair rise from three different sitting heights (30 cm, 38 cm, and 43 cm), to ascend and descend 14 stairs (stair height = 6 inches), to stand up from left and right kneeling position and to stand up from a supine position on the floor. Modifications during these tasks were assessed using a previously described tool (i.e. summary modifications score (MOD). [1]) The MOD showed excellent reliability and within-participant repeatability (Spearman rank and ICCs > .90).

Chair rise.

Participants were asked to perform the sit-to-stand (STS) task from three different chairs of different heights (i.e. seat pan heights ≈ 16.9 inch (≈ 43 cm), ≈ 14.9 inch (≈ 38 cm) and ≈ 11.8 inch (≈ 30 cm). [50]) Participants were seated with feet flat on the floor, about hips' width apart, with their heels against a piece of wood directly in line with the edge of the seat pan. Arms were crossed and held against the chest.

Participants were given the following directions: "When I lower my arm and say 'GO,' please stand up from the chair as quickly as you can without using your hands. Once in a standing position please continue to hold the position until I say 'DONE.'" If participants were unable to complete the activity with arms crossed, then directions were: "When I lower my arm and say 'GO,' please stand up from the chair as quickly as you can. You may now use your arms or hands to push yourself up. Once in a standing position please continue to hold the position until I say 'DONE.'"

Stair climbing.

Participants were observed walking up and down one flight of standard stairs (14 steps, step height = 19 cm). The directions for this task were as follows: "This flight of stairs has 14 stairs. When I say 'GO,' please go up/down the stairs as fast as you can. Try not to use your hands for external support." For participants unable to complete the task without support, the modified directions were: "This flight of stairs has 14 stairs. When I say 'GO,' please go up/down the stairs as fast and as safely as possible. If needed, use your hands on the rails."

Rise from kneeling (both sides).

This task was performed from a half-kneeling position with the hip and knee joints at ≈ 90º of flexion. With a chair placed in front of them, participants were instructed to initiate standing while placing their hands across their chest. Participants were then given these directions: "When I lower my arm and say 'GO', rise to a standing position." For participants who could not complete this task as initially instructed, the modified directions were: "When I lower my arm and say 'GO' rise to a standing position. You may use your hands and the chair to push up."

Supine rise.

In a supine position with a chair placed 90 to 100 centimeters away from them, participants were given the following directions: "When I lower my arm and say 'GO', rise to a standing position." The modified directions for this task were: "When I lower my arm and say 'GO', rise to a standing position. You may use the chair as needed."

Treating the Summary Modifications Score (MOD)

A summary task modification score (MOD) was calculated such that a higher MOD score represented a higher level of observed task modification (Appendix F). To calculate a MOD score, each one of the eight tasks was attributed a score between 0 (no modification) and 5 (refusal) (Appendix F). Scores were then summed across tasks to create a summary of task modification score (i.e. the MOD), with a range of 0 to 40.

Measuring Lower Extremity Muscle Strength

Lower extremity strength measures were obtained using an isokinetic dynamometer (Biodex, System 3 Pro, Biodex Medical Systems, Inc., Shirley, NY, USA.). Briefly, an isokinetic muscle contraction is obtained by using special training equipment that increases the resistance as it senses that the muscle contraction is increasing. Therefore, the muscle contracts and shortens at a controlled, constant rate of speed (angular velocity). For the purpose of this paper, lower extremities muscle strength was measured at angular velocities of 0° per second (later referred to as an isometric muscle contraction) and 60° per second i.e. (latter referred to as an isokinetic muscle contraction). Peak isometric and isokinetic measures of muscle strength were obtained from the left and right hip and knee extensors, and ankle plantar flexors.

Hip extensors.

Testing of the hip extensors was performed in the supine position.[327-331] The ipsilateral greater trochanter was palpated so the axis of the dynamometer was aligned with the greater trochanter.[329] The pelvis (at the level of iliac crest) was stabilized with straps and a pad. The lower border of the thigh cuff connected to the lever arm was placed just proximal to the lateral femoral condyle. The isometric strength measures were taken at 10º, 60º, and 95º of hip joint flexion range of motion (ROM).

Knee extensors.

Testing of the knee extensors was performed in the sitting position with the thigh held steady to the sitting surface by a stabilizing strap.[332, 333] Ipsilateral hip joint was positioned at an angle 110º of flexion. The axis of rotation of the dynamometer was aligned with the knee joint.[334] The thigh of the ipsilateral limb was held steady to the sitting surface by a stabilizing strap. The isometric strength measures were taken at 10º, 60º, and 110º of knee joint flexion ROM.

Ankle plantar-flexion.

Testing of the ankle plantar flexors was performed in the semi-reclining position with the knee joint of the tested limb stabilized at 30º of flexion. The axis of rotation of the dynamometer was aligned with the ipsilateral talocrural joint. The isometric strength measures were taken at -30º, 0º, and 5º degrees of ankle joint dorsi-flexion ROM.

Calculating a Composite Measure of Lower Extremity Muscle Strength

Peak strength measures obtained at 95º of hip joint flexion, 60º of knee joint extension, and 5º of ankle joint dorsiflexion were considered for subsequent data analyses because these peak strengths yielded the highest strength output and were highly correlated with the total MOD score. Peak strength measures obtained at an angular velocity equal to 60º per second from hip and knee extensors, and ankle plantar flexors, were considered for subsequent data analyses. Five trials were allowed to produce the highest raw isometric and isokinetic strength outputs (Newton-meter; Nm) for each muscle group from each limb. Next, combined peak strength was generated separately for each level by calculating the mean peak output from the right and left sides. For example, once isometric and isokinetic measures of strength were obtained from the left and right hip extensors, the combined mean peak strength for the hip extensors was calculated such that mean peak hip output = (peak left hip extensors + peak right hip extensors)/2. Then both raw isometric strength-to-body-weight ratios and raw isokinetic strength-to-body-weight ratios were calculated. Lastly, a net anti-gravity composite measure of isometric and isokinetic lower extremity muscle force production in the sagittal plane (NETforce) was calculated by summing the peak strength to weight ratios (Newton*meter per kilogram body weight (N*m/KgBW)) from the three muscle groups.

In summary, the calculated composite measures of lower extremity muscle strength for each muscle group were as follows:

- Calculating right and left raw peak strength output from hip and knee extensors, and ankle plantar flexors.
- Rawhip = (right raw hip + left raw hip)/2, Rawknee = (right raw knee + left raw knee)/2, Rawankle = (right raw ankle + left raw ankle)/2.

  - Composite peak raw strength = (Rawhip + Rawknee + Rawankle).
- Strength to weight ratios = composite peak raw strength/body weight.

Data Analysis

All data analyses were performed using SPSS (version 18; SPSS Inc., Chicago, IL, USA). A *p*-value of less than 0.05 was considered statistically significant.
The principle aim of this study was to determine a clinical strength cut-off point for both isometric and isokinetic strength to predict likelihood of task modification in elderly adults living independently in the community. In order to determine the best cut-off point for each strength index, three analyses were used: (a) logistic regression (both bivariate and multivariate), (b) *discriminant* function analysis, and (c) ROC curve analysis. The logistic regression analyses were used to determine the predictive power of each strength index alone (i.e., bivariate analysis) and when controlling for relevant biological and psychological covariates (i.e., multivariate analysis). The logistic regression analyses also provided a probability of task modification needs curve from each strength index. The *discriminan*t function analysis provided a sensitivity and specificity balance point of each strength index in predicting task modification. This balance point was the unit along the strength scale that maximized both sensitivity and specificity of the assessment tool. Finally, the ROC curve analysis provided a continuous measure of sensitivity and specificity aligned with continuous strength to improve the clinical utility of the study results. With a continuous scale clinicians can tailor the strength cut-off point to the needs of their specific populations.

In addition to the primary aim of determining a clinical strength cut-off point it was hypothesized that mean lower extremity strength measures would be significantly lower in older adult task-modifiers. This hypothesis was tested using a one-tailed independent samples t-test. Further, it was hypothesized that lower strength would predict increased probability of task modification. The previously described logistic regression analyses were used to test this hypothesis. Comparisons of means between the Task-Modifiers (TM) and the Non-Task-Modifiers (NTM) in terms of age, body mass index (BMI), Mini Mental State Examination (MMSE), the PFSF-36v2 scores, and the isometric and isokinetic NETforces were performed using Student's independent t-test. A chi-square test of independence was performed to examine the relation between non-parametric variables such as sex and the number of reported medical conditions and task modifications.

Results

Participant Characteristics and Strength Measures:

Data for this study was collected from 53 community dwelling, Caucasian, older adults, age 65 years or older. As a group, they averaged 76.3 years of age (SD = 5.2 years, range 66-89). Of the 53 participants, 39.6% (n = 21) were males (77.0 ± SD = 5.2 years of age). By comparison, females comprised 60.4% (n = 32) of the sample (75.9 years ± SD = 5.3 years of age).

Table 1a provides additional descriptive statistics for each group (i.e., TM versus NTM) on all study variables. Table 1b provides the results of a series of independent samples t-tests examining mean differences between the TM and NTM groups on both primary strength variables and relevant covariates. Collectively, these results indicate that the TM group is older, self-reported more physical difficulty, and generated lower peak leg isometric and isokinetic strength compared to the NTM group. However, the two groups are equivalent with regard to BMI, and cognitive ability. Table 1a also presents a chi-squared analysis of the number of medical conditions across task modifications groups. Results indicate that the group of task-modifiers does not differ from the group of the non-task-modifiers groups on number of medical conditions.

Table 2 presents bivariate correlations among all study variables and a continuous measure of task modification. As previously mentioned, the lack of correlation between the Mini Mental State Exam and all other study variables is particularly noteworthy. This lack of association was most likely a result of a ceiling effect, with most participants scoring at the top of the scale. With the exception of sex, all covariates correlated significantly with both isometric and isokinetic leg strength and the continuous measure of task modification. Sex did not correlate significantly with the continuous task modification measure but did correlate with both strength indices.

Peak Leg Strength as Predicator of Task Modification in Community dwelling Older Adults:

Tables 3a – 3d present the results from the bivariate and multivariate logistic regression analyses. In the bivariate analyses (i.e., Tables 3a & 3c) both isometric (Exp(B) = 0.302; 95% CI: .156, .585) and isokinetic (Exp(B) = .251; 95% CI: .113, .557) strength predict task modification group membership. Interpretation of these results indicates that a one unit increase in leg isometric strength is associated with a 3.31 folds decreased likelihood (OR: 1/0.302 = 3.31) of being in the TM group, and that a one unit increase in isokinetic strength is associated with a 3.98 folds decreased likelihood (OR: 1/0.251 = 3.98) of being in the TM group. The multivariate analyses (i.e., Tables 3b & 3d) suggest that isometric strength predicts TM group membership over and above other covariates (i.e., sex, age, BMI, MMSE, PFSF-36v2, and number of reported medical conditions), whereas isokinetic strength only approaches significance in predicting TM group membership when controlling for the same group of covariates. Comparing the results from the bivariate and multivariate logistic regression analyses, the multivariate models yielded rather similar odds ratios for isometric strength (OR = 3.70, Exp(B): 0.27; 95% CI: 0.09, 0.79). The odds ratios for isokinetic strength slightly changed (OR = 3.22, Exp(B): 0.31; 95% CI: 0.09, 1.04). In sum, even when controlling for covariates, a one unit increase in isometric strength is associated with a 3.70 folds decreased likelihood of being in the TM group, and a one unit increase in isokinetic strength is associated with a 3.22 folds decreased likelihood of being in the TM group. The isokinetic strength results should be interpreted with caution because it failed to reach significance at the .05 level. With a *p*-value of .06, however, there remains a strong trend towards significance for isokinetic strength, controlling for a variety of covariates.

Attempting to generate the most parsimonious clinical model of task modification (i.e. a clinical decision model with the minimum number of covariates needed to optimally predict task modifications among older adults living independently), five bivariate unadjusted logistic regression analyses, with each of the aforementioned covariates as the sole independent variable and the task modification group as the dependent variable were conducted. These bivariate tests were conducted using Bonferroni adjusted alpha levels of .008 per test (.05/6 = .01) yielding a statistical significance only for age (Exp(B): 1.28; 95% CI: 1.09, 1.45; $p = .002$) and the PFSF-36v2 (Exp(B): 0.95, 95% CI: 0.92, 0.98; $p = .004$). Next, two separate multivariate logistic regression analyses with either the isometric or the isokinetic NETforces as the independent variable, controlling for age and PFSF-36v2 score, were conducted. The results of the parsimonious isometric multivariate model indicated that isometric leg strength predicted TM group (OR = 2.50; Exp(B) = 0.4; 95% CI = 0.195, 0.822, p = 0.013) independent of age and PFSF-36v2, neither of which predicted TM (*p*'s > .05). Similarly, the results of the parsimonious isokinetic multivariate model indicated that isokinetic leg strength predicted TM group (OR = 2.42; Exp(B) = 0.414; 95% CI = 0.174, 0.986, $p = .046$) independent of age and PFSF-36v2, neither of which predicted TM (*p*'s > .05). Collectively, these findings further confirm our hypothesis regarding the inverse relationship between higher leg strength and the modification of daily tasks among older adults living independently in the community.

Defining Leg Strength Cut-off Points:

Having confirmed that measures of peak isometric and isokinetic leg strength can independently and accurately predict task modifications in a group of older adults living independently in the community, it is valuable to further explore exploit the data to characterize performance levels (i.e. strength cut-off points) expected to be found in representative populations of task-modifiers versus non-task-modifiers. While measuring isokinetic strength requires sophisticated, expensive equipment (i.e. isokinetic dynamometers) and trained personnel, measures of isometric strength may be done quickly and reliably in a variety of clinical settings with simple, easy-to-use equipment (e.g. handheld dynamometer). Therefore, from a clinical perspective, it is useful to evaluate whether measuring leg isometric strength may capture the same predictive power as measuring leg isokinetic strength. To examine this, we first conducted two separate, *discriminant* function analyses with either the isometric (Table 4a) or the isokinetic (Table 4b) NETforces as the sole independent predictor of task modification classification. We also further analyzed the results obtained from the *discriminant* analyses data using receiver-operator characteristic curves (ROC curve) (Figure 6). The ROC curve analysis shows the sensitivity and 1-specificity according to varying strength cut-off points for the dichotomized task modification classification.

For isometric NETforce (Table 5a & Figure 5a), a score of 4.24 will correctly classify 77.4% of the sample, suggesting this value as a potential strength cut-off point for the isometric NETforce, balancing sensitivity and specificity (sensitivity = 74.1%, specificity = 80.8%). Similarly, for isokinetic strength (Table 5b & Figure 5b), the *discriminant* function analysis suggested an optimal strength cut-off score of 2.77 to correctly classify 77.4% of the sample, balancing sensitivity and specificity (74.1 and

80.8% respectively). These potential strength cut-off points were compared to results from ROC analyses. Specifically, using ROC curve analysis, we also wanted to compare the predictive power of task modification using the isometric NETforce, versus the isokinetic NETforce. Tables 6a and 6b show that the area under the curve for both the isometric and the isokinetic NETforces is significantly ($p < 0.05$) different from a diagonal line that indicates zero predictive ability of the test. Figure 6 illustrates that the isometric strength accounted for 82% of the area under the curve and isokinetic strength accounted for 81% of the area under the curve in the ROC analyses. Testing the null hypothesis that the curves are the same yielded a *p-value* = .87 meaning that, clinically, the isomeric and isokinetic strength indices provide a similar diagnostic accuracy in terms of identifying task modifiers among community dwelling older adults.

Health may be conceptualized as a continuous variable. In the area of medicine, a threshold, or cut-off point ("C") is the line distinguishing "healthy" from "ill" along this continuum. Furthermore, depending on the medical intervention in question, it may be important to select a cut-off point that is either highly sensitive or highly specific. For example, a high specificity would allow for an economic selection of pathological cases, where only a few false positive cases might get an "unnecessary" treatment. On the other hand, high sensitivity is necessary to include all persons with the pathology. While high sensitivity ensures that any patient who needs the treatment receives it, it does so at the cost of more false positives.

The decision of whether to use high sensitivity or high specificity may also depend on the risk-to-benefit ratio of the treatment. For example, if the risk of providing a treatment is high, then it makes sense to use a high specificity value so there will be fewer false positives receiving this treatment when they do not need it. However, if the treatment is considered a low cost and a low risk (as in the case of physical exercise) then it makes much more sense to use sensitivity as the guide to the cut-off point. As clinicians may have various preferences in balancing sensitivity and specificity, Tables 5a and 5b include charts with strength scores and the associated sensitivity and specificity probabilities for increased clinical utility.

Collectively, the findings strongly suggest that measures of leg strength alone are a good predictor of task modifications among older adults living independently. Furthermore, the isokinetic score did not perform better than the isometric score, meaning that a score of isometric leg strength is as good a predictor of task modification as the score of the isokinetic leg strength.

Discussion

Aging is associated with increased risk of clinical mobility disability, defined as difficulty or dependency in carrying out mobility tasks essential to independent living [2] Many apparently healthy older adults maintain independence by using daily task modifications to minimize the discrepancy between their physical abilities and the challenges set forth by the environment. Use of daily task modification is a symptom of pre-clinical disability among older adults.[14, 46, 50] Regardless of level of independence, people who are considered pre-clinically disabled are at higher risk for developing clinical mobility disability within a matter of months. [47, 91] Data from this study provide new evidence of two groups of pre-clinical disability, defined based on differences in a composite of leg muscle strength in the sagittal plane. Two main aims of this study were to examine lower extremities NETforces differences across task-modifiers (TM) and non-task-modifiers (NTM), and to identify levels of isometric and isokinetic NETforces cut-off points that are associated with daily task modifications in community dwelling older adults living independently in their own residence. We hypothesized that isometric and isokinetic NETforces would be significantly decreased within the TM group. The results of the current study show that there are significant isomeric (-30%) and isokinetic (-33.5%) strength differences between the TM and NTM groups. Furthermore, the odds of a person generating isomeric NETforce equal to 2N*m/KgBW becoming TM were between three to four times the odds of a person generating 1N*m/KgBW becoming TM.

We hypothesized that specific isometric and isokinetic strength cut-off points could independently differentiate between task-modifiers and non-task-modifiers, and that neither of the strength tests would be superior to the other in terms of diagnostic accuracy. The study results yielded specific isometric (4.24 N*m/KgBW) and isokinetic (2.77N*m/KgBW) strength cut-off points associated with daily task modification. Both the isometric and the isokinetic strength cut-off points provided similar diagnostic accuracy in terms of sensitivity and specificity.

Age-related decreases in muscle strength [305, 335, 336] predispose individuals to clinical mobility disability, hospitalization, and mortality. [305, 335] The current study supports the use of NETforce decrements as a bio-marker of age-related declining mobility. In a five-year prospective study, Rantanen et al.[336] showed that isometric muscle strength deficits predicted ADL dependence (defined as self-reported need for help in eating, dressing, bathing, toileting, walking indoors, or transferring from a bed or a chair) such that those in the lower third were at two to three times greater risk of becoming dependent, compared to those in the upper third of strength. Over a median of 5.90 years, Manini et al.[272] showed that measures of knee extension predicted the onset of severe mobility limitation (a significant difficulty with walking a quarter mile, or climbing 10 steps, or the inability to complete those tasks) in initially well-functioning older adults aged 73.6 ± 2.85. Consistent with these findings, our results showed that NETforces were associated with early signs of mobility decline. Uniquely, our results showed that a composite measure of lower extremity isometric strength (isometric NETforce) could predict TM group membership in a sample of older adults living independently in the community. Because a need to modify tasks of daily living is a major symptom of pre-clinical disability, this finding support previous findings[337], suggesting that strength measures obtained at a single time point may be enough to predict future clinical mobility disability. Specifically, in the current study, persons whose isometric NETforce were higher by only 1N*m/KgBW, reduced their likelihood of belonging to the TM by 64%. Essentially, after using a multiple regression procedure accounting for age, sex, body mass index, number of reported medical conditions, and the PFSF-36v2, the direction of these results was not altered. Thus, these results underscore the independent contribution of isometric NETforces to age-related need to modify tasks of daily living. In a separate, yet similar multiple regression procedure, the isokinetic NETforce was used as the independent variable in place of the isometric NETforce. Prior to controlling for the covariates, the odds ratio for task modifications for high isokinetic leg strength compared to low isokinetic leg strength was 3.98 (Exp(B) = 0.251, 95% CI = 0.113, 0.57, p =.001). Based on this model, the amount of variance in the dependent variable (i.e. TM versus NTM group classification) was equal to 36.9%. In this case, controlling for age, sex, body mass index, number of reported medical conditions, and self-reported physical function (PFSF-36v2), altered the direction of the association such that the odds ratio changed to 0.424 (95% CI = 0.143, 1.262, p = 0.123). This was evidence that, as opposed to measures of isometric NETforce, measures of isokinetic NETforce may not be as sensitive to change in physical mobility among older adults who are pre-clinically disabled. One possible explanation for the differences between the isometric and the isokinetic regression models may be related to the fact that assessment of muscle strength requires a maximal *voluntary* effort. Voluntary effort affects muscle force production via increased descending drive. The larger this descending drive is, the greater the pool of firing motor neurons recruited in the spinal cord, and the faster those motor neurons fire. Previous studies have shown that aging is associated with decreased central drive. [338, 339] Recruiting a larger pool of motor neurons requires more time. Using a Biodex machine to test peak lower extremity strength in older adults (76 ± 6 years), Ordawy et al. [340] reported that peak strength values were inversely related to speed of contraction. Accordingly, it appears that measures of isometric strength are better indicators of strength among older adults. Older adults who modify tasks of daily living are considered high risk for future mobility disability [23, 46]. Our results support the use of an easily implemented screening tool such as isometric NETforces to identify older adults living independently who are pre-clinically disabled.

The association found between the isometric and isokinetic NETforces decrements and performance-based measure of age-related mobility decline, such as the MOD, extends the results of previous studies reporting isolated muscle strength deficits in older adults with mobility decline [300]. In a study by Hernandez et al.[278], participants self-rated their ability to stoop, crouch, or kneel (SCK). Those self-reporting difficulties with SCK presented with a significant decrease in normalized trunk extensor, knee extensor, ankle dosiflexor, and plantar-flexor isometric muscle strength. Interestingly, hip extension strength was not different between groups. Others have found that reduced hip extension muscle strength is associated with parameters of gait such as step length [341;342]. A number of studies used knee extension strength to predict a functional independent category. [134, 185, 272, 273, 301, 302, 343] Hasegawa et al.[300] examined the best predictor of the functionally independent category from hip flexors, hip extensors, knee flexors, knee extensors, and ankle dorsiflexors. The normalized hip extensors accounted for the most variability when performing ADL. Inconsistencies regarding the contribution of hip versus knee extensors to functional mobility may be explained through the findings by Winter [276] and Hof [277]. Specifically, Winter and Hof suggested that net anti-gravity force production is central to maintain mobility independence. Net anti-gravity force is the sum of the sagittal extension moments obtained from hip and knee extensors and ankle plantar flexors. To the best of our knowledge, the current study is the first to link NETforces to age-related mobility decline. Further, the current study used a performance-based assessment of mobility decline (i.e. daily task modifications) instead of a self-report measure. Our results suggest that loss of NETforces in the sagittal plane is associated with declining mobility in community dwelling older adults. When dealing with age-related mobility decline, clinicians should consider all the major extensors in the lower extremities so they can determine the relative contribution of each individual muscle group to the NETforces.

The results of the current study showed that both the isometric and the isokinetic models yielded a similar diagnostic accuracy of task modifications among community dwelling older adults. The isometric model yielded a strength cut-off point of 4.24 N*m/KgBW associated with a sensitivity and specificity of 80.8% and 74.1% respectively. The isokinetic model yielded a strength cut-off point of 2.77N*m/KgBW associated with a sensitivity and specificity of 80.8% and 74.1% respectively. In the current study, an isokinetic dynamometer (Biodex) was used to evaluate NETforces in community dwelling older adults. The Biodex is considered the gold standard for overall muscle strength testing. Moreover, the reliability and validity of using the iskokinetic equipment in testing muscle function at the hip, knee, and ankle joints were confirmed.[329, 340] There might be some issues related to the use of a Biodex in the clinic, let alone in the community, however. Compared to the handheld dynamometer, the Biodex machine is expensive, requires extensive training, and is less portable. Using a Biodex and the handheld dynamometer to measure isometric strength of the quadriceps, Martin et al.[344] found a strong correlation between the two forms of strength measures (r = .91, $p < 0.0001$). To the best of our knowledge, this is the first study to compare the diagnostic accuracy of isometric and isokinetic NETforces cut-off points using one study population. It appears that the results of this study support the use of portable tools measuring isometric strength in the lower extremities to establish functionally relevant NETforces cut-off points.

Aging is associated with a chronic loss of muscle mass (sarcopenia [26, 108]). For many years sarcopenia has been used to describe both loss of muscle mass and muscle strength[116]. Recent studies showed that, compared to muscle mass, age-related loss of muscle strength (dynapenia[34, 36]) is a stronger predictor [305, 335, 336]of mobility disability, hospitalization, and mortality among older adults [305, 335] Clark and Manini [36] proposed a working decision algorithm to classify people with dynapenia, suggesting that abnormal NETforces are central to the diagnosis of dynapenia among older adults. By examining independently living community dwelling older adults who modify tasks of daily living, it was possible to identify NETforces cut-off points associated with supposedly independent functioning older adults. These cut-off points can then be used to draw a line between "normal" and "abnormal" NETforces associated with moderate dynapenia.

Although the current study focused on muscle groups that were important to performing tasks in the upright position, there are other muscle groups both in the sagittal and frontal planes (e.g. hip and knee flexors, hip abductors, or ankle evertors) that may contribute to the functional tasks tested in this study. Further, this cross-sectional study provides data on the association between NETforces and the completion of functional tasks. While these data are promising for the use of strengthening programs in this pre-clinically disabled group, this conclusion should be taken with caution and requires further longitudinal study to ensure its safety and efficacy with this population.

Conclusions

The premise of this field initiated research paper is that as people age, they are at a higher risk to become functionally limited [134] Many older adults modify daily tasks allowing them to continue and function independently. Modifying daily tasks is a clinical sign of a sub-clinical condition, prognostic of future mobility disability even in apparently "healthy" older individuals. Our data showed that NETforces deficits predict need to modify daily tasks. From both the clinical and practical perspectives, the identification of task modification and pre-clinical disability bio-markers is useful only to the extent that they can be used to improve interventions and clinically relevant outcomes, which in turn may increase patient satisfaction and decrease healthcare costs. Isometric or isokinetic NETforces cut-off points both may be used as objective bio-markers to identify older adults at high and low risk of future mobility limitation. However, in comparison to peak isokinetic strength, measuring peak isometric strength does not require sophisticated, expensive equipment. If the ultimate goal is to make muscle strength testing an integral part of health screening among older adults living independently, then compared to isokinetic testing, measuring peak isometric leg strength may render similar predictive accuracy, while being better suited to implementation in the reality of a busy clinical practice. Future longitudinal research should focus on investigating whether prescribing strength and functional exercise to increase lower extremities muscle strength helps to reduce levels of daily task modifications and incidence of mobility disability among older adults

Chapter VIII: Final Thoughts

Lower extremity muscle strength appears to be associated with daily task modification in community dwelling older adults, as evidenced by lower extremity force decrements observed in task-modifiers. Lower extremity strength cut-off points discriminated between participants with and without the target condition (i.e. task modification). The discriminative potential of a test can be by quantified by measures of sensitivity and specificity. Briefly, the sensitivity of a diagnostic test is an indication of the test's ability to detect those individuals who actually present with the target condition ("true positive rate"). In turn, the specificity of a diagnostic test is an indication of the test's ability to detect those individuals who actually do not present with the target condition ("true negative rate") [345]. In the current study, we identified isometric and isokinetic lower extremity strength cut-off points based on the optimal combination of sensitivity and specificity. Depending on the aim of the clinical decision-making, it may be important to select a cut-off point that is either highly sensitive or highly specific. High sensitivity is necessary to include all persons with the pathology, but it results in more false positives. High specificity results in fewer false positive cases that receive an "unnecessary" treatment. In instances where the risk of providing a treatment is low, as in the case of physical training to improve muscle performance, it makes sense to use sensitivity as the guide to the optimal cut-off point, so that all patients who need the treatment receive it.

Table 1a provides additional descriptive statistics for each group (i.e., task-modifiers - TM vs. non-task-modifiers - NTM) on all study variables. Table 1b provides the results of a series of independent samples t-tests examining mean differences between the TM and NTM groups on both primary strength variables and relevant covariates.

	Task-Modifiers N = 26		Non-Task-Modifiers N = 27	
Males (%)	38		62	
Females %)	56		44	
	M	SD	M	SD
Age (years)	78.85	4.84	73.89	4.34
BMI (Universal Units)	27.80	4.66	25.82	2.78
PFSF-36v2 (Max. = 100)	69.23	26.52	89.44	12.27
Mini Mental State Examination (Max. = 30)	29.92	.27	29.59	1.75
Isometric Strength (N*m/KgBW)	3.52	.88	5.03	1.30
Isokinetic Strength (N*m/KgBW)	2.26	.70	3.35	1.45

# of Reported Medical Conditions	Count (N)	Count (N)
0	1	0
1	0	2
2	4	4
3	3	8
4	7	5
5	3	5
6	5	3
7	3	0
χ^2 test	χ^2 Value (df) = 9.59 97)	*p*-value = .21

Table 1b provides the results of a series of independent samples t-tests examining mean differences between the TM and NTM groups on both primary strength variables and relevant covariates.

	t-test for Equality of Means						
	t	Df[b]	*p*-value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
# of Medical Conditions	-1.50	51	.140	-.68	.45	-1.58	.23
Age	-3.93	51	.000	-4.96	1.26	-7.49	-2.42
BMI	-1.87	40.51	.068	-1.99	1.06	-4.13	.155
PFSF-36v2	3.54	34.95	.001	20.21	5.71	8.62	31.81
MMSW	-.95	51	.348	-.33	.35	-1.03	.37
Isometric NETforce	5.00	45.81	.000	1.52	.30	.91	2.13
Isokinetic NETforce	4.51	45.75	.000	1.09	.24	.61	1.58

a. These tests were conducted at alpha of .07 (.05/7) to maintain the experiment-wise alpha level at .05.
b. Cases with non-integer degrees of freedom are adjusted for a violation of Levene's test of homogeneity of variance.

Table 2. Correlation matrix for primary variables and covariates.

		1	2	3	4	5	6	7
1. Sex	r	-						
	p-value	-						
2. Age	r	-.107						
	p-value	.446						
3. BMI	r	.086	.042					
	p-value	.541	.763					
4. MMSE	r	.149	-.020	-.016				
	p-value	.288	.887	.909				
5. SF-36	r	-.154	**-.449****	**-.578****	-.004			
	p-value	.271	**.001**	**.000**	.977			
6. Isometric strength	r	**-.338***	**-.448****	**-.512****	.103	**.476****		
	p-value	**.013**	**.001**	**.000**	.463	**.000**		
7. Isokinetic strength	r	**-.282***	**-.478****	**-.502****	.123	**.514****	**.890****	
	p-value	**.040**	**.000**	**.000**	.382	**.000**	**.000**	
8. Continuous Modification Scale	r	.215	**.527****	**.454****	.089	**-.694****	**-.684****	**-.669****
	p-value	.122	**.000**	**.001**	.527	**.000**	**.000**	**.000**

* $p \leq 0.05$
** $p \leq 0.01$

Table 3a. Bivariate logistic regression parameters predicting treatment modification group membership from measurements of peak leg isometric strength.

Overall Model Fit		
-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
53.326	.316	.421

	Logistic Regression Parameters						95% C.I. for Exp(B)	
	B	S.E.	Wald	df	*p*-value	Exp(B)	Lower	Upper
Isometric Strength	-1.196	.337	12.609	1	.000	.302	.156	.585
Constant	5.005	1.431	12.233	1	.000	149.134		

	Classification Table		
	Predicted		
Observed	No Modifications	Yes Modifications	Percentage Correct
No Modifications	20	7	74.1
Yes Modifications	5	21	80.8
Overall Percentage			77.4

Table 3b. Multivariate logistic regression parameters predicting treatment modification group membership from peak leg isometric strength.

Overall Model Fit		
	Parameter	Value
Model 1	χ^2(df)	22.79 (6)***
	-2 Log Likelihood	50.67
	Cox & Snell R Square	.35
	Nagelkerke R Square	.47
Model 2	χ^2(df)	30.09 (7)***
	-2 Log Likelihood	43.07
	Cox & Snell R Square	.44
	Nagelkerke R Square	.58

***$p < .001$

	Logistic Regression Parameters						95% C.I. for Exp(B)	
	B	S.E.	Wald	df	*p*-value	Exp(B)	Lower	Upper
Model 1								
Sex	1.14	.77	2.23	1	.14	3.14	.69	14.08
Age	.247	.10	6.12	1	.01	1.28	1.05	1.56
BMI	.079	.12	.40	1	.53	1.09	.85	1.38
MMSE	.622	.92	.46	1	.50	1.87	.31	11.33
PFSF-36v2	-.021	.03	.71	1	.40	.98	.93	1.03
Medical Conditions	.031	.24	.02	1	.89	1.03	.65	1.65
Constant	-38.59	30.81	1.57	1	.21	.00		
Model 2								
Sex	-.255	.97	.07	1	.79	.775	.12	5.18
Age	.130	.12	1.28	1	.26	1.14	.91	1.43
BMI	-.118	.15	.63	1	.43	.89	.66	1.19
MMSE	1.067	1.00	1.13	1	.29	2.91	.41	20.88
PFSF-36v2	-.036	.03	1.54	1	.26	.97	.91	1.02
Medical Conditions	-.143	.26	.29	1	.59	.87	.52	1.46
Isometric Strength	-1.29	.55	5.64	1	.02	.27	.09	.79
Constant	-29.59	32.99	.80	1	.37	.00		

	Classification Table		
	Predicted		
Observed	No Modifications	Yes Modifications	Percentage Correct
No Modifications	22	5	81.5
Yes Modifications	4	22	84.6
Overall Percentage			83.0

Table 3c. Bivariate logistic regression parameters predicting treatment modification group membership from peak leg isokinetic strength.

Overall Model Fit		
-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
56.267	.277	.369

	Logistic Regression Parameters						95% C.I. for Exp(B)	
	B	S.E.	Wald	df	*p*-value	Exp(B)	Lower	Upper
Isokinetic Strength	-1.384	.408	11.513	1	.001	.251	.113	.557
Constant	3.783	1.150	10.814	1	.001	43.933		

	Classification Table		
	Predicted		
Observed	No Modifications	Yes Modifications	Percentage Correct
No Modifications	20	7	74.1
Yes Modifications	6	20	76.9
Overall Percentage			75.5

Table 3d. Multivariate logistic regression parameters predicting treatment modification group membership from peak leg isokinetic strength.

	Overall Model Fit	
	Parameter	Value
Model 1	χ^2(df)	22.79 (6)***
	-2 Log Likelihood	50.67
	Cox & Snell R Square	.35
	Nagelkerke R Square	.47
Model 2	χ^2(df)	27.00 (7)***
	-2 Log Likelihood	47.04
	Cox & Snell R Square	.39
	Nagelkerke R Square	.53

***$p < .001$

	Logistic Regression Parameters						95% C.I. for Exp(B)	
	B	S.E.	Wald	df	*p*-value	Exp(B)	Lower	Upper
Model 1								
Sex	1.14	.77	2.23	1	.14	3.14	.69	14.08
Age	.247	.10	6.12	1	.01	1.28	1.05	1.56
BMI	.079	.12	.40	1	.53	1.09	.85	1.38
MMSE	.622	.92	.46	1	.50	1.87	.31	11.33
PFSF-36v2	-.021	.03	.71	1	.40	.98	.93	1.03
Medical Conditions	.031	.24	.02	1	.89	1.03	.65	1.65
Constant	-38.59	30.81	1.57	1	.21	.00		
Model 2								
Sex	.351	.87	.16	1	.69	1.42	.26	7.77
Age	.15	.11	1.67	1	.19	1.16	.93	1.44
BMI	-.02	.14	.03	1	.86	.98	.74	1.28
MM	1.051	1.01	.1.08	1	.30	2.86	.39	20.84
PFSF-36v2	-.03	.03	1.03	1	.31	.98	.92	1.03
Medical Conditions	-.204	.27	.57	1	.45	.82	.48	1.38
Isokinetic Strength	-1.180	.623	3.58	1	.06	.31	.09	1.04
Constant	-35.74	32.67	1.19	1	.28	.00		

	Classification Table		
	Predicted		
Observed	No Modifications	Yes Modifications	Percentage Correct
No Modifications	19	8	70.4
Yes Modifications	6	20	76.9
Overall Percentage			73.6

Table 4a. *Discriminant* function analysis contingency table for peak isometric leg strength.

Group Statistics

	Mean	Std. Deviation
No Modifications	5.0330	1.29746
Yes Modifications	3.5169	.87742
Total	4.2892	1.34062

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Isometric strength	.674	24.638	1	51	.000

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.483	100.0	100.0	.571

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.674	19.904	1	.000

Classification Results[a]

			Predicted Group Membership		
			No Modifications	Yes Modifications	Total
Original	Count	No Modifications	20	7	27
		Yes Modifications	5	21	26
	%	No Modifications	74.1	25.9	100.0
		Yes Modifications	19.2	80.8	100.0

a. 77.4% of original grouped cases correctly classified.

Table 4b. *Discriminant* function analysis contingency table for peak isokinetic leg strength.

Group Statistics

	Mean	Std. Deviation
No Modifications	3.3499	1.03706
Yes Modifications	2.2578	.69936
Total	2.8142	1.03763

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Isometric strength	.718	20.046	1	51	.000

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.393[a]	100.0	100.0	.531

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.718	16.741	1	.000

Classification Results[a]

			Predicted Group Membership		
			No Modifications	Yes Modifications	Total
Original	Count	No Modifications	20	7	27
		Yes Modifications	5	21	26
	%	No Modifications	74.1	25.9	100.0
		Yes Modifications	19.2	80.8	100.0

a. 77.4% of original grouped cases correctly classified.

Table 5a. Sensitivity and specificity table from ROC analysis for isometric strength.

Area Under the Curve: Test Result Variable(s):Isometric strength

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.823	.059	.000	.708	.939

a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Coordinates of the Curve
Test Result Variable(s):Isometric strength

Positive if Greater Than or Equal To[a]	Sensitivity	1 - Specificity
.5959	1.000	1.000
1.9844	1.000	.962
2.4037	1.000	.923
2.4636	.963	.923
2.5541	.963	.885
2.6477	.926	.885
2.7842	.926	.846
2.8918	.926	.808
2.9166	.926	.769
2.9702	.926	.731
3.0052	.926	.692
3.0290	.926	.654
3.0782	.926	.615
3.1653	.889	.615
3.2669	.889	.577
3.3434	.889	.538
3.4326	.852	.538
3.5471	.852	.500
3.6091	.852	.462
3.6143	.852	.423
3.6173	.852	.385
3.6201	.852	.346
3.6961	.852	.308
3.8622	.815	.308
3.9625	.778	.308
3.9839	.741	.308
4.0514	.741	.269
4.1312	.741	.231
4.2414	**.741**	**.192**
4.3373	.704	.192
4.3543	.704	.154
4.4371	.667	.154

4.5309	.667	.115
4.6892	.630	.115
4.8413	.593	.115
4.8652	.556	.115
4.8816	.556	.077
5.0090	.556	.038
5.1731	.519	.038
5.2512	.481	.038
5.3371	.444	.038
5.3852	.407	.038
5.4593	.370	.038
5.5960	.370	.000
5.7110	.333	.000
5.8410	.296	.000
5.9390	.259	.000
6.0560	.222	.000
6.3657	.185	.000
6.5874	.148	.000
6.6545	.111	.000
6.8448	.074	.000
6.9996	.037	.000
8.0218	.000	.000

a. The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive ordered observed test values.

Table 5b. Sensitivity and specificity table from ROC analysis for isokinetic strength.

Area Under the Curve: Test Result Variable(s):Isokinetic strength				
			Asymptotic 95% Confidence Interval	
Area	Std. Error[a]	Asymptotic Sig.[b]	Lower Bound	Upper Bound
.808	.061	.000	.688	.927

a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

Coordinates of the Curve		
Test Result Variable(s):Isokinetic strength		
Positive if Greater Than or Equal To[a]	Sensitivity	1 - Specificity
.2789	1.000	1.000
1.2845	1.000	.962
1.3133	1.000	.923
1.4070	1.000	.885
1.4788	1.000	.846
1.5159	1.000	.808
1.5772	1.000	.769
1.6238	1.000	.731
1.6543	1.000	.692
1.6656	.963	.692
1.7065	.926	.692
1.7798	.926	.654
1.8232	.889	.654
1.8545	.852	.654
1.9001	.815	.654
1.9578	.815	.615
2.1259	.815	.577
2.2740	.815	.538
2.3237	.815	.500
2.3599	.778	.500
2.4381	.778	.462
2.5622	.778	.423
2.6130	.778	.385
2.6298	.741	.385
2.6534	.741	.346
2.6676	.741	.308
2.6964	.741	.269
2.7286	.741	.231
2.7702	**.741**	**.192**
2.8276	.704	.192
2.8601	.667	.192

2.8781	.667	.154
2.8928	.667	.115
2.9341	.667	.077
2.9863	.630	.077
3.0776	.593	.077
3.2944	.593	.038
3.4491	.556	.038
3.4896	.519	.038
3.5526	.481	.038
3.6023	.444	.038
3.7234	.407	.038
3.8648	.370	.038
3.9026	.333	.038
3.9304	.296	.038
3.9921	.259	.038
4.0667	.222	.038
4.1055	.185	.038
4.1223	.185	.000
4.1557	.148	.000
4.5526	.111	.000
4.9786	.074	.000
5.2000	.037	.000
6.3755	.000	.000

a. The smallest cut-off value is the minimum observed test value minus 1, and the largest cut-off value is the maximum observed test value plus 1. All the other cut-off values are the averages of two consecutive ordered observed test values.

Figure 1: Frequency distribution of Mini Mental State Examination (MMSE) scores

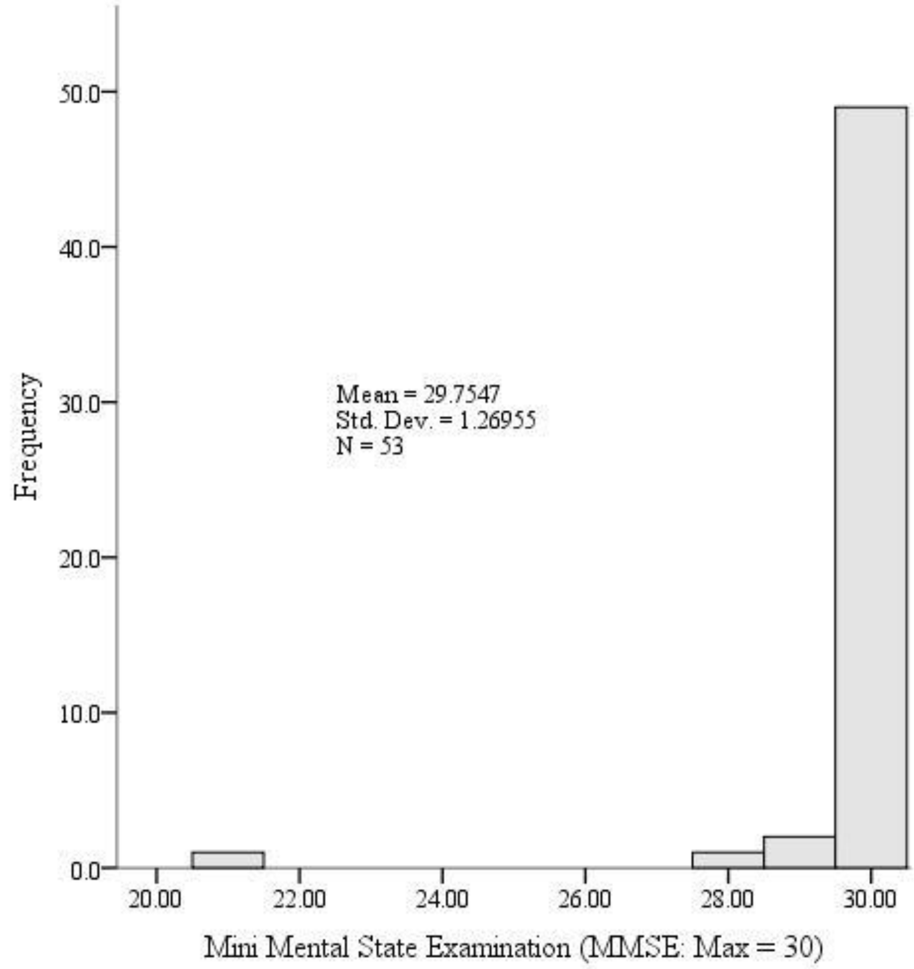


Figure 2: Frequency distribution of summary of task modification (MOD) scores

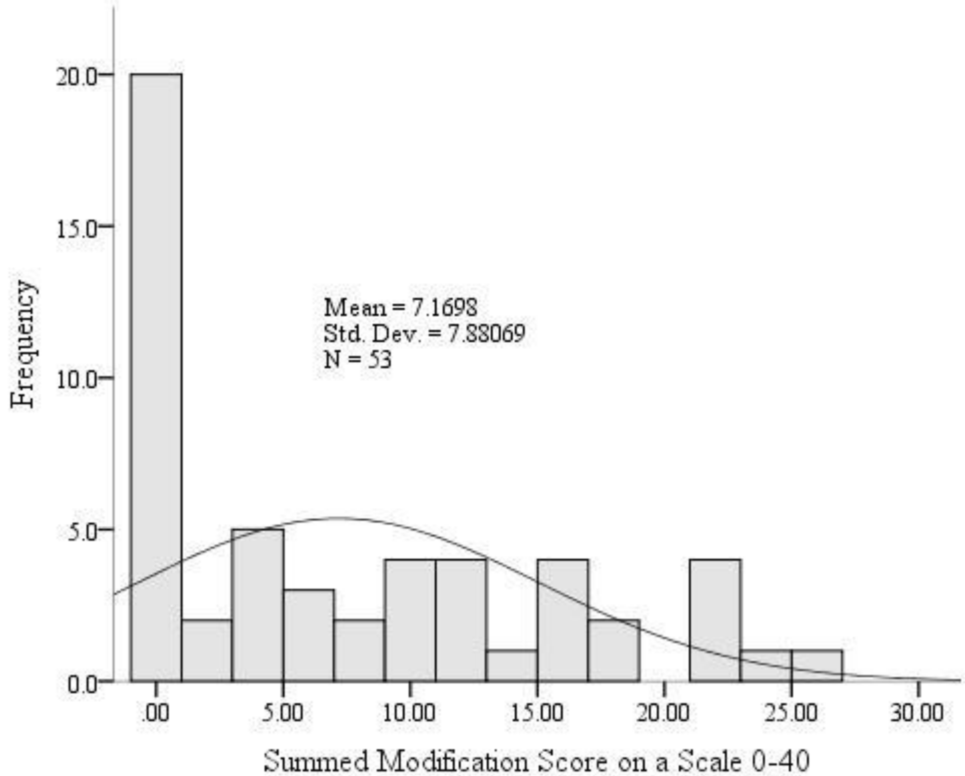


Figure 3a: Isometric leg strength versus continuous measure of task medications score

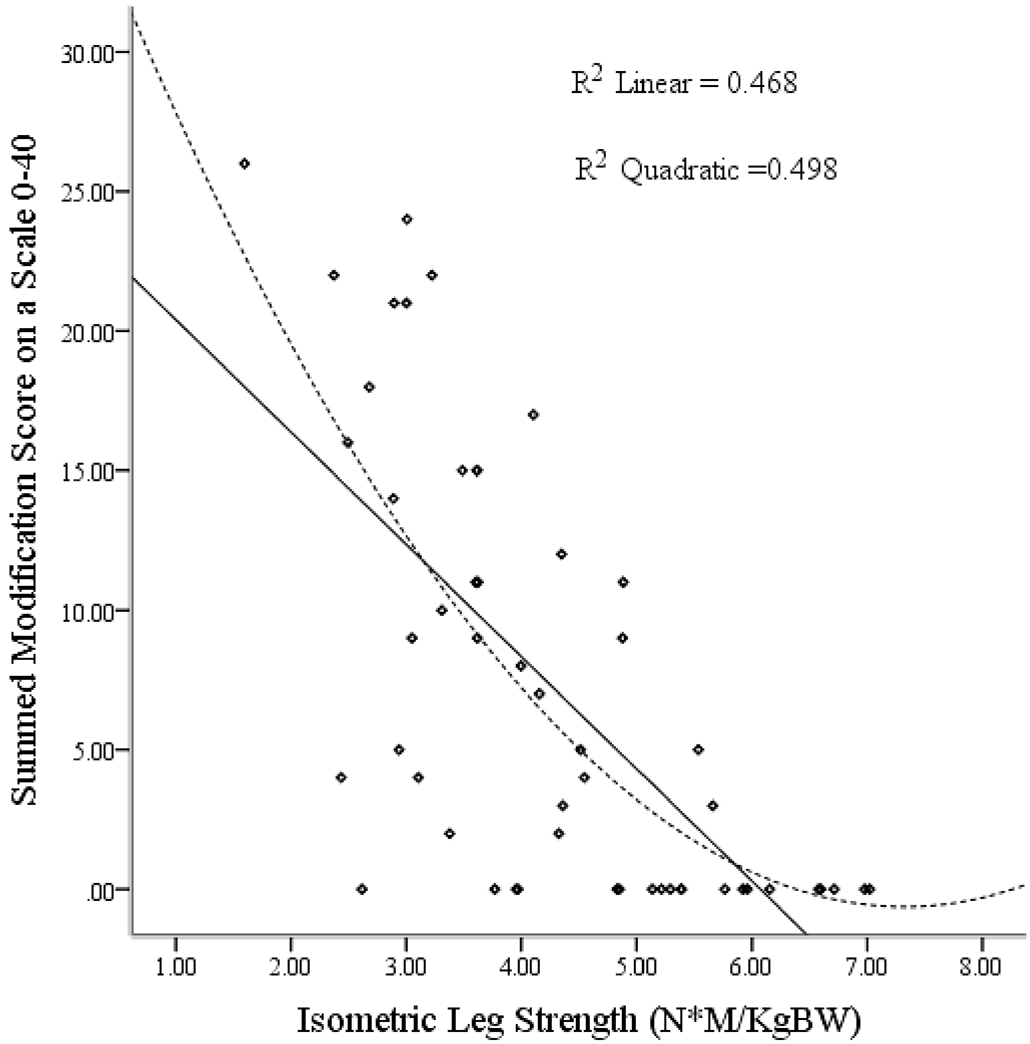


Figure 3b: Isokinetic leg strength versus continuous measure of task medications score

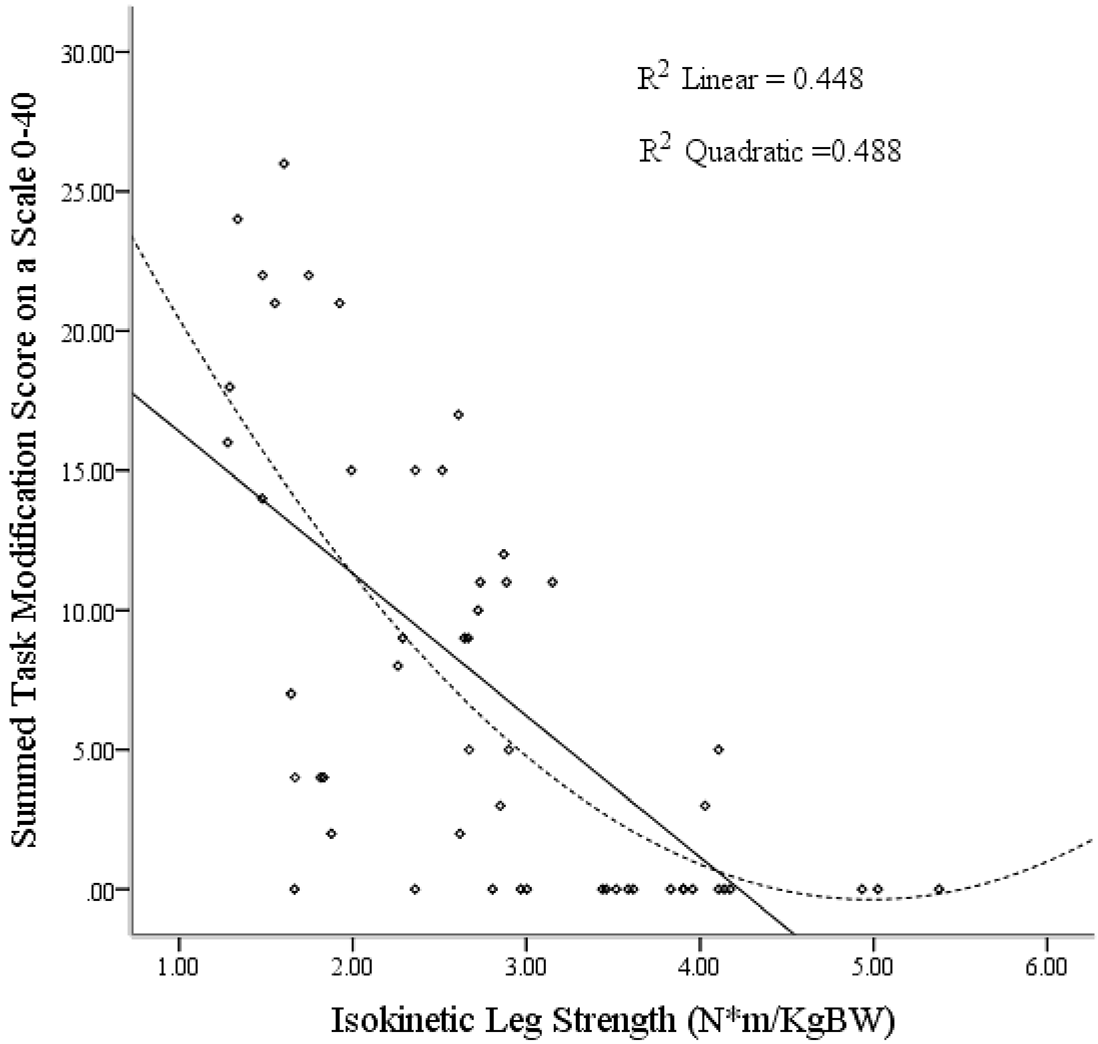


Figure 4a: Distribution of isometric leg strength according to task modification classification. The cross line inside the box is the median. The box contains the values between the 25th and 75th percentiles (interquartile range). The brackets contain the full range of values indicating that there were no values more than 1.5 times the interquartile range from the median.

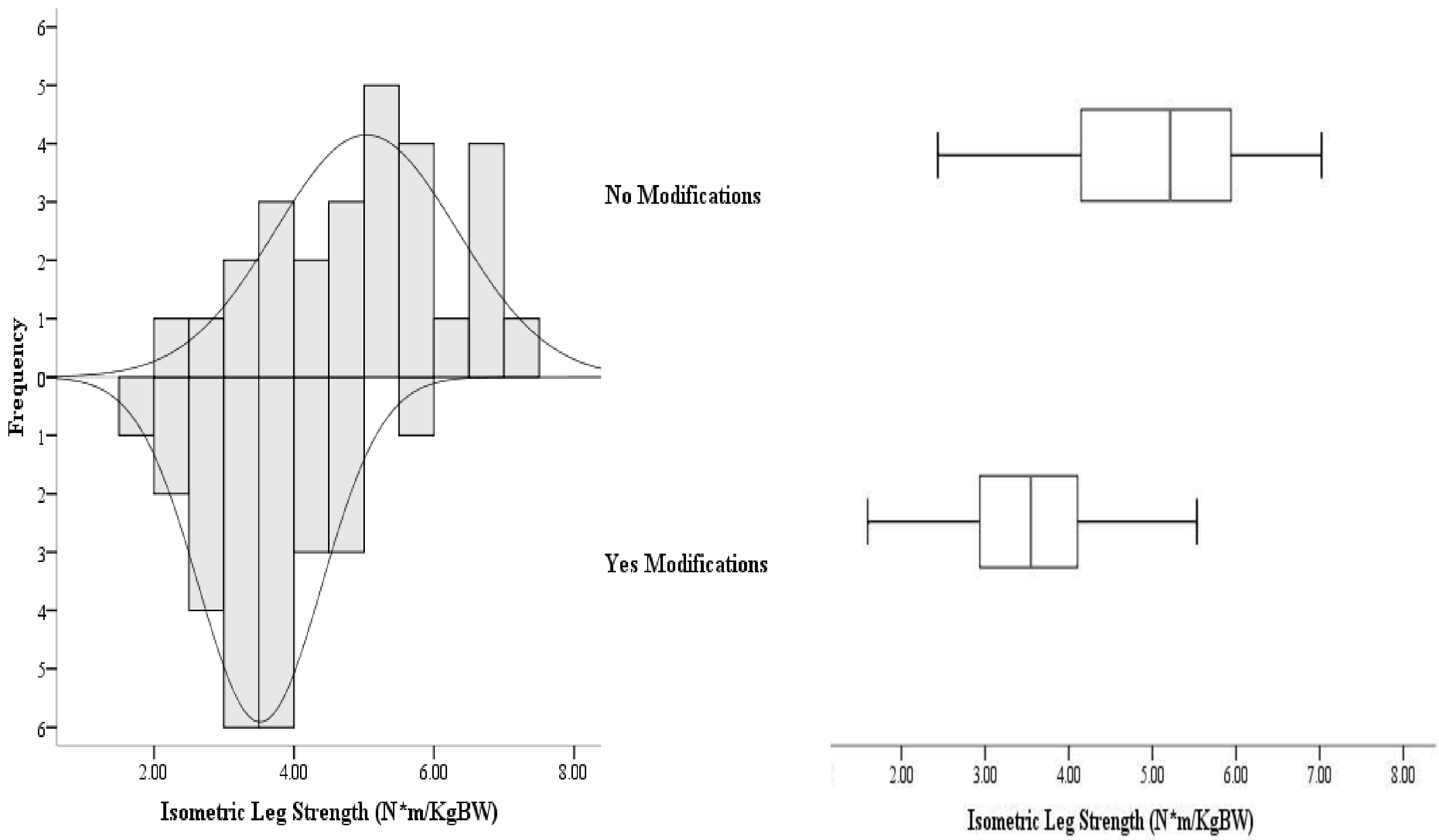


Figure 4b: Distribution of isokinetic leg strength according to task modification classification. The cross line inside the box is the median. The box contains the values between the 25th and 75th percentiles (interquartile range). The brackets contain the full range of values indicating that there were no values more than 1.5 times the interquartile range from the median.

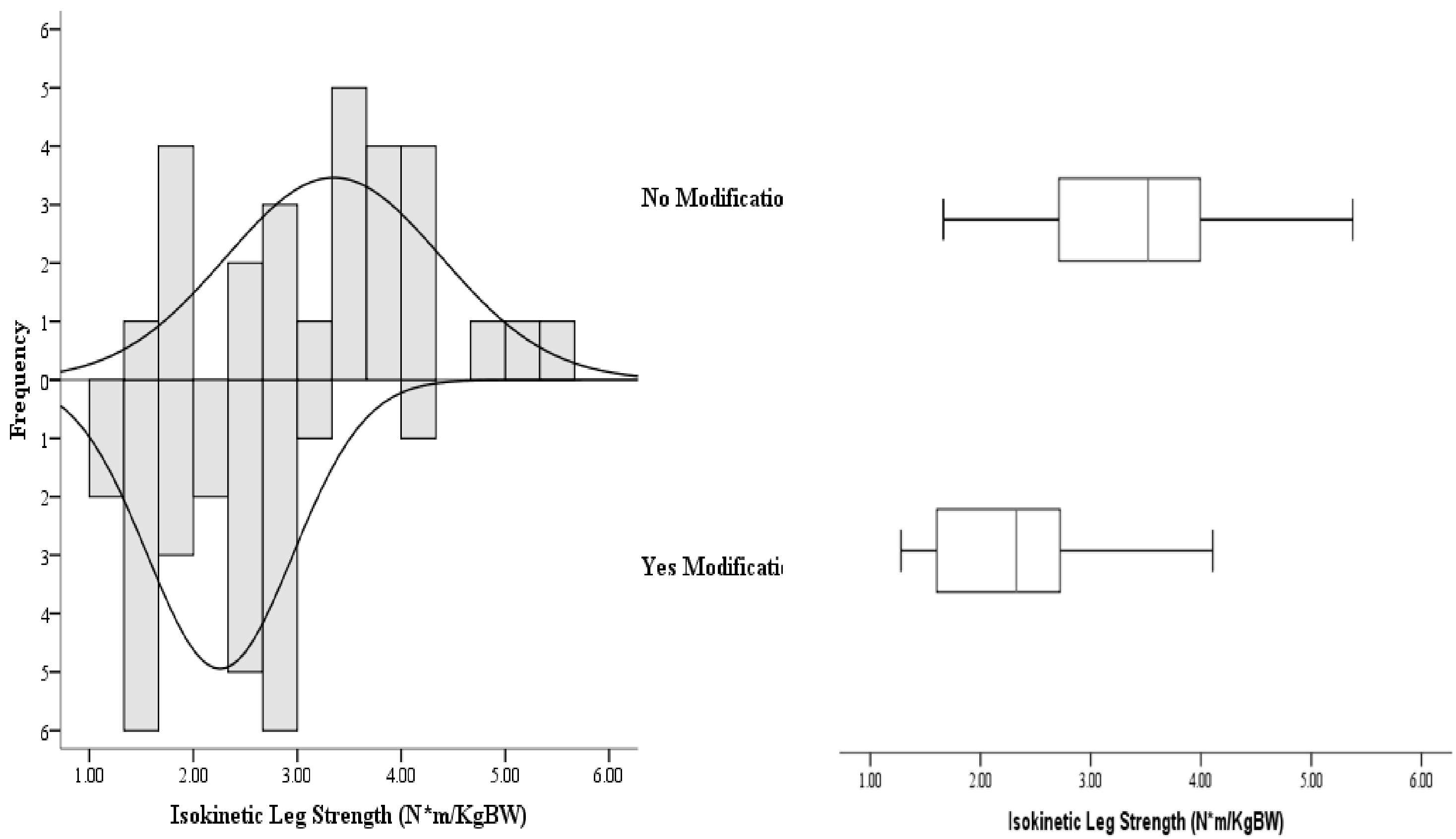


Figure 5a: Distribution of isometric test scores of study participants who were task-modifiers (squares) versus non-task-modifiers (triangles). Each square or triangle simultaneously represents a participant's isometric leg strength score and the score's associated percentile rank. Consequently, 20 (81%) of the 26 study participants who were classified as task-modifiers had an isometric leg strength of 4.24 (N*m/KgBW) or less, whereas only 7 (26%) of the 27 non-task-modifiers had an isometric strength of 4.24 (N*m/KgBW) or less.

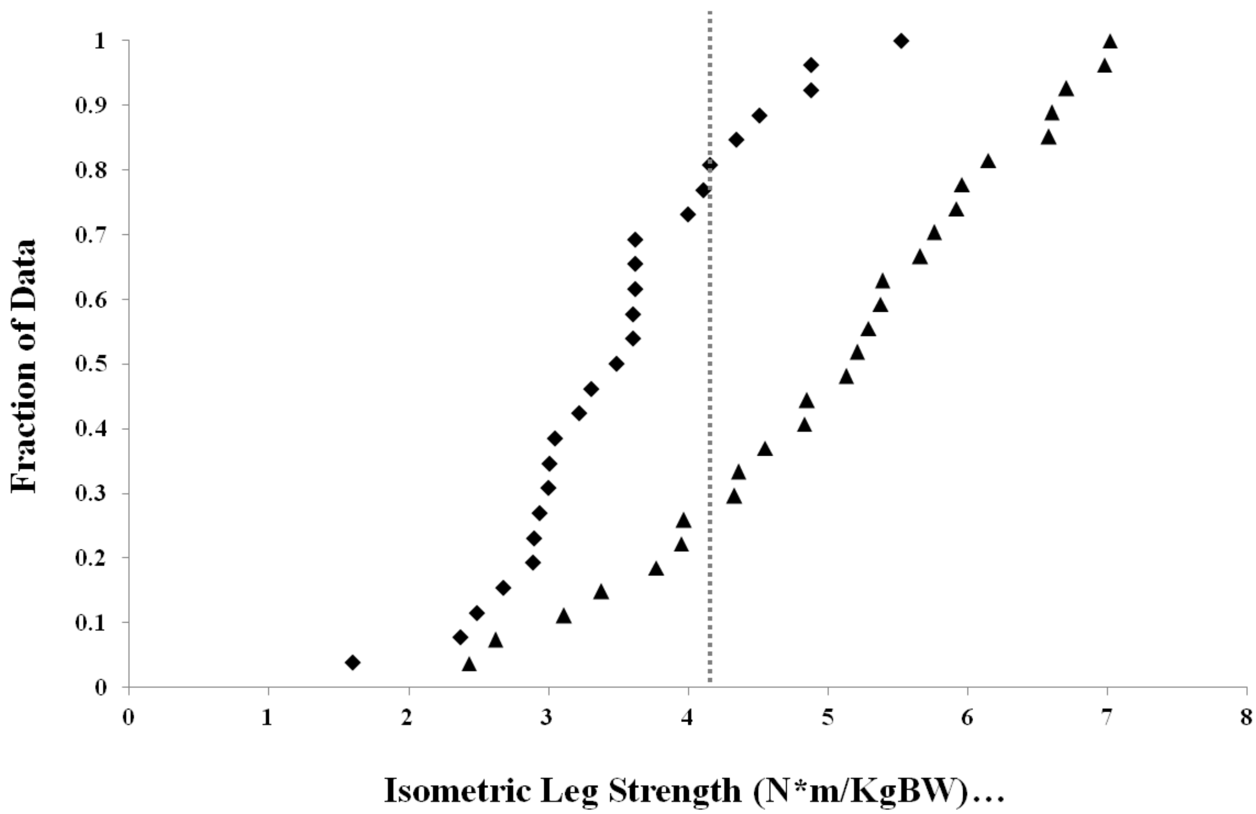


Figure 5b: Distribution of isokinetic test scores of study participants who were task-modifiers (squares) versus non-task-modifiers (triangles). Each square or triangle simultaneously represents a participant's isometric leg strength score and the score's associated percentile rank. Consequently, 20 (81%) of the 26 study participants who were classified as task-modifiers had an isokinetic leg strength of 2.77 (N*m/KgBW) or less, whereas only 7 (26%) of the 27 non-task-modifiers had an isokinetic strength of 2.77 (N*m/KgBW) or less.

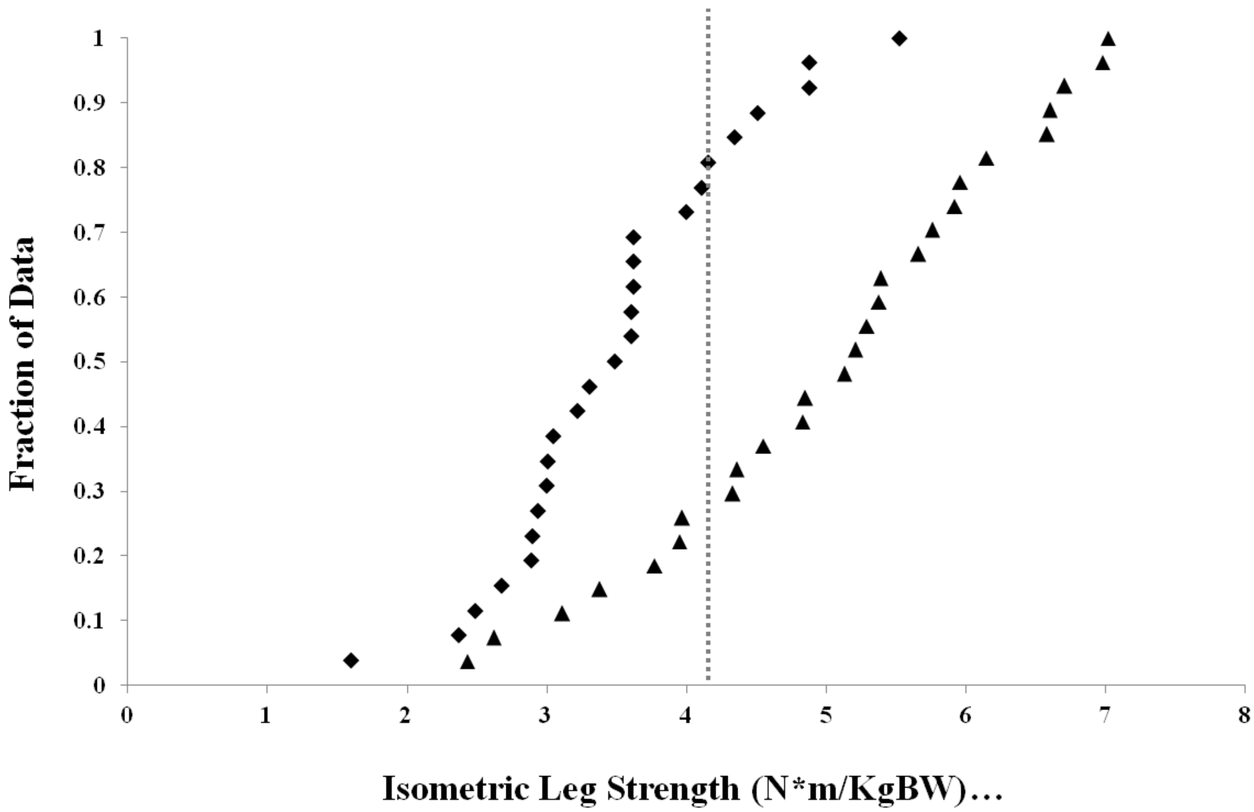
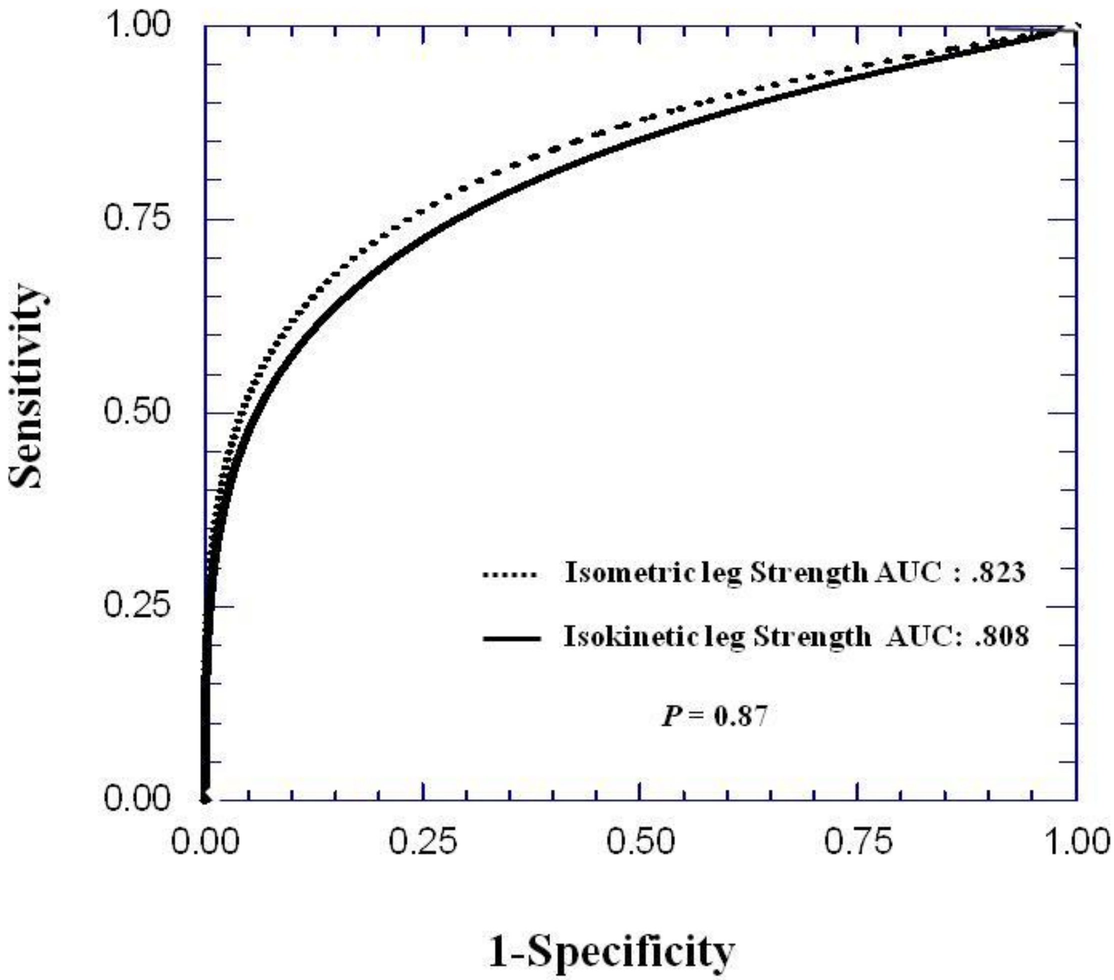


Figure 6. Receiver-operator characteristic curves showing sensitivity and 1-specificity for prediction of task modification according to varying strength cut-off points by the dichotomized task modification classification (0 = no task modification, 1 = task modification). AUC indicates the area under the curve; *p*-value is for the test of the null hypothesis that the area under the isometric and the isokinetic curves is the same.



APPENDICIES

Appendix A: Criteria Used to Define Frailty

Weight Loss: "In the last year, have you lost more than 10 pounds unintentionally (i.e., not due to dieting or exercise)?" If yes, then positive for weight loss criterion. At follow-up, weight loss was calculated as: (weight in previous year - current measured weight)/(weight in previous year) = K. If K ≥ 0.05 and the participant does not report that he/she was trying to lose weight (unintentional weight loss of at least 5% of previous year's body weight), then frail for weight loss = Yes.

Exhaustion: Using the CES-D Depression Scale, the following two statements are read. (a) I felt that everything I did was an effort; (b) I could not get going. The question is asked "How often in the last week did you feel this way?" 0 = rarely or none of the time (< 1 day), 1 = some or a little of the time (1 to 2 days), 2 = a moderate amount of the time (3 to 4 days), or 3 = most of the time. Participants answering "2" or "3" to either of these questions are categorized as frail by the exhaustion criterion.

Physical Activity: Based on the short version of the Minnesota Leisure Time Activity questionnaire, asking about walking, chores (moderately strenuous), mowing the lawn, raking, gardening, hiking, jogging, biking, exercise cycling, dancing, aerobics, bowling, golf, singles tennis, doubles tennis, racquetball, calisthenics, swimming. Kcals per week expended are calculated using standardized algorithm. This variable is stratified by gender.

Men: Those with Kcals of physical activity per week < 383 are frail.

Women: Those with Kcals per week < 270 are frail.

Gait Speed: stratified by gender and height (gender-specific cut-off a medium height).

Men	Cut-off for time to walk 15 feet
Height ≤ 173 cm	≥ 7 seconds
Height > 173 cm	≥ 6 seconds
Women	
Height ≤ 159 cm	≥ 7 seconds
Height > 159 cm	≥ 6 seconds

Grip Strength: stratified by gender and body mass index (BMI) quartiles:

Men	Cut-off for grip strength (Kg) criterion for frailty
BMI ≤ 24	≤ 29
BMI 24.1-26	≤ 30
BMI 26.1-28	≤ 30
BMI > 28	≤ 32
Women	
BMI ≤ 23	≤ 17
BMI 23.1-26	≤ 17.3
BMI 26.1-29	≤ 18
BMI > 29	≤ 21

Appendix B: Health Questionnaire

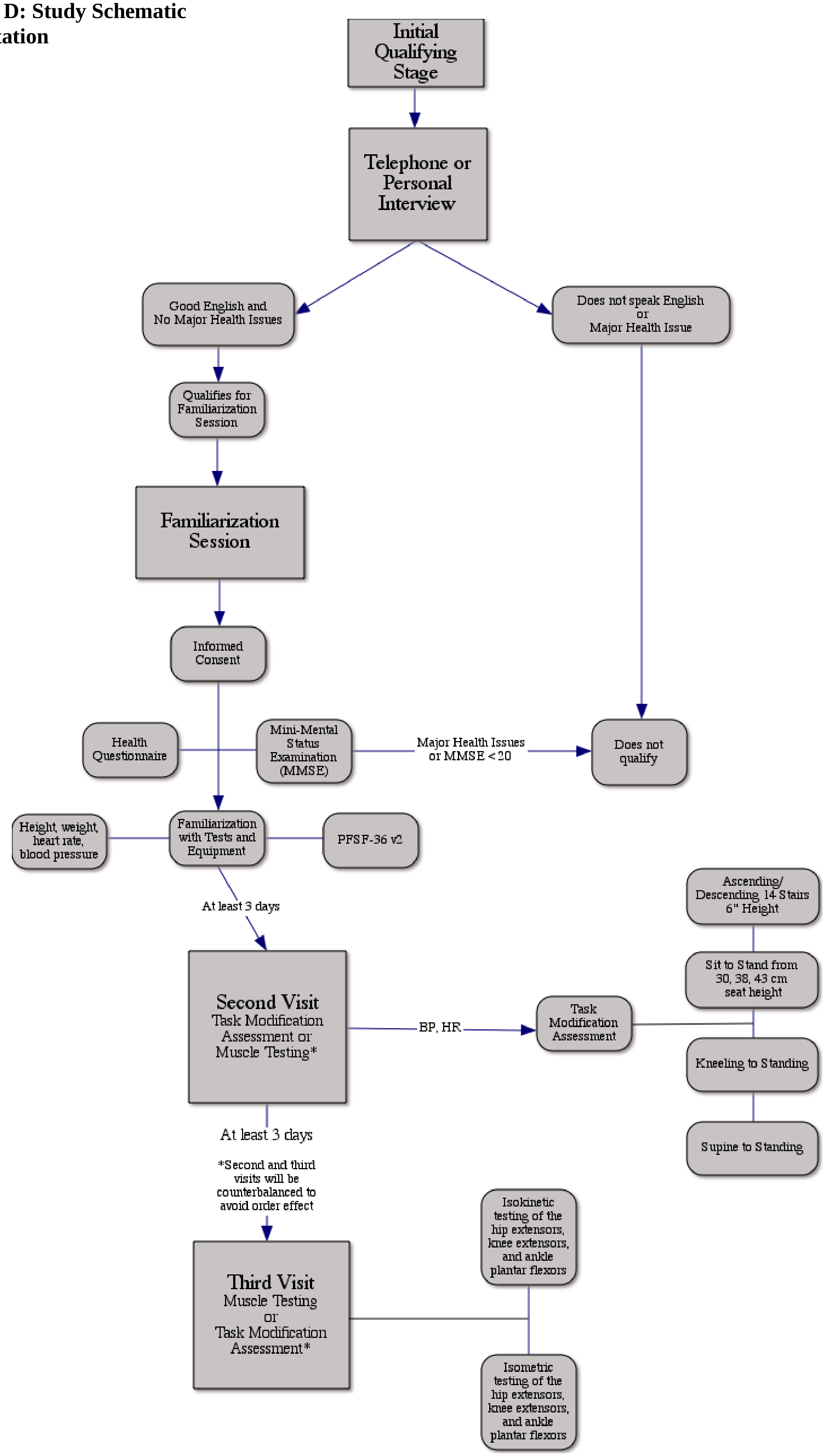
What is your date of birth?			
Gender	**M**	**F**	
Ethnicity			
	Yes	**No**	**Comments**
1. Have you ever been told by a doctor that you have a heart condition and that you should only do physical activity recommended by a physician?			
2. Has any woman under the age of 65 or man under the age of 55 in your family had complications resulting from heart or other cardiovascular diseases (e.g., heart attack)?			
3. Have you ever had a heart attack?			
4. If the answer to question 3 is "yes," was your heart attack within the last year?			
5. Do you get chest pains while at rest and/or during exertion?			
6. If the answer to question 5 is "yes," has a physician diagnosed these pains?			
7. While at rest, do you frequently experience heart beats that are irregular, very fast, or very slow?			
8. Do you lose your balance because of dizziness or do you ever lose consciousness?			
9. Do you have high blood pressure (i.e., a reading of more than 140/90)?			
10. If the answer to question 9 is "yes," is your high blood pressure currently being treated by medication (for example: 'water pills')?			
11. Are you currently being treated for any heart or circulatory condition, such as vascular disease, stroke, angina, hypertension, congestive heart failure, poor circulation, valvular heart disease, blood clots, or pulmonary disease?			
12. Do you experience shortness of breath at any of the following times: a) at night in bed; b) while relaxing during the day; or c) after mild exertion?			
13. Have you ever (past or present) used tobacco products (e.g., smoked cigarettes, chewed tobacco, smoked a pipe, etc.)?			
			Comments

14. Have you ever been diagnosed with "chronic obstructive pulmonary disease (COPD)"?			
15. Do you have Diabetes?			
16. Do you have any un-cleared wounds or cuts on your feet that do not seem to heal?			
17. Have you unintentionally lost 10 or more pounds in the past six months?			
18. Do you experience pain in the buttocks, back of the thighs, or calves while walking?			
19. Have you ever had (past or present) any bone or joint problems?			
20. If the answer to question 19 is "yes," have you ever had a fracture of the hip, knee or spine? If YES indicate when (month/year)			
21. Have you ever been diagnosed with a spinal problem or do you experience frequent low back pain?			
22. Have you fallen more than twice in the past year (no matter what the reason)?			
23. Have you ever been diagnosed with high cholesterol?			
24. Has your physician ever specifically told you not to do "heavy" or "hard" exercise?			

Appendix C: "MINI-MENTAL STATE EXAMINATION (MMSE)"

Question	Answer/response	Score
What is the year?		
What is the season?		
What is the date?		
What is the day?		
What is the month?		
Name the country we live in		
Name the state we live in		
Name the county we live in		
Name the town we live in		
Name the facility we are in		
Repeat 3 objects: "car, box, shirt" or "Train, pot, pants"		
Serial 7's (up to 5) or spell "WORLD" backword		
Repeat the 3 objects		
Name a pencil		
Name a watch		
Repeat "No ifs, ands, or buts"		
"Take a paper in your right hand, fold it in half, and put it on the floor"		
"Close your eyes"		
Write a sentence: "Oh what a beautiful morning, oh what a beautiful day"		
Copy design triangle/squre)		

Appendix D: Study Schematic Representation



Appendix E: Pre-Qualifying Functional Capacity Classification

1) In the last year, have you lost more than 10 pounds unintentionally?
0 = NO
1 = YES

2) How often in the last week did you feel that everything you did was an effort?
0 = rarely or none of the time (< 1 day)
1 = some or a little of the time (1-2 days)
2 = a moderate amount of the time (3-4 days)
3 = most of the time

3) In the last week, how often did you feel that you could not get going?
0 = rarely or none of the time (< 1 day)
1 = some or a little of the time (1-2 days)
2 = a moderate amount of the time (3-4 days)
3 = most of the time

4) Can you get up from a chair by yourself?
0 = no difficulties
1 = some or little difficulties
2 = a lot of difficulties
3 = unable

5) Can you walk up/down one flight of 10 stairs by yourself?
0 = no difficulties
1 = some or little difficulties
2 = a lot of difficulties
3 = unable

6) Can you walk ¼ (quarter) of a mile by yourself?
0 = no difficulties
1 = some or a little difficulties
2 = a lot of difficulties
3 = unable

Summary Scale: maximum score (frail, expected to perform below threshold) = 16, minimum score (independent; expected to perform above threshold) = 0

Functional Capacity:
High = 0
Low ≥1

Appendix F: Task Modification Scale

	0	1	2	3	4	5
Chair rise (30, 38 & 43 cm)	Rises in a steady & controlled action	Stomps feet, rocks body, extends arms or elbows to thighs	Scoots to the front of the chair or makes multiple attempts	Uses hands on any part of chair for assistance	Needs investigator assistance	Refuse
Stair ascent and descent	Reciprocates in a steady & controlled action	Noticeable hesitations or unsteadiness	Non-constant brushing/grabbing or light continuous grasp of the handrail	Constant grabbing the handrail (pulling or bracing for support	Does not reciprocate and/or uses the handrail	Refuse
Kneel rise	Rises from kneeling position without the use of hands	Light use of hand/s on chair or knee (no shift in body weight)	Forcefully uses one or two hands on the chair causing a shifting of body weight	Kneels to the floor but requires assistance to rise	Cannot kneel to the floor	Refuse
Supine rise	Rises in a steady & controlled action (with or without role to prone position)	Uses one or two hands on top of thigh or lightly touches chair.	Bear crawl – two hands on floor, crawl into upright position	Forcefully uses one or two hands on the chair causing a shifting of body weight	Needs investigator assistance	Refuse

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- **Ph.D. :** Department of Exercise Science/Science Education, Syracuse University, Doctor of Philosophy. Degree awarded in May, 2012: Dissertation Title: ***"Lower Extremities Muscle Strength is Associated with Daily Task Modifications among Older Adults 65 Years of Age or Older"***
- **Doctor of Physical Therapy:** MGH Institute of Health Professions, Doctor of Physical Therapy Transitional program. Degree awarded in December, 2008
- **MHS.:** School of Physical Therapy, Washington University, St. Louis, Missouri: 1994 - 1997. Health Sciences/Physical Therapy. Degree awarded in August, 1997
- **BPT.:** School of Medicine, Department of Physical Therapy, University of Tel-Aviv, Israel: 1985 – 1990. Degree awarded in August, 1990

Certifications:

- OCS: Board Certified Orthopedic Specialist by the American Physical Therapy Association
- CSCS: Board Certified Strength & Conditioning Specialist by the American National Strength and Conditioning Association

Employment and Positions Held:

- Clinical Assistant Professor, College of Health Professions, Department of Physical Therapy Education, SUNY upstate Medical University: 2003-Present
- Physical Therapist, Mary Mauro-Bertolo Physical Therapy Services Out-Patient Clinic, Cicero, New-York: 2003-Present
- Graduate Assistant/Teaching Assistant, Syracuse University, School of Education, Department of Exercise Science: 2002-2003
- Assistant Professor of Physical Therapy, Division of Health and Human Studies, Department of Physical Therapy, Utica College of Syracuse University, Utica, NY: 1998-2001
- Assistant Academic Clinical Coordinator, Utica College of Syracuse University, Utica, NY: 1998–2001
- Physical Therapist, HealthSouth Out-Patient clinic, Utica, New-York: 1999
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Peer Reviewed Publications:

- Manini,T.M.; Cook,S.B.; Vanarnam,T.; Marko,*M*.; Ploutz-Snyder,L., Evaluating task modification as an objective measure of functional limitation: repeatability and comparability, J.Gerontol.A Biol.Sci.Med.Sci., 2006, July;61(7): 718-725.
- Manini,T.M.; Marko,*M*.; VanArnam,T.; Cook,S.B.; Ferenhall,B.; Burk,J.; Ploutz-Snyder,L., Efficacy of Resistance and Task-Specific Exercise in Older Adults Who Modify Tasks of Everyday Life, J.Gerontol.A Biol.Sci.Med.Sci., 2007, Jun; 62(6):616-623.
- *Marko,M*.; Neville,C.G.; Prince,M.A.; Ploutz-Snyder,L.L., Lower extremity force decrements identify early mobility decline among community dwelling older adults. Submitted to Physical Therapy Journal in January, 2012 – Accepted with revisions.

Peer Reviewed Scientific and Professional Presentations:

- "Lower Extremity Muscle Strength is Associated with Modifications of Daly Tasks Among Older Adults ≥65 Years Living Independently in the Community" Presented at a physical therapy conference organized by the New York Physical Therapy Association
- "Food for Thought: understanding the role of nutritional concepts in physical therapy practice" at the Physical Therapy Spring Symposium held at SUNY Upstate Medical University in 03/2006.
- "Survival of the Fittest: Simple Tools for Cardiovascular Risk Stratification in Physical Therapy Practice" at the Physical Therapy Spring Symposium held at SUNY Upstate Medical University in 03/2006.
- "The Scientific Art of Exercise Prescription" at the Physical Therapy Spring Symposium held at SUNY Upstate Medical University in 03/2005.

Non-Peer Reviewed Presentations:

- Lectures on issues related to wellness @ prevention, exercise prescription and physical performance
- Plan and participate in health fairs at SUNY Upstate Medical University
- SUNY Upstate Healthlinks Speaker
- Survival of The Fittest: its all about Healthy Choices: Volunteer speaker at Congregation Bet – Shalom.
- Fit for Life Public Event: Central District NYPTA PT Month activity 2004
- Participated in the Eighteen Annual Charles R. Ross Research Poster Session: 12-02-04. Title: Influence of Isotonic Contraction Velocity on Localized Muscle Activation Pattern and Fatigue
- Participated in the Nineteen Annual Charles R. Ross Research Poster Session: 11-30-05. Title: Sex Differences in Human Muscle Function Following Exercise at Differing Contraction Velocities

Funded/In Review Grant Activity:

- Recipient of the 2009 Research Enhancement Grant – College of Health professions at SUNY Upstate Medical University ($2250)
- Recipient of the 2006 Research Enhancement Grant – College of Health professions at SUNY Upstate Medical University ($2180)
- Recipient of the 2006 School of Education, Creative Research Grant – Syracuse University ($610)
- Recipient of the 2005 School of Education, Creative Research Grant – Syracuse University
- Recipient of the 2003 School of Education, Creative Research Grant – Syracuse University
- Recipient of the 2003 Sydney Young Research Grant – Syracuse University ($500)

Awards:

- Winner of the 2011 Robert S. Salant Award to best research in the New-York Physical Therapy Association Conference held on October 29, 2011 in Rye, New-York.

Membership in Scientific/Professional Organizations: include positions held

- American Physical Therapy Association
- American National Strength & Conditioning Association

Services to the University/College/School on Committees/Councils/Commissions:

- Wellness Committee at SUNY Upstate Medical University - 2005 - 2008
- College of Health Professions Social Committee: 2005 - Current

Continuing Education Attended:

- Selective Functional Movement Assessment (SFMA) Certification Seminar: 2012
- Functional Movement Screen (FMS) Combo Levels 1 and 2: 2011
- Motivational Interviewing: 2011
- Proprioceptive Neuromuscular Facilitation (PNF) seminar: 2010
- American National Conference for Personal Trainers: 2010
- Part I: High-Velocity Low-Amplitude Thrust Manipulation of the Spine, Pelvis & Thorax: 2009
- The International Conference on Strength Training: 2008
- Impaired Patterns of Posture & Function: 2007
- Differential Diagnosis & Manual Therapy of the Secondary Disc Related Disorders of the Lumbar Spine: Disc, Facet Joint, Segmental Instability: 2007
- Building the Ultimate Back: From Rehabilitation to High Performance: 2006
- Differential Diagnosis & Manual Therapy of the SI Joint and Primary Disc-Related Disorders of the Lumbar Spine: 2006
- APTA Workshop for New Faculty. Sponsored by the Education Section: 2005
- APTA Florida Chapter Conference for Clinical Educators: 2000
- Central New York Symposium on Exercise Physiology and Sports Medicine: 2002
- Mid-Atlantic Regional Conference of the American College of Sports medicine: 2002

- APTA Combined Section Meeting: 2001
- APTA Florida Chapter Conference for Clinical Educators: 2000
- APTA Workshop for New Faculty. Sponsored by the Education Section: 1999

Areas of Current Teaching Responsibilities in the Entry-Level (DPT) and the Transitional (tDPT) Programs:

- Physical Modalities
- Wellness & Prevention
- Applied Clinical Decision Making
- Movement Analysis
- Patient/Client Management: The Spine
- Physiology of Exercise