RELATIONSHIP OF EXERCISE TOLERANCE, EXERCISE INTENSITY, AND PHYSICAL PERFORMANCE IN FRAIL ELDERLY INDIVIDUALS RESIDING IN A LONG-TERM CARE FACILITY

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DEDICATION

With great respect and admiration, I dedicate this work to Mrs. Loal Balentine, my grandmother, whose love, wisdom, and belief in me have been an inspiration for my entire life. The life lessons learned at her knee have instilled in me a love of family and an understanding of real values.

I would like to further dedicate this attainment of my long-standing dream to my mother, who has loved and supported me regardless of the life choices I have made and who, I hope, will appreciate that challenges can be overcome if you just reach for the stars.

The completion of this dissertation is dedicated also to John, who has continued to love and support me even though my single-minded determination has been a puzzlement

and

to Philip, Melody, and Carol, who have forgiven the long hours of study and the many days of absence that went into my years of intellectual pursuit.

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ABSTRACT

Relationship of Exercise Tolerance, Exercise Intensity, and Physical Performance in Frail Elderly Individuals Residing in a Long-Term Care Facility

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Literature regarding the relationship between physiologic capacity and physical performance is limited and non-conclusive among the frail elderly. The purposes of this study were to examine the relationship of physiologic response to activity and physical performance using lower extremity activities, to describe performance capabilities, and to propose thresholds of performance in a sample of 78 frail older adults residing in long-term care facilities. Physiologic performance was evaluated using measures of heart rate during five minutes of walking and during a low level seated exercise test. Ratings of perceived exertion were determined following the exercise test. Physical performance was determined by timed chair rise and sit, challenged standing, 8-foot walk speed, and 5-minute walk distance. The subjects were tested in one session at the residential facility. All tests followed the same sequence with scheduled rest periods: challenged stands, walking speed test, five repetitions of chair rise and sit, rest break, 5-minute walk test, rest break, and seated step test. The subject's heart rate was monitored throughout and recorded during the last three minutes of the 5-minute walk and during the seated step test. The subject's heart rate was allowed to return to the resting rate between the test as indicated.

Pearson product-moment correlation coefficients for heart rate measures and physical performance measures of walking speed demonstrated no relationship in the frail sample. Likewise, Spearman rank-order correlation analyses found no relationship between the ability to rise from a chair repeatedly and heart rate measures. Challenged stands also did not demonstrate a relationship to the recorded heart rate values in the frail sample. However, the 5-minute walk distance was found to have a fair relationship to walking speed ($r = .35$) for the frail sample. The 5-minute walk test and the physical performance measures exhibited fair to good relationships to each other and were safe, acceptable, and discriminative measures.

The physical performance measures were objective, sensitive to different levels of physical capacity, and easily administered in spite of the frail status of the subjects. When combined, the walk speed, challenged stands, chair rise and sit, and the 5-minute walk distance were useful in describing the elderly in the sample. The heart rate data was easily obtained from the subjects, but was not as useful in determination of physical performance capabilities. Based on the data from the study, performance thresholds for the 5-minute walk was ≤ 380 feet, walking speed was $\leq .75$ feet/second, challenged stands was inability to stand in tandem, and chair rise and sit was ≥ 27.69 seconds to perform five repetitions.

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CHAPTER 1

INTRODUCTION

Nature of the Study

The goal of health care for the older adult is to assess and maintain function into very old age. The outcome is successful aging and prolonged independence with maintenance of a good quality of life. Inherent in the achievement of such goals and outcomes is an understanding of physical and physiological function and performance in the elderly, especially the frail elderly at highest risk of decline and dependence. Literature regarding the relationship between physiologic capacity and physical performance is limited and non-conclusive. In addition, conflicting research exists as to whether intervention directed at physical functional training will improve physiologic capacity or conversely, whether physiologic training improves functional performance abilities.[1, 2]

The ability of the human body to meet the demands of daily living is dependent on the interaction of vital physiologic and physical performance factors. Likewise, the ability to meet the added stress of unusual or strenuous physical and physiological activity is dependent on the systems' reserve capacity.[3] Reserve capacity implies a flexibility within the biological system such that when the need arises the individual can draw on the physiologic reserve to ensure adequate physical performance of the task. Theoretically, a threshold point may exist in physical and physiological performance above which reserve capacity is limited and the individual would not be able to meet added physical demand or function.

Researchers have proposed that a threshold of physiologic and functional reserve exists for the older adult and may be of great importance in the sedentary frail older adult.[3, 4] Frail older adults, with reliance on shrinking physical and physiological reserves, are functioning with limitations in performance and are at high risk for added decline to eventual dependence.

Statement of the Problem

The clinical expectation of functional improvement is based on the construct that physical performance is inherently dependent on physiologic efficiency and similarly, physiologic efficiency is dependent on maintenance of an adequate level of physical performance.[5, 6] Without adequate physiologic strength, cardiac output, ventilation, and metabolic processes, physical performance would become difficult and functional limitations would be the inevitable outcome. Theoretically, when an individual decreases daily physical activity, the physical parameters of performance would decline to dependence. Likewise, if functional decline is evident, the factors of physical activity, tolerance, and performance would be adversely affected. The elderly residing in nursing centers may exhibit changes in physiologic and physical performance which would adversely affect functional performance. The graphic model in Fig 1 describes the interdependent factors associated with physical activity and function in the frail elderly.[5]

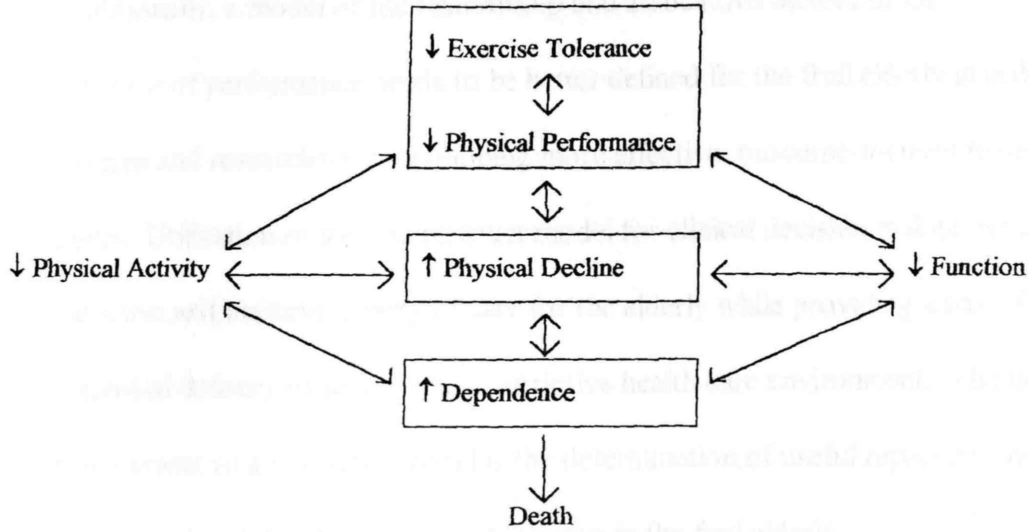

Fig 1 —Model of Interdependence of Physical Activity and Function Relating to Frailty

While such a construct is founded in basic research, little is known about the relationship of the physiologic factors and physical performance in the frail elderly. Studies seem to indicate that the frail elderly are functioning at or beyond performance thresholds physically and physiologically[3, 4, 7-10], but poor physical performance may not correlate with poor physiologic capacity depending on the particular task. The lack of a demonstrated relationship between the factors of performance may be due in part to a paucity of literature involving measures of physical performance and related physiologic response in the frail elderly. A better understanding needs to be developed of physiologic and physical frailty and the relationships of these two factors in terms of performance capacity.

Additionally, a model of the relationship and associative factors of the interdependence of performance needs to be better defined for the frail elderly in order to assist clinicians and researchers in developing more effective, outcome-focused treatment interventions. Utilization of such a construct model for clinical decision making would be more productive and improve quality of care for the elderly while providing a basis for more economical delivery of services in a restrictive health care environment. The initial step in development of a construct model is the determination of useful representative variables of physiological and physical performance in the frail elderly.

Since an adequate model was not found in the reviewed literature, a study investigating the physiologic and physical performance indicators in the frail elderly was needed and the results used to further define the relationships and the possibility of performance thresholds. Therefore, this study was designed to examine the relationship of physiologic response to activity and physical performance using lower extremity activities in a sample of frail older adults residing in long-term care facilities.

Justification

Physical performance measures have been defined in recent literature as consistent predictors of functional decline and nursing home admission in the community-dwelling elderly.[11-16] In addition, physical performance scores have been used to indicate a threshold performance with which clinicians may identify older individuals at risk for decline to frailty.[12, 13, 17] Physiologic measures such as strength and aerobic capacity have been examined in active and sedentary healthy older adults and in patient samples.[18-23] Comparable physiologic thresholds have been proposed but lack sufficient definition due to the physiologic heterogeneity of the frail elderly population.[24-27] The literature appears to indicate that a relationship exists between the physiologic components like strength, response time, and aerobic capacity and physical performance tasks such as walking, stair climbing, rising from a chair, and caring for oneself in the community-dwelling elderly.[6, 17, 22, 28-43] However, contradictory outcomes in functional improvement were found when physiologic training versus functional-based training was undertaken in more frail samples.[2, 44]

Little research was found on the relationship of physiologic measures and physical performance in the frail elderly with existing dependence and disability.[1, 2, 22, 44] Additionally, the feasibility and usefulness of physical and physiologic measures requiring extra effort in the presence of existing performance limitations have not been well documented in the literature. Even less is known about the performance capabilities and test response in the elderly residing in institutions. Physiologic measures of heart rate, maximal and submaximal VO_2, strength, and muscle metabolism appear to be appropriate for use in community-dwelling elderly. Physical performance measures of timed chair rise, standing balance, walk speed, and walk distance may be useful in determination of performance status for most frail elderly. The correlational and predictive relationship of the measures is of current interest to researchers, geriatricians, and health professionals working with frail elderly.

Fried et al[45] proposed that measures of physical function could be categorized into four groups of related performance tasks: 1) activities primarily dependent on mobility and exercise tolerance; 2) complex integrative tasks primarily dependent on cognition and sensory input; 3) basic activities of daily living; and 4) upper extremity activities. The investigators suggested that grouping physical function tasks in this way may assist in identification of the underlying physiologic impairment and lead to quantifiable physiologically-based outcome measures. Further, difficulty in performance of specific physical tasks appeared to have a physiological basis in common. The relationship between physiologic capacity and physical performance tasks in the frail elderly requires further research in order to clinically define the cause and effect potential for increasing disability and decline.

Purposes

This study was performed with the following purposes:

1) examine the relationship of the selected measures of physiologic and physical performance indicative of mobility and exercise tolerance in the frail institutionalized older adult.

2) to expand the body of knowledge on performance capability of frail subjects.

3) to determine the usefulness of the variables in describing threshold performance in frail elderly with emphasis on the descriptive qualities of the measures.

Research Inferences and Relationships

Physical and physiologic performance capabilities and performance limitations will be examined in the frail sample. Clinically practical inferential relationships (relationships having small or no statistically significance but may more clearly define a population[46]) and threshold models were evaluated and discussed as follows:

Performance Capabilities

1. The frail subjects were evaluated for determination of physical performance capabilities in completing the test measures of repeated chair rise and sit, challenged standing, 8-foot walk speed, and the 5-minute walk.
2. The usefulness and acceptability of the test equipment and methodology was examined for the heart rate monitoring system and the low-level exercise test as indicators of physiologic performance in the elderly residing in long-term care facilities.
3. The effect of frailty on resting, walking heart rate, and seated step test heart rate was described for the sample.
4. A low-level exercise test and ratings of perceived exertion were examined to determine the usefulness and descriptive nature of a fatiguing effort.

Inferential Relationships

1. Measures of seated step test heart rate using a low-level exercise test were examined for the relationship to scores of challenged standing, chair rise and sit, and walk speed.

2. Average walking heart rates recorded during a 5-minute walk were examined for the relationship to challenged standing, chair rise and sit, and walk speed.
3. The distance walked in five minutes was evaluated for the relationship to challenged standing, chair rise and sit, and walk speed.
4. The level of perceived exertion obtained following the low-level exercise test was examined for the relationship to the seated step test heart rate recorded during the exercise test.

Threshold Models

1. The 5-minute walk distance was examined for clinical usefulness as a threshold descriptor of exercise tolerance in the frail sample.
2. The walk speed of the frail sample was compared to existing literature to describe probable population parameters and thresholds.
3. Repeated chair rise and sit was evaluated for usefulness in identification of thresholds and descriptive value in the frail elderly.
4. Challenged stands were measured to determine the utility and sensitivity of the measure in determination of threshold performance for the frail elderly.

Population inferences were established for each relationship based on 95% confidence intervals. For the variables to be clinically useful and practical, relationships between variables were examined for the ability to more clearly define a population as well as exhibit acceptable statistical associations. Acceptable statistical relationships have been defined as little or no relationship ($r \leq .25$), fair relationship ($r = .25$ to $.50$), and moderate relationships (r= .50 to .75), and good to excellent relationships (r= >.75).[47] The research expectation was that at least a fair (r = .25 to .50) relationship will be demonstrated between the physiologically-based measures of heart rate and exertion and the physical performance measures. Additionally, a reasonable confidence interval (95%) would present a range within which population scores would theoretically be located.[46]

Research Limitations

Possible limitations of the study which may influence the interpretation of the data were medication interference, obesity, motivation, single trial model, environmental obstacles and distracters, and limited task performance in the frail sample. Research has demonstrated that some medications may influence physical and physiologic performance, but limited data was available to define the impact of even the most common medications (diuretics and anti-anxiety drugs) on exercise response in the elderly.[48, 49] Unfortunately, the elderly subjects in the present were usually taking multiple medications and stopping all medications would have been unethical. Attempts were made to exclude individuals taking beta blockers that are indicated to be beta-1 selective which have been proven to interfere with heart rate response to exercise.[49]

In a related study, which is discussed in Chapter 3 and was undertaken prior to the present study, central or regional obesity (specifically defined by Guccione[50] as an accumulation of adipose tissue in central visceral regions of the body) was found to be a possible limitation in transmission of heart rate data to a portable receiving device. Older sedentary males and females are prone to the accumulation of fat in the central areas.[51] Therefore, obesity may limit the use of heart rate as a monitoring tool in some frail elderly. Efforts were made to position the monitoring device for optimal continuous readings.

A further confounding limitation may be a lack of motivation in the frail elderly residing in an institution. The complex behavioral aspect of motivation is not well understood in the frail elderly. Avers and Gardner[52] discussed motivation in the context of rewards versus cost of behavior; and Kemp[53] described motivation as complex, being derived from personal desires and cultural beliefs. Older adults in long-term care facilities may not feel motivated to perform fully on tests that require more than usual effort (cost of behavior) and which have limited benefits for the participants (rewards). Many residents of long-term care facilities may be under the assumption that "rest" in old age is better (cultural). In addition, the resident is usually in a passive role, ministered to by a, sometimes too, willing staff. All of these motivational aspects may combine to result in a self-limiting response to the added demands of unaccustomed exercise. Since a standardized tool does not exist for the accurate determination of motivation in frail subjects, control of performance motivation was problematic and thus, the possibility of poor motivation was accepted.

The limitation of one trial may also confound the results. In the related study (Chapter 3), the variability of physical performance measures was not deemed to be a problem in day to day and over time in a sample twelve frail elderly. However, a learning effect has been documented in walking tests in community-dwelling elderly.[54, 55]

Attrition, frail status of the targeted sample, and subject inconvenience are the primary constraints supporting the use of a single trial model.

The long-term care environment is a complex, busy situation with numerous obstacles and distracters to optimal physical performance for the frail elderly. Physical obstacles such as laundry carts, "wet floor" markers, and medicine carts are common in the corridors and may limit continuous walking. Distracters in the form of roommates, other interested residents, and inquisitive staff may decrease the individuals ability to successfully complete a task.[56] Efforts were made to control the environment by removing obvious obstacles, however, unanticipated or unobserved distracters may have continued to be present due to the complexity of institutional facilities.

Lastly, the frail elderly may not be fully able to perform the battery of physical and physiologic measures in the study. Several researchers have demonstrated that community-dwelling elderly can complete performance and exercise tests without undue incident[12, 57]; but little is known about exercise tolerance of more frail elderly.

Conceptual Definitions

Conceptual definitions to be explored further in Chapter 2:

1. normal aging - time-dependent physical and physiologic loss of ability to adapt to increases in performance demands[3, 5, 58]
2. physiologic performance - basic processes of the underlying, support mechanisms involved in muscle, neural, and metabolic responses to stimuli[5]

3. physical performance - ability to perform activities of daily living and meet ones functional needs[12]
4. reserve capacity - flexibility in the physical and physiologic systems which allows response to added performance demands
5. physiologic threshold - a point defining limited reserve physiologic capacity
6. physical threshold - a point defining limitations in physical performance
7. functional threshold - a point indicating risk of decline to dependence on others
8. functional limitations - inability to perform usual tasks and roles[59]
9. frailty - multifaceted inability to carry out important practical and social activities of daily living[24]
10. hardiness - ability to carry out necessary activities of daily living and maintain usual social role[24]
11. frail older adult - adult over age of 65 with limited ability to carry out practical and social functions[24]
12. submaximal exercise - exercise requiring less than maximal physical and physiologic effort with a pre-determined endpoint[60]
13. symptom-limited exercise - exercise requiring a level of physical or physiologic performance limited by fatigue or symptoms which prevent continuance of the exercise[61]
14. exercise tolerance (endurance) - physical and physiologic ability to tolerate sustained activity

15. strength - ability to generate maximal or required force [5]

16. neurologic function - ability to perform complex tasks requiring adaptation and rapid response[62]

17. mechanical function - coordinated musculoskeletal performance of tasks of living[63]

18. metabolic function - physical utilization of circulating nutrients and oxygen in performance of tasks[63]

In summary, research describing the relationship of physical and physiologic performance measures have not been well documented in the literature. The possibility of descriptive performance thresholds has been proposed by several investigators, but presently little research is available to support the feasibility of such thresholds in frail elderly. Limited research is currently available to describe the physical and physiologic performance capacity of the frail elderly residing in long-term care facilities. Review of the relevant literature examining normal aspects of aging, physical and physiologic performance, frailty, and threshold performance will be presented in Chapter 2.

CHAPTER 2

LITERATURE REVIEW

The purposes of the study were to examine the physical measures of repeated chair rise and sit, challenged standing, 8-foot walk speed, and 5-minute walk distance and the physiologic measures of resting heart rate, seated step test heart rate, 5-minute walk heart rate, and ratings of perceived exertion for correlational relationships, performance thresholds, usefulness and value as population descriptors in a sample of frail elderly residing in institutions. The literature review focused on normal aging processes involving the cardiopulmonary, nervous, and musculoskeletal systems; physical and physiological performance; frailty; performance parameters indicative of frailty; and the relationship between physical and physiologic parameters in the frail elderly. The literature review expands the conceptual definitions presented in Chapter 1.

Normal Aging Changes

Although the concept of normal aging may be a misnomer due to the heterogeneity of the process, the sample of interest in the study was defined as frail, not having aged "normally". Normal aging may be thought of as predictable physical and physiologic changes in the absense of pathology. Use of the qualifier frail necessitates exploration of what is not considered frail by current thought. Normal will be discussed in terms of aging changes that occur to some degree regardless of modifiers such as physical activity or diet.

Cardiopulmonary Changes

The cardiopulmonary system plays a major function in the ability to sustain activity over a sufficient period of time. The system must maintain the required level of energy via the oxidative mechanisms, that is the ability to take in enough oxygen, to have a sufficient pulmonary circulation to transfuse the oxygen, and sufficient peripheral extraction to utilize the oxygen once delivered. In addition, oxidative enzymes of succinate dehydrogenase (SDH), 3-hydroxyacyl-CoA-dehydrogenase (HAD), cytochrone oxidase (CYTOX), and citrate synthase (CS) need to present in adequate amounts in the exercising muscle. The factors of interest in the context of activities of daily living, which are generally considered to be dependent on submaximal effort, are heart rate , stroke volume, oxygen delivery, aerobic capacity, and extraction of circulating oxygen by contractile tissues.[3]

Resting heart rate has shown little significant difference between young and old healthy individuals in cross-sectional analyses. [26, 64, 65] Resting heart rate also was found to remain reliable over time in frail elderly (R Zabel, unpublished data, 1997). Kostis et al [65] reported no significant effect of age or between day and night monitoring on minimal and average heart rates in a sample (N=101, mean age 48.8) of community-dwelling males and females. The subjects were monitored using 24-hour ambulatory electrocardiography and maximal exercise stress testing procedures. The sitting heart rate, however, may be associated with lower readings in both aging men and women.[66]

Unlike resting heart rates, exercising heart rates do exhibit significant decline with aging.[65, 67, 68] A simple formula is used frequently to exemplify the direct relationship of maximum heart rate and age (220 minus the age). However, the formula has been shown to be inaccurate and may either underestimate or overestimate the older adult's true maximum heart rate.[68] During maximal stress testing, steeper increases in heart rates (r=.68, p=.001) and lower maximal heart rates (r=.43, p=.008) were noted with increasing exercise intensity in older subjects when compared with younger subjects.[65] Likewise, a large review of medical literature agreed that age accounts for a large portion of the variance in maximal heart rate (73%) and that heart rate maximum declines significantly as one ages.[67] The investigators also postulated that maximum oxygen consumption and maximum heart rate are linearly related to age regardless of fitness level. Therefore, the use of either should be appropriate to assess performance in even frail, unfit elderly. However, research to support this premise is lacking in the literature.

Functional capacity declines with age as result of changes in both cardiac performance and efficiency in the peripheral vascular system.[35] The heart responds to aging much the same as all connective tissue with stiffening and decreased distensibilty.[5] Stroke volume at rest shows age-related effects with a 0.5% to 0.7% decrease per year from age 20 to 80 years.[58] The combination of the heart rate and stroke volume changes are usually well compensated at rest and with submaximal activity in physically active well elderly, but result in a 20 to 30 percent reduction in maximal cardiac output and therefore, the maximal aerobic capacity as one ages.[6]

Early studies found that older subjects were able to sustain stroke volume during submaximal effort, but exhibited decreased stroke volume during heavy exercise.[69] The possible causal factors for the smaller stroke volume at maximal exercise levels were suggested to be changes related to myocardial perfusion, a stiffer ventricular wall, decreased myocardial contractility, slowed diastolic filling, and increased peripheral vascular resistance.[42]

Interestingly, several related studies reported that the maximum stroke volume actually exhibited an increase with aging as a compensatory mechanism for the lowered maximum heart rate; the older adult is extracting more circulating oxygen at lower work loads.[25, 70] Both of the referenced studies examined samples of healthy subjects without signs of heart disease. One could extrapolate that an aged individual without heart disease would be more fit than the average sedentary older adult and that the average older adult would possibly demonstrate the reduced stroke volume reported in the previous studies.

A study to examine aerobic capacity was undertaken in a sample of fourteen women with a mean age of 75.7.[71] The women participated in an eight week exercise program involving standing and sitting physical training. The outcome variables were heart rate (HR), systolic blood pressure (SBP), and rate-pressure product (RPP=SBP X HR) determined by performance on a graded step test pre and post participation in the exercise program. Significant decreases were observed after training for resting SBP, and

RPP, and for submaximal HR (-5.3% change), SBP (-8.0% change), and RPP (-13.9% change). Interestingly, the control group in this study also exhibited significant decreases in resting (-11.8% change) and submaximal SBP (-6.4% change) which the investigators theorized may have been due to familiarity with the testing procedure at post-test or possible medication interference. The results may have been more clinically relevant if the exercise protocol had been extended, medications were more controlled, and a follow-up exercise test performed.

The best indicator of cardiopulmonary efficiency is the ability to achieve maximal oxygen consumption (maxVO_2). Maximal oxygen consumption has been shown to decline progressively with age. While continued physical activity increases the maxVO_2, the decline remains correlated to age.[72]

A third controlled study using a sample of 83 patients (mean age of 68 ± 5 years) post-coronary events evaluated changes in the peak and submaximal oxygen consumption, treadmill work capacity, minute ventilation, heart rate, and systolic blood pressure following an exercise conditioning program of 3 and 12 months duration.[29] The intervention group demonstrated a 47% increase in maximal work capacity (defined as increase in exercise duration) when compared to the control group on treadmill performance after 3 months of aerobic training consisting of treadmill walking, cycling, and rowing. All patients exhibited improvements in the aerobic parameters with the intervention group demonstrating greater changes in peak oxygen consumption at both 3 and 12 months (16 and 20% for the intervention group compared to 7 and 14% for the control group). However, the intervention group achieved a lower heart rate and minute ventilation at a standard submaximal workload whereas the control group did not achieve any significant changes. The intervention subjects benefited from an aerobic conditioning of 3 month duration and continued to make significant gains at 12 months.

In response to the onset of light activity, older men (aged 60+) demonstrated a 40% longer oxygen deficit than did the younger men in a study examining the influence of age on exercising capacity.[73] In the same study, the investigators reported that the ventilation threshold (signaling a probable shift to anaerobic glycolysis) was approximately 30% lower in the older group. However, the ventilation was maintained at a level sufficient to perform sustained submaximal activity like walking.

With aging, the thoracic wall becomes less compliant resulting in an increase in the work of breathing by about 20%.[74] With increasing age, the functional ability of the lung to move air in and out is evidenced by an increase in the residual volume (air remaining in the lung after forced expiration) and a decrease in the vital capacity (maximum air that can be exhaled following a complete inspiration).[41] These changes result in a more rapid increase of ventilation frequency rather than utilizing deeper breathing (increased tidal volume) during exertion.[73] Ades et al[75] reported the oxygen debt was increased and the ventilation threshold was lowered in the sedentary older adult which resulted in an increase in dyspnea at lower workloads.

The peripheral extraction of oxygen at rest and during submaximal exercise has been found to remain relatively unchanged in older active men, but older women exhibit an increase in the arteriovenous difference (difference in oxygen content of arterial and venous blood and is indicative of peripheral utilization of circulating oxygen) due to possible reduction in the mechanical efficiency of the myocardium and exercising muscle.[6, 72, 76] In studies of the mechanical efficiency in older adults, the researchers reported a decrease to 21.5% efficiency during exercise activity.[68] Possible explanations for the decrease in exercising efficiency are loss of lean body mass resulting in deposition of fat in the muscle, joint stiffness resulting in increased effort with movement, and loss of tissue compliance resulting in decreased resiliency following muscle work. In addition, factors such as decreased capillary concentration in muscle tissue and increased blood flow to the skin could theoretically combine to result in reduced oxygen extraction in exercising muscle of some elderly.[76] The changes also occur with disuse and limited physical activity as well as with aging.[72] Therefore, the older adult residing in a long-term care facility may not demonstrate the physiologic capacity to effectively utilize circulating oxygen.

In summary, few changes were noted in the literature concerning heart rate and oxygen consumption during rest and submaximal exercise in older independent individuals. Respiratory function and ventilation does not appear to limit exercise capacity or response in healthy older adults. In the frail elderly, the more rapid onset of ventilatory compensation for oxygen utilization combined with the lung volume changes and the larger oxygen deficit may be indicative of a limited capacity to respond to increasing workloads resulting in earlier fatigue.[73] Work efficiency was found to decline to a greater degree in residents in a nursing home when compared with an age-matched independently-living sample (9% work efficiency in the more frail compared to 17% in the independent subjects).[77] Whether similar results would be found in a more frail sample is doubtful since many frail individuals may be functioning very near their maximum performance during activities of daily living like bathing and dressing.

Nervous System Changes

The ability to react to stimuli in the immediate environment using neural mechanisms is complex and is well beyond the scope of this study. However due to the variables of interest, a review of several relevant age-related nervous system changes will be discussed in limited detail.

In studies examining the time required to discriminate length differences in two lines placed parallel, the researchers found that the time shortened from childhood to young adulthood and lengthened progressively beyond the age of 50.[78] Further, the results indicated that as the differences in lines decreased the older adults took longer to make discriminatory decisions. The clinical implications of the findings are that older adults may take longer to make movement decisions and may make different decisions if presented with tasks requiring discrimination between distances. For example, walking along a marked 8 or 10 foot course versus walking down a corridor with no visual distance markers.

Discrimination is also a factor in the process of decision-making concerning sensory signals and appropriate responses to signals. Research has shown that as the signal becomes more complex and the response requires more speed and accuracy of movement older adults exhibit longer reaction time and demonstrate more erroneous movement patterns than do young adults.[43] The age differences in speed and accuracy may be associated with sensory confusion or overload in the ability to make complex integrative movements.

The relationship between aging, attentional demands, and postural stability is an area of current interest among researchers.[8, 56, 79] Stelmach et al [79] utilized 7-second standing arm swinging as a challenge to static stability while asking the subject to perform a concurrent mathematics task. The results indicated the older adults took longer to return to normal quiet stance when compared with a young sample. Similarly, Shumway-Cook[56] found differences in postural responses in older and younger subjects when the task complexity was increased by adding a secondary cognitive task or by increasing the challenge to the balance. The researchers also reported that in subjects with documented balance impairments the problems with task integration were more evident with even less complex and challenging conditions. Maylor and Wing[8] examined age differences in postural strategies following introduction of secondary cognitive visuo-spatial tasks. The findings indicate that the older adults consistently demonstrated increased postural reaction times with addition of the secondary task. Older adults have been shown to be more reliant on peripheral visual cues for postural reactions and in conditions where peripheral vision is absent or limited falls increase in frequency.[80]

Clinically, the expectation is that the older adult will have difficulty in balance performance in the presence of distracters or visual disturbances.

Older adults tend to require longer periods of time to commit to a movement response and a longer time to correct inaccurate movement.[43] The time taken to initiate movements requiring substantial muscular force have been reported to increase by 18% from stimulus to first EMG activity, 17% from EMG to beginning muscle contraction, and 33% to movement response. A slightly less time to movement response is theorized to be the result of movement taking place before attainment of full muscle recruitment.

To summarize, several investigators have examined the relationship of voluntary movement and postural control in relation to aging.[80, 81] Slowed reaction times may be the result of age-related deterioration of both the voluntary control and postural control systems. The degree of contribution from each system is yet unclear and may be dependent on whether the movement requires only lower extremities or both upper and lower extremities in completion of the task.

Musculoskeletal Changes

Many of the normal age-related changes like loss of lean muscle mass, increased postural sway, decreased walk speed, decreased step and stride length, and decreased axial mobility are thought to attribute to functional changes associated with walking and physical performance.[5] Likewise, age-related decline in joint flexibility and the associated stiffening of connective tissues are contributing factors in performance limitations.[63] Bone loss accompanies aging to some degree and may predispose the elderly to traumatic injury.[82, 83]

The most prominent age-related change in skeletal muscle is the loss of lean body mass resulting from a decline in muscle fiber number. Three types of skeletal muscle fibers have been identified in adults: type I (slow-twitch high-oxidative fibers), type IIA (fast-twitch high-oxidative), and type IIB (fast-twitch slow-oxidative).[84] The slow twitch fibers are useful in provision of stability as in holding postures, while fast twitch fibers promote quick responses as in preparatory, anticipatory, and postural reactions. However, several theories have been proposed concerning which muscle fiber types decline with aging. Some studies attribute the decline to a selective loss of type II fibers, while others report an increase in tensor response in type I fibers. The decline in muscle fibers is not uniform in all muscles and is more prominent in the lower extremities than in the upper extremities which are in more constant use in activities of daily living.[85]

Muscle strength has been shown to exhibit a high correlation to the size of the force-producing muscle.[82] Elderly residing a nursing home were found to have significantly lower maximal quadriceps strength when compared to age-matched independent elderly subjects.[77] In addition, the researchers found that the more frail elderly were unable to sustain an adequate force for a period of time during lower extremity exercise. The loss of muscle mass and concomitant strength is of major importance in the elderly at risk of functional decline. The loss in strength will likely be evident in performance of tasks requiring quick and repeated muscle response as in timed stepping activities.

Since disturbances in gait and balance may produce disability and functional dependence in as many as 13% of older individuals, the most common area of research examining the relationship of strength to performance in the elderly has taken place using the lower extremities and the capacity to walk or rise from a chair.[1, 22, 33, 36, 38, 44, 86, 87] Early research sought to examine the association of repeated chair rises and knee flexor and extensor strength in a sample of 139 normal, healthy men and women of various age groups (age range 20 - 85 years) and a sample of 6 patients with polymyositis with significant results.[86] The investigators reported a correlation of .71 for the time to stand from a chair 10 times and age for women and .88 for the men in the sample. The results of the comparison between knee flexor and extensor strength and the chair rise time demonstrated mean decrements in performance and strength as a function of age. Interestingly, the results found men to be stronger in all age groups but that the difference became less with older age. In the oldest healthy group, the time to stand 10 times from a chair was not significantly different between males and females. The investigators concluded that chair rise was positively associated with strength and exhibited little gender bias in the healthy elderly subjects.

Functional capacity and muscle strength were analyzed in an similar study involving 52 men and women between 78-81 years of age.[33] The functional capacity was determined using walk speed over 30 meters and a stepping task using various heights; strength was determined from maximal contractions of the right knee extensors, plantar and dorsiflexors, elbow flexion and extension, and grip. However, the researchers found no significant correlation between knee extension strength and the functional capacity tests but did not include a chair rise test as in the previous study. Although a significant correlation was not found in the test sample, the authors concluded adequate strength is important for practical purposes like performance of daily tasks and community independence.

In a related study, Rantanen et al[87] researched the association between maximal isometric strength in grip, arm flexion, knee extension, and trunk flexion and extension and mobility and functional tasks which included maximal walking speed over 10 meters, serial stepping to steps of various heights, and self-report of chair rise using a sample of 75-year-old males and females. The investigators reported a significant correlation ($p<.001$) between all strength measures and walking speed over 10 meters in the female subjects. Men in the study also demonstrated significant correlations ($p=<.05$) in all of the strength measures except grip. Unlike the earlier reported study, the researchers concluded that maximal isometric strength demonstrated a significant positive association with functional mobility as indicated by performance of walking, rising from a chair, and stepping.

Bassey et al[22] examined the relationship of leg extensor power and functional performance using a very old sample (N=26, mean age males=88.5, females=86.5). Leg extensor power was determined using a maximal eccentric push on a foot pedal. Functional performance measures consisted of a single chair rise time, climbing speed for ascension and descesion of four steps, and normal walking speed over 6.1 meters (20 feet). The results indicated leg extensor power was significantly correlated with each of the performance measures: chair rise r=.45 males and .83 women; climbing speed r=.76 males and .85 women; walking speed r=.58 males and .93 females. The investigators concluded that for the females in the study muscle power was crucial for performance whereas the males appeared to have a greater muscle power reserve. The females in the study appeared to be functioning very close to the threshold for muscle and physical performance with little reserve from which to draw on during maximal muscle tests.

Recent prospective research in the area of functional thresholds in older adults and clinically relevant predictors of physical decline to dependence demonstrated a relationship between walking velocity, quadriceps strength, and nursing home placement.[17] The investigators collected strength and walking velocity data on 588 older adults with a mean age of 77 years who resided in a continuing care retirement community, homebound, or ambulatory settings. The data were collected at baseline, 2 years, and 4 years in order to determine predictive relationships of the variables and decline below a threshold value of walking velocity which was associated with nursing home placement. A threshold velocity of 11.5 m/min was found to be an accurate predictor of nursing home status at the 2 year follow-up; this cutpoint velocity correctly classified the subjects into categories of outside the nursing home (87%) and nursing home resident (65%). The findings indicated that quadriceps strength was associated with the decline in walking velocity and also was significantly associated with velocities below the threshold. Thus, the physiologic performance of the quadriceps during tests of strength proved to be associated with the physical performance measure of walking speed for the test sample. While this study differs from a previous study of walking speed[88], the prospective nature of the study's design and the large sample size support the generalizability and practical significance of the findings.

Physiologic muscle strength has been implicated as a causal factor in frequent falls in the elderly.[89] This association was examined further by Hwang and Reinsch[90] using a sample of 91 independent, community-dwelling, active older males and females with a mean age of 75.6 years. Lower extremity strength was determined with repeated chair rises (10) and a break dynamometry test. Falls were monitored for one year and the subjects were classified into categories of fallers and nonfallers. The baseline strength data were then utilized to determine whether elderly individuals with weaker lower extremity strength would experience falls. Surprisingly, the results did not find a significant correlation between fallers and nonfallers and lower extremity strength. The authors concluded that other factors such as environmental hazards may pose a greater falls risk than physiologic strength for active older adults. However, the data supports the concept of a possible threshold of functional adaptation such that the older adult may be limited in the reserve capacity to adapt when faced with a performance challenge. The investigators did find the repeated chair rise to be a useful tool to indicate dynamic lower extremity strength in the community sample of older adults.

Studies to examine changes in strength capacity and physical performance following a strength-focused training intervention in the elderly have been reported in recent literature.[1, 36, 37, 44] In a controlled study to examine the effects of aerobic cycling and strength training on mobility and gait velocity, Sauvage et al[44] found that mobility scores involving walking short distances, standing from a chair, and bending over did improve significantly (p=.004) as did overall lower extremity strength (p=.01) following 12 weeks of training, but the association with improved activities of daily living or decreased falls was not determined. Likewise, Judge et al[37] reported that in a sample of 31 active elderly subjects (mean age 82.1 years) from two assisted living settings the maximal lower extremity torque increased by 32% (p=.001) and the gait velocity increased by 8% (p=.006) following 12 weeks of resistance, isokinetic, and balance training. Carryover into other areas of physical performance was not examined.

In a frequently referenced study, Fiatarone et al[1] used a program of high intensity resistance exercises in a sample of very elderly nursing home residents (N=100, mean age 87.1 years) to examine changes in muscle strength and physical performance. Pre-training strength was determined using a one repetition maximum concentric hip and knee extension contraction. Gait velocity over a 6.1 meter course and level of daily physical activity were used as measures of physical performance. The investigators documented a significant increase in strength (p=.001) and in daily physical activity (p=.03) following 10 weeks of progressive resistance training of the lower extremities. This study supports the strength capacity model as demonstrated in the increase in daily activities found in the exercise group. The investigators indicated the improvement in strength was associated with increases in functional mobility and physical activity;

however, further research is needed to determine the possibility of psychological and emotional changes as the result of participation in the study.

Functional-based physical performance and muscle strength was analyzed in a sample of 14 community-dwelling elderly women following 16 weeks of total body conditioning.[36] The investigators utilized data obtained from transcutaneous electromyographic muscle activity of the biceps during carrying activities and of the rectus femoris during standing from a chair and walking velocity over 6 meters to indicate physical performance. In addition, dynamic strength was tested using one repetition maximum of upper and lower extremity large muscle groups. The results showed isotonic and isometric strength increases as well as significant improvements in walking velocity. Electromyographic activity exhibited a decrease during functional performance in all muscle groups which may be associated with more efficient muscle response to demands.

Physical performance does seem to be associated with the strength capacity of the appropriate muscle groups. Research appears to support the concept of focused strengthening as an intervention to improve physical performance in the lower extremities. However, the relationship to physiological performance, activity tolerance, and the carryover into daily living tasks remains unanswered. The relationship of strength capacity and functional limitation in the frail elderly needs further analysis.

The age-related decline in joint flexibility is an important contributing factor in the performance of activities of daily living like bathing and dressing as well as functional mobility. The decline may be related not only to advancing age but also to lifelong joint stress, disuse, poor posture, and disease processes like arthritis. In a study examining the use of resistance and stretching exercises in elderly women (N=46, age 65-89), the investigators reported differences in shoulder flexion and shoulder abduction range of motion when compared to estimates of normal flexibility.[91] Other ranges were comparable or exceeded the estimates of flexibility for younger adults. The functional limitations associated with loss of flexibility are dependent on which joint or joints are limited and the mobility needs of the individual. The upper extremities appear to exhibit less decrease in flexibility than the lower extremities which would support the association with disuse.[92] The upper extremities are very important for self-care functions such as dressing, bathing, and eating. Functionally, the older adult may respond to the age-related decrease in range through subtle compensations like placing required objects within easier reach or by slowing the gait. However, the compensations may eventually be contributory factors in further flexibility decline to the point that the individual has little physical reserve.

Loss of bone mass does accompany aging and is the result of bone reabsorption. The loss in bone mass may lead to physical frailty due to the resulting decrease in bone density and thickness limiting the tolerance of bony stress from falling. Functional integrity of bone may be measured by photon and x-ray absorptiometry and computed tomography, but these diagnostic techniques are not practical clinically and will not assess potential for physical frailty.[5] Indicators of function like physical performance measures combined with the diagnostic tests would more likely identify the individual with abnormally high bone loss.

In summary, most researchers agree that a progressive decline is evident in musculoskeletal performance capacities with aging. However, many of the changes may be altered or slowed with maintained physical activity and many of the age-related changes do not appear to be problematic until late in life (after age 80). Pendergast et al[3] proposed that muscle function decline appeared the most important due to the tremendous impact of muscle performance on ADLs and independence. The ability to respond to added demands of performance is related to aerobic and strength physiologic reserve capacity. The frail elderly may have little or no reserve capacity and may demonstrate difficulty performing physical tasks that require added effort.[4] Few changes were noted in the literature concerning heart rate and oxygen consumption during rest and submaximal exercise in older independent individuals. A more rapid onset of ventilatory compensation for oxygen utilization and a larger oxygen deficit may be associated with a limited capacity to respond to increasing workloads resulting in earlier fatigue.[73] Work efficiency was found to decline to a greater degree in residents in a nursing home when compared to independently-living elderly.[77] Slowed reaction times were noted as the result of age-related deterioration of task-dependent voluntary postural control. The importance of the various age-related physical and physiological components to decline in performance requires further research.

Physical Performance Testing

Physical performance is the ability to perform the physical work involved in meeting the habitual demands of independent living and recreation and is the outcome of locomotor efficiency.[93] Locomotor efficiency requires coordination among the major physical and physiologic components involved in performance of external work and motion. As proposed by Stones and Kozma[93], measurement of physical performance yields a behavioral estimate of biomechanical energy expenditure and the response of the individual to changes in duration and difficulty of the biomechanical demand of a performance task.

Physical performance measures should be sensitive assessments of the individual's performance on a specific task and should be evaluated in an objective, reproducible manner using an established criteria, which may be timing or number of repetitions.[94] The aging of the population has stimulated a demand for brief, meaningful measures to assess physical performance in the elderly. Researchers and clinicians have responded to the demand with a plethora of proposed measurement tools. Indeed, the broad clinical use of the tools may have been hampered by the confusing number of different measures. Several of the more current and popular assessment tools will be discussed in the context of validity, reliability, and usefulness in the frail elderly.

Useful and simple clinical measures of physical performance have been defined and investigated in samples of community-dwelling and institutionalized older adults by several researchers.[12, 13, 38, 95] The clinical measures generally included an assessment of mobility and balance and were compared to a more traditional measurement tool which had established validity and reliability or were examined for the usefulness of the tool to predict functional dependence and decline. In addition, comparisons have been made between physical performance-based assessment methods and self-report.[34, 96] Physical performance impairments have also been examined for the usefulness in predicting risk of specific occurrences which have been found to be highly associated with morbidity such as falls or vertebral compression fractures.[83, 97, 98]

FISCIT Studies

A pre-planned meta-analysis using data from six sites of the Frailty and Injury: Cooperative Studies of Intervention Trials (FISCIT) indicated that gait velocity, balance function, and chair rise time were strongly associated with Instrumental Activities of Daily Living (IADL).[38] IADL's are activities which involve higher level functions like shopping and recreation.[99] Gait velocity was assessed using a timed walk over different distances (3-40 meters) with the instruction to walk at a self-selected pace. A final analysis was made of four out the six sites with a significant relationship found between gait velocity and performance of IADL's ($p<.002$, regression slope=$-.79\pm.25$). Balance function was examined using a three test scale which combined the ability to maintain balance for at least 10 seconds in parallel, semi-tandem, or tandem stance positions. Significant relationships were found in the ability to maintain stance in the more challenging positions (tandem) and in the ability to perform IADL's ($p<.001$, regression slope=-.29±.09). A slowed time to perform a single chair rise without using the arms was reported to exhibit a weak relationship to IADL's (regression slope=.14±.05). In conclusion, the authors proposed that performance measures are appropriate screening tools and do exhibit a significant relationship to IADL's status. Further, the investigators support the concept that performance indicators should be useful in designing effective interventions to improve IADL independence. Unfortunately, the lack of standardization across the sites limits the generalizability of the methods and data to the population of older adults even though the sample size was large (N=2190).

Activities of Daily Living Scale

The Activities of Daily Living Scale (ADL scale) is a valid and reliable basic scale used to assess physical function. The instrument was introduced by Katz et al[100] in 1963 and has been used in a variety of populations and settings. The instrument is a self-report questionnaire limited to basic self-care items of bathing, feeding, and getting on/off toilet. The ADL scale is useful in its simplicity and wide acceptance, but may lack a wide enough range of activities to be helpful in evaluating physical performance. The tool is mentioned in the context of this study due to the recognizability of the instrument and to indicate the probable inefficiency of the tool in identification of individuals at risk of functional decline. In addition, recent literature has shown that subjective self-report instruments used as singular indicators of function are not as appropriate as the objective assessment of physical performance.[12, 95]

Self-Report and Performance

Guralnik et al[12] compared personal or proxy self-report functional status to a battery of performance measures in a sample (N=5,000) of adults over the age of 71 years in an effort to describe the relationship and prediction usefulness of the battery. The performance measures involved timed standing in positions of side by side (parallel standing), semi-tandem, and tandem stance, 8-foot walk, and chair rise and sit 5 times. The ability to stand in challenged positions was timed for 10 seconds and the subjects were ranked on an ordinal scale of 0=unable to stand in any position to 4=tandem standing for 10 seconds. The walk speed was obtained by timing the subject walking 8 feet "at the usual speed, as if walking down the street to the store". Rising from a chair was obtained by timing the subject rising quickly from an 18" chair without using the arms to push beginning with the initial rise and ending with the final rise of 5 repetitions.

The scores were then combined into a summary performance score with an ordinal system of categorization (0=poorest performance and 12=highest performance). The results indicated that the measures were correlated and combined yielded a more defined evaluation of performance status. The Spearman correlation coefficients were reported as follows: walk speed to chair stands, .48; walking and standing balance, .39; and chair stands and standing balance, .39. The results indicated a strong relationship exists between the performance measures and self-report disability such that the subjects with the poorest performance also reported the greatest need for assistance in activities of daily living. The study reported that, while disagreement was found between the self-report status and actual timed performance (for example, 13.6% of the subjects who were unable to complete the 8-foot walk had reported they could walk one- half mile without help), the combination of the two tools was a significant predictor of nursing home admission and mortality. In particular, the questions of ability to climb stairs for the men and the question of ability to walk one-half mile for the women and the summary performance scale were appropriate to identify individuals at risk.

Gait speed and activities of daily living (ADL) were also evaluated in a sample of 161 older adults (mean age 78.5 years) in a geriatric hospital.[95] The researchers timed gait speed over approximately 7 feet on three different same-day tests to obtain a mean gait speed. The activities of daily living were evaluated using a Barthel Index.[101] The relationship of gait speed to ADL was defined categorically by time to complete the walk such that individuals recording speeds of <.82 ft/sec were more likely to be dependent for one or more ADL functions (p<.01) while individuals recording 1.15 to 1.80 ft/sec were more likely to be independent (p<.001). The investigators indicated that subjects scoring >1.80 ft/sec were less likely to be independent in ADLs and less likely to be living alone. The explanation of this anomalous finding was not well documented in the results of the study and warrants further research and discussion.

Large epidemiological studies have added much to the knowledge concerning the relationship of performance and self-report. In a study involving 9,704 women (mean age 71.7 years) at four clinical sites, performance measures of static balance, walk speed, and strength were compared to a self-report questionnaire concerning community walking, stair climbing, meal preparation, housework, and shopping.[34] The results indicated a strong predictive relationship existed between physical performance and self-report of function as evidenced by slowed gait speed and poor balance scores recorded for individuals reporting ADL disability ($p \leq .0001$). The investigators concluded that functional decline is multi-factoral with behavioral, physical, and physiological components.

Timed Tests of Performance

Tests of physical performance have been examined for usefulness in identification of community-dwelling older adults who were at risk for the onset of functional decline.[13] The usual tests are timed performance of chair stands, rapid gait, 360° turn, and bending over. Timed tests have been combined with qualitative tests using transfer and balance scales.[98] The subjects who scored in the slower category during the initial test exhibited a more accelerated decline to dependency during follow-up testing 1 year later (16% rate of functional dependence compared to the fastest category of 5.3% rate of dependence). Rapid gait velocity, 360° turn, and bending over demonstrated a similar association to rate of functional decline. Therefore, the investigators reported all of the timed tests were found to have a significant relationship to the onset of functional dependence ($p < .05$).

Even though the timed performance measures appear to be useful in an elderly population for screening risk of falls, the authors concede that identification of older adults at risk for functional decline is multifaceted and requires assessments that combine physical performance tests which are necessary to design an optimal intervention strategy. The results were standardized, well-documented, and were more representative of the community-dwelling older adults (N=664). However, the question still remains whether the measures would be sensitive enough to define risk of additional decline and functional limitations which may prevent the elderly in a long-term care facility from rising from a chair or toilet or getting out of their room to go to the cafeteria.

In addition, physical performance measures of timed chair rises and walk speed were examined as predictors of falls risk in frail older adults residing in a nursing home (N=303 with mean age 81±7.5 years) when compared to biomechanical measures of balance using force platform tests of sway in quiet standing.[97] The subjects were timed while rising to full stance and then sitting down three times. Walk speed was calculated using a timed walk along a 10-foot course at the subject's self-selected pace. Of the 303 participants, 203 (67%) were able to complete the chair rise without using their arms and 267 (88%) were able to perform the timed walk. The results indicated that the performance scores were not consistently correlated with the biomechanical measures of balance and appeared to be of no greater value than performance measures in the prediction of falls in the frail test sample. While frail ambulatory older adults in this study were capable of completing the tests, the investigators recognize the need for further research to develop appropriate instruments to measure risk in more frail nursing home residents.

Summary of Physical Performance

In summary, use of a combination of standardized anatomical, biomechanical, behavioral, physical, and functional assessment tools appears to provide the best overall evaluation of mobility problems leading to falls and concomitant decline in the elderly.[98] Items to include in such an assessment would be postural sway, activities assessment to define risk-taking behaviors, lifestyle, physiological and physical indicators of activity tolerance and endurance, as well as assessment of the ability to coordinate internal and external work to perform a functional task to completion.

Physiologic Performance Testing

Physiologic performance tests involve measurement of the underlying support processes which allow and sustain performance. The tests are usually performed in a laboratory or clinical setting with cumbersome equipment and elaborate monitoring systems. Three common techniques are presented: 1) metabolic energy expenditure (Vo_2 or metabolic equivalents [METs]); 2) heart rate; and 3) rate of perceived exertion (RPE).[102]

Metabolic Energy Expenditure During Exercise Tests

Metabolic energy expenditure may be directly measured by determination of oxygen uptake during the performance of an exercise stress test. The exercise stress test commonly involves maximal exercise effort on a treadmill or exercise ergometer with a

12-lead electrocardiograph and instrumentation to sample respiratory gases in order to define the functional aerobic capacity of the individual.[103] Two problems exist in the use of such maximal testing in a frail elderly population residing in a long-term facility. The first is the relative clinical inaccessibility of the instrumentation required to obtain the measure in the majority of long-term care facilities. Secondly, the elderly in long-term care facilities usually have a complicated medical history of orthopedic or neurological deficits which make the use of the treadmill or bicycle ergometer unsafe or functionally impossible. Health statistics from the 1990 U.S. Department of Health and Human Services indicated essentially a linear relationship between the percent of elderly residing in nursing homes and the number of activities of daily living dependencies.[104] Activities of daily living dependencies correlates with functional deficits.[7] Consequently, the use of the traditional exercise test may not be appropriate for the frail elderly.

The clinical usefulness of exercise testing is determined by the test's appropriateness to identify symptomatic limitation of activity tolerance.[102] Many times clinicians are required to estimate the functional impact of a presenting condition or disability using limited objective or subjective measures. Impairment[•] may be measured using standard tools such as degrees of range of motion, but definition of disability[τ] and handicap[‡] requires critical determination of the more complex interactions of physical,

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• alterations in anatomic, physiologic, or psychologic structures or functions resulting in underlying changes in the normal state[50]
τ patterns of behavior leading to long-term overall functional decline[50, 59]
‡social disadvantage associated with a disease, impairment, functional limitation, or disability[50]

physiologic, and environmental aspects of function.[102] Exercise tests may provide a means to assess physiologic reserve capacity or the ability of the individual to respond to increased metabolic demands placed on the system.[105] Older adults demonstrate limited reserve capacity and may be at higher risk of diminished performance if stressed.[4] Therefore, exercise tests may be useful in the elderly to define the status of the reserve capacity and assist in a more effective intervention.

Jones[102] has proposed that by using an objective assessment of the physiologic system's contribution to exercise tolerance, the clinician may gain a clearer understanding of the patient's impairment and potential for disability allowing for a more physiologically-based documentation of disability. Jones further states that exercise testing should be a clinical procedure repeated over a period of time rather than performed once by "physiologists in their ivory laboratories". Clinical exercise testing requires use of a patient-specific simple, standardized approach.

In the elderly, exercise testing may be utilized as in any patient population for purposes of : 1) fitness level assessment[61]; 2) determination of position on the frailty-hardiness continuum[24]; 3) establishing a more directed intervention[102] ; and 4) more objective assessment of improved outcome[102].

Exercise tests are classified as maximal and submaximal. Maximal exercise tests requires the individual to perform to fatigue or symptoms which prohibit performance or to a plateau of oxygen consumption where no further increase in heart rate is noted.[61] Submaximal exercise tests are defined by a pre-determined endpoint.[60] The endpoints may be a percentage of the age-predicted heart rate maximum, a pre-determined exercise stage, or achievement of specific level on a scale of perceived exertion.

The tests are usually administered using the treadmill, bicycle ergometer, or stepping, with the treadmill being the most common.[103] In all modes of exercise testing, the work is increased incrementally to the pre-determined or maximal level using a standardized protocol. The Balke protocol uses a treadmill with a constant speed of 3 mph and a staged workload increase by altering the grade from zero in equal steps of 2.5 percent every 1 minute or in disabled patients every 2 minutes.[106] The Balke has been modified for use in an elderly population by decreasing the constant speed to 2 mph and increasing grade from zero in 2 percent increments every 2 minutes.[107] The modification appears safer for the ambulatory older adult without significant balance deficits.

The Bruce treadmill protocol is performed in four stages of increasing speed and grade from Stage 1 at 1.7 mph and 10 percent grade to Stage 4 at 4.2 mph and 16 percent grade.[108] Each stage of the Bruce protocol is maintained for 3 minutes which allows a more disabled or unfit individual to adapt more readily to the exercise.

The same general guidelines of incremental staging is used for graded exercise tests on the bicycle ergometer. The power output is usually expressed in watts.* The protocols use stages of 2- to 4-minutes with an initial resistance between zero and 15 or 30 watts per stage.[103] The bicycle ergometer has the advantage of being portable, safe,

* Watts=(braking force)(π diameter of wheel)(frequency of rotation)[102]

easily regulated, and relatively inexpensive.[102] Bicycle ergometry was used successfully to examine the effect of aging on oxygen consumption and ventilation threshold in a sample of 79 sedentary men.[73] All of the subjects completed two bicycling exercise tests with no significant differences reported in the peak oxygen consumption attained by each of the four test groups (ages of groups were 35 to 45 years, 45 to 55 years, 55 to 65 years, and 65+ group whose mean age was 71.4±4.9 years). In addition, the investigators indicated that the use of the submaximal ramped tests allowed safe estimation of oxygen kinetics across age spans.

However, the treadmill and the bicycle ergometer may not be appropriate for the more frail elderly. The treadmill test may be problematic due to biomechanical difficulties of unstable knees, balance changes, and anxiety related to the unfamiliar instrument.[109] The treadmill has also been shown to have limited association to "real life".[110] Likewise, the bicycle ergometer may produce unsatisfactory results due to positional discomfort, quadriceps weakness, and difficulty in maintaining pedaling sequence and pace.[111] The bicycle ergometer has also been found to result in an abnormally high heart rate which may be related to the momentary isometric contraction associated with lower extremity cycling just previous to the downward push phase.[72]

The Master step test is a simple field test using either altered step heights and incrementally more frequent stepping rates to change the work load.[103] One disadvantage of the step test is the apparent lack of standardization in the administration of the test. The more common step test protocol[112] uses a constant step height with increased rate of stepping using music to increase the tempo, but a variation of both height and step frequency has been recommended by Nagle et al[106] as a more appropriate means of assessing maximal work capacity. However, standing step tests may be unsafe for the elderly for several reasons. First, the older adult may have subtle balance problems that may become a safety issue as the test becomes more stressful. Secondly, age-related quadriceps strength changes may make the test too difficult for the more frail older adult. In addition, the elderly generally have difficulty in maintaining safe balance during short periods of single-limb stance.[31]

A relatively safe, graded exercise test, which has previously been referred to as the chair step test[107], allows the frail older adult to remain in a seated position during the testing procedure.(Appendix A.1) The test involves four incremental stages of lower extremity stepping to a target placed in front of the individual. The test was modified based on the Balke test to allow adequate time at each workload (step) for steady state attainment.[113] The test begins at 2.3 METS and increases slowly after 2 to 5 minutes at each stage. The test has been promoted descriptively as a safe means of exercise testing for the frail elderly; however, research to support the use of a seated exercise test like the chair step test was not found in the literature.

The elderly may exhibit serious clinical symptoms which may become evident with light to moderate exercise. A reluctance exists among researchers and clinicians to utilize an exercise test requiring maximal effort. Skinner[61] recommends that, with the exception of research, older adults should not have a maximal exercise test. Shephard[72] described a theoretically linear relationship between heart rate and 50 to 100 percent oxygen consumption Therefore, submaximal tests which have safe endpoints of 75 percent to 85 percent age-adjusted maximum heart rates should stress the older individual sufficiently to assume a linear relationship with oxygen consumption.[111] Submaximal tests do have limitations in the ability to accurately predict actual functional capacity because of the heterogeneity of maximal heart rate in the elderly. In a study designed to identify subjects whose maximal heart rates were considerably above or below the age-predicted maximal heart rate, the investigators found that old age and higher resting heart rates were evident in the subjects with maximum heart rates above the age-predicted level.[27] In addition, the investigators reported that age accounted for 36% of the overall variance of maximal heart rate (42%) in a multiple regression model. Astrand reported a coefficient of variation of 10 to 15 percent when compared with measured maximal oxygen consumption.[19]

Metabolic equivalents (METs) represent an estimate of the average person's resting metabolism or oxygen uptake.[103] One MET is assumed to be equal to an oxygen uptake of 3.5 ml/kg/min. Using the MET concept, the clinician can estimate the oxygen cost of exercise for a particular individual based on body mass and the estimated MET level of the activity. However, age is related to many normal musculoskeletal and cardiovascular changes in exercise responses. For example, maximal oxygen uptake and performance decline by about 35% by age 65.[58] In addition, resting cardiac index (ratio of cardiac output to surface area) declines 20 to 30% between 30 to 80 years of age, and breathing capacity at age 80 is about 40% that of a 30-year-old.[58]

To summarize, predicted maximal values are useful for determination of the aerobic potential of large population where risk of unexpected or abnormal responses are more likely and for frequent monitoring of exercise capacity change from week to week.[114] Therefore, caution should be exercised in the interpretation of an individual's submaximal estimation of maximal oxygen consumption and functional exercise capacity, but the submaximal exercise test remains the safest, most appropriate approach to exercise testing in the older or sicker individual. Unfortunately, the classification of physical activity based on exercise intensity by MET levels was developed using subjects between the ages of 20 to 30 who were healthy, active adults.[115] Therefore, the use of the established levels may underestimate the cost of exercise and activity for the sedentary and frail elderly.

Heart Rate - Estimation of Exercise Tolerance

During dynamic exercise involving large muscle groups, a relatively linear relationship has been reported between heart rate and oxygen uptake.[102] Measurement of heart rate provides a safe, indirect method to estimate the tolerance of exercise. The method most commonly used to determine the target heart rate response to exercise is the heart rate reserve/range (the difference between the resting heart rate and the maximal exercising heart rate). The Karvonen formula is a traditional age-based formula (220-age) to estimate the maximal heart rate and training intensity without performance of a maximal graded exercise test.[116] However, controversy exists between researchers in the use of age-based maximal heart rate as an indicator for exercise tolerance in the elderly due to the tendency to overestimate or underestimate the exercising intensity.[10, 27] Maximal heart rate declines with advancing years and may be affected by gender, poor motivation, muscle weakness, orthopedic problems, and numerous noncardiac causes of limitations in performance.[117]

In addition, Grieg et al[110] reported that instrumentation appears to influence the measurement outcome of heart rate during usual pace walking on a treadmill. The researchers proposed that the treadmill was less representative of the exercise demands of walking on the floor as the heart rate for treadmill walking was found to be consistently higher. Similarly, higher predicted energy costs appear to be more associated with treadmill walking than with floor walking in the older adult.[118]

The estimation of exercise tolerance using seated step test heart rates is supported by several recent studies examining the relationship of heart rate to exercise training.[29, 119-121] In a study using a sample of 70- to 79-year-old men and women, Hagberg et al[119] examined the cardiovascular responses to exercise following a 12 week intervention. An increase in the maximal and submaximal heart rates were recorded during a graded exercise test as well as a decrease in the rate of perceived exertion. Similarly, Pollock and colleagues[121] reported that average exercising heart rates for a group of sedentary men (mean age = 55 years) progressed from 149 beats/minute to 155 beats/minute following an exercise intervention of 20 weeks duration.

Ades, Waldman and Gillespie[29] measured symptom-limited and submaximal heart rate responses in a sample of older coronary patients pre- and post-exercise conditioning as indicators of exercise capacity. The investigators reported lower heart rates at a standard workload which appeared to support the use of heart rate measures to define symptom-limited and submaximal exercise efficiency.

Submaximal heart rates are also reliable indicators of exercise intensity and are appropriate estimates of exercise tolerance. Several studies with clinically and statistically significant findings in community-dwelling older adults have been reported in the literature.[30, 71, 75, 122] Ades et al[75] reported lowered submaximal indices of heart rate at standard workloads following a training program of treadmill walking in a sample of older coronary patients (mean age= 68 ± 5 years). In a study of older veterans (mean age at 4 month posttest = 70 years), Morey et al[122] found submaximal heart rate had decreased following a training program of aerobic and strengthening exercises. In addition, the researchers reported the changes in heart rate, strength, and flexibility were maintained at a two year follow-up, indicating that the physiologic measures were useful indicators of aerobic and functional capacity.

Amundsen et al [71] evaluated the training effect of calisthenics in a sample of elderly women (mean age = 75.7 years) using submaximal exercise testing heart rate. The investigators found that heart rate decreased over the eight weeks of the training in the sedentary sample. No attempt was made by the investigators to examine associated changes in physical performance measures following the intervention.

The consensus in the studies is that the physiological response to exercise or activity can be measured using a standard measure of submaximal heart rate in community-dwelling elderly. However, further research needs to be done to determine if the same effect will be evidenced using a more frail sample of elderly.

Ratings of Perceived Exertion

Ratings of perceived exertion (RPE) are most commonly used to obtain subjective data concerning the degree of effort required for the performance of physical tasks. and is generally considered to be an adjunct to heart rate monitoring.[60] Two scales have been introduced by Borg[124] and are presented in Table 2.1.

Table 2.1 —Borg's Ratings of Perceived Exertion and Revised Category-Ratio Scales

RPE scale (15-grade)		Category ratio scale	
6		0	Nothing at all
7	Very, very light	0.5	Very, very weak (just noticeable)
8		1	Very weak
9	Very light	2	Weak (light)
10		3	Moderate
11	Fairly light	4	Somewhat strong
12		5	Strong (heavy)
13	Somewhat hard	6	
14		7	Very strong
15	Hard	8	
16		9	
17	Very hard	10	Very, very strong (almost maximum)
18			Maximal
19	Very, very hard		

Adapted from Borg GV. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377-387.

The subjective information may describe overall body exertion (chest pain or dyspnea) or local perception of strain (muscle fatigue or weakness).[123] The rate of perceived exertion (RPE) or Borg scale was developed as the result of the clinical observation that young men could approximate their exercising heart rate based on a numeric scale coordinated with intensity descriptors.[124, 125] The scales were devised to integrate peripheral and central indicators of work.

The first is the classic 15-grade RPE scale which has verbal descriptors intended to include sensory, peripheral, and central effort.[126] The 15-grade RPE scale has been used most frequently to rate entire body work during exercise such as the treadmill or the bicycle ergometer. The second is a modification of the 15-grade RPE scale, referred to as the category-ratio scale, with 0 to 10 ratio values, descriptors, and categories.[124] A rating of 12 to 13 (somewhat hard) on the 15-grade scale corresponds to approximately 60 percent of the heart rate maximum and a rating of 16 (hard) corresponds to approximately 85 percent.[60] Comparatively, the ratio scale would indicate 60 percent and 85 percent of heart rate maximum at 4 and 6, respectively.[125]

The newer category-ratio scale was proposed by Borg as a simple alternative to the “6-20” 15-grade scale.[124] The rationale for the use of the simplified scale was that the verbal descriptors were understandable by more people and were more useful for the non-clinical lay population. In a follow-up study using the category-ratio scale of perceived exertion, Borg et al[127]demonstrated that the perception of exertion appeared to increase linearly with increasing power demands, and the category-ratio assumed close to the same appearance as the estimation of overall perceived effort using the older 15-grade scale. However, using the category-ratio scale for estimation of central effort appeared to result in greater response variation when compared to use of the same scale for determination of peripheral (local) muscle function. Therefore, Borg et al[127] concluded that the category-ratio scale appeared to be more useful in describing muscular effort and the 15-grade ratings of perceived exertion may be best for describing more centrally-mediated effort.

Pandolf et al[128] postulated that in older adults the local and central factors could be rated separately using the 15-grade RPE scale to determine central responses and the category-ratio scale to indicate local effort. Local muscle fatigue and effort was furtherdefined as leg aches, leg cramps, aching muscle, muscle tremors, leg twitching, heavy legs, and shaky legs.[128] However, findings in a study by Noble et al[129] did not confirm the independent nature of local and central factors of perceived exertion. The investigators compared the category-ratio scale ratings of leg effort, leg pain, and cardiorespiratory response to blood and muscle lactate and heart rate using a bicycle ergometer in a sample of ten healthy men. The results indicated no difference between the ratings of perceived leg effort and pain and the cardiorespiratory ratings.

The disagreement between the reviewed studies was partially explained by Noble et al[129] as a difference in the rating instruction given to the subject. The authors proposed that if subjects were instructed to evaluate the amount of exertion or power production during an effort, the response would be somewhat different than if the subjects were asked to describe the sensation or feeling of the physiological effort. Therefore, the conclusion was made that the instruction given the subject should be planned, monitored for consistency, and appropriate for the scale.

The reviewed studies also investigated the question of whether subjects would be able to distinguish between the local muscle effort and the central factors associated with exertion.[128, 129] Noble et al[129] proposed that the subjects may be unable to differentiate between small changes in local or central factors of exertion, but would be able to distinguish large intensity differences. Since heart rates increase linearly with workload and blood and muscle lactate demonstrate a more curvilinear response, a reasonble assumption may be that lactate responses represent smaller differences to increased intensity and, therefore, are more appropriately described using the category-ratio scale.[129]

Ratings of perceived exertion appear to be the most useful in estimation of effort in situations in which the heart rate may not be a sufficient predictor of intensity of exercise as in patients on beta-blocking medications.[6] Several considerations need to be made prior to using RPE scales in estimation of effort. Borg[124] conceded that a perfect scale was not available, and that the category-ratio scale may be the appropriate choice for determination of exertion when musculoskeletal responses are expected to be the dominant factor. A second consideration involves the relationship of the ratings and the mechanisms of the exercising task. Pandolf et al[128] reported that local muscle fatigue seemed to play a more significant role in ratings of effort during cycling tests while central factors such as breathlessness may have had a greater influence in treadmill activities. The third consideration is the willingness of the individual to truthfully indicate the level of perceived effort.[125] Lastly, the wording of the instruction given to the subject should be consistent and planned to obtain an accurate estimation of subjective exertion.[129] At this time, research in the use of ratings of perceived exertion and exercise effort in the elderly is too sparse to draw any conclusions or performance assumptions about central or local fatigue or willingness to indicate truthful level of effort.

Summary of Physiological Tests

The overall analysis of the literature related to physiologic testing appears to indicate that predicted maximal values are useful for determination of the aerobic potential of large population where risk of unexpected or abnormal responses are more likely and for frequent monitoring of exercise capacity change from week to week and that the submaximal exercise test remains the safest, most appropriate approach to exercise testing in the older or sicker individual.[114] The classification of physical activity based on exercise intensity by MET levels was developed using subjects between the ages of 20 and 30 who were healthy, active adults, making generalization to the sedentary, frail older adult questionable.[115] Submaximal heart rate tests are appropriate and useful in community-dwelling elderly.[71] Ratings of perceived exertion may not be as appropriate for use in the elderly due to factors associated with willingness to maximally perform and inconsistency in truthful indication of effort.

Concurrent Physical and Physiological Test: Timed Walking

The use of the timed walking test as an estimate of exercise tolerance has been promoted in literature due to the simplicity, quantifiability, and relationship to function of the measure.[20, 23, 54, 55, 130-133] Self-selected, comfortable walk speed has been shown to be the speed which requires the lowest cost of energy and is therefore suggested to be appropriate in determination of walking capacity and efficiency.[134] Cooper[130] utilized the 12-minute run field test as an inexpensive, portable means of estimating maximum heart rate and endurance. The study examined the correlation of the 12-minute performance test with maximal oxygen consumption obtained using a treadmill in a sample of 115 Air Force officers and airmen (mean age 22 years). The results indicated a high correlation ($r=.90$) in the maximal treadmill test and the 12-minute distance. Even though the study's results are not generalizable to other age groups due to the probable high fitness level of the young male subjects, the study did determine the reproducibility and ease of using a more simple timed distance test as an indicator of exercise tolerance.

However, the 12-minute run appears to be time consuming and exhaustive for deconditioned older adults and for individuals with disease processes. Butland et al[55] researched the use of two, six, and 12-minute walking tests in a sample of ten older patients (mean age 61±11 years) with documented respiratory disease. The investigators found that the less fit subjects could complete the 12-minute test, but demonstrated an initial burst of speed followed by a slow, more comfortable constant pace. The pattern of pacing tended to support the use of tests of less time. The investigators reported high correlations (ranging from .87 to .96) with the highest correlation between the six-minute and the 12-minute walk distance. The high correlations between the three walk times supports the similar usefulness of the measures to estimate exercise tolerance in deconditioned subjects. The authors concluded that, while all of the tests could feasibly be used, the six-minute test was an appropriate compromise time to optimize results.

The six-minute walk was compared with a functional status measure and a maximal exercise test to determine the validity of the walk to reflect exercise capacity in patients (N=57, mean age 64.7±8.3 years) with chronic heart failure or chronic lung disease.[132] The results indicated a moderate, but significant, correlation of -.45 to -.47 between the six-minute walk and the measures of functional status. The correlation between the walk and the exercise ergometry test was .58 which was stronger and indicative of validity of the shorter walk time. However, one weakness in the study design which may account for the lower correlations with functional status is the choice of self-report functional scales instead of physical performance measures which have been found to more reflective of actual performance.[12]

In a similar study, the six-minute walk was evaluated in another sample of 26 patients with chronic heart failure with conflicting results.[23] The walk was found to exhibit a curvilinear relationship with maximal oxygen consumption such that the subjects with lower maximal VO_2 tended to vary greatly in the distance walked in six-minutes while the subjects with higher maximal VO_2 were more consistent. Theoretically, the shorter test may not have challenged the healthier subjects sufficiently to evaluate tolerance of the activity. The researchers concluded the six-minute walk was an appropriate tool to assess exercise capacity in individuals with functional limitations but not as useful with the less involved subjects.

With the reliability and validity better established for the six-minute walk time , researchers began to examine an even shorter time (5 minutes) which seemed to be more convenient and better tolerated by deconditioned and more frail subjects.[20, 54] Price et al[20] utilized the 5-minute walk to assess aerobic fitness for five subjects (mean age 59 years) with arthritis. Pre- and post-test walk distances and maxVO_2 were reported to be highly correlated (r_s=.87), supporting the validity of the 5-minute walk as an assessment of aerobic fitness in individuals with low exercise tolerance. Also of importance in the study, the researchers indicated no adverse effects like pain or muscle soreness from the walk test concluding that the subjects tolerated the shorter time well. Knox et al[54] examined the reproducibility and learning effect of twelve repeated 5-minute walks in a sample of patients with chronic obstructive airways disease (N=36, mean age 63). The greatest learning effect (33% increase in distance) was noted when the subjects repeated the twelve walks on three consecutive days leading the investigators to conclude that, when using short walk times repeated over short intervals, motivation and attitude may play an important role in the achieved distance. With subjects tested following longer intervals, the learning effect was less evident.

Standardization of both procedure, type, and amount of encouragement are important aspects warranting consideration in the determination of the usefulness of timed walk tests. With exception of the Cooper study[130], the researchers used instructions to walk as fast as possible and cover as much distance as could be accomplished in the allotted time. Two studies instructed the subjects to walk briskly but to choose a pace that could be maintained for the full time.[20, 55] Guyatt et al[131] reported increased distances in both the 2- and 6-minute walk with encouragement given every 30 seconds using standardized, random phrases like "Keep up the good work" or "You're doing well". In the same study, the researchers found no effect of time of day or order of test on the walk distances.

In summary, use of standardized, short walk tests (five or six minutes) appear to be reliable and valid assessments of exercise tolerance in unfit individuals. The clinician may be able to use either timed 5- or 6-minute assessment test successfully and could feasibly make the decision based on time efficiency and patient preference. However, insufficient data exist to determine if a shorter walk test is an appropriate, useful, and sensitive estimation of exercise tolerance in the frail elderly.

Performance Indicators of Frailty

In contemporary literature, frailty has been utilized as a descriptor of the individual's presenting status or potential status. Frailty has been used in some cases to describe presentation of illness and infirmity indicative of specialized care.[135] In other instances, the term frailty has been utilized to define the diminished ability to carry out the important practical and social activities of daily living.[24] Frailty, then, is multifaceted and would require different qualifiers depending on the intended purpose of the term. Physical, physiological, functional, and social factors may be postulated as the qualifying components of frailty.

Geriatricians have proposed many determinants of frailty, including illness, reserve capacity, functional disability, caregiver availability and capability, gender, age, income, and ability to cope.[24, 135] Determinants like caregiver availability and capability, gender, age, income, and coping may be categorized as the psychosocial and behavioral factors contributing to frailty. A good many of such factors are circumstantial and require interventions from community and social services to direct the individual's movement toward less frailty. The fact that illness and frailty are interrelated would not be disputed by health professionals at any level. However, the impact illness may have on functional performance, and therefore nearness to frailty, is variable and may be related to the amount of directed intervention. Disagreement occurs in determining the direction (ie. physical, physiologic, or functional) of the intervention. The following sections will focus on a description of physical and physiological indicators of frailty, present a model of frailty, and discuss the relationship between physical and physiological performance related to frailty.

Physical Frailty

The classic definition of physical is “pertaining to the body” and its needs.[136] Therefore, the limited ability to perform ADLs, rise from a chair, walk across the room or down the hall, and to maintain balance in challenged standing are indicators of physical frailty. Physical frailty, then, is more associated with performance abilities to meet one's functional needs, i.e., meeting the basic survival functions of feeding, bathing, and dressing as well as meeting the higher level needs of community interaction and recreation. Physical frailty is characterized by impairments of physical abilities such that the individual can not function independently. Therefore physical frailty could be referred to descriptively as "functional frailty". Physical frailty, as defined, is a major factor in long-term care decisions for more than 3.25 million older Americans with estimates of annual costs from $54 billion to $80 billion.[137] By the year 2030 as a large segment of the population ages, the cost of physical frailty could grow to $132 billion unless health providers intervene appropriately to reduce the deleterious effects of frailty.[104]

The primary physical aspects of frailty may be summarized into neurological, mechanical, and metabolic capacities of control and function.[62, 63] Neurological control is evident by an inability to perform complex tasks in an environment requiring adaptation and rapid response. Mechanical frailty is associated with the inability to coordinated performance of the musculoskeletal system in completion of the practical tasks of daily living. Appropriate function of the biomechanical system requires the presence of adequate muscle strength, flexibility, and bony integrity.[63] Metabolic frailty is associated with the limitations in physical utilization of circulating nutrients and oxygen to perform meaningful tasks. The cardiopulmonary system is fundamental in maintenance of adequate energy since the energy-producing cells are dependent upon oxygen.[63]

Physiologic Frailty

Physiologic may be defined as "pertaining to the basic processes underlying the functioning of an organism or species".[136] Therefore, physiologic frailty is associated with deficits in the underlying, support mechanisms and processes that are involved in muscle, neural, and metabolic responses to stimuli.(Table 2.2)

Table 2.2.— Physiologic Frailty by Mechanism and Indicator[40, 43, 69, 72, 85]

Mechanism	Indicator
Neural	Increased reaction time Increased processing time
Muscular	Alterations in type I to type II muscle fiber ratio Decrease in cross-sectional muscle size
Metabolic	Decreased metabolic thresholds Decreased resting muscle oxidative capacity Decreased VO_2 maximum

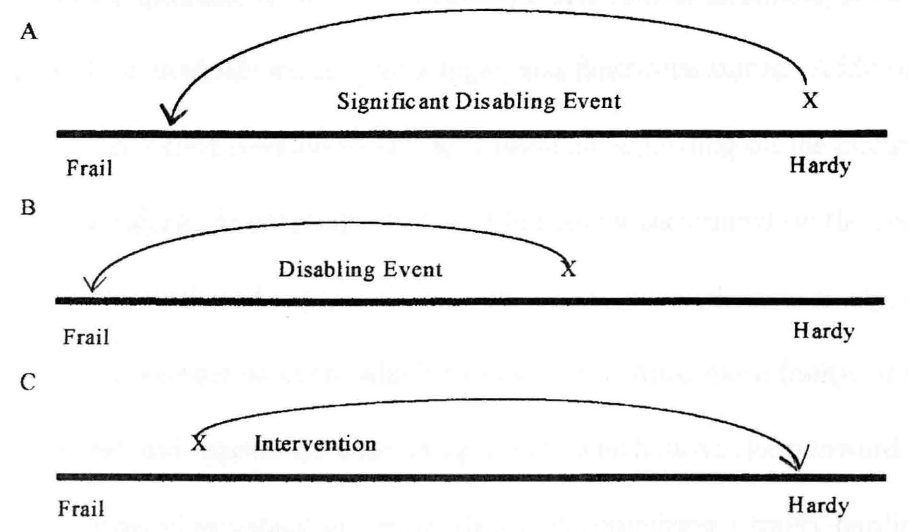
The frail older adult exhibits a decrease in the capacity to respond to increased physiologic demand. The decrease in maximal oxygen consumption, maximal heart rate, stroke volume, and peripheral extraction of circulating oxygen is evidence of limitations in physiologic reserve.[69, 72, 76] In a study examining the effects of endurance exercise on the vastus lateralis muscles of young and old subjects, Meredith and colleagues[40] reported a decrease of resting muscle oxidative capacity of 41% in the older group. In addition, the possible loss of type II muscle fibers which tend to have a high level of the calcium-activated actomyosin adenosine triphosphatase (ATPase) activity may have contribute to the decrease in oxidative metabolism noted in the study.

In summary, little is available to document physiologic frailty. However, measurement of heart rate, ventilation, and muscle response during activities that requires utilization of physiologic reserves may be the most appropriate for the frail elderly.

Frailty-Hardiness Model

Researchers have theorized that as the human body ages, a linear reduction occurs in physiologic function such as a reduction in maximal aerobic capacity and muscle strength.[138-140] A linear reduction in physiologic function suggests a "critical point" below which functional decline and dependence become the inevitable outcome. The "critical or breaking point" is strongly associated with increased or high age.[140] The term implies that a significant marker exists which is indicative of failing physiologic and functional reserves and that the individual has limited physical ability to recover from a disabling event. Physiologic and functional "critical or breaking points" have not been clearly described in current literature. Likewise, the relationship of physiologic and functional points is even less well understood. Problematic performance and point determination requires the use of measures which are both reliable and stable for use in the targeted population.[141]

Brown et al[24] proposed a conceptual model of defining the frail elderly where the individual would be rated along a frailty-hardiness continuum (Fig 2.1).



Based on Brown I, Renwick R, and Raphael D. Frailty: constructing a common meaning, definition, and conceptual framework. *Int J Rehab Res* 1995; 22:317-328.

Fig 2.1 —Frailty-Hardiness Continuum Model

Brown et al[24] proposed to define frailty in terms of social, physiologic, and functional determinants which contribute to the performance of important practical and social activities of daily living. The individual's specific position on the continuum line is likely to be dependent on the complex interactive dependency between the many contributing factors. The concept of a frailty-hardiness continuum leads the investigators to further propose the possibility of a determinant threshold where the individual may be positioned closer to frailty than to hardiness. The determinant threshold would have the potential to identify a point on the continuum where one direction is moving closer to frailty while the opposite direction is moving closer to hardiness. The position on the frailty-hardiness continuum, ie. above or below the determinant threshold, is varied depending on the individual's social, physiologic, and functional status. Additionally, the older adult may alter their position along the continuum depending on the circumstances surrounding a qualifying determinant. The possibilities for movement on the continuum are: a) they may be hardy and experience an event which moves them to frailty; or b) they may be frail and experience an event which moves them toward more frailty; or c) the elderly may be frail and experience intervening events which move them toward hardiness.

Several areas of investigation ensue when conceptualizing a frailty-hardiness model. First, definition of the determinants of performance in the elderly population would be necessary for development of the continuum. Secondly, clarification of the critical performance threshold for each of the determinants is required to establish need for and type of intervention to move the individual in the appropriate direction on the continuum. Thirdly, the interactions of the performance determinants need to be explored and understood. In answering such questions, investigators could then establish an overall frailty threshold and more effectively define elderly at risk for movement to frailty and functional decline.

Interrelationship of Physical and Physiologic Performance

The relationship between performance of a motor task and the underlying physiology of the task is not well understood. For example, an individual with identified weakness in the quadriceps can walk a required distance down the hall but be unable to stand from a chair without assistance or an individual can rise from a chair but be unable to walk a short distance in a functional timeframe. Chodzko-Zajko and Ringel[32] attempted to demonstrate the association of physiologic measures and motor performance in a sample of 70 males (mean age 63±12 years). The physiologic variables analyzed were pulmonary function, blood lipids, body weight, blood pressure, and maximal oxygen uptake. The motor performance was assessed using discriminatory reaction time. The investigators reported a correlation of -.53 between the physiologic measures and age which was concluded to indicate an overall decline in physiological status with age. Higher levels of physiologic status were significantly correlated with faster reaction times ($r=-.36$ to $-.40$, $p=.001$). However, the study would have been more clinically applicable if the motor variable had been a more functionally-oriented physical task.

Physiologic factors associated with physical frailty were examined in a randomized, placebo-controlled study involving 100 very elderly (mean age 87.1 years) men and women residing in a nursing home with positive results.[1] The subjects underwent a regimen of high-intensity progressive resistance training of the hip and knee extensors for purposes of functional strengthening. The findings indicated a strength increase of 113±8 percent, a 2.7±1.8 percent increase in cross-sectional thigh muscle area, an increase of

11.8±3.8% in gait speed, and an improvement of 28.4±6.6% in stair climbing power in the exercising group. Importantly, an overall increase in daily physical activity was also noted in the exercisers. In a sample of community-dwelling healthy elderly (N=14, mean age 67), the researchers reported a 36% decrease in the muscular effort (recorded using normalized EMG) required by the biceps in a carrying task following a strengthening program.[36] Conversely, in a study involving 14 male nursing home residents (mean age 73 years), the researchers found no significant improvement in the physiologic measure of oxygen uptake following a 12-week program of lower extremity strengthening and aerobic training, even though improvements were noted in muscle endurance and strength, functional balance, and gait speed.[44]

The association of physiologic function and physical performance requires further research and clarification, but a consensus is emerging which supports an association between physiologic measures such as heart rate and oxygen consumption and more functionally-based measures such as walk tests for community-dwelling elderly.[142, 143] Based on the literature findings, independent task performance is multifaceted and the most useful measures of physical and physiological performance continue to elude the clinician. The extrapolation of the research findings to include the more frail older adults in the nursing home seems optimistic. A tremendous need continues to exist for definition of useful, simple, meaningful tools which would allow the clinician to effectively screen individuals with the purpose of designing interventions based on quantifiable performance-oriented outcomes.

Summary of Complete Literature Review

Based on the review of the literature, the following assumptions and conclusions are proposed:

1. Normal aging processes result in changes in performance capacity of the cardiopulmonary, nervous, and musculoskeletal systems regardless of modifiers like physical activity.
2. Normal aging and limitations of functional reserve in physical and physiological performance are exacerbated in the frail elderly and may lead to decline and dependence.
3. Evaluation of performance is best achieved by combining physical and physiologic indicators of performance such as task performance and heart rate monitoring.
4. Timed walk tests, walk speed, and chair rise and sit are appropriate measures to determine physical and physiologic performance in community-dwelling elderly.
5. Submaximal and symptom-limited exercise testing is safe and useful in community-dwelling elderly.
6. Frailty is multifaceted, involving both physical and physiologic performance, social, and behavioral components.
7. Questionable interaction exists between physical interventions and improvement of physiologic performance.
8. A limited number of studies were found which examined: a) the use of physical performance measures in the frail elderly; and b) the use of physiological measures

like heart rate monitoring during activity in the frail elderly.

9. A paucity of literature exists which evaluated the relationship of measures of physical and physiologic performance in the frail elderly.

CHAPTER 3

RELATED STUDY

TITLE: The Reliability and Stability of Measures of Heart Rate, Lower Extremity Physical Performance, and Ambulatory Activity Levels in Elderly Residents in a Long-Term Care Facility

Introduction

Theoretically, the elderly residing in an institution would exhibit more intra-individual variability and instability due to lower levels of function and dependence. Brown et al[1] attempted to describe the variance and heterogeneity of the dependent elderly using terms of frailty and hardiness. Frailty may be thought of as impairments in strength, endurance, balance, and mobility which increase the risk of falls, injury, and dependence while hardiness may be thought of as the opposite, i.e., limited impairments.[1, 2] Determination of frailty and hardiness has been accomplished using instruments of self-report or measured physical performance with the greatest volume of documented research being done with community-dwelling samples of older adults.

Self-report of performance has been widely utilized to determine physical function in the elderly due to the relative ease and safety of administration.[3] Therapist-directed and patient - directed questionnaires have been shown to be valid and reliable in samples of older adults, but may lack the sensitivity of physical and physiologic measures in evaluating "real" functional status.[4-6] Smith et al[3] conducted a study with a sample of 193 persons aged 69 or older to examine the short-term variability of physical function indicators using a self-report questionnaire. Telephone contact was made with the subjects twice with a 3 week time-lapse between contacts. The interview consisted of queries describing activities of daily living tasks such as walking short distances, bathing, and toileting, as well as higher level community function questions like carrying groceries and heavy housework capabilities. The investigators reported high agreement between the self-report of lower level activities (95 to 98%) but more variability in higher level physical function like carrying groceries or pushing/pulling heavy objects (57 to 75% agreement). The apparent inconsistency of self-reported physical performance of more difficult tasks supports the possibility of decreased stability over time of higher level performance measures in the elderly.

Research has been done using a variety of physical and physiologic measures in samples of community-dwelling elderly with the intent of demonstrating the reliability and stability of the measurement tools.[7-10] Direct observation of performance and function has been recommended by several geriatricians as the most accurate analysis of functional status.[11-13] Glick and Swanson[11] examined the usefulness of a series of upper and lower extremity movements in predicting dependence in a sample of 197 residents over age of 65 years residing in long-term care facilities. The investigators reported the combination of upper extremity fine motor activities of daily living tasks and lower extremity tasks of turning while walking accounted for 84% of the variance noted between the subjects. Guralnik et al[13] indicated that performance measures such as timed walking, rising and sitting to a chair, and standing balance were adequate to predict subsequent disability and nursing home admission.

Some research evidence suggests that a learning effect may be related to the variability of certain performance measures in the elderly.[7, 9] Butland et al[7] and Knox et al[9] reported improvement in timed walk distance between the first and subsequent walk tests. In addition to the learning effect, error variance in physical performance may be affected by day to day variations in air temperature, environmental differences, mood, and other physical or psychological variables so frequently observed in the elderly.[14]

A small amount of research is available which evaluates the internal consistency over numerous trials and stability over time of measures of physiologic response to physical performance.[8, 10] Reynolds et al[10] determined that institutionalized elderly women (mean age: 83.5) exhibited a predominance of sedentary activities with lower daily heart rates and fewer variations in a 24-hour heart rate recording than did an independent group of elderly women (mean age: 73.5) The investigators reported that institutionalized women spent much of the time in quiet sitting with physical activity limited to walking between rooms or straightening up. Gretebeck and Montoye[8] examined the variability of the mean heart rate during waking hours over a 7-day period in a sample of 30 males aged 24 to 67 years. The researchers determined the intra-individual variability of the subject's average heart rates over the time period to have a correlation coefficient of .62.

Statement of the Problem

Many of the reviewed studies reported results from younger, independent samples, but very few examined whether the same results could be expected in the frail elderly. Largely because of the frail nature of the institutionalized elderly, even fewer investigators have been willing to pursue research in this population and clinical information is sorely lacking as to the scientific value of performance measures. In order for geriatric research findings to be clinically meaningful, internal consistency and stability over time must be established for useful physical measures other than self-report for this subset of the elderly population so at risk for decline.

Purpose and Research Questions

This study was undertaken with the primary purpose being to examine the consistency and stability of a number of simple physical and physiological measures which have been indicated by the literature[15-17] as measures of performance and exercise tolerance in a sample of elderly residing in a nursing home.

Research Questions

1. Will heart rate remain internally consistent using trials of test, re-test (72 hours lapse), and re-test (two weeks lapse) and stable from trials three weeks apart as an estimate of cardiovascular fitness and endurance using a telemetric heart monitoring system and repeated low level exercise tests and 5-minute walks in a sample of elderly individuals residing in an institution?

2. Will measures of lower extremity performance as indicated by challenged standing, chair rise and sit times, and walking speed over 8-foot exhibit internal consistency between three trials and stability over trials given three weeks apart in a sample of institutionalized elderly?
3. Will measures of exercise tolerance using a 5-minute walk distance remain internally consistent between trials and stable over time in a sample of elderly individuals?

Methods and Procedures

The physiologic variables utilized in the study were resting heart rate, heart rates obtained during a seated exercise test and average of the walking heart rates recorded during the last 3 minutes of the 5-minute walk test.[15, 16] The physical performance variables utilized in the study were first described by Guralnik et al[17] in community-dwelling elderly and consisted of time to perform five repetitions of chair rise to sit, challenged stands, and walking speed over eight feet. In order to examine the internal consistency and stability of exercise endurance, a 5-minute walk distance was obtained for each subject.

The following section will describe the subjects, instruments, and procedures for administration of the test measures. Recruitment and the criteria for research involving the frail elderly residing in long-term care is outlined. Scoring of the various lower extremity tests is explained.

Design

The study was designed to determine the reliability, stability, and usefulness of physical and physiologic measures using a test, re-test, re-test model. All subjects were given three series of tests over a three week period consisting of a seated step test, timed lower extremity performance tests (challenged stands, chair rise and sit, and 8 foot walking speed), and the 5-minute walk. The first two test series (trial 1 and trial 2) were given within 72 hours of each other. The third test series (trial 3) was administered following a two-week period. The timing was such that three weeks lapsed between trial 1 and trial 3.

Subjects

Fifteen subjects ranging in age from 73 to 84 years (mean age: 79 years) met the criteria (dissertation study) and were enrolled in the study. However, complete data sets were collected on only twelve of the fifteen subjects over the course of three weeks. Complications from congestive heart failure, an unrelated fall, and instrumentation error resulted in three subjects being eliminated from the final analyses. All of the subjects required assistance with ADL performance and were considered to be frail. All of the subjects had resided in the long-term care facility for at least 6 months prior to the study and were not receiving any form of skilled physical or occupational therapy. Permission and signed consent was obtained from nursing home administration, subject and family representative, and primary physician prior to subject participation in the study.

Equipment

Heart Rate Monitor

The device utilized to monitor heart rate throughout the sitting exercise test and the physical performance tests was the Polar Accurex® II* portable telemetric heart rate monitoring system. The system consists of a chest belt with imbedded transmitting electrodes and an adjustable elastic strap and a wrist receiver.

Timing Device

The timing for all of the measures was done using a standard stop watch which was calibrated by the manufacturer to 1/100th of a second accuracy. The stop watch (Model #507) was manufactured by Advance Health Tech.†

Step Target

The step target was designed and built by the investigator with carpentry assistance from a physical therapy student at the University of Central AR.(Appendix A.2) The device was approximately 24" wide and constructed of wood. The targets were constructed of 1/2" wooden dowel rods and were located at 6 inches, 12 inches, and 18 inches. The device has a folding support base to promote stability and ease of management.

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* Polar CIC Inc, 99 Seaview Blvd, Port Washington, NY 11050
† LCD Service, 26400 W Eight Mile Rd, Southfield, MI 48034

Procedures

All of the subjects were given three series of tests consisting of a seated exercise test[15], timed lower extremity performance tests as defined by Guralnik et al[17], and a 5-minute walk. The first two test series were given within 72 hours and the third test series was performed two weeks following the second trial. Prior to testing on each test day, the subjects' sitting blood pressure and resting heart rate were obtained following a five minute quiet period. The test instructions were repeated as necessary using standardized terms to insure understanding of required performance on subsequent test days. Attempts were made to re-test the subjects near the same time on all tests days (≈90% successful).

The twelve subjects performed timed lower extremity exercises in a standardized order on each trial as described by Guralnik et al.[17] The subject was asked to rise and sit from an 18" chair one time. If the single chair rise was performed safely without the use of the arms, the subject was timed while repeating five repetitions of the chair rise and sit. The subject then was asked to stand in a semi-tandem foot position for 10 seconds. If the subject could remain balanced for 10 seconds in semi-tandem, the subject was asked to stand in tandem for 10 seconds. If the subject could not maintain the semi-tandem position, the subject was timed for 10 seconds while standing with the feet side-by-side. Due to the reluctance and anxiety of the frail subjects , the stance positions were modified to allow a small amount of space (no more than 1") between the feet in the side-by-side, semi-tandem, and tandem positions. Scoring of the challenged stands was based on the work published by Guralnik et al[17] and is described in Appendix B.

Following the challenged stands, the subjects were asked to walk twice at a self-selected usual pace for eight feet while being timed. Eight feet were marked off in the subject's room. The subject was asked to begin the walk two feet beyond the first marker and to continue the walk two feet past the second marker, then turn and walk back to the initial starting point. The walking speed was determined by averaging the timed values of the two 8-foot walks. Following completion of the second 8 foot walk, the subject was encouraged to rest to allow the heart rate to return to the resting rate.

When the subject's heart rate had returned to resting, the subject was asked to walk at a pace that would allow a continuous walk for five minutes. Encouragement was given as previously described by Guyatt et al[18] at standardized intervals during the last three minutes of the walk. Heart rate was recorded every thirty seconds beginning at three minutes and continuing to test completion at five minutes. The walk distance was measured in feet using a count of 12" tiles of the facility floor and a tape measure where necessary. The subjects were allowed to slow the walk pace as needed but were encouraged to continue walking for the entire five minutes. The subject was allowed to use an assistive device if usually required for daily activity and safety.

The subjects were again encouraged to rest for five minutes; and in most subjects, a rest of approximately five minutes was sufficient to attain the resting heart rate before performing the seated step test. The test required the subject to sit in an 18" chair with a target device placed on the floor in front of the chair.(Appendix A.2) The test has been referred to as the chair step test and was introduced by Smith and Gilligan[15] as a safe alternative means of exercise testing the frail elderly. The test is staged with four possible levels of performance. The subject began at the lowest level (6" target step) and was timed for five minutes, proceeding to a higher level every five minutes to the highest stage (18" target step with concurrent arm lift), to fatigue, or to age-adjusted maximum heart rate at which point the test is halted. The test step cadence was 15 complete steps per foot per minute; the subject lifted one foot to touch the instep to the target rung and back to footflat in two seconds yielding a step frequency for one foot of 15 steps per minute. All subjects were allowed to practice for 15 to 30 seconds prior to initiation of the test. Heart rate was recorded at two and five minutes during the chair step test.

Data Analysis

The question of internal consistency of the variables between trial 1, trial 2, and trial 3 was assessed using analysis of variance and report of the associated Cronbach's alpha. Cronbach's alpha is a statistic recommended to indicate internal consistency in repeated measures on several factors.[19] Stability of the variables given a time lapse of three weeks was determined using test-retest data from trial 1 and trial 3 and correlation coefficients. Comparison of data collected on the two trials was analyzed using a Pearson product-moment correlation for the continuous variables of resting heart rate, seated step test heart rate, mean 5-minute walk heart rate, 8-foot walking speed, and the 5-minute walking distance. Spearman rank-order correlation coefficients were calculated for the ordinal data obtained from scoring the challenged stands on the two trials.

Chair rise and sit presented a unique statistical problem in that only 2 of the twelve test subjects could rise without using their arms to push. Spearman rank-order correlation coefficient was calculated to determine if the subjects who were unable to rise on test day 1 were associated with an inability to complete the task on test day 3.

Results

Trial 1 descriptive statistics are presented in Table 3.1 for the resting heart rate, heart rate recorded during the seated step test, average heart rate recorded during the 5-minute walk, 5-minute walk distance, and the 8-foot walking speed.

Table 3.1. —Means (± standard deviations) and Ranges for Resting Heart Rate (RHR), Seated Step Test Heart Rate (HR_{SST}), Average 5-minute Walk(HR_{Wlk}), 5-Minute Walk Distance, and 8-Foot Walking Speed for Trial 1

Trial 1 Variables	Mean (±SD)	Range
RHR•(n=12)	80 (±11)	61 - 92
HR_{SST}•(n=10)	85(±11)	68 - 101
HR_{Wlk}•(n=12)	96(±6)	87 - 105
5-minute walk distance† (n-12)	452(±379)	48 - 1320
8-foot walking speed‡ (n=12)	1.21(±1.04)	.25 - 3.38

beats per minute

nearest foot

nearest one hundredth foot per second

Trial 2 descriptive statistics are presented in Table 3.2 for the resting heart rate, heart rate recorded during the seated step test, average heart rate recorded during the 5-minute walk, 5-minute walk distance, and the 8-foot walking speed. Table 3.3 gives the descriptive statistics for the research variables for Trial 3.

Table 3.2. —Means (± standard deviations) and Range for Resting Heart Rate (RHR), Seated Step Test Heart Rate (HR_{SST}), 5-minute Walk Heart Rate (HR_{Wlk}), 5-Minute Walk Distance, and 8-Foot Walking Speed for Trial 2

Trial 2 Variables	Mean (±SD)	Range
RHR•(n=12)	80 (±10)	60 - 94
HR_{SST}•(n=10)	88(±12)	64 - 101
HR_{Wlk}•(n=12)	100(±7)	90 - 110
5-minute walk distance† (n-12)	427(±379)	62 - 1430
8-foot walking speed‡ (n=12)	1.41(±1.30)	.31 - 4.81

•beats per minute

†nearest foot

‡nearest one hundredth foot per second

Table 3.3. —Means (± standard deviations) and Range for Resting Heart Rate (RHR), Seated Step Test Heart Rate (HR_{SST}), 5-minute Walk Heart Rate (HR_{Wlk}), 5-Minute Walk Distance, and 8-Foot Walking Speed for Trial 3

Trial 3 Variables	Mean (±SD)	Range
RHR•(n=12)	78 (±11)	61 - 97
HR_{SST}•(n=10)	84(±12)	61 - 100
HR_{Wlk}•(n=12)	100(±8)	88 - 112
5-minute walk distance† (n-12)	493(±421)	60 - 1540
8-foot walking speed‡ (n=12)	1.36(±1.27)	.25 - 4.15

•beats per minute

†nearest foot

‡nearest one hundredth foot per second

Minimum, maximum, and mode for the ordinally scored challenged stands over the three trials is given in Table 3.4. The frail subjects demonstrated a higher mode score corresponding to the ability to remain in semi-tandem for 10 seconds on trial 1 compared to trial 2 and 3 which indicated more subjects could maintain only the side-by-side position for the required 10 seconds.

Table 3.4. —Minimum, Maximum, and Mode for Trial 1, Trial 2, and Trial 3 of Challenged Stands Scores• (n=12)

	Scores•		
	Minimum	Maximum	Mode
Trial 1	0	4	2
Trial 2	1	4	1
Trial 3	0	4	1

•Score 0 = unable to stand for 10 seconds, Score 1 = able to stand in side by side 10 seconds, Score 2 = able to stand in semi-tandem for 10 seconds, Score 3 = able to stand in semi-tandem for 10 seconds and 3-9 seconds in tandem, and Score 4 = able to tandem stand for 10 seconds[12]

Cronbach's alpha coefficients• for the three test days were determined to be as follows: resting heart rate: 0.88; seated step test heart rate: 0.92; 5-minute walk heart rate: 0.87; challenged stands: 0.96; 8-foot walking speed: 0.97; and 5-minute walk distance: 0.97.

The variability of the continuous measures over the three week time period was

• Cronbach's coefficient alpha is used for statistical documentation of internal consistency.[20]

determined using test-retest data from trial 1 and trial 3. The Pearson correlation coefficient calculated for resting heart rate was .54 (n=12), seated step test heart rate was .87(n=10), average 5-minute walk heart rate was .61 (n=12), 8-foot walking speed was .97(n=12), and 5-minute walking distance was .99 (n=12). The Spearman rank-order correlation coefficients for the ordinally-scored challenged stands was determined to be 0.90 (n=12).

A floor effect was evident in the repetitious chair rise and sit task for the frail elderly sample. Only two of the twelve subjects could complete the five repetitions of chair rise and sit without using the arms to push, with times ranging from 26.80 seconds to 30.01 seconds on trial 1 and 19.77 seconds to 24.16 seconds on trial 2. On trial 3 one subject was able to complete only three of the five repetitions while the other subject recorded a faster time of 15.98 seconds. The remaining ten subjects were given a score to "0", corresponding to being unable to perform the repeated chair rise and sit task, for purposes of analysis.

All of the twelve subjects were included in a Spearman rank-order correlation analysis to determine the coefficient for the subjects who were unable to perform the rise on test day 1 and the subjects who were also unable to perform the five repetitions of chair rise and sit on test day 3 ($r_s = 0.98$). The calculated internal consistency statistic (coefficient alpha) for trial 1, trial 2, and trial 3 of repeated chair rise, including the subjects able to complete the task and the subjects unable to complete the task, was determined to .84.

Discussion and Conclusions

Discussion

The primary purpose of the study was to examine the consistency and stability of simple physical and physiological measures of heart rate during a seated step test and five minutes of walking, chair rise and sit, challenged standing, 8-foot walking speed, and 5-minute walk distance in a sample of 12 elderly subjects residing in a nursing home.

The use of a telemetric device for monitoring heart rate was acceptable, safe, and comfortable for the majority of the subjects. However, the instrument lacked sensitivity in reading the heart rate in one obese individual. Due to the high percentage of central (mid-section) obesity in the elderly, limitations such as this may prevent generalizability of the heart rate results and should be interpreted cautiously.

The resting heart rate taken after quiet sitting for five minutes demonstrated a correlation coefficient of 0.54 between trial 1 and trial 3 . The means (Table 3.1 - 3.3) do not appear dissimilar and the standard deviations remained fairly consistent from trial to trial; however, the internal consistency (alpha coefficient 0.88) of the three trials (trial 1, 2, 3) was lower when compared to the other physiologic and physical measures used in this study. A possibility exists that the variance was the result of pre-test anxiety. The subjects demonstrated a trend toward higher resting heart rates between trial 1 and trial 3 which may be indicative of greater anxiety associated with trial 3.(Fig 3.1) A possible explanation for the increased anxiety and elevated resting rate on the third trial may be the awareness that the tests required an unaccustomed deviation from the usual routine and sedentary activity level. The sample size was too small to make definitive assumptions concerning the resting heart rate, but other factors such as pre-test activity, mood, and level of emotional stress may be significant factors in the use of physiologic measures in the frail elderly.

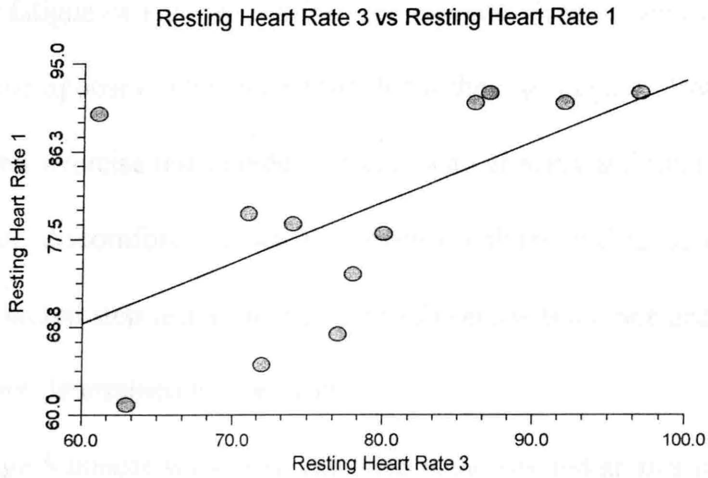

Fig 3.1.— Trend Comparison between Trial 1 and Trial 3 Resting Heart Rate

The subjects consistently were able to attain only Stage 2 of the chair step test before requesting to stop the test. The subjects indicated quadriceps fatigue and knee joint discomfort as the reasons for stopping. Given the low seated step test heart rate, the fatigue appears to be peripherally-mediated (musculoskeletal weakness) rather than cardiovascular limitations. The heart rates remained consistently low (Cronbach's alpha = 0.91, p=.05) during the seated step test. These findings are in agreement with other studies which reported lower heart rates associated with fatiguing exercise test performance ,as well as, higher heart rates associated with submaximal performance in the older adult when compared to younger adults.[21, 22] The lower heart rates in the small sample of frail elderly are most likely indicative of the unfit musculoskeletal status of the subjects. However, poor motivation should not be overlooked as a possible explanation of the low level of exercise test performance. Stamford[23] reported that many frail elderly are reluctant to exercise beyond the initial onset of fatigue. Since the usual reason for stopping was fatigue or knee discomfort, the repeated dynamic motion of knee extension to flexion appears to be more difficult for the frail subject. Beals et al[24] used a bicycle ergometer exercise test in older subjects with arthritis and found that the subjects did not indicate any discomfort or residual problems with the cycling activity. The usefulness of the seated step test as an indicator of exercise tolerance and capacity in the frail elderly was not determined by the study.

The average 5-minute walk heart rate also demonstrated an increase in variance with a moderate correlation ($r= 0.61$, Cronbach's alpha 0.87). Observationally, the exercising heart rate increased from a mean of 96 beats per minute in trial 1 to 100 bpm in trial 3 indicating the possibility of a greater effort in the third walk. Such an assumption is supported by the slight increase in the mean walking distance noted on the third walk in nine (75%) of the twelve subjects.(Fig 3.2) The variation in walking distance over time has been reported by several other researchers.[7, 9] In the previous studies, the data determined that at least two or more walks were necessary to produce more stable results. In the frail sample, two or more consecutive walks were not feasible or acceptable to the subjects. A limitation may have been introduced as the result of the single five minute walk test. Even so, the internal consistency and stability of the walk distance was high (r=.99, Cronbach's alpha .97).

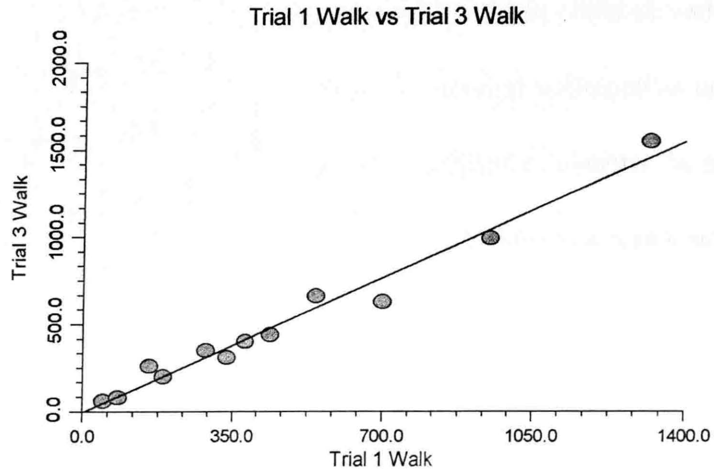

Fig 3.2.— Trend comparison between Trial 1 and Trial 3 Walk Distances for 12 subjects.

The challenged stands proved to be reliable and consistent over time in the sample of frail elderly subjects. The majority of the subjects (90%) were unable to maintain the tandem foot position for ten seconds. The stability of the challenged stands appears to be stronger than the results reported by Bohannon[25] for standing balance in older adults over two trial. Due to the frailty of the test sample, all of the subjects required physical support to attain the test positions and were monitored closely for safety during the test.

The chair rise and sit proved to be very problematic for the frail sample. The measure consistently identified the more frail subjects who were unable to stand without using the arms to push across all trials. These findings support the conclusions of Guralnik and colleagues[17] that repeated chair rise and sit is a valid and useful indicator and predictor of frailty.

The walking speed over the 8-foot course demonstrated a possible learning effect from trial 1 to trial 2, increasing from a mean walking speed of 1.21 seconds to 1.41 seconds. Butland et al[7] identified a learning effect in walk trials of varied duration with the greatest effect noted in the shorter walks. All subjects appeared to demonstrate a similar learning effect as the measure exhibited consistency between the three trials and appeared stable between trials 1 and 3. In addition, the test was easily administered and acceptable to the subjects.

Conclusions

In summary, the data supports the following assumptions:

1. Seated step test and 5-minute walk heart rates remained stable and consistent for subsequent tests performed within 72 hours and in three weeks time in the study's small sample of frail elderly. Resting heart rate exhibited more variability over the same time frame.
2. The lower extremity performance measures exhibited high reliability ($r \geq .75$) and stability over the three weeks of testing. The chair rise and sit presented difficulty for the frail sample and proved to be an appropriate descriptive measure of functional status.
3. The 5-minute walk distance remained stable and reliable for the frail sample with a small increase in the distance from trial 1 to trial 3 which may be attributed to a learning effect.

Further research using a larger sample size needs to be conducted to evaluate the sensitivity of the variables to change and response to intervention in the frail elderly. In the present study, the chair rise and sit proved to be the best indicator of the low functional status of the subjects. The measures were found to be safe with some modifications (i.e., small amount of distance between feet in challenged stands); useful; acceptable; reliable; and consistent over time. The sample size was small, thus limiting the generalizability of the findings. However, the results and modifications may be used to form the basis of a larger project in the frail elderly.

Portney[26] has recommended that reliability should exceed .90 in order to insure valid interpretations of most clinical measurements. However, the authors concede that a test with moderate or good reliability may add sufficient information to research when examined in conjunction with other tests. Using this criterion, the three test days demonstrated acceptable levels of internal consistency, or homogeneity. However when three weeks of time lapsed between trials, comparison of tests did not exhibit similar levels of stability with more variance and heterogeneity, especially in resting and 5-minute walk heart rates.

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CHAPTER 4

METHODS AND PROCEDURES

Chapter 4 describes the methods and procedures utilized in determination of the physical and physiological performance in the sample of institutionalized frail elderly. In particular, methodology is provided for testing and scoring the performance measures of repeated chair rise and sit, challenged standing, 8-foot walk speed, and the 5-minute walk. The low-level exercise test, the seated step test, is described and performance requirements for the four stages are given. An explanation of the test equipment utilized in data collection is provided in Chapter 4. Also included in the chapter are the eligibility criteria and subject description. The analyses used to determine the relationships and population inferences are explained with the varied statistical tests enumerated for clarity.

Design

The purposes of the study were to examine the relationships, population inferences using confidence intervals, and descriptive performance of physical and physiological measures. The study was a descriptive analysis of exercise tolerance and intensity and lower extremity function on a short battery of performance tests in a group of frail elderly residents in long-term care facilities. The outcome variables analyzed in the study are highest seated step test heart rate on the seated step exercise test and the heart rate obtained by averaging the recorded heart rates during the last three minutes of a 5-minute walk, physical performance scores of chair rise and sit, standing, and walk speed over 8-feet, 5-minute walk distance, and the rate of perceived exertion.

Subjects

According to the data published by the U.S. Department of Health and Human Services in 1990, 1.4 million persons aged 55 years and over were found to reside in nursing homes.[104] Of those residents, 93% were aged 65 years and over, 78 % were 75 years and over, and 42 % had passed their 85th birthday. Therefore, to maximize the generalizability of the results to institutionalized individuals, the sample recruited for this study consisted of frail subjects age 65 years and older residing in a long-term care facility. Following medical record screening, physician notification, and patient/family permission, a sample of 80 frail subjects of 65+ years of age was selected to participate in the study with 78 completing the required tests for inclusion in the final analysis. Voluntary participation in the study was explained to both the subject and, when appropriate, the family representative. The subjects were considered to be frail if they 1) required the assistance of another person or special equipment to perform the activities of daily living (ADL) or 2) required personal help or supervision to perform instrumental activities of daily living (IADL) as indicated by self-report.[104] ADL's were defined as bathing, dressing, getting in or out of bed or chair (transferring), mobility, and using the toilet.[100] The IADL's were considered to be limited meal preparation, shopping, doing light housework, doing heavy housework, and getting outside of the facility.[144] The participants gave a self-report summary of the required assistance from a person and/or inability to perform one or more of the defined ADL or IADL activities. Additional eligibility criteria for the study were as follows:

1. no current history of acute cardiopulmonary, neurological, musculoskeletal, or cardiovascular conditions which would limit use of heart rate as an indicator of activity tolerance
2. ability to sit upright unsupported in an armless straight-back chair for 20 minutes
3. no more than a -10 degree loss in bilateral knee extension range and 100 degrees of knee flexion range in both knees
4. ability to follow and repeat a one-step command
5. able to voluntarily sign or have a representative sign a consent form approved by the Human Subjects Review Committee of Texas Woman's University and the University of Central AR-Conway, AR.
6. ability to see a visual target placed 12 inches in front of chair
7. ability to hear metronome or verbal timing cue
8. resting heart rate not exceeding 100 bpm
9. blood pressure not exceeding 200 mmHg systolic and 110 mmHg diastolic at rest in sitting [71]

Acceptance into the study was based on a review of the current medical record by a licensed physical therapist and nursing facility personnel in consultation with the resident or primary physician. All races and ethnic groups who met the inclusion criteria were eligible to participate. Demographic information of age, medications, and primary diagnoses were determined from subject and/or facility record. Subjects were asked to refrain from drinking caffeine beverages or eating a large meal within two hours of testing.

Equipment

The chair rise and sit and the seated step test were done using standard armless straight chairs which were available from the cafeteria area in all of the nursing facilities. The chairs were metal or wood framed with firm vinyl-covered cushions and were 17 to 18 inches from the floor to seat.

The challenged standing, chair rise and sit, walk speed, and 5-minute walk time were accomplished using a hand-held stopwatch.[•] The stopwatch was checked for accuracy every 20 uses by comparing the second count to a metronome[†] count. Times were recorded to the nearest .01 of a second The measurement of distance for the 8-foot walk was accomplished using a retractable tape measure[‡] with sticky removable labels placed two feet beyond each end of the 8-foot markers to indicate beginning and end points. The determination of the seated step test and walking heart rates was accomplished using the Accurex® II heart rate monitor[§] with chest strap electrodes and a wrist receiver. The seated step test targeting apparatus used in the study is a prototype

[•] Health Tech, Inc. Model #507. LCD Service, 26400 W Eight Mile Rd, Southfield, MI 48034
[†] Willner Taktell Piccolo Metronom. West Germany
[‡] Great Neck Power Tape. C316E. Sears, USA
[§] Polar CIC, Inc, 99 Seaview Blvd., Port Washington, NY 11050

design. The device was constructed of wood with 1/2 dowel rods placed at the target heights of 6, 12, and 18 inches mounted on a folding square base.(Appendix A.2)

Resting blood pressure was taken during initial screening and immediately before starting the first test using a standard adult cuff sphygmomanometer and auscultatory stethoscope.† The blood pressure was taken using the left upper arm in quiet sitting following a five minute rest period.

Procedure

Due to the frailty and institutionalized status of the subjects, administrative permission was obtained from the nursing home director, director of nursing, and any other required entities (directors of research, social services, or personal caregiver) prior to subject recruitment in the facility. Human subject approval and a copy of the proposed research with the consent form was placed on file in the administrator's office at all facilities. In addition, documentation from the Arkansas Office of Long-Term Care describing research criteria with nursing home elderly and the protection of the subjects' rights was included in the packet.[145] Subjects were screened for inclusion following notification of family and physician. Consent forms (Appendix C) were signed by the patient or responsible representative before testing began.

The heart rate monitor was cleaned with alcohol between subjects and fitted to the subject prior to beginning the tests; the monitor remained on the subject for the entire test period (30 to 45 minutes). The monitor was placed on the anterior thorax just below the

† Welch Allyn Tycos, Arden, NC, USA

breasts and positioned to obtain a consistent signal on the wrist receiver. The receiver was placed on the right wrist in 98% of the subjects; the other 2% had bony anomalies from old, healed fractures which necessitated use of the left wrist for heart rate monitoring purposes.

The tests were completed on the same day in a consistent order:

1. Timed challenged stands with shoes on (<1" heel) or off if safe
2. 8-foot walk; the walk was repeated twice.
3. Chair rise and sit was timed for five repetitions.
4. Subjects were allowed to rest for five minutes or until the heart rate returned to the resting rate.
5. 5-minute walk was performed.
6. Subjects were again allowed to rest for five minutes or until the heart rate returned to the resting rate.
7. Seated step test was performed.
8. Subject was asked to rate the level of perceived exertion immediately following completion of the seated step test.

Upon completion of the tests, the subjects were allowed to sit quietly with the heart rate monitor in place until the heart rate returned to resting level.

A short summary explanation was given at the start of the tests. Then each test was verbally explained and demonstrated to the subjects just prior to initiation of the testing to decrease confusion and enhance understanding of the instructions. The subjects were allowed to practice once on the 8-foot walk, chair rise and sit, and the challenged standing. The subject was allowed to practice the sequence of the seated step test for ≈15 seconds, followed by a short rest, before beginning the test.

Timed challenged stands

All subjects were measured using tests of timed standing in tandem, semi-tandem, and side-by-side foot positions.[12] All subjects began with shoes off or with low-heeled shoes on (<1" heel) in a semi-tandem position with the heel of one foot placed to the side of the great toe of the other foot with no more than one inch between the heel and side of toe. If the subject could not maintain the semi-tandem position for 10 seconds, a time was evaluated in side-by-side standing, which required the subject to stand with the feet side by side with no more than one inch between the feet for 10 seconds. If the subject was able to maintain the semi-tandem position for 10 seconds, a more challenging test requiring the subject to stand with the feet in tandem position with the toes of one foot less than one inch away for the heel of the other foot was timed for 10 seconds. The subject was allowed to self-select the forward foot in the semi-tandem and/or tandem test positions.

The subject was allowed to hold onto a surface or the investigator until achieving a safe level of stability. When the subject indicated readiness and was no longer holding for support, the 10 second timing began. The test was stopped when the required time was met, the subject stepped out of the test position, or grabbed onto a surface or the investigator. The investigator remained close to, but not touching, the subject for safety during the entire test. Scoring for the stands was described by Guralnik et al[12] and was followed in this study. The scores are based on an ordinal scale of 0=unable to maintain even the side-by-side foot position to 4=10 seconds in the tandem foot position. The remaining intervening scores are based on amount of time spent in the varied positions (Appendix B).

Walk speed

A course was measured using a tape measure for eight feet plus two feet at either end and marked using small colored sticky labels. The subject was instructed to walk the specified distance "as if you are walking over to turn on the television" which was intended to elicit a self-selected comfortable pace.[12] The subject performed the walk twice, one after the other while being timed. The timing began when the forward foot crossed the first 8-foot marker and ended when the trailing foot crossed the second 8-foot marker. The two walk times were averaged and converted to a velocity measure of feet per second (8 feet/average of two walks) for data analysis. The subjects were allowed to use any assistive device that was customary for them.

Chair rise and sit

The subjects were instructed to perform five repetitions of stand up and sit down as quickly as possible from sitting in a straight chair without using the hands or arms for assist. The subject was observed performing the chair rise one time prior to the beginning of the timing to ensure understanding and ability to safely stand. The investigator remained in close proximity to the subject to assist in case of loss of balance. Timing began as soon as the subject's buttocks cleared the seat and ended with the subject fully reseated in the chair. This procedure differs from the method used by Guralnik et al [12] in which the subjects were timed from first rise to last rise. The method utilized in this study allows for timing of five complete rise to sit movements with the subject beginning and ending in sitting. The subjects were encouraged to have shoes on during the performance of the stands for safety.

Scoring of the chair rise and sit test was similar to the recommendations in previous studies by Guralnik, et al[12]. The previously referenced scoring procedure was determined using a community-dwelling sample while the present sample was much more frail; but the methodology was deemed appropriate and useful in the present study. The amount of time required to rise and sit five times was scored by calculating a frequency distribution and defining percentile frequencies such that subjects' times falling within the first 25th percentile recorded the fastest speeds and were assigned a score of "4"; subjects within the 25th percentile to the 50th percentile were given a score of "3"; subjects whose times were in the 50th percentile to the 75th percentile were assigned a "2"; and subjects with the slowest times were in the 75th percentile to the 100th percentile, equating to a score of "1". Subjects not able to perform the chair rise without use of the arms were given a "0". In this way, all subjects could remain part of the analysis.[12] Frail elderly usually use assistance to stand from a chair and previous research supports the ability of the chair rise to correlate well with frailty and functional decline. [22, 146] Therefore, the subjects unable to perform the rise to sit are considered "typical" of the individual residing in a long-term care facility and are appropriate to remain in the analysis.

5-minute walk

The walk took place in the lighted corridors of the nursing centers. Timing began when the subject walked across a mark at the door threshold and continued for five minutes. The ending point was indicated by placement of a sticky label on the floor at the end of the five minutes. The sticky labels were used in order to limit any safety hazards to the other residents walking in the corridors.

The subject was instructed to walk "without stopping for five minutes". In addition, the subjects were told to walk as fast as safety allowed, but to continue walking for the full time period. The subjects were allowed to use any customary assistive device. The subjects were allowed to slow the initial fast pace to a speed that could be maintained for the five minutes.[20, 132]

Encouragement was given according to the recommendations of reviewed research.[131] One of four standardized phrases were given every 30 seconds during the last 3 minutes of the walk. The phrases were randomly selected by the investigator and were "You are doing well.", "Keep up the good work.", "You are making good time.", or "Keep walking, you have ____ minutes left".

The heart rate was recorded every 30 seconds during the last three minutes of the walk. According to reviewed findings, subjects have been found to walk fastest during the first two minutes of a walk test and then level off to a constant pace in the remaining time.[55] This seems to support the theory of steady state and should be more indicative of exercise tolerance and endurance. The subject's recorded heart rates were averaged and analyzed as the submaximal heart rate representative of exercise tolerance.

The 5-minute walk distance was measured using a stepping count of the one foot square tiles on the corridor floors and, when the tiles were inappropriate or unavailable, the distance was measured using a retractable tape measure to the nearest foot. The tile squares were randomly measured for closeness to the required twelve inches prior to beginning the walk. If inconsistencies were found routinely, distance determination was made using the tape measure. While a certain amount of error is inherent in this measurement method, the practicality was deemed more important in the "real world" of the crowded, cluttered corridors in the nursing centers, which limited the precise calculation of walk distance. The walking heart rate obtained by averaging the recorded heart rates during the 5-minute walk and the distance covered in feet were used for data analysis.

Seated step test

The subjects were seated comfortably in a straight padded chair with the target placed at a distance which allowed for knee extension without undue hip movement into flexion. The seated step test consisted of four stages (Appendix A.1) requiring extension of alternating knees to touch the instep of the foot to a target height of 6", 12", or 18".[107] In addition, the last stage of the test (which no subject was able to reach) involved lifting the arm to 90 degrees of shoulder flexion while extending knee to touch the 18" target.

The subject was instructed to pace the alternating steps to a one second count of up and down. The investigator used the stopwatch to provide accurate verbal pacing cues. The one second count yielded a stepping frequency of one second to lift the foot to touch the target and one second to return the foot to the floor, resulting in 15 steps per foot per minute. A 15-second practice time was allowed to ensure understanding of the stepping frequency following by a rest to allow the heart rate to return to the resting level prior to beginning the test.

Heart rates were recorded at two and five minutes of each stage.[107] The test was stopped when the subject reached 80% of the age-adjusted maximum heart rate, indicated lower extremity fatigue, refused to continue, or when indicated by American College of Sports Medicine guidelines (Appendix A.3).[60] The test took 15 to 20 minutes to complete. The subject remained seated following completion of the seated step test to allow recovery to the resting heart rate and to observe for any adverse signs of abnormal exercise response.[60] The peak heart rate attained during performance of the seated step test was considered to be the seated step test heart rate and was utilized in the data analysis for this study.

Ratings of perceived exertion (RPE)

Since musculoskeletal fatigue was anticipated to be the predominant factor limiting performance during lower extremity activity in the frail sample, the ratings scale utilized in the study was the category-ratio scale, which is more indicative of peripheral effort such as leg effort.[127](Table 2.1) Immediately following completion of the seated step test, the subjects were instructed to indicate "how much effort was used during the test" by marking the highest level of perceived effort using the numeric as well as the descriptive indicators. So the ratings could be marked without an extended delay at the end of the test, the instruction for marking the ratings scale was briefly explained to the subject using terms of "effort put forth" or "overall work required" in completion of the task prior to beginning the seated step test. The scale was reproduced in large, bold numbers and letters in black ink on white paper to decrease the visual difficulties that may be present in the elderly subject. In order to decrease the possibility of investigator bias, instruction was kept to a minimum. The numeric indicator from the scale was used to analyze the relationship of the RPE to the seated step test heart rate obtained from the seated step test.

Data Analysis

Power analysis was done using N=78, a_2=.05, ES=.40 (medium effect size or moderate correlation).[147] The probability of detecting a moderate relationship between the variables of seated step test heart rate, average 5-minute walk heart rate, 5-minute walking distance, rate of perceived exertion, and the physical performance measures of challenged standing, walk time and speed, and chair rise was determined to be .95, which is good power to reject or accept the null hypothesis that "r =0" is present. The choice of a moderate effect size was made since a lesser correlation would have little estimation value clinically. In other words, a lesser correlation would indicate the variables are not related, so that one variable is not predictive of the other variables.

Correlational statistics were utilized to develop inferential estimation parameters with confidence intervals. Pearson product-moment correlations were used to determine the relationships of the parametric variables of seated step test heart rate, average walking heart rate, 5-minute walking distance, and walk time and speed. Follow-up confidence intervals were calculated using Z-scores and 95% confidence. Means, standard error (SE), and standard deviation (SD) were calculated for the 8-foot walk speed, the seated step test heart rates, the 5-minute distance, and the 5-minute average walking heart rate. Spearman correlations were used to analyze the relationship of seated step test heart rate, the average walking heart rate, the 5-minute walking distance, and the nonparametric ordinal data of the chair rise and sit and challenged stands score. Descriptive statistics of median and mode are determined for challenged stands and rise to sit scores.

Separate Pearson product-moment correlation coefficients (r) were determined for:

1) seated step test heart rate and 8-foot walk speed
2) average 5-minute walk heart rates and 8-foot walk speed
3) 5-minute walk distance and 8-foot walk speed

Means, standard deviations, standard errors, minimum, maximum, median, mode, and range of the data were computed for all parametric variables. The correlational coefficients were transformed to a Fisher's Z statistic and 95% confidence intervals were determined for each correlation.[148] Statistical significance was determined for each coefficient with at least a weak relationship using $p \leq .05$.

Spearman rank-order correlation coefficients (r_s) were computed between the ordinal variables of:

1) seated step test heart rate and challenged stands score
2) seated step test heart rate and chair rise and sit score
3) 5-minute walk heart rate and challenged stands score
4) 5-minute walk heart rate and chair rise and sit score
5) walk distance and challenged stands score
6) walk distance and chair rise and sit.
7) ratings of perceived exertion and seated step test heart rate

Median and mode were determined for the challenged stands and chair rise tasks. Frequencies and percentiles were calculated for the recorded time of the five chair rises. Descriptors, numeric level of ratings of perceived exertion, and frequency were computed for the total number of subjects completing the seated step test (n=73). Determination of descriptive statistics for subjects using assistive devices for the walk tasks were calculated for 5-minute walk distance, 8-foot walk speed, and 5-minute walk heart rate.

Correlation statistics were interpreted as little or no relationship if r=.00 to .25, a fair relationship if r=.25 to .50, and a moderate relationship if r=.50 to .75, and r=>.75 as a good relationship.[47] Results were interpreted based on clinically meaningful associations and the relative accuracy of the relationship in making inferential population estimates based on the confidence intervals.

CHAPTER 5

RESULTS

The purposes of the study were to examine the physical measures of repeated chair rise and sit, challenged standing, 8-foot walk speed, and 5-minute walk distance and the physiologic measures of resting heart rate, seated step test heart rate, 5-minute walk heart rate, and ratings of perceived exertion for relationships and value as test measures to describe the performance parameters of the frail elderly residing in institutions. Subject gender, primary diagnoses, prevalence and the observed performance effect of medications, and the use of assistive devices are presented in Chapter 5. The results of the descriptive analyses of the frail sample's performance capabilities are presented in Chapter 5 by order of the variables as follows: heart rate, chair and sit, challenged stands, 8-foot walk speed, and 5-minute walk. The results of the correlational analyses and appropriate confidence intervals for determination of the relationships between the physical performance variables and the recorded seated step test heart rate and average 5-minute walk heart rates are presented according to the relationships proposed in the study: 1) relationship of the seated step test heart rates and the scores on challenged standing, chair rise and sit, and walk speed; 2) relationship between average 5-minute walk heart rates and the scores on challenged standing, chair rise and sit, and walk speed; and 3) relationship between the 5-minute walk distances and the scores on challenged standing, between seated step test heart rates and ratings of perceived exertion is presented. The last section of Chapter 5 presents the results of crosstabulation analyses of chair rise and sit, challenged stands, 8-foot walk speed, and 5-minute walk distance with identification of performance threshold indicators.

Subject Demographics

The sample was made up of 40 men and 38 women residents ranging in age from 67 years to 98 years with a mean age of 81.94 ±7.08 years who were living in several long-term care facilities. However, the test sample was atypical for the elderly in the gender ratio. The test sample was nearly 1:1 female to male whereas the National Center for Health Statistics indicates the ratio of institutionalized individuals in the same age group to be more like 2:1 female to male.[106] One of the test sites was a Veteran's Administration nursing home in which the men far outnumbered the women. In the other test sites, the women outnumbered the men resulting in the observed 1:1 ratio.

One subject on medication for treatment of prostate cancer responded abnormally to the seated step test with a rapid rise in heart rate inappropriate for the low level of performance. Obese subjects and those with bony thoracic changes required adaptations in the position of the heart rate monitor's chest strap. Placement of the transmitter strip in the left lateral quadrant proved to be more effective for accurate monitoring in these subjects. Placement on the back was useful during the 5-minute walk test, but was problematic during the sitting exercise test secondary to discomfort associated with leaning back in the chair. The device reported heart rate data discontinuously if placed in areas with calcific bone changes, as over a healed wrist fracture or rib anomalies.

All of the 78 subjects were able to complete the challenged stand test at some level. Sixty-one of the subjects were able to complete the chair rise and sit task without using arms to push (14 were unable to rise and were given a score of 0 for analysis); three refused to perform more than one chair rise repetition. Three subjects were considered to be outliers for the 8-foot walk; one exhibited bradykinesia related to Parkinson's disease and two recorded very fast times of >7.92 feet/second, leaving 75 subjects with appropriate data for inclusion in the final analyses. For the 5-minute walk, 76 subjects completed the test satisfactorily and were included in the final analyses; one subject with Parkinson's disease covered <120 feet in 5 minutes and was considered an outlier and a second less frail subject recorded over 1250 feet, making him an apparent outlier for the sample.

Of the 78 test subjects, only 73 participated in the seated step test and were used in the correlational analysis of seated step test heart rate and the ratings of perceived exertion. Data from five subjects were eliminated from the analyses for the following reasons: 1) two subjects refused to perform to fatigue; 2) one subject on oncologic medication responded with an abnormally high heart rate (120 bpm) at the lowest level of the seated step test and the test was stopped for safety reasons; 3) one subject with mild dementia could not maintain the one second stepping frequency and sequence; and finally 4) one subject with residual deficits from a stroke had difficulty extending his left knee and could not complete the test. Descriptive statistics of the subjects are presented in Table 5.1.

Table 5.1.— Characteristics of Frail Participants (n=78)

Characteristics	Number (Percent total sample)
Age (mean ± SD)	81.94 ± 7.08 years
Gender	
Male	40
Female	38
Primary diagnoses	
Hypertension	27 (35%)
Congestive heart failure	18 (23%)
Atrial fibrillation	12 (16%)
Mild dementia	10 (13%)
Parkinson's disease	8 (10%)
Misc.(OA, CVA, CA)	18 (23%)
Medications	
Antihypertensives	27 (35%)
Diuretics	21 (27%)
Antianxiety	14 (18%)
Antidepressants	10 (13%)
Parkinson's	8 (10%)
Oncologic	5 (6%)

Thirty-five percent of the test subjects were found to be diagnosed with hypertension which was slightly lower than the national average (42%) for individuals over 65 years of age and dependent with 1 - 2 activities of daily living.[104] In a study by Guccione et al[50], the results showed in a sample of over 1700 aged men and women that congestive heart failure was reported in 21.4% of the subjects. In the present study, a similar percentage (23%) had a diagnosis of congestive heart failure. In an additional study to evaluate physical disability in over 5000 men and women, congestive heart failure and hypertension were found in 4.1% and 48.8% respectively in subjects reporting difficulty walking, climbing stairs, transferring, and ADL/IADL duties.[45] Therefore, the present sample appears to be a fair representation of the frail aged population in presenting diagnoses.

Antihypertensive drugs and diuretics were the most prevalent medications currently on the medical charts for the frail sample. Antihypertensive medications generally have little effect on resting or submaximal exercising heart rate.[60] The drugs may be associated with a prolonged cool-down period, and in the present study, the subjects did require several minutes to five minutes for the heart rate to return to the resting status following the walk test. Whether the prolonged rest period was associated with a medication or is more a factor of poor cardiovascular fitness cannot be determined by the present data.

Diuretics have been shown to have little or no effect on heart rate values during rest or exercise as long as potassium is maintained at adequate levels.[60] The most commonly prescribed diuretic in the study sample was a “loop” furosemide and potassium supplementation was generally given with the drug. Therefore, the assumption was made that the subjects on a “loop” diuretic were receiving adequate amounts of potassium.

Approximately one-third of the subjects were taking drugs classified as anti-anxiety or antidepressants. The effect of tranquilizers, diazepam, and other such medications on exercise is relatively unknown in humans. Animal studies seem to indicate a reduction in the resting heart rate but limited research is available concerning response to exercise.[149, 150] The subjects in the present study seemed to represent a fairly normal distribution of resting and exercising heart rates, thus limiting the possibility of a drug interaction.

The majority (85%) of the subjects did not use an assistive device regularly and were safe independent ambulators. Descriptive statistics of the subjects who used a device during the walk tests (5-minute walk and the 8-foot walk) are given in Table 5.2.

Table 5.2.— Means (± standard deviations) of Subjects by Usage of Assistive Device for Ambulation during 5-Minute Walk Test and 8-Foot Walk Speed Test with Average 5-minute Walk Heart Rate (HR_{Wlk})

Categories of Usage (n, %total sample)	HR_{Wlk}[a]	5-Minute Walk[•]	8-Foot Walk Speed[†]
Used No Device (n=63, 85%)	96.7 (±10.2)	536 (±214)	1.36 (±.35)
Regular "J" Cane (n=3, 4%)	94.8 (±11.2)	720 (±356)	1.11 (±.32)
Quad Cane (n=1, 1%)	96	180	.50
Walker (n=2, 3%)	92.3 (±18.1)	316 (±6)	.88 (±.10)
Rolling Walker (n=6, 8%)	94.2 (±6.2)	314 (±73)	.77 (±.58)

[a]beats per minute
•nearest foot
†nearest one hundredth foot/second

The subject who used a four-prong cane had a left residual disability from a stroke several years prior to inclusion in the study. While he did complete the walk tests, he required a much longer time to go 8 feet and he walked very slowly in the hall covering only 180 feet in 5 minutes. Subjects using rolling walkers walked shorter distances in the hall and took longer to walk the 8 feet than did any of the other groups (excluding the previously described subject with stroke disability).

Performance Descriptives

The tests were performed by the majority of the participants without incident and with relevant clinical ease in spite of the frail status. Descriptive analyses of the physical and physiologic performance scores were used to describe the performance abilities of the frail sample and are given by the measurement variable.

Heart Rate Response

The resting heart rate was determined for the 78 frail subjects in sitting following a 5-minute rest. The estimate of submaximal heart rate utilized in the data analyses was the average heart rate recorded during the 5-minute walk for 76 subjects. The seated step test heart rate was the heart rate recorded during the subjects' last stage of the seated step test for 73 subjects.

The range of the average walking heart rates recorded during the 5-minute walk was 76 bpm to 124 bpm. Comparison of the 5-minute walk heart rate and the mean pre-activity resting rate demonstrated approximately a 23% increase in the walk heart rate. The range of the seated step test heart rates recorded using the chair step exercise test was from a low rate of 65 bpm to a high rate of 126 bpm. A comparison of the mean seated step test heart rate and the mean resting heart rate resulted in an average increase of 20% in the heart rate. The heart rate responses were similar for the 5-minute walk and the seated step test performance in the frail subjects. The descriptive statistics for the resting, 5-minute walk, and seated step test heart rate data are given in Table 5.3.

Table 5.3.— Means (± SD) and SE of the Physiologic Variables of Resting Heart Rate, 5-minute Walk Heart Rate (HR_{Wlk}), and Seated Step Test Heart Rate (HR_{SST})

VARIABLES (bpm•)		
Resting Heart Rate (n=78)	HR_{Wlk} (n=76)	HR_{SST} (n=73)
78 bpm(± 12) SE = 1.33	96 bpm(± 10) SE = 1.15	94 bpm(± 12) SE = 1.44

•beats per minute

Chair Rise and Sit

Of the 78 subjects in the study, data from 75 subjects were used in the final analyses (three subjects refused to continue after completing a single rise). Of the subjects evaluated on the repeated chair rise task, 14 (19%) could not rise without using the arms to push. For the subjects completing the five repetitions of the chair rise and sit, a difference of 8.75 seconds was found between the scoring cutpoints for the lowest score of 1 and the highest score of 4. Distribution of the recorded performance times, percentage unable to perform the task, mean, and calculated percentile frequencies of the timed scores for the chair rise and sit times are given in Table 5.4. The scoring ranges and cutpoints are defined in the lower portion of the table. The scoring method was formulated similar to the scoring method documented by Guralnik et al [12] in a large sample of community-dwelling elderly.

Table 5.4. —Chair Rise and Sit Performance with Mean, Percentile Times, Percentage Unable to Complete, and Scoring Categories for Subjects Completing the Test (n=75)

Unable to Complete Task (% total sample)	19%
Mean (±SD) of Able Subjects (n=61)	22.83 (±6.06)
1st Percentile	45.30
5th Percentile	38.40
10th Percentile	32.84
25th Percentile	27.69
50th Percentile	22.80
75th Percentile	18.94
90th Percentile	15.75
95th Percentile	15.13
99th Percentile	11.91
Scoring Category	Cutpoint (seconds)
Score = 1 (16%)	≥ 27.69
Score = 2 (23%)	23.00 to 27.69
Score = 3 (26%)	19.60 to 22.80
Score = 4 (34%)	≤18.94

The ordinal scores ranged from 0 to 4, with the most frequently assigned score for the sample being 4. The median score for the frail sample was 3. The data exhibited a range of 33.39 seconds from the longest time of 45.30 seconds to the fastest time of 11.91 seconds. The standard deviation was calculated to be 6.06 seconds for the subjects completing the five repetitions. The positive skewness of the raw scores for the subjects able to complete the repeated chair rise and sit task and the percentage unable to rise without using the arms to push are graphically depicted in Fig 5.1.

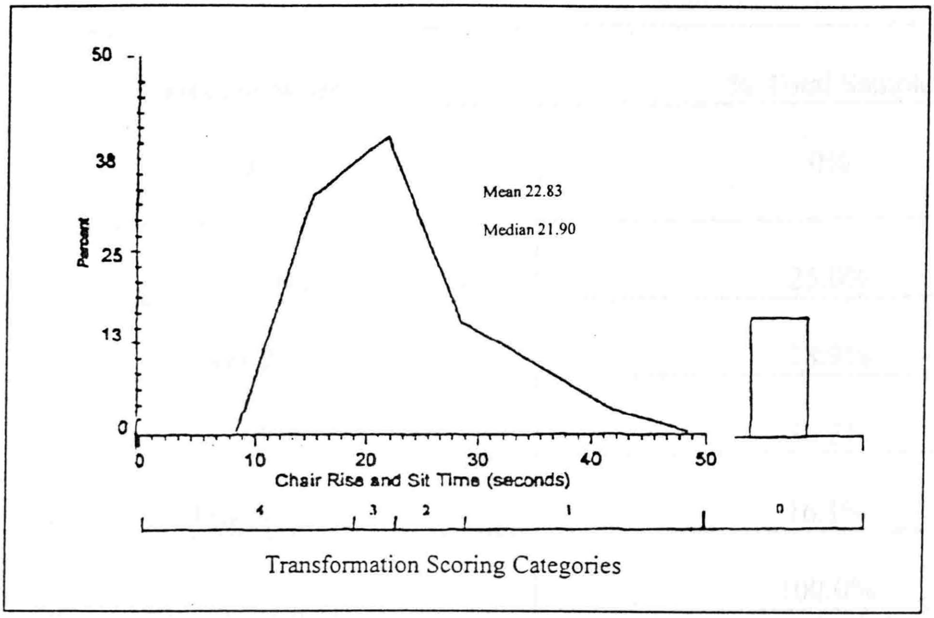

Fig 5.1 —Percentile Distribution of Chair Rise and Sit Times for the Subjects Able to Complete Five Repetitions of the Task and the Percent of the Subjects Unable

Challenged Stands

The ordinal scoring methodology for the challenged stands is given in Appendix B and was based on a previous study by Guralnik et al[12] in a large sample of community-dwelling elderly. All of the subjects in the present study were able to complete the challenged stands task at some level. The most frequently assigned scores (n=45) for the sample were 2 or 3, indicating stability for 10 seconds in the semi-tandem foot position and at least an attempt at the tandem position.(Table 5.5) The scores exhibited a tendency to cluster around 2 or 3, resulting in approximately a normal distribution of scores on the challenged stands, with the smaller number of subjects scoring low and high. The median score for the sample was 2, while the mode was 3.

Table 5.5— Challenged Stands Performance Percentage (%) Distribution for Categorical Scoring[12]

Category Score*	% Total Sample
0	0%
1 (n=20)	25.0%
2 (n=22)	28.9%
3 (n=23)	30.2%
4 (n=13)	16.1%
n = 78	100.0%

*Score 0 = unable, Score 1 = able to stand in side by side 10 seconds, Score 2 = able to stand in semi-tandem for 10 seconds, Score 3 = able to stand in semi-tandem for 10 seconds and 3-9 seconds in tandem, and Score 4 = able to tandem stand for 10 seconds[12]

The distribution of the scores for the 78 frail subjects on the challenged stands is demonstrated in Fig 5.2.

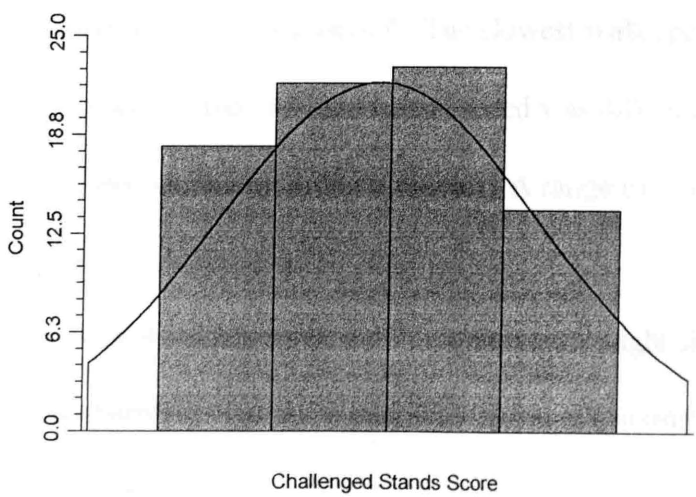

Fig 5.2 —Distribution of Challenged Stands Scores for 78 Subjects

8-Foot Walk Speed

Distribution of performance times, mean, and calculated percentile frequencies are given in Table 5.6 for the 8-foot walk speed.

Table 5.6.— Distribution of performance, mean, and percentile times for 8-Foot Walk Speed

		Walk Speed (feet/second)
	Mean (n=75)	1.52(±.75)
	1st Percentile	.48
n=19	5th Percentile	.52
	10th Percentile	.75
	25th Percentile	1.03
n=38	50th Percentile	1.31
	75th Percentile	1.86
n=18	90th Percentile	2.62
	95th Percentile	2.90
	99th Percentile	4.04

Of the 75 subjects completing the 8-foot walk, 45 (60%) were able to perform the task with an average speed of ≥1.03 feet/second. The slowest walk speed recorded for the frail sample was .48 feet/second and the fastest walk speed was 4.04 feet/second with a mean walk time of 1.52 feet/second (± .75 feet/second). A range of 3.53 feet/second was found in the walk speed.

The walk speeds on the 8-foot walk test demonstrated a slight skewness toward the slower speeds. The distribution of the 8-foot walk speed is demonstrated graphically in Fig 5.3 for the frail sample.

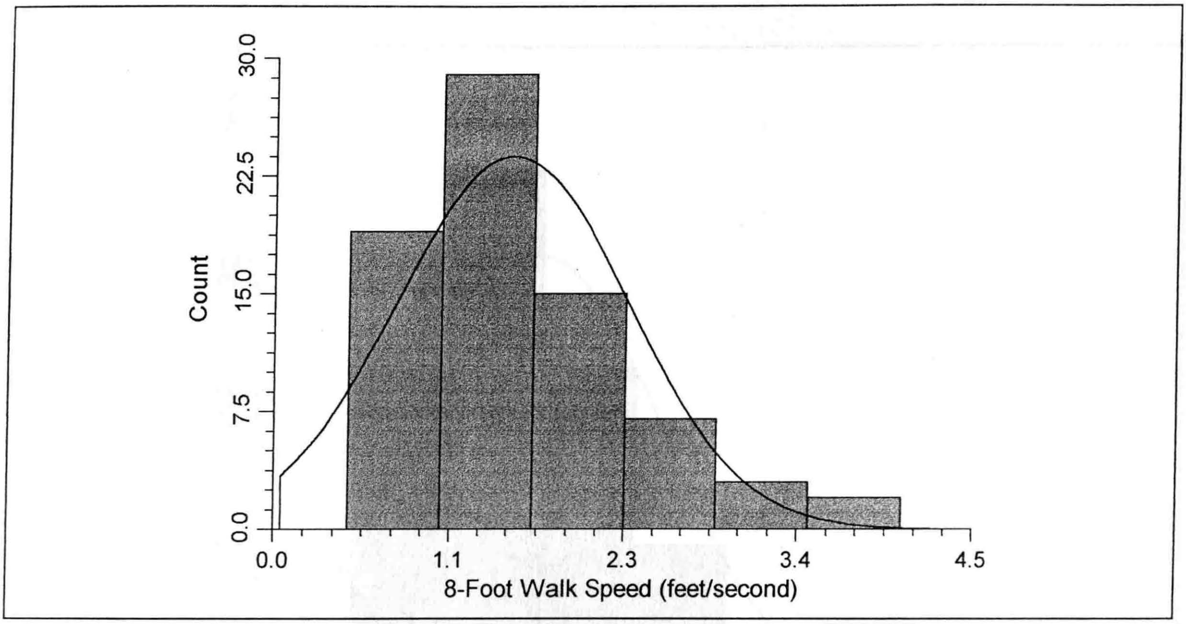

Fig 5.3 —Distribution of 8-Foot Walk Speeds for 75 Subjects

5-Minute Walk

Of the 78 subjects in the sample, 76 were able to continuously walk for five minutes. Encouragement and control of distracters (curious onlookers and avid conversationalist) were important factors in maintaining an uninterrupted walk. Encouragement was given on a regular basis during the last three minutes of the walk and appeared to motivate some subjects to complete the test. The subjects were instructed to continue walking even though the pace may have diminished considerably toward the end of the walk time. The test was performed without incident and was accepted well by the frail subjects. The mean distance was 529 feet (±237 feet), however, the distribution of the walk distances tended to cluster around 380 feet, thus the data exhibited positive skewness.(Fig 5.4)

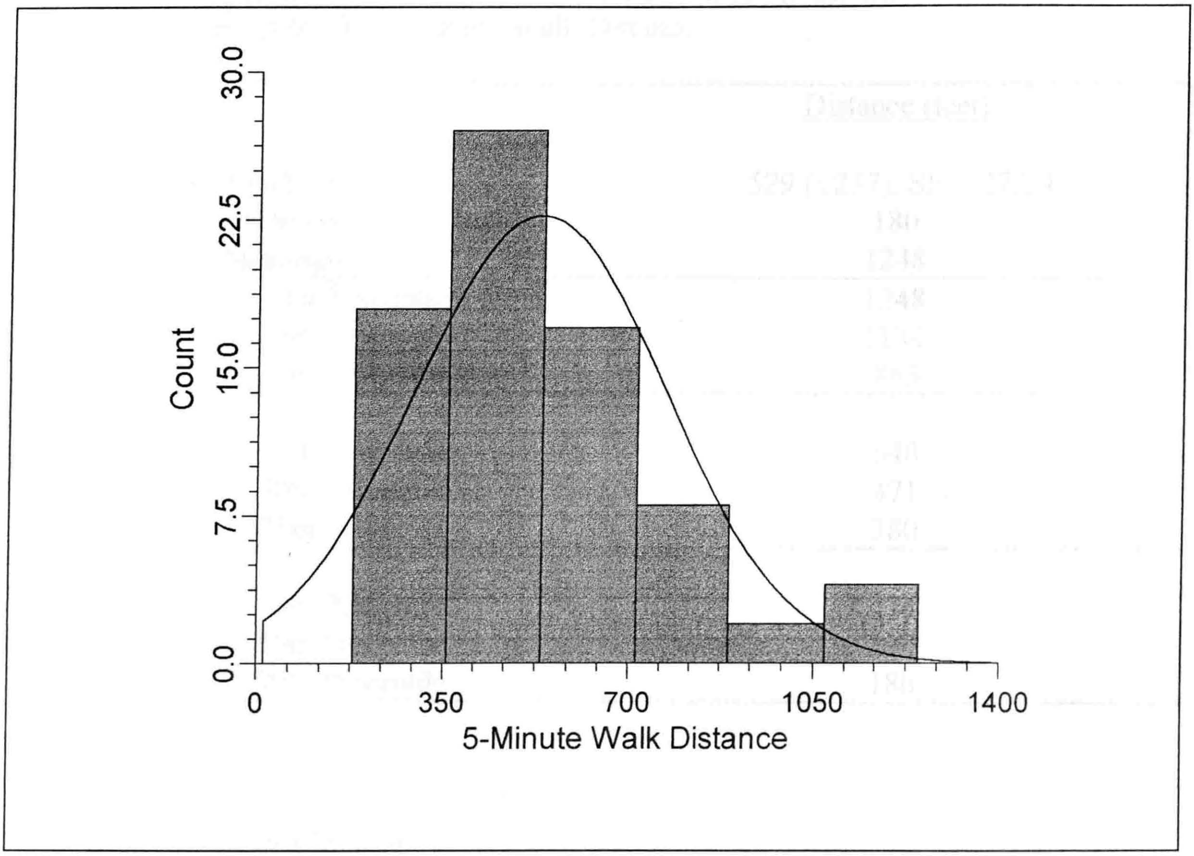

Fig 5.4 —Distribution of 5-Minute Walk Distances for 76 Subjects

The minimum distance walked by the subjects was 180 feet, while the maximum distance covered in five minutes was 1248 feet. The range of 1068 feet demonstrates the heterogeneity in walking capabilities among the frail subjects in the sample. Percentile frequencies indicated that the majority (> 50%) of the frail subjects walked between 640 and 380 feet in the five minutes time. Percentile frequency distribution, descriptive statistics, and percentiles are given in Table 5.7 for the 5-minute walk distance recorded for 76 subjects.

Table 5.7. —Mean (±Standard Deviation), Standard Error (SE), and Distribution of Distances by Percentiles for 5-Minute Walk Distance

		Distance (feet)
	Mean (n=76)	529 (±237), SE = 27.29
	Minimum	180
	Maximum	1248
n=18	1st Percentile	1248
	5th Percentile	1134
	10th Percentile	863
n=40	25th Percentile	640
	50th Percentile	471
	75th Percentile	380
n=18	90th Percentile	274
	95th Percentile	220
	99th Percentile	180

Ratings of Perceived Exertion

The ratings of perceived exertion using the category-ratio scale were indicated following the seated step test for 73 subjects. The mode of the sample was determined to be 3 which corresponds to the descriptor of "moderate" effort expenditure. The subjects were asked to indicate the "effort" required to perform the seated step test. The results of the ratings of perceived exertion analysis are presented in Table 5.8. However, the use of the category-ratio scale for determination of aerobic exercising effort may have resulted in responses that were an inaccurate representation of the "true" effort. The category-ratio scale has been traditionally utilized to indicate musculoskeletal effort rather than aerobic effort.

Table 5.8.— Ratings of Perceived Exertion with Number of Subjects and Percent of Total Sample at Each Level

Level Value (n)	Level Descriptor	% Total Sample (n=73)
0.5 (4)	Just Noticeable	5.4%
1 (1)	Very Weak	1.4%
2 (5)	Weak (light)	6.8%
3 (35)	Moderate	47.3%
4 (21)	Somewhat Strong	29.4%
5 (5)	Strong (heavy)	6.8%
6 (1)		1.4%
7 (1)	Very Strong	1.4%
8 (0)		0.0%
9 (0)		0.0%
10 (0)	Very, Very Strong	0.0%

Inferential Relationships

The results of the correlational analyses and determination of appropriate confidence intervals among the physical performance variables and the heart rates recorded with the seated step test and the 5-minute walk test are presented by the proposed relationship. The result is given for the correlation between the heart rates recorded during the seated step test and the ratings of perceived exertion obtained following the exercise test.

 # 1 Measures of the seated step test heart rate using a low-level exercise test were examined for the relationship with the scores of: a. challenged standing; b. chair rise and sit; and c. walk speed.

a. Due to the ordinal scoring of the stands, a Spearman rank-order correlation coefficient was determined for the seated step test heart rate and the challenged stands with a resulting $r_s(73) = .03$, 95% CI = - .20 to .25. No correlation was found between the seated step test heart rate and scores on the challenged stands.

b. Since ordinal scoring was also used for the chair rise and sit, Spearman rank-order correlation was utilized to examine the relationship between the seated step test heart rate and scores on chair rise and sit with the resulting coefficient, $r_s(73) = -.06$, 95% CI = -.29 to .17. No correlation was found between the seated step test heart rate and scores on repeated chair rise and sit.

c. Walk speed, being a continuous variable, was examined to determine the relationship to the seated step test heart rate using a Pearson product-moment correlation with a resulting correlation coefficient, $r(73) = .02$, 95% CI = -.10 to .14. No correlation was present between the seated step heart rate and walk speed in the sample.

#2 **Average walking heart rates recorded during the 5-minute walk were examined for the relationship to: a. challenged stands; b. chair rise and sit; c. walk speed.**

a. A Spearman rank-order correlation coefficient was calculated for the average 5-minute walk heart rates and the ordinally scored challenged stands with determination of $r(76)= .03$, 95% CI = -.20 to .25. For the frail sample, no correlation was found between the 5-minute walk heart rate and challenged stand scores.

b. A Spearman rank-order correlation was calculated for the average 5-minute walk heart rate and the ordinally scored chair rise and sit with $r_s(73) = .04$, 95% CI = -.19 to .27. No correlation was found between the average 5-minute walk heart rates and scores on the chair rise and sit.

c. Pearson product-moment correlation coefficient was determined for the average 5-minute walk heart rates and the walk speed at $r(75) = .12$ ($p>.05$), 95% CI = .00 to .24. Little correlation existed between 5-minute walk heart rate and walk speed.

#3 **The distance walked in five minutes was evaluated for the relationship to: a. challenged stands; b. chair rise and sit; c. walk speed.**

a. Results of the Spearman rank-order correlation between the five minute walking distance and the challenged stands are $r_s(76) = .23$ ($p < .05$) and 95% CI = .11 to .35. The correlation is considered to be weak, even though the coefficient approached fair (.25 to .50) in the frail sample.(Fig 5.5)

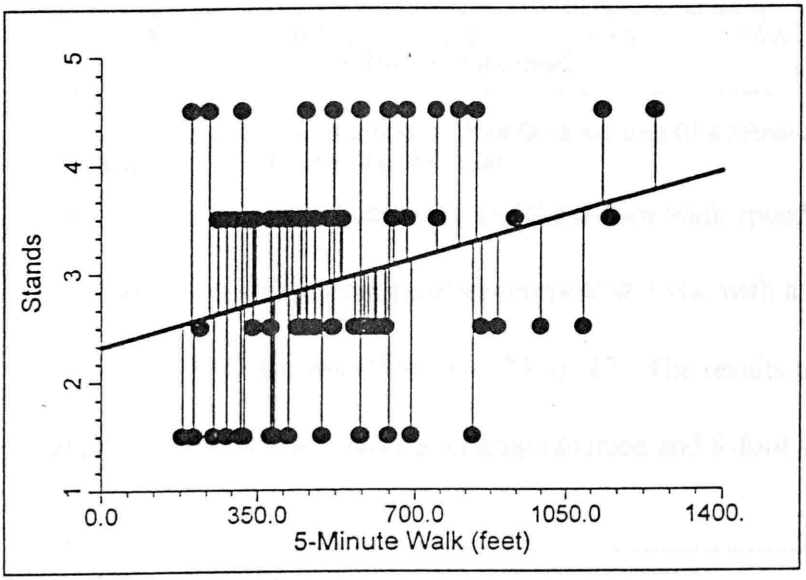

Fig 5.5 —Relationship of 5-Minute Walk Distance and Challenged Stands Score with Trend Line and Residuals

b. A Spearman rank-order correlation was determined for the five minute walk distance and the ordinally scored chair rise and sit with a resulting $r(73) = .44$ ($p < .05$) and 95% CI = .32 to .56. The results indicate that a fair relationship exists between the distance walked in five minutes and the ability to perform repeated chair rise and sit without using the arms to push.(Fig 5.6)

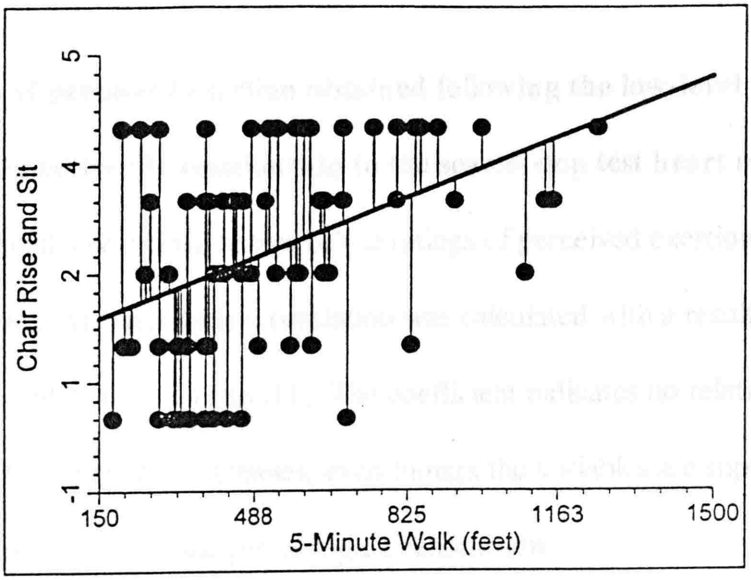

Fig 5.6 —Relationship of 5-Minute Walk Distance and Chair Rise and Sit Score with Trend Line and Residuals

c. The five minute walking distance and the 8-foot walk speed were correlated using a Pearson product-moment statistic with a resulting $r(75) = .35$ ($p< .05$) and 95% CI = .23 to .47. The results indicated a fair relationship between 5-minute walking distance and 8-foot walk speed.(Fig 5.7)

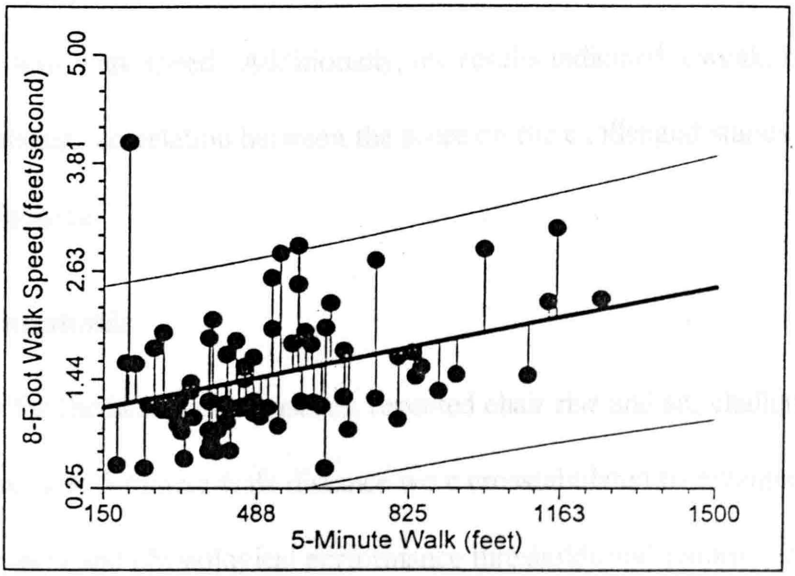

Fig 5.7 —Relationship of 5-Minute Walk Distance and Walking Speed with Trend Line and 95% Confidence Levels

#4 The level of perceived exertion obtained following the low-level exercise test was examined for the relationship to the seated step test heart rate.

a. Due to the ordinal nature of the ratings of perceived exertion scale, a Spearman rank-order correlation was calculated with a resultant $r_s(73) = .01$, 95% CI = -.11 to .11. The coefficient indicates no relationship exists between the two variables, even though the variables are supposedly measuring a similar physiologic phenomenon.

In summary, the calculated correlation coefficients indicated that, for the frail subjects, little or no relationship was present between the physical performance measures of challenged stands and repeated chair rise and the physiologic measures of exercising heart rate. The data in the present study indicated no relationship between the ratings of perceived exertion and seated step test heart rate. The distance walked in five minutes exhibited a fair correlation with the ability to rise repeatedly from a chair without using the arms and with 8-foot walk speed. Additionally, the results indicated a weak, but statistically significant, correlation between the score on the challenged stands test and the 5-minute walk distance.

Performance Thresholds

The data for the heart rate measures, repeated chair rise and sit, challenged stands, 8-foot walk speed, and 5-minute walk distance were crosstabulated to examine the possibility of physical and physiological performance thresholds and parameters for the frail sample. Demarcated performance thresholds are given for each of the physical performance measures of challenged stands, chair rise and sit, 8-foot walk speed, and 5-minute walk distance.

Chair Rise and Sit

The performance of the sample on the 5-minute walk distance and heart rate, seated step test heart rate, and the 8-foot walk speed by scores on the repeated chair rise and sit is presented in Table 5.9.

Table 5.9. —Crosstabulation using Means (±standard deviations), Standard Errors (SE), and Occurrence Frequency for Chair Rise and Sit and Continuous Variables

Chair Rise Score (n,% sample)	5-Minute Walk•	HR_{Wlk}†	HR_{SST}‡	8-Foot Walk Speed*
Score = 0 (n = 14, 19%)	381(±121) SE = 33.45	98(±11) SE = 2.80	92(±8) SE = 2.41	1.14(±.93) SE = .26
Score = 1 (n = 6, 8%)	513(±176) SE = 66.61	91(±7) SE = 1.98	92(±14) SE = 4.44	1.47(±.94) SE = .28
Score = 2 (n = 8, 11%)	524(±209) SE = 58.07	99(±9) SE = 2.55	93(±10) SE = 2.71	1.31(±.43) SE = .12
Score = 3 (n = 23, 32%)	567(±266) SE = 52.14	100(±12) SE = 2.94	96(±14) SE = 3.56	1.53(±.61) SE = .15
Score = 4 (n = 22, 30%)	594(±213) SE = 46.39	95(±12) SE = 2.61	91(±15) SE = 3.11	1.86(±.68) SE = .15

•in nearest foot
†average heart rate during 5-minute walk test in beats per minute
‡seated step heart rate in beats per minute
*in feet/second

Of the 61 subjects able to complete the task of repeated chair rise and sit, 21 (31%) were given a score of 4 indicating that the time to complete the five repetitions without pushing with the arms was <18.94 seconds; while 10 (13%) were assigned a score of 1 which corresponded to >27.69 seconds. Thirty (50%) of the 61 frail subjects attained a score of 2 or 3 indicating a time between 19.60 and 27.69 seconds. Based on the results, the performance threshold for chair rise and sit in the frail sample is ≥ 27.69 seconds for five repetitions or a score equivalent to 1. The heart rate data demonstrated similarity in all subjects. Subjects unable to repeatedly rise from a chair walked an average of 213 feet less than subjects scoring the highest (taking the least amount of time to complete five repetitions) on the task. The walk speed demonstrated a difference although not as obvious as the walk distance.

Challenged Stands

Of the 78 subjects, 19 were assigned a score of 1 (inability to stand in the semi-tandem position, but able to stand for 10 seconds in side-by -side position). Interestingly, 45 (60%) of the subjects were able to control balance in the semi-tandem foot position for 10 seconds (score of 2 or 3). Fourteen (18%) of the subjects were able to maintain the tandem foot position for the required 10 second time period (score of 4). Collectively, 64 (82%) of the frail subjects were unable to complete the tandem standing task.

Based on the data, only 18% of the sample were able to maintain the tandem stance position for the required 10 seconds which defined the subjects with the best performance on the standing task within the frail sample. Therefore, based on the data from the frail sample, the performance threshold for challenged standing, which is indicative of more frailty in the sample, is the ability to remain stable with the feet placed in close (1" between heel of one foot and toes of other foot) tandem for 10 seconds.

Heart rate data did not demonstrate obvious changes based on the challenged stand scores. Performance descriptives are presented in Table 5.10 for the frail sample by challenged stand scores.

Table 5.10.— Descriptive Performance Challenged Stands and Continuous Variables

Stands Score (n,% sample)	5-Minute Walk(feet)	HR_{Wlk} †	HR_{SST} ‡	8-Foot Walk Speed (ft/sec)
Score = 1 (n = 19, 25%)	421(±177) SE = 42.95	95.4(±8.99) SE = 2.06	94(±7) SE = 1.67	1.16(±.45) SE = .11
Score = 2 (n = 23, 28.9%)	567(±222) SE = 47.27	97(±14) SE = 3.17	92(±16) SE = 3.30	1.69(±.55) SE = .12
Score = 3 (n = 23, 30.2%)	495(±215) SE = 44.93	94(±12.91) SE = 2.69	94(±13) SE = 2.69	1.46(±.87) SE = .18
Score = 4 (n = 13, 16.1%)	658(±306) SE = 81.96	94(±8.12) SE = 2.25	95(±14) SE = 3.94	1.58(±.75) SE = .21

†average heart rate during 5-minute walk test in beats per minute
‡seated step heart rate in beats per minute

8-foot Walk Speed

Of the 75 test subjects included in the analysis of walk speed, 68 (90%) completed the 8-foot walk with a speed of ≥.75 feet/second. The decline in performance of the 8-foot walk below .75 feet/second was larger than at any other point in the data. Subjects walking the slowest over 8 feet were also found to record the shorter distances in the 5-minute walk test. Based on the crosstabulation of the data from the 5-minute walk heart rate, the seated step test heart rate, and the 5-minute walk distance in the frail sample, the performance threshold for the 8-foot walk speed was determined to be ≤.75 feet/second for the 8-foot course. The performance on 5-minute walk distance, walk heart rate, and seated step test heart rate of the sample using walk speed is presented in Table 5.11.

Table 5.11.— Mean, Standard Deviation (SD), and Standard Error (SE) of 5-Minute Distance, 5-Minute Heart (HR_{Wlk}), and Seated Step Test Heart Rate (HR_{SST}) for Subjects Recording Speeds in the Fastest 10th percentile, the Slowest 10th percentile, and Subjects Scoring Between>.75 feet/second and<1.95 feet/ second on the 8-Foot Walk

Walking Speed• (n,% total sample)	5-Min Walk†	HR_{Wlk}‡	HR_{SST}‡
≤ .75, mean .58 (n=9, 11%)	398(±146) SE = 48.5	95(±6) SE = 2.05	94(±8) SE = 2.73
>.75 and <1.95, mean 1.31 (n=49, 65%)	509(±221) SE = 31.9	97(±13) SE = 1.83	92(±1.86) SE = 1.86
≥ 1.95, mean 2.61 (n=17, 23%)	674(±275) SE = 66.7	97(±7) SE = 1.76	96(±15) SE = 3.56

•feet/second
†feet
‡beats per minute

5-Minute Walk Distance

Of the 76 subjects completing the 5-minute walk, the mode for walk distance was found to be 380 feet which also corresponds with the 75th percentile of the frequency distribution; 17 (24%) subjects walked distances which were less than 380 feet (mean distance 277 feet, SD = 52 feet). Comparatively, subjects recording 5-minute walk distances ≥ 380 feet exhibited a mean distance of 608 feet (SD = 217 feet). The subjects walking the shorter distances demonstrated less heterogeneity than did the subjects walking greater distances. The data presented in Table 5.12 describes the performance of the sample on walk speed and heart rate based on the recorded 5-minute walk distance.

Table 5.12.— Mean, Standard Deviation (±SD), Standard Error (SE) of 8-Foot Walking Speed, 5-Minute Walk Heart Rate (HR_{Wlk}), and Seated Step Test Heart Rate (HR_{SST}) for Subjects Walking ≤ 380 Feet and Subjects Walking ≥640 Feet on 5-Minute Walk Test

5-Minute Walk Distance• (n, % total sample)	Walking Speed†	HR_{Wlk}‡	HR_{SST}‡
≤ 380, mean 277 (n=18, 24%)	1.43(±1.02) SE = .24	94(±8) SE = 1.97	90(±12) SE = 2.95
≥ 640, mean 852 (n=20, 26%)	1.67(±.64) SE = .14	96(±12) SE = 2.68	93(±14) SE = 3.12

•feet
†feet/second
‡beats per minute

Therefore, the subjects with the shorter 5-minute distances exhibited less variance than did the subjects with greater recorded distances, indicating the more frail individuals performed similarly. Based on these results, the performance threshold differentiating the most frail was a walk distance of 380 feet in five minutes.

Summary of Results

Of the 78 test subjects, all were able to complete the stands, 61 (78%) completed the repeated chair rise and sit, 75 (96%) completed the 8-foot walk, 76 (97%) were able to continuously walk for five minutes, and 73 (94%) were able to participate in the seated step test. The tests were performed without incident, were easily administered, and were accepted by the majority of the frail subjects. The heart rate data remained lower than the age-adjusted maximum rate regardless of the mode of activity (5-minute walk or seated step test). Eighteen subjects in the sample (23%) could not rise from a chair without using their arms to push. Forty-seven (60%) of the subjects could remain safely balanced with the feet in the semi-tandem position for 10 seconds. The frail subjects demonstrated heterogeneity in the 8-foot walk speed with a distribution from .48 to 4.04 feet/second. Likewise, a wide distribution of distance (180 to 1248 feet) was evident in the 5-minute walk. Only 12 (16%) of the subjects required an assistive device for ambulation safety. Little or no relationship was found between the physical performance variables and the heart rate data. No relationship was found between the ratings of perceived exertion and the seated step test heart rate data. However, the distance walked in five minutes exhibited a fair correlation with the ability to repeatedly rise from a chair ($r_s = .44$) and with 8-foot walk speed ($r = .35$).

CHAPTER 6

DISCUSSION AND CONCLUSION

Discussion

The purposes of the study were to evaluate plausible relationships among the variables and, secondarily, to describe performance capabilities and performance thresholds for elderly residing in long-term care facilities. The sample in the present study was made up of men and women with a combined mean age of 81.94 ±7.08 years living in several long-term care facilities. The physical performance measures in the study were 8-foot walk speed and 5-minute walk distance, challenged standing balance, and ability to repeatedly rise from a chair. The physiologic performance measures were average walking heart rates recorded during a 5-minute walk, heart rates achieved during the seated step test, and ratings of perceived exertion recorded immediately following the seated step test. The subjects with poorer physical performance tended to demonstrate poorer performance on each of the physical variables. However, physical performance did not correlate with heart rate performance.

As in previous studies, the tests were found to be useful in evaluating physical performance, practical for the clinician and the setting, and safe for most of the test subjects.[12, 14, 31, 34, 38, 86, 88, 95, 98, 133, 151] While the measures were acceptable, easy, and safe, the measures did not appear to be of equal usefulness in describing the physical and physiologic performance in the sample. Based on the descriptive performance and crosstabulation analyses, information outlining the usefulness of the measures in the present study is presented in Table 6.1.

Table 6.1.—Usefulness of Test Variables in Sample of Frail Elderly

Variable	Usefulness
Heart Rate	
5-Minute Walk	Limited to monitoring
Seated Step Test	Limited usefulness
5-Minute Walk	Useful and discriminative
8-Foot Walk Speed	Useful and discriminative
Chair Rise and Sit	Useful and discriminative
Challenged Stands	Limited discriminative usefulness

Heart Rate

The mean resting heart rate for the sample was found to be 78±12 beats per minute which is comparable to heart rate data presented by Rodeheffer et al[25] where the reported mean resting heart rate was 77 bpm for a similar sample of older adults. Likewise, Kostis et al[65] reported ranges of resting heart rate from 71 to 99 bpm with an average of 79 bpm over a 24 hour monitoring period in men and women ranging in age from 16 to 68 years. The subjects in the present study demonstrated similar heart rates with a range of 54 to 103 bpm. Sheffield et al[152] reported that sitting heart rate was inversely associated with age, although the relationship was weak (r= - .33). The resting heart rate in this study was recorded in a sitting position and, therefore, a comparison cannot be made with static standing heart rates to support or refute the previous observations in the elderly.

Exercising heart rates have been found to be related to age, although response to submaximal demands demonstrates less age-effect.[64-66, 73, 109, 152] Investigators theorize the age-related changes in exercising heart rate may be due in part to a reduction in sensitivity of β-adrenergic receptors and to a decline in the response to respiratory mediated events.[26, 152] The mean 5-minute walk heart rate (96 bpm) and the seated step test heart rate (94 bpm) of the present study's sample of frail elderly seems to support the concept of reduced heart rate response to submaximum exercise demands. Another possibility is that the sample was not motivated enough to expend true effort in either the 5-minute walk or in the seated step exercise test. Such a phenomenon was suggested by Serfass and colleagues[111] and supported by several early studies in exercise testing for elderly subjects[19, 153]. The heart rates recorded during the 5-minute walk and the seated step test for this study demonstrated very little difference indicating that similar effort was given for each test. Therefore, the conclusion is that the frail sedentary subjects slowed the walk pace and stopped the exercise test due to lower extremity fatigue before reaching near maximum heart rate.

For the seated step test, the most common symptom limiting continued performance was quadriceps fatigue (88% of the subjects). Most often the local muscle response was described as a "crampy" discomfort which agrees with the recommended definition of fatigue by Pandolf and associates.[128] Using the age-adjusted maximal heart rate formulation and the mean age of the study's sample, the mean maximum heart rate would be 138 bpm.[116] With the recommended safe limit for the elderly at 85% age-adjusted heart rate maximum, the mean observed heart rate for this sample should be 117 bpm.[111] Therefore, use of heart rate performance during an exercise tolerance test or an exercise test may not be adequate to describe expected physical performance in functional activities, to develop an exercise prescription, or to monitor change following an intervention in the frail elderly.

The lack of motivated effort in the present sample may explain the poor correlation between the physical performance and physiologic response. The expectation was that the frail subject was functioning at near the maximal physiologic limit and an association could be observed both in physical and physiologic parameters.

The average heart rates associated with walking for older adults aged 60 - 80 years have been determined for slow pace at 92 bpm, for normal pace at 103 bpm, and for fast pace at 119 bpm.[134] The mean heart rate during the 5-minute walk test in the present study was 96 bpm, which is slightly below the published average for normal walk speed of 103 bpm. The exercising heart rate was slightly above the rate associated with a slow pace, but not near the average fast walking heart rate. Therefore, the conclusion is that the test subjects were walking at a slow to normal pace compared to a more fit sample. The slowed walking pace was not unexpected given the inclusion criterion of frailty for the present study.

5-Minute Walk

The 5-minute walk test was found to be an acceptable test of exercise tolerance in the frail elderly sample by both the investigator and the subjects. The test was completed by the majority of the subjects, although the walking pace tended to slow drastically in the last 2 minutes of the test for most of the subjects completing the test. The slowed pace is evidenced by the average five minute walk speed of 1.74 feet/second. This value is much slower than the published fast walking speed of 4.92 feet/second for healthy active seniors.[134] The slowed walking pace over five minutes attests to the frail, unfit status of the study sample.

The distance covered in five minutes (mean 529 feet) was also much shorter than other studies using similar methods and subjects. Both Guyatt et al[132] and Lipkins et al[23] evaluated the distance walked in six minutes in older subjects with congestive heart failure. The first study reported that in a sample of patients with congestive heart failure and a mean age of 64.7±8.3 years the walk distance was found to be 475 meters (1558 feet) to 490 meters (1608 feet).[132] Extrapolation of the data to a five minute timeframe indicates the distance covered would be between 1298 and 1340 feet. In the second study, a group of adults (mean age 58 years) with congestive heart failure walked 559 meters (1834 feet) in six minutes or, using extrapolation of data to five minutes, 1528 feet in five minutes. In two additional studies using a 5-minute walk test in samples of older subjects with arthritis or respiratory problems, the investigators documented mean distances from 280 meters (820 feet) to 541 meters (1775 feet).[20, 54] The range of distances for the present study was 180 to 1248 feet with a mean of 529 feet which supports the heterogeneity in even the frail elderly. In general, the frail subjects in this study walked shorter distances than in any of the reviewed studies.

Two possible rationales may be proposed to explain the difference between the present study and previous research. First, the present sample is unique in that the subjects are frail, very elderly, and residing in nursing facilities. The subjects were sedentary with limited opportunity or motivation to walk for periods longer than several minutes in duration. Literature has shown that with a decline in physical activity the ability to perform becomes compromised.[58, 72] Secondly, energy expenditure for fast paced walking has been shown to increase for the elderly.[134] It was postulated that the stride length and cadence decreases with age. Reasonably, these changes may be exacerbated with additional decline and frailty such that the elderly subjects compensated for the increased energy demands by slowing the walking speed to a more comfortable, less demanding pace. Research has shown that adults will normally choose the most energy efficient pace for continued walking.[134] Thus, the decreased distances noted in the present study supports the concept that the frail elderly have limited physiologic reserve, and rather than respond with increased metabolic and physical effort may opt instead to compensate by slowing to a more comfortable speed.

The study was conducted onsite in the corridors and rooms of the nursing facilities with the intent of improving the clinical significance of the results. However, the nursing facilities' corridors presented possible methodology problems that required astute observation to prevent test interference. Infrequently, the obstacles inherent in the long-term care environment like laundry carts, other residents walking or wheeling down the hall, and housekeeping paraphernalia caused breaks and inconsistencies in the walk, requiring that the test be repeated. In addition, distracters, like other residents or staff attempting to talk to the subject in the midst of the walk, occasionally affected the ability of the subject to remain on task.[56]

The 5-minute walk did successfully identify subjects who were more frail, i.e., subjects demonstrating difficulty with challenged stands and repeated chair rise were also associated with the shortest distances in five minutes. However, the 5-minute walk test was found to have a weak correlation with the ability to stand in challenged foot positions and 8-foot walk speed; and only a fair correlation to chair rise and sit. No other studies were found that compared walk distance and physical performance measures to support the present findings.

8-Foot Walk Speed

Walking speed has been shown to predict functional independence in community-dwelling elderly.[12] Walking speed is known to decline 12% to 16% per decade after age 60.[154] A Swedish study examined a group of healthy 70-year-old men and women and found the usual walking speed to be 3.94±.66 ft/sec for the men and 3.61±.66 ft/sec for the women.[155] In similar studies comparing young and old subjects, mean walking speeds for usual paced gait was reported from 1.38±.19 ft/sec to 4.53±.76 ft/sec.[95, 156, 157] In studies involving institutionalized elderly, walking speeds were found to be slower, with means ranging from 1.38 ft/sec to 2.62 ft/sec in one study; and means from 1.31 ft/sec to 2.30 ft/sec in another study.[2, 95]

In the present sample, the walking speed, using an 8-foot course described by Guralnik et al[12] and instruction to walk at the usual speed, was determined to have mean speed of 1.52±.75 ft/sec. The study by Guralnik et al[12] reported that in a large sample of elderly residing in the community the walking speed was 1.40 ft/sec for the slowest group and 2.58 ft/sec for the fastest group. Even though the present study involved frail elderly, the walking speed was slightly faster (0.09%) than the slowest speed given in the similar study. Nearly one-half of the subjects were able to complete the 8-foot walk with speeds greater than 1.48 seconds but only 7 (9%) were able to achieve a time of ≥2.58 ft/sec which was the best time recorded in the community-dwelling sample referenced above. The most obvious decline in walking speed was noted from .75 to .66 ft/sec, which defined the slowest 10% of the sample. The results support the usefulness of walk speed to identify individuals who are more frail. The test also proved capable of differentiating levels of frailty, that is more functionally dependent subjects walked slower over the eight foot distance.

The variability of the walk speed in the present sample was greater than previous studies and may have been indicative of the functional differences in the sample. Although all were considered frail by criteria definition of need for activities of daily living (ADL) or instrumental activities of daily living (IADL) assistance, some were dependent in IADL rather than ADL which indicated a higher functioning level. Such an assumption is supported by other research which proposed that walking speed could reflect ADL status in elderly subjects.[95]

The possibility of a threshold walk speed to predict physical decline has been postulated by several investigators.[17, 95] The investigators proposed threshold values at .63 ft/sec to .82 ft/sec. Based on the results of the present study, approximately 68 (90%) of the frail sample walked faster ($\geq$.75 ft/sec) than the threshold range while the remaining subjects were indicated to be functioning (walk speeds = $\leq$ .66 ft/sec) below the threshold for adequate performance. The findings are clinically important in describing the functional level of the frail sample and in identification of nearness to a functional threshold. Walking speed measures are feasible and useful measurement tools to evaluate the frail elderly and to justify intervention based on thresholds.

Walk speed was found to be related to both the ability to rise from a chair repeatedly and in the ability to walk greater distances in five minutes. Walk speed had little to no relationship to heart rate values. Therefore, the physical performance measure does exhibit a predictive relationship to other physical measures, but does not appear to be useful in estimating the physiologic parameters used in this study.

Chair Rise and Sit

Performance of repeated chair rise and sit without use of the arms was evaluated for the total sample. Indicative of the frail status of the subjects, approximately 19% of the sample could not complete the rise. The number of subjects unable to complete the task is slightly less than the percentage found in previous studies which was from 21.6% to 35% in samples of community-dwelling elderly.[12, 158] Alexander and coworkers[158] sought to evaluate elderly individuals who were able to rise from a chair with little difficulty; therefore, the higher percentage reported by the investigators may have been the result of a recruiting bias rather than a true representation of the population percentage.

The variation of the actual times for completion of the task was indicated by a range of 11.91 to 45.30 seconds and is evidence of the wide variance in functional skills observed in the sample. The heterogeneity of the present sample was similar to other studies evaluating chair rise in the elderly in which standard deviations were found to be from 30 to 50% of the mean.[158, 159] The standard deviation in the data for this study was approximately 27% of the mean for those completing the five rises.

In addition, the score of 4 was assigned to subjects requiring ≤18.94 seconds to complete the task, which is much longer than the times recorded by Guralnik and colleagues.[12] The wide range of the recorded times also resulted in wider scoring intervals than were defined by Guralnik et al[12] and are indicative of the heterogeneity of the institutionalized elderly. Some of the scoring difference may be further explained in the method of timing the five repetitions. In the present study, the subject was timed from initial sitting position to the final sitting position whereas the above referenced study timed from initial sitting position to the last standing position which would yield a slightly shorter time than reported in this study.

The present sample took approximately twice as long to complete the task as did a "high functioning" sample of elderly of comparable age in a study to examine the relationship of physical performance and aging.[11] The investigators reported that repeated chair rise exhibited a great degree of change with age and decline. Thus, the findings in this study support the concept that the ability to rise from a chair is adversely affected by decline and limitations in physical activity.

Several studies have associated repeated chair rise with lower extremity strength and endurance.[12, 86, 90] Hwang and Reinsch[90] found no significant difference in the time to rise from a chair 10 times and computerized strength assessments of the major muscle groups of the lower extremity. Given the level of difficulty observed in the present frail sample, the test may have clinical value as an estimator of general lower extremity weakness, but is non-specific and was found to have only a fair to good correlation to other physical measures. The five repetitions of chair rise in the present study did not appear to fatigue the subjects enough to be considered a measure of muscle endurance, nor did the test appear to cause notable increases in respiration or heart rate which would indicate cardiovascular challenge. Therefore, the conclusion is that the test as given was not sufficient to estimate muscle or cardiovascular endurance in the elderly sample. Further research is required to examine the aspect of muscle fatigue during repeated physical performance in frail elderly.

As in previous studies[11, 12, 22], the test was found to useful in categorizing subjects with poorer physical performance. For example, subjects assigned a score of 0, which indicates inability to perform the test, covered the shortest distance in five minutes and recorded the slowest walking speeds indicating these subjects were more frail. Theoretically, the repeated chair rise and sit would be appropriate as an estimator of frailty. Given the observed difference between those subjects scoring 0 and the next performance level (score of 1), the inability to complete five repetitions may be an appropriate threshold value to identify individuals at greatest risk for added physical decline.

The repeated chair rise and sit exhibited no correlation with physiologic heart rate measures. The possible explanation for the lack of a relationship may be with the use of the heart rate measure in this sample. The point was made in the previous section that elderly subjects may not be motivated to perform at levels that require added effort or for the amount of time required to obtain an accurate heart rate response to submaximal effort. Many questions concerning the relationship between the ability to perform repeated chair rise and sit tasks and physiologic performance remain unanswered and should be explored further.

Challenged Stands

Static balance performance was assessed by asking the subject to maintain balance while standing with eyes open in one of three foot positions for 10 seconds: 1) semi-tandem; 2) tandem; or 3) side-by-side. All of the frail subjects could hold the side-by side foot position for 10 seconds, but only 13 (16%) could maintain balance in the tandem position. This is a considerably smaller percentage than in previous studies using similar measures of balance, but in samples of community-dwelling elderly.[12, 34] Those studies reported percent able to perform the tandem stand at 50% to 64% in a more fit sample of subjects. Literature examining balance scores in frail institutionalized elderly is limited, and of the few available studies, clear description of the methodology is lacking, making comparisons difficult. However, several research endeavors have found a significant correlation between balance scores and impaired function.[34, 160] Therefore, the assumption was that the more frail elderly would be expected to score lower on tests of challenged balance.

More than half of the present sample did maintain static balance in the semi-tandem position which appears to agree with the findings by Cress et al.[160] However, comparison with this and other research was done with caution due to the lack of procedural and scoring clarity in the reviewed studies. Some studies used only a semi-tandem test[97] while others asked the participant to stand only in tandem[11, 34], and still others evaluated balance in one of the three foot positions, but scored using a 0 - 5 scale.[160] Support for the present findings was also sparse since a limited number of studies are available with samples residing in long-term care settings.

The ability to maintain balance in the tandem position for 10 seconds was useful in identifying subjects with poor performance in walking distance and in the ability to rise from a chair suggesting that a threshold challenged stands score of 4 may be appropriate to identify elderly at risk of further physical decline. Scores on challenged stands were poorly correlated to walk speed even though both have been shown to predict impaired physical performance.[34]

Several possibilities may explain the findings in the present sample. Balance reactions are known to deteriorate in the presence of added distracters.[56] Therefore, the "real" environment in which the tests were conducted may have introduced some unexpected attentional distracters; (e. g., a roommate or staff entering the room in the middle of the test). If the distraction was observed, the test was repeated. However, a possibility exists that distractions may have been unseen and may have resulted in a limitation error in the performance score. Secondly, the use of wide-based stance and gait patterns were frequently observed in the frail sample. The individuals were unaccustomed to and uncertain of assuming the narrow-based position required for proper administration of the test. Therefore, physical balance performance may have been more limited by anxiety and uncertainty than by actual ability.

Since all of the subjects could perform the stands at some level, the test appears to be appropriate for use in the frail elderly. The challenged stands test proved to be safe and easy to administer. Although the test was not as sensitive as the repeated chair rise and sit, the challenged stands appeared to be useful in differentiating the subjects with poorer performance. However, a relationship between challenged stands score and the physiologic heart rate measures was not found in this study.

Seated Step Test

The seated step test proved to be useful and challenging for the sample of frail subjects. The test required a fatiguing effort from the subject and several subjects refused to push themselves beyond the initial onset of fatigue. The subjects responded more consistently to verbal cueing for establishment of a rhythmic stepping sequence than to the metronome, which seemed to make some subjects anxious and distracted. In addition, conversation and added distracters were kept to a minimum during the test as has been advised by several studies concerning the elderly and performance tasks.[43, 56]

All of the subjects completed 5 minutes each at Stage 1 (6" step) and Stage 2 (12" step), but only 19 (25%) of the subjects attempted to continue beyond Stage 2.(Appendix A.1) Of these 19 subjects, 2 attempted Stage 4, but could not complete the 5 minute time. The majority of the frail subjects indicated lower extremity (muscle) fatigue as the reason for stopping the test. A few complained of knee discomfort and one subject indicated lateral hip and knee discomfort as her reason to stop.

Motivation and encouragement have been shown to improve performance on fatiguing tests.[131] The elderly in the present sample lacked the motivation to perform at peak levels and encouragement seemed to have limited usefulness. The institutionalized setting may be an environment where the subjects are not accustomed to extending themselves to meet added physical and physiologic demands and encouragement elicits an adverse reaction. The effect of the specific environment on performance during a low level exercise test requires further investigation.

Ratings of Perceived Exertion

The ratings of perceived exertion requested following completion of the exercise test demonstrated no correlational relationship to the seated step test heart rate values, that is, the heart rate values did not correspond well with perception of greater peripheral effort. More than three-fourths of the sample indicated a ratings of perceived exertion of 2 to 4 with the median and mode being 3, which corresponds to lighter work and weak to moderate effort.[127] Thus, the median and mode corresponds to low exercising heart rate, blood lactate accumulation, and working capacity.[129, 161] The 5-minute walk heart rate demonstrated similar submaximal effort. Therefore, the indicated ratings of perceived exertion appears to be an accurate description of expended effort.

However, the ratings of perceived exertion descriptors do not seem to agree with the level of quadriceps fatigue reported by subjects as the reason for stoppage of the seated step test. Either the ratings of perceived exertion were an insufficient measure of actual effort or, more likely, the subjects' reported an inaccurate level of fatigue. Although disagreement exists in the literature, the 15-grade RPE scale (6 - 20) may have been more appropriate for determination of effort given the subjects' instruction to indicate overall effort, with no specific instructional reference to leg effort. The use of the category-ratio scale may have resulted in a methodolgical limitation in the present study.

However, Noble et al[129] suggested that in exercise activities involving the lower extremities (walking or running) local muscle factors may "overpower" the aerobic factors of perceived effort. Therefore, the possibility exists that in the deconditioned elderly ratings of perceived exertion would be subjectively based on local factors not central factors regardless of the ratings scale. Comparing the mean seated step test heart rate and the 15-grade RPE scale (adding a 0 to the number corresponding to the mean heart rate on the scale as described by Borg[124]) , the level of perceived exertion would be "light" which is close to the "moderate" level indicated by the present sample using the category-ratio scale.

Morgan[162] suggested that perceived exertion has an important psychometric component and is an extremely complex sensation involving not only physiologic but emotional factors. Furthermore, Morgan[162] reported that the relationship between actual work and ratings of perceived exertion may be adversely affected by depression and anxiety resulting in either an under- or over-estimation of the effort. The lack of evidence to support a correlational relationship in the present study seems to suggest that a complex interaction of psychological and physiological factors may be affecting the findings in the frail elderly.

In summary, the physical performance measures were objective, sensitive to different levels of physical capacity, and easily administered in spite of the frail status of the subjects. When combined, the walk speed, challenged stands, chair rise and sit, and the 5-minute walk distance presented a fair estimation of the physical performance capacity of the individual. Given the confidence intervals, the estimation of performance should hold true in 95% of the time in replicative studies with similar samples and methods. The heart rate data was easily obtained from most of the subjects, but lacked the sensitivity of the physical performance tests. Within the constraints of the present study, the results suggest that the relationship between physiologic factors and physical performance may be poorly associated in the frail elderly and that low levels of physical performance were more related to musculoskeletal factors than cardiovascular limitation in this sample.

Conclusions

The purpose of this study was to examine the relationship and usefulness of selected measures of physiologic and physical performance which were indicators of physical mobility and tolerance in frail institutionalized elderly. In particular, the study was designed to determine the relationship among measures of physical performance and the physiologic response to prolonged walking and a low level exercise test. Additionally, the results were intended to assist in determination of clinically important physical and physiologic threshold values useful in describing and identifying levels of frailty in the elderly.

Statistically, the data comparing the results of physical tests with the physiologic exercise response found little to no relationship between the measures. Based on the statistical analyses and the descriptive findings and within the limitations of the study, the following conclusions are proposed:

1. While the seated step test was safe, useful, and challenging in the frail sample, the lack of motivation and the rapid onset of quadriceps fatigue limits the feasibility of

accurate heart rate data for use in exercise prescription. The seated step test heart rate response was not related to the individual's ability to perform physical tasks such as repeated rise from a chair or walk at functional speeds. With reasonable certainty, the lack of a relationship would hold true in the majority of frail institutionalized elderly with similar characteristics.

2. The average walking heart rate recorded during the 5-minute walk was not related to the ability of the frail individual to perform physical tasks requiring repeated use of the lower extremities. However, the telemetric device was useful to monitor the sedentary older adults for adverse heart rate response to the extended walk duration.

3. The distance walked in five minutes was related to the performance on physical tests and may be a good descriptor of expected performance during repeated rises from a chair, stance in challenged positions, and a short distance walk. The results demonstrate the 5-minute walk was a useful, safe, and clinically effective measure of physical performance. However, the distance was not useful in determination of exercise tolerance parameters such as 5-minute walk heart rate performance in the frail elderly, who tend to slow their walk pace significantly.

4. A methodological limitation existed with the choice of the category-ratio scale as an indicator of perceived exertion in the sample. Therefore, cautious interpretation of the ratings of perceived exertion data was warranted as a possibility exists that the responses may have differed somewhat with the use of the 15-grade scale. The

results of the seated step test and ratings of perceived exertion did not support the reported level of fatigue in this sample of frail elderly. The data suggest that other unidentified factors are affecting the relationship between the heart rate and the level of reported work, but conclusions concerning the relationship is difficult to make from the present study.

The concept of frailty has been described as "losses of physiologic reserve" that results in diminished physical performance capabilities.[105] Frailty has also been referred to as a state leading to or predictive of disability and dependence on others for daily care.[24, 105] Frailty was defined as multifaceted, involving decreased ability to perform secondary tasks, decreased strength, decreased aerobic capacity.[5] In addition, several authors described the possibility of a performance "threshold limit" below which individuals would become increasingly dependent.[24, 105] All of the subjects in the present study were considered frail; however, the data demonstrated that heterogeneity exists within the category of frailty. The different physical capabilities of the frail sample may be further explained by identification of levels of frailty using demarcations based on performance thresholds. The physical and physiological data collected during the study will hopefully aid in the development of a model to better describe thresholds of physical performance among frail elderly. Based on the data collected in the present study, a summary of the proposed thresholds for determination of levels of frailty associated with task performance within the frail sample residing in long-term care facilities is presented in Table 6.2.

Table 6.2.— Summary of Proposed Physical Performance Thresholds for Determination of Frailty Levels in the Frail Elderly

	Performance Thresholds
Chair Rise and Sit	≥ 27.69 seconds/5 repetitions
8-Foot Walking Speed	≤.75 ft/second
5-Minute Walk Distance	≤ 380 feet
Challenged Stands	Unable to tandem stand

Of clinical significance, the development of such a model may assist in a more accurate description of performance difficulties and, therefore, the most effective intervention (strengthening, endurance training, or functional training) for the frail elder at risk of additional decline. If a range of performance thresholds were described for the frail elderly, allocation of healthcare dollars may be more wisely utilized to address the appropriate areas of deficit or loss of functional reserve, thereby altering the decline to physical dependence.

The present and related studies confirm the feasibility of using a portable telemetric heart monitoring system in the frail elderly, but the value of physiologic measures as tools to gauge change in performance response following intervention or to indicate acute adverse performance response can not be determined from this study. Therefore, research is warranted to define the practical usefulness of the simple tool in clinical monitoring of the frail elderly. Secondly, the influence of the complex and busy institutional environment on performance can not be definitively determined by this study and requires further controlled research. Although indicated as a possible limitation in the present study, the willingness to perform during strenuous and fatiguing activities (motivation) may have an effect on physical performance and warrants additional examination. The influence of muscle fatigue on the performance of repeated tasks such as the chair rise and sit need further investigation. Finally, further research is warranted to support the use of the thresholds of physical performance to identify frail elders at greatest risk of decline.

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APPENDICES

APPENDIX A.1: Seated Step Test

APPENDIX A.2: Seated Step Test Target Device

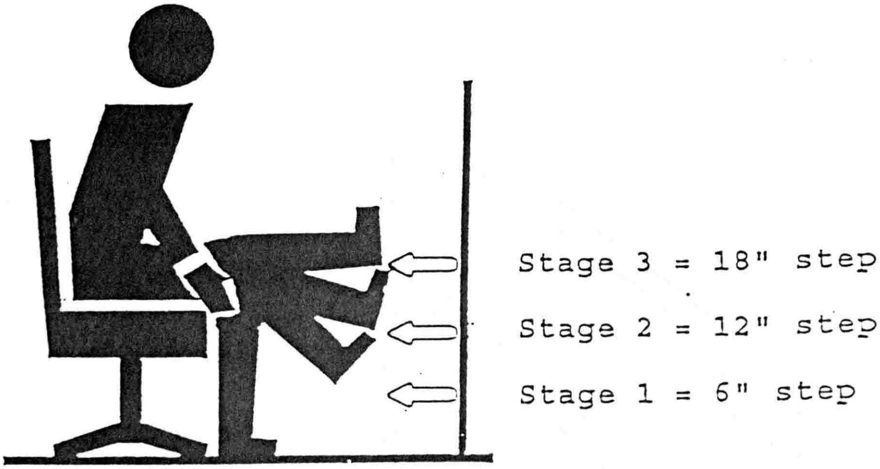
APPENDIX A.3: Guidelines for Stopping Seated Step Test

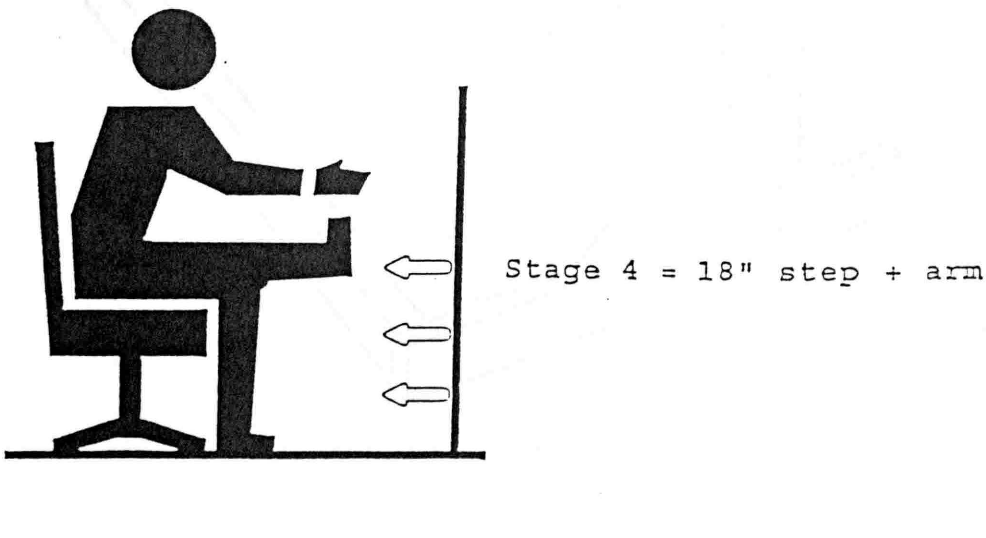
APPENDIX B: Scoring for Challenged Stands

APPENDIX C: Human Subjects Consent Form

APPENDIX A

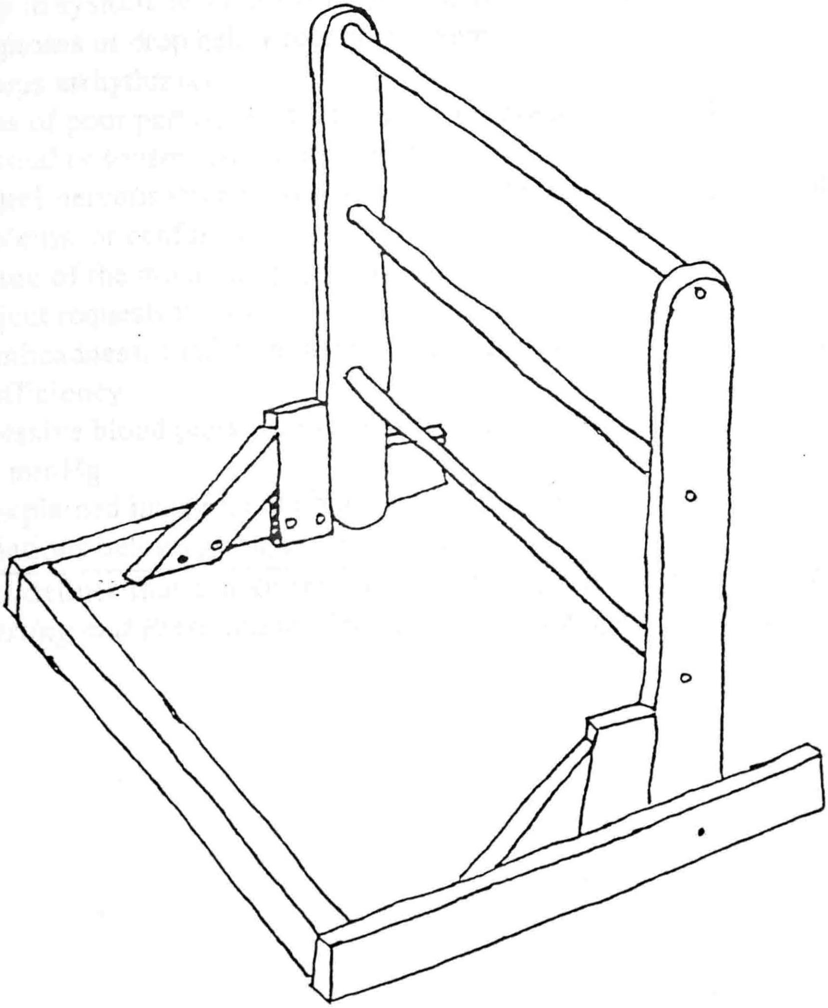
APPENDIX A.1: Seated Step Test





Adapted from Smith EL and Gilligan C. Physical activity prescription for the older adult. *Physician and Sportsmed.* 1983;11:91-101.

APPENDIX A.2: Seated Step Test Target Device



APPENDIX A.3: Guidelines for Stopping Seated Step Test

Absolute Indications	
1.	Acute myocardial infarction or suspicion of a myocardial infarction
2.	Onset of moderate to severe angina
3. or	Drop in systolic blood pressure with increasing workload accompanied by signs symptoms or drop below resting pressure
4.	Serious arrhythmias
5.	Signs of poor perfusion, including pallor, cyanosis, or cold and clammy skin
6.	Unusual or severe shortness of breath
7.	Central nervous system symptoms, including ataxia, vertigo, visual or gait problems, or confusion
8.	Failure of the monitoring system
9.	Subject requests to stop
10.	Lightheadness, confusion, nausea, and signs of severe peripheral circulatory insufficiency
11.	Excessive blood pressure: systolic greater than 250 mmHg; diastolic greater than 120 mmHg
12.	Unexplained inappropriate bradycardia: pulse rise slower than two standard deviations below age-adjusted normals

Based on guidelines found in *American College of Sports Medicine: Guidelines for Exercise Testing and Prescription*. 3rd edition. Philadelphia, PA:Lea & Febiger, 1986: 13-21.

APPENDIX B

APPENDIX B: Scoring for Challenged Stands

	Beginning Position for All Subjects•		
	Side-by-Side (seconds)	Semi-tandem (seconds)	Tandem (seconds)
Score = 0	0-9 Tried but unable Not attempted	<10 Tried but unable Not attempted	-
Score = 1	10	0-9 Tried but unable Not attempted	
Score = 2	-	10	0-2 Tried but unable Not attempted
Score 3	-	10	3-9
Score 4	-	10	10

•starting position for all subjects and dependent on semi-tandem performance, the subject may move to side-by-side or full tandem for categorical score.

Based upon Guralnik JM, Simonsick EM, Ferruci L, et al. A short physical performance battery assessment of lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Geron: Med Sci.* 1994;49:M85-M94.

APPENDIX C

TEXAS WOMAN'S UNIVERSITY
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713/794-2070

Title: Relationship of Exercise Tolerance, Exercise Intensity, and Physical Performance in Frail Elderly Individuals Residing in a Long-Term Care Facility

The purpose of this study is to determine if measures of how much I can exercise and how well I can tolerate the exercise is related to my ability to get up and sit down from a chair, stand with my feet in various positions, walk 8 feet, and walk in the hall for 5 minutes. The study will take place in the place where I live.

I understand that I will be asked to perform an exercise test called the chair-step test. The test will involve sitting in a chair and raising my feet one at a time to touch a step placed at various heights (6 inches, 12 inches, and 18 inches) in front of me. The last stage of the test will require me to raise my arms one at a time when I raise my feet.

I understand that I will be asked to stand up from a chair five times without using my arms.

I understand that I will be asked to stand without my shoes on with one foot slightly in front of the other for 10 seconds. If I cannot stand in this way for 10 seconds, I will be asked to stand with my feet side by side for 10 seconds. If I can stand with one foot slightly in front of the other for 10 seconds, I will be asked to stand with one foot all the way in front of the other for 10 seconds.

I understand that I will be timed while I walk 8 feet at my usual pace. I will repeat the walk twice.

I understand that I will be asked to walk as far and as fast I can for 5 minutes. My heart rate will be recorded during the walk. The distance I walk will be also be measured and recorded.

I understand that the tests will be given on one day with a total required time of one hour with rests if needed. The tests will be supervised by a physical therapist with the permission and cooperation of the facility and my physician. I understand that my agreement to participate in the study means that I will try to complete all testing. If I miss one of the tests, I understand that I can make it up the next day. However, if I can not complete the tests in this way, my test results will not be used in the study.

I also understand that I should not eat food or drink colas, tea, or coffee within 2 hours before I am to be tested.

I understand that the minimal risks possible with the tests will be controlled by the investigators as follows:

1. Effects from the exercise like dizziness, nausea, chest pain, shortness of breath, severe fatigue, back or leg pain and soreness, confusion, and drop in pulse.

   The investigator will be present at all testing. I may request the test be stopped. I understand that I must tell the investigator if I experience any of the above problems.

2. Injury, muscle soreness, or fall during testing.

   I will have the tests and equipment explained to me and be given practice time before testing. I will also be allowed to rest between tests if needed. I understand the investigator will be closely watching me during the testing.

3. Discomfort from the chest heart monitor.

   I understand the strap will be adjusted for proper fit.

4. Discomfort from the chair.

   I may ask for a cushion to be placed in the chair.

5. Heart attack during testing.

   I understand the personnel will be CPR certified and will follow the safety guidelines for exercise testing. The investigator will be aware of the facility emergency procedures. I understand my heart rate will recorded throughout the tests.

6. Privacy invasion if my name is used when discussing or writing about the study.

   I understand the results of my tests will be given a number and stored in the investigator's office at the University of Central AR in Conway, AR.

7. Time inconveniences.

   I understand the tests will be pre-arranged at my convenience when possible.

8. Disclaimer statement.

   Efforts will be made to prevent any unforeseen complications that could result from this research. Medical services and compensation for injuries occurring as a result of my participation in the research are not available. The investigators are prepared to advise me in the case of adverse effects, which I should report to them promptly. Telephone numbers for the investigator and her advisor are at the end of this form.

I understand that no direct benefits, money, or medical services will be provided to me by the investigator, Texas Woman's University, or the University of Central AR. The information will be used to benefit others by promoting a better understanding of exercise and daily activity in the elderly.

I understand my signature indicates I understand the requirements and the risks of the study and that I voluntarily consent to participate. I may stop performing the exercises at any time by either stopping or by notifying the researcher without any penalty to me. I understand the care provided at the nursing facility will not be affected by this study.

I understand I have the right to contact Reta J Zabel at (501) 450-5552, Dr. Elizabeth Protas at (713) 794-2069, or Office of Research and Grants Administration at (817) 898-3375 if I have any questions. A copy of this form will be kept in this facility for my reference if needed.

____________________________________ ____________________

Signature Date

____________________________________ ____________________

Witness Date

I am unable to sign because of medical or social reasons and voluntarily give my permission for my representative to sign below:

_______________________________________ ____________________

Guardian or Authorized Representative Date